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Risk Assessment for Fishing Vessels at Fishing Grounds

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ABSTRACT: Safety and efficiency of fishing fleet activity depend largely on the quality of management decisions. Cause-and-effect relationships of accidents involving fishing vessels were identified by means of an analysis of emergencies and fishing incidents. The suggested method of risks calculation is based on the use of statistical methods, fuzzy sets/expert estimations method and the probability theory. The following most common tasks are presented and solved:
- there is an impact of two or more independent negative factors/events on the vessel such as failure of a sonar, a vessel operator error, another vessel operator error.
- a transport vessel carries out loading and unloading of fishing vessels under different environmental conditions. The value of the risk of an emergency incident is determined.
- the fishing vessel navigation performs under various meteorological conditions. A priori probability of incident-free operation is calculated according to expert estimations.

1 INTRODUCTION

1.1 *Research field*

There is no universally accepted general definition of a risk, but one commonly applied and authoritative resolution in most industrial contexts, defines the risk as "a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence" (Kristiansen 2010). According to the International Maritime Organization (IMO), the risk is the "combination of the frequency and the severity of the consequence", which thereby articulates two components of the likelihood of occurrence and the probability of severity of the (un)predictable consequences. "Safety management objectives of the company should…establish safeguards against all identified risks" as stated in paragraph 1.2.2.2 of the ISM Code (International Safety Management Code). According to ISO 8402:1995/BS 4778 the risk management which includes the maritime risk assessment is defined as: "The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence."

Many scientists have studied the problem of risk management and risk assessment in different fields, particularly in maritime transportation. It is necessary to mention one of the recent books devoted to this problem (Kristiansen 2010). The author considers all aspects of maritime risk and safety from engineering and operational perspectives, as well as safety requirements. The book describes the problem in the fields of shipping management, ship design and naval architecture and transport management, as well as safety management, insurance and accident investigation.

Some paper at the TransNav' conferences and journal have presented results from investigations in the field of navigation. For example, the navigational risk is defined (Gucma 2008) as the product of probability of failure occurrence and the consequences it can cause. The possibility of applying risk analysis in the area of ship handling with the focus on the human factor (Kobyliński 2009) was investigated.

The researchers (Jin et al. 2002) developed a fishing vessel accident probability model for fishing areas. The results indicate that medium-sized vessels have the highest accident probability, while small vessels have the lowest ones. The suggested probability model is an important building block in the development and quantitative assessment of management mechanisms related to safety in the commercial fishing industry. An approach to fishing safety policy was also elaborated (Perez-Labajos 2008). In the field of fishing safety policy, it is acknowledged that the development of a working legal framework of reference is a vital prior condition for the implementation of measures aimed at improving safety.

An analysis of problems of the safety of marine cargo transportation including methods and models of risk assessment are given in recent publications (Moyseenko & Meyler 2011, Kirichenko et al. 2014). Both organizational aspects of safety of the marine transportation of different kinds of cargo and risk management are considered there.

Fishery has been and remains one of the most dangerous of all human activities. A feature of oceanic fishery and the transport service of the fishing fleet at the fishing grounds is that all operations are carried out under conditions of impacts from many internal and external factors and the "aggressive" environment. The safety and effectiveness of the fishing fleet largely dependent on the quality of management decisions related to the safety of navigation and fishing.

In this regard, the actual task is the risk assessment and management during oceanic fisheries. The problem of risk management in the fishery has been studied by scientists and experts of some European countries (Perez-Labajos 2008), in particular countries around the Baltic Sea (Final Report 2014). But it is necessary to note that this problem has not been sufficiently developed. Cause-and-effect relationships of accidents involving fishing vessels are identified by means of the analysis of emergencies and fishing occurrences. Methods of calculating the level of a predicted risk for various combinations of negative factors in the external and internal environment are elaborated. The suggested method of risks calculation is based on the use of statistical methods, the fuzzy sets/expert estimations method and the probability theory.

