Forecasting the occurrence of risks and the dynamics of their development in navigation

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Abstract: *Analysis of claims incoming over the past years and the industry data on losses in supply chains allows to identify the most common risks and pay attention to the necessary measures to protect cargo during transportation.*
Sometimes it is difficult to establish the relationships between a specific event and business, then logisticians use a probabilistic approach. They predict how events can develop in the future. Each outcome is calculated and assessed as a separate risk.
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1. Introduction

The risks in the international supply chain are the probability that a particular event with negative consequences will occur. In order to minimize risks, negative events that can occur in the course of maritime traffic are predicted.

There is no single and universal transport risk assessment tool. In every particular case specialists make a list of all possible risks and determine the share of each one. What factors affect safety and profitability of international cargo transportation and how to minimize logistics risks?

Of the variety of risks that are most often encountered in multimodal transportations we can distinguish three main groups: 1) risks of vehicle breaking down and loosing cargo; 2) risks of accidents and emergencies not entailing loosing vehicles and cargo; 3) risks of failures of equipment that ensures the transportation and security of cargo. Based on the analysis of a large number of accidents of marine vessels and ground vehicles, we can conclude that, in general, the accident scenario has been developing according to the scheme shown in Figure 1 [1].

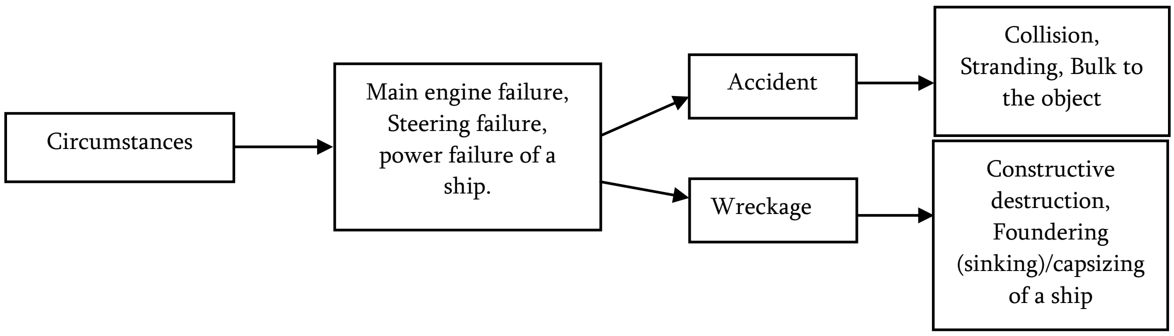

Fig.1. *A generalized scheme of scenario for the development of an emergency situation*

To minimize the risks of losses in international trade, logisticians consider different scenarios, and specialists must have indirect routes and solutions in stock. They regularly monitor the requirements and conditions of regulators: what transport and which communication routes will remain available. Let us consider some methodological basis for forecasting the occurrence of risks of emergencies and the dynamics of their development with an example from navigational practices.

The vessel proceeds to the port on course 20 degrees along the coastline. Analysis of vessel's technical condition and statistics of failures of equipment (main engine and steering) shows that there is a probability of their failure. So, during 3 years, the forced of the main engine occurred 28 times. The main cause was cracks in the cylinder heads, steering failures occurred 5 times (note that the vessel in question was far from being in the best technical condition, and its age was over 20 years). In this regard, to ensure the safety of navigation, it is advisable to develop a methodology for forecasting of risks of the occurrence and development of an emergency.

The initial information to analyze the situtation is as follows: distance to the coastline - 15 miles, the coastline is rockier, depths under the keel more than 150 meters. wind 7 m/sec from NNE, southerly current at a speed of 1-1.5 knots. In this situation, there are risks of the main engine or steering failure.

The first task of the emergency ship’s captain is to inform the ship owner and insurance company about the incident and situation, as well as contact the passing ships and ask to stay within a few hours until a more complete assessment of the situation and making a decision on the involvement of rescuers.

The first task of the ship's chief engineer is to find out the causes of an engine stop and the nature of the damage.

The main threat is that the vessel may, under unfavorable circumstances, be thrown onto a rocky shoal. Thus, the ship and the crew may face an emergency situation (ES). In order to assess the situation and make a decision, we will use the methods of scenarios and the fault tree. The method of scenarios is a complex method of forecasting complex processes with structural shifts. It consists in establishment of a logically connected sequence of events of step-by-step transition from the existing state of the forecasting object to its future state. Usually, when forecasting by scenario method, there is always a time coordinate, that is, the process takes place over time.

Figure 2, illustrates the dynamics of ES development. [1]

The two worst cases of the ES development dynamics are presented in the scenario. The analysis of the scenarios suggests that the worst case scenario includes events 1 - 2 - 3 - 6 - 8 - 9 - 11 - 14 - 15. However, the second case 1 - 2 - 3 - 7 - 8 - 10 - 12 is also dangerous, but such a danger may arise only in case of the strengthening of the wind up to a “storm” level. Let us assume the weather forecast for the next three days is favorable (during the forecast period weather conditions in this area are favorable).

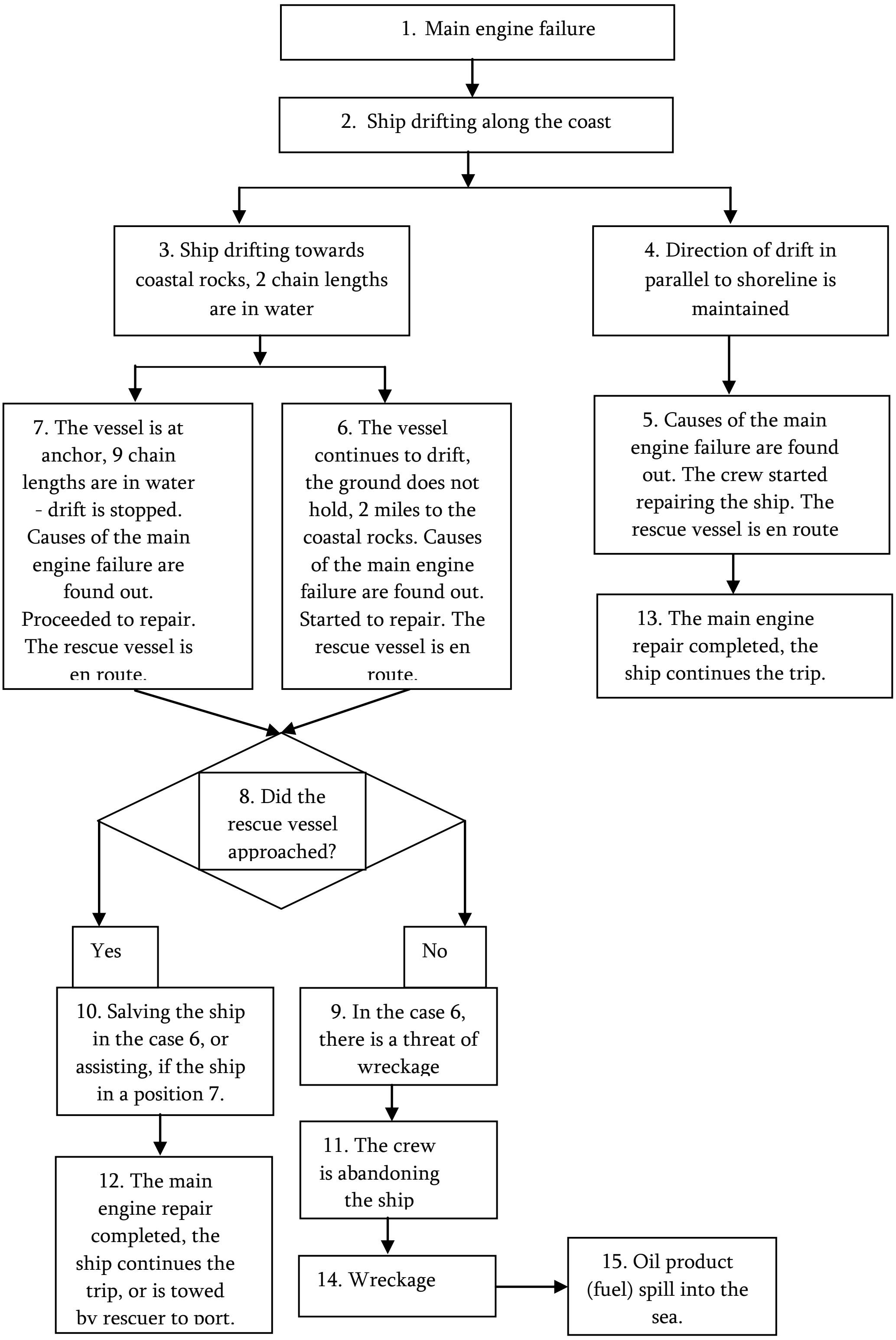

Figure 2. *The ES development scenario*

2.Preconditions and means for resolving the problem

Let us consider the threats posed by the case 1 of emergency development. In this case, the anchor does not hold, since the depth is more than 120 m, and the ground is stony, as a result, with wind force of 7 m/sec and the current speed is 1.5 knots, the vessel will drift about 1, 7 miles per hour. In this case, the vessel will drift for 6.5 hours to a depth of 120-150 meters. At that depth (the vessel will be 3.5 miles from the shoal), the anchor will be on the ground, but since the ground is rocky, the vessel will drift at about 0.4 miles per hour, that is, the vessel will be on the shoal in 8.7 hours. Thus, the ship will be on the coastal shoal with stony ground in 15 hours from the moment of stopping (engine failure).