1.2 *Scenario of emergency development*

There are a variety of risks which inherent to the work of the fishing fleet at the fishing grounds and cargo transportation to a port. In the frame of this paper selection of risks in four main groups is considered:

1. the risk of vessel and cargo losses;
2. the risk of accidents and emergency incidents that would not imply the loss of a vessel and cargo;
3. the risk of the failure of technical facilities providing storage, transportation and cargo safety;
4. the risk of arising fishing accidents (for example, a damage or loss of fishing gear).

The analysis of a large number (over 500) of accidents / incidents of emergency occurring with fishing and transport vessels (Moyseenko et al. 2014a) makes it possible to conclude that the scenario of an emergency during operation of the fleet at the fishing ground and the transport service of fishing vessels is developed in the most general form according to the scheme shown in Figure 1.

This paper defines the circumstance as a condition or a set of conditions that directly or indirectly contribute to an emergency or are the direct cause of an accident. For example, de-energizing a vessel bounding for berthing can often be the cause of an emergency and accidents. Under certain circumstances (lack of necessary information about the weather, approaching a hurricane, tsunami, etc.), severe weather conditions cause emergency situations resulting in a vessel being dashed against the rocks, structurally destroyed and flooded. Thus, the circumstances generate the risk of failures, errors, irresistible forces of nature that cause accidents (collisions, groundings, losses of the vessel and cargo).

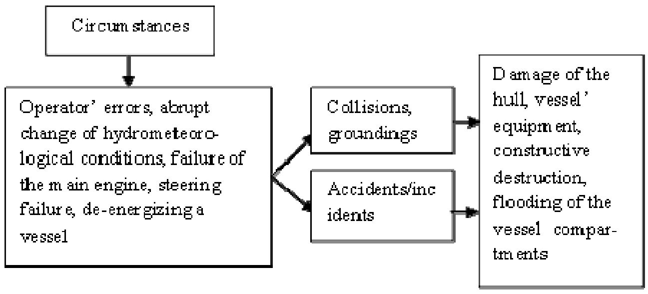

Figure 1. General scheme of accident scenario development

The scenario of the development of emergencies and disasters of fishing and transport vessels during cargo operations and transportation is shown in Figure 1. It can be used as a general model in the calculation of the risk of disaster emergency in the process of the fishing vessels work at the fishing ground and the fishing fleet transport services (Moyseenko et al. 2014b).

2 METHODS OF THE RISK ASSESSMENT OF FISHING VESSELS ACCIDENTS AND EMERGENCY INCIDENTS DURING THE OCEANIC FISHERY

2.1 *Types of fishing incidents*

An emergency fishing incident is, first of all, the loss of the fishing gear. It is associated with such "provocative" reasons as failures of technical equipment, errors of vessels operators while fishing, meteorological conditions, etc. For example, failures of equipment such as a sonar can cause a snag and a loss of the trawl when trawling on heavy (e.g. rocky) grounds.

A failure of a trawl winch can also cause fishing gear damage, because the operator will not be able to control the process of the trawl movement, in particular when changing a horizon of trawling, etc.

Operator errors are primarily due to the incorrect assessment of the situation, especially when working in a group of vessels, and therefore a wrong choice of a vessel manoeuvre. An operator error may also happen due to a wrong estimation of the degree of influence of meteorological conditions on the process of fishing. For example, there is a risk that vessel stability will lose with the threat of squally gusts when hauling gear and capsizing the vessel (Moyseenko et al. 2014b).

Assessment of the risk of accidents and fishing emergency incidents can be done by experts and methods of the probability theory. However, it is necessary to have a representative statistical basis, i.e. a large amount of accidents data and fishing incidents in order to use rigorous mathematical methods. Moreover, these data should be grouped by the type of vessels, fishing grounds, types of accidents/incidents, fishing gear, causes and consequences, time of year/season. However, such a statistical basis, properly systematized, does not exist today.

2.2 *The emergency risk assessment during fishing by the group of vessels*

Due to the lack of statistics about fishing vessels accidents/incidents during fishery it is possible to apply the method of expert estimates using the fuzzy sets theory. Let us consider the most common practice of emergency situations and methods for risk assessment of negative consequences.

Three independent events, the occurrence of which could cause a critical situation and fishing accident/incident can occur during the process of trawling by the group of vessels: the first (A_1) - sonar failure; the second (A_2) – an operator error; the third (A_3) – another vessel operator error. It is required to find the probabilistic risk assessment of fishing accident/incident. The solution algorithm consists of several steps.

The first step is determining expert estimates of the probability that during the trawling process none of the events (A_1, A_2, A_3) will appear. Experts defined the minimum and maximum values of probabilities. Then the calculation is performed by the formulae (Ventzel & Owcharov 1973, Moyseenko et al. 2013):

$$P_i^{exp} = (P_i^{min} + 4P_i^{mp} + P_i^{max})/6 \quad (1)$$

where P_i^{exp} = a priori probability of the i-th failure expectation; P_i^{min} = the minimum value of the i-th probability of the failure; P_i^{mp} = the most probable value of the probability of the i-th failure (Formula 2); and P_i^{max} = the maximum value of the i-th probability of the failure.

$$P_i^{mp} = (2P_i^{min} + P_i^{max})/3 \quad (2)$$

The dispersion is calculated by the formula:

$$\delta^2 = [(P_i^{max} - P_i^{min})/6]^2 \quad (3)$$

Let us suppose that the result of calculations of a priori probabilities of the occurrence of events $P(A_1)$, $P(A_2)$, $P(A_3)$ which are respectively equal to 0.95, 0.90, 0.85 has been determined.

The second step is the probability that none of the independent events A_i will appear. It can be calculated by multiplying the probabilities (Ventzel & Owcharov 1973):

$$P(A_1A_2A_3) = P(A_1)\cdot P(A_2)\cdot P(A_3) \quad (4)$$
$$P(A_1A_2A_3) = 0.95\cdot 0.90\cdot 0.85 = 0.727$$

The probabilities that there will be the i - th event is respectively equal to:

$$1 - 0.95 = 0.05;\ 1 - 0.90 = 0.10;\ 1 - 0.85 = 0.15$$

Thus, the probability that all three events may appear during the process of fishing, and cause an accident, is:

$$P(A) = 0.05\cdot 0.10\cdot 0.15 = 0.00075$$

Thus, the probability (risk) of a critical situation appearance when a vessel works in the group of vessels is equal to 0.00075.

An analysis of a solution to such a type of practical problems shows that as a rule, the probability of the joint occurrence of these events is small. But the probability of critical situations increases dramatically in terms of the work on fishing vessels during the autumn-winter period at small fishing grounds and a large gathering of vessels there.

For example, when the fishing fleet operates in the region of Antarctica in the winter period with a priori probabilities of 0.85; 0.75; 0.70 (these are evaluations by experts who know this area of operation well) the probability of the risk of a fishing accident/incident increases to 0.011. To neglect such a risk is dangerous.

2.3 *The risk assessment of accidents/incidents in the case of a co-occurrence of two or more dependent events*

Let us define an event B_i as the cause of the i-th damage of fishing vessel/fishing gear/environment (marine pollution). The risk of the fishery can be estimated by a mathematical expectation of the damage after the possible accident. The price of the risk is calculated by formulae (Topalov & Torskiy 2007, Moyseenko et al. 2014a):

$$R = M(w) \quad (5)$$

where $M(w)$ = a function of a damage.

Components of the fishing risk of accidents or the damage to the vessel can be represented by the following expression:

$$R= M(w) = \Sigma P(B_i)\cdot w_i \quad (6)$$

where $\sum P(B_i)$ = the probability of the event B_i; and w_i = the estimated amount of a damage price.

Let us consider methods of the risk assessment of accidents R_A. For this goal the event is defined causing the i-th type of the damage to the vessel/fishing gear after an accident B_i:

$$B_i = A \cap C_i \quad (7)$$

where A = the event of a fishing accident/incident; and C_i = the event of implementation of the fishing accident/incident according to the i-th scenario.

The probability of the event associated with the damage to the vessel after the accident is defined by the expression (8), because A and C_i are joint events (Ventzel & Owcharov 1973):

$$P(B_i) = P(A \cap C_i) = P(A)P(C_i | A) \quad (8)$$

Substituting (8) into (6) we obtain:

$$R_A = \sum P(A)P(C_i | A)\, w_i \quad (9)$$

The value of $P(A)$ is the causal component in the risk of an accident R_A and the second value $\Sigma P(C_i | A) w_i$ describes the expected consequences of the accident.

Evaluation of casual components of the risk is carried out by statistical methods, methods of the fuzzy sets theory and expert estimates and simulation modeling techniques of emergencies/scenarios.

Evaluation of the expected consequences of accidents/incidents with fishing vessels is mainly based on the analysis of "the event tree" using a mathematical apparatus (Abchuk 1983, Ventzel & Owcharov 1973, Topalov & Torskiy 2007). Let us consider the example of the practical implementation of the method.

A voyage of any fishing vessel is carried out under various meteorological conditions. Let us assume, in particular, that the vessel's operating time under good weather conditions is 50 %, under bad weather conditions is 30 %, but the vessel can operate on fishery. Under the most severe weather conditions the vessel's operating time is 20 % and the vessel either may operate or not. According to experts estimations of a priori probabilities of trouble-free operations under conditions of the good, bad and heavy weather are calculated by formulae (1 – 3). Let the value of them be, respectively 0.98; 0.95; 0.80. It is necessary to determine the probability that the voyage will complete without fishing accidents/incidents.

Let us introduce the notation: A = the event of the successful completion of the trip; and B_1, B_2, B_3 = events of the vessel operations under different weather conditions. Then:

$P(B_1) = 0.50$; $P(B_2) = 0.30$; $P(B_3) = 0.20$

The event A occurs in a case of the appearance of one of the events B_1, B_2, B_3, which form a complete group of disjoint events. Then the probability of the event A is the sum product of the probabilities of each event of B_1, B_2, B_3 on the conditional probability, respectively.

$$P\{A\} = \sum_{i=1}^{n} P\{B_i\} P\{A | B_i\} \quad (10)$$

Conditional probabilities:

$P(A | B_1) = 0.98$; $P(A | B_2) = 0.95$; $P(A | B_3) = 0.87$

The probability that the voyage will be carried out without fishing accidents and incidents is calculated by the formula (10):

$P(A) = 0.5\cdot 0.98 + 0.3\cdot 0.95 + 0.2\cdot 0.87 = 0{,}949$

Thus the probability of a favourable outcome of the trip of a fishing vessel is equal to 0.949 and a probabilistic assessment of the risk of a fishing accident or incident is: 1 – 0.949 = 0.051, respectively.

If for example the amount of the damage (in the case of an accident or incident) is equal to \$100,000 the price of the risk is equal to 0.051·100,000 = \$5,100. The possible commercial profit of the vessel work at the fishing ground is expected to be equal to \$50,000. The estimated amount of the price of the risk is not a considerable sum in comparison with a possible commercial profit for the fishing vessel of the medium size.

2.4 *The integrated risk assessment*

The integrated risk assessment during oceanic fishery can be represented (Moyseenko et al. 2013) as:

- the sum of probabilities of accidents at each stage of fishing operation of the fishing vessel;
- the average-weighted probability of the risk of an accident;
- the average-weighted price of the risk of an accident;
- the total amount of the risk price at each stage of fishing operation of the vessel.

The algorithm for making the integrated risk assessment can be presented by sequential steps:

1. To define the probability of the failure according to statistical data or expert assessments (mini-max).
2. To define the weight estimates of the j-type failure mode/conditions those have caused the accidents.
3. To estimate the conditional probability of the event Bi (accidents of the i-type). The calculation is performed for all j, i, and l (stages, routes, modes of transportation).

4 To define values of the maximum probability, what types of failures/conditions are most likely to lead to the event Bi (accidents of the i-type).
5 To make the integral assessment of an emergency or the event Bi probability. The integral assessment P(Bil|Ajl) is calculated according to the law of addition of probabilities.
6 To calculate the average cost of the risk as a sum of products of weighted estimates of the j-type of the failure and the i-type of the damage at the ground l, to the cost of risk. This cost is determined by multiplying the probabilities of an accident arising to the amount of the damage from it.
7 To compare the calculated cost of the risk with the permissible amount of the risk. It is recognized that if there are no casualties, and the cost of risk is less than the expected commercial profit, the risk may be acceptable.

3 CONCLUSIONS

The risk assessment methodology in oceanic fisheries is based on the use of the general model of the scenario of emergency situations, the theory of fuzzy sets and expert assessments. The calculation of risk assessments should take into account the causal relationships in the logic of "the circumstances/conditions - cause - consequences."

The proposed risk assessment methodology includes both methods for calculating the probability of risk assessments during the oceanic fishery and calculating the price of the risk, i.e. the expected amount of the damage of the vessel, cargo, environment in a case the situation of the risk will be realized (the accident occurs).

To make a decision regarding the admissibility of the risk (assuming that there is no threat to human life) the value of the risk price should be compared with the expected commercial profit of the fishing vessel operation. In the case where the expected profit is higher than the risk price, such a risk for commercial reasons is acceptable. Calculations of probabilistic risk assessments make it possible to estimate the degree of the risk and to develop measures to reduce the level of risk to its allowable values. Risk management will improve the safety of the fishing fleet in oceanic fishery.

REFERENCES

Abchuk V.A. 1983. *Risk theory in the marine practice*. Leningrad: Sudostroenie (in Russian)

Final Report of Flagship Project 2014. “To lay the groundwork for developing a plan to reduce the number of accidents in fisheries”. EU strategy for the Baltic Sea region. Baltic Sea Advisory Council. http://www.bsac.dk/archive/ Dokumenter/Flagship%20Project/BSAC%20Safety%20Report%20FINAL.pdf

Gucma M. 2008. Combination of processing methods for various simulation data sets. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 2(1): 11-15

Jin D., Kite-Powell H.L.Thunberg, E. Solow A.R. & Talley W.K. 2002. A model of fishing vessel accident probability. *Journal of Safety Research*, 33: 497-510

Kirichenko A.V., Latukhov S.V., Nikitin V.A. & Ragev O.A. 2014. *Organizational and technical foundations of ships and port facilities security.* S.-Petersburg: SUMRF of Adm. S.O Makarov Publ. House (in Russian)

Kobyliński L. 2009. Risk analysis and human factor in prevention of CRG casualties. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 3 (4): 443-448

Kristiansen S. 2010. *Maritime Transportation: Safety Management and Risk Analysis.* Elsevier

Moyseenko S.S. & Meyler L.E. 2011. *Safety of marine cargo transportation.* Kaliningrad: BFFSA Publ. House (in Russian)

Moyseenko S.S., Meyler L.E. & Faustova O.G. 2013. Formation of the integrated risk assessment of a disaster in multimodal cargo transportation. *Proc. X Baltic intern. maritime forum, Swetlogorsk 28–31 May 2013*. Kaliningrad: BFFSA Publ. House (in Russian)

Moyseenko S.S., Meyler L.E., Bondarev V.A. & Faustova O.G. 2014a. Analysis of the problem of risk assessment in commercial fishing. *Proc. XI Baltic intern. maritime forum, Swetlogorsk 26–30 May 2014*. Kaliningrad: BFFSA Publ. House (in Russian)

Moyseenko S.S., Skrypnik V.P. & Faustova O.G. 2014b. Differential-integral approach to modeling the processes of development of emergencies in navigation and ocean fishing. *Bulletin of State University of sea and river fleet of admiral S.O. Makarov* 4(26): 47-53. (in Russian)

Perez-Labajos, C. 2008. Fishing safety policy and research. *Marine Policy*, 32: 40-45

Topalov V.P. & Torskiy V.G. 2007. *Risks in navigation*. Odessa: Astroprint (in Russian)

Ventzel E.S. & Owcharov L.A. 1973. *Theory of probability*. Moscow: Nauka (in Russian)