Assume that the cause of the main engine failure is related to a crack in the bottom of the cylinder piston and damage to the exhaust-gas receiver (due to the explosion of oil cooling the bottom of the piston). In this case, in order to put the cylinder unit back into operation, the piston must be replaced and a bandage put on the crack in the receiver. According to experts, these works will take 15-17 hours. Consequently, it is necessary to "hold" the vessel at a safe distance from the coastal shoal for at least 18 hours.

In this regard, the rescue ship must be in the area of the emergency ship in full readiness in the next 5-6 hours. The decision to involve a rescuer in the towing should be made on the basis of the analysis of the emergency development dynamics.
In order to isolate cause and effect linkages and make prognostic estimates of the ES development, we will develop a fault tree reflecting the dynamics of the ES development (Fig. 3).

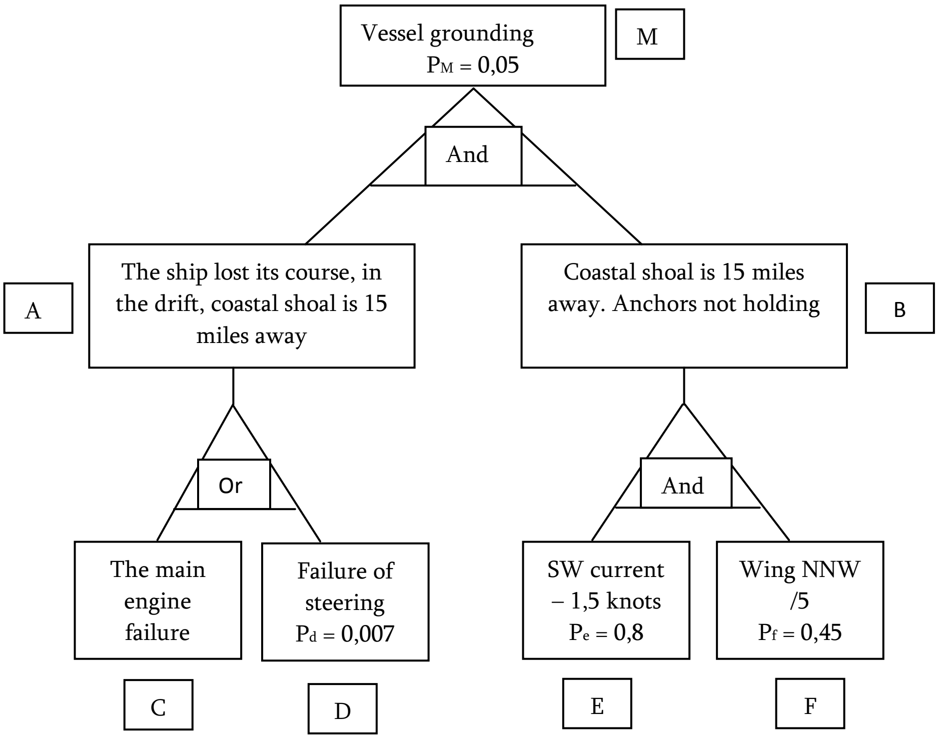

***Fig. 3.** The fault tree – ES developments (vessel grounding)*

The top of the tree (M) is where the ship runs aground and is damaged, two events may lead to the grounding, these are the branches of the tree. These events are connected to the top of the tree by a "wicket" [2] by condition "and", because grounding can occur if both of these events occur simultaneously.

When calculating the probabilistic estimates of the occurrence of events, there are difficulties in determining their quantitative values. There may be two cases here: 1) the law of distribution of random variables/events is known and there is representative statistical sampling, which is typical for frequently recurring events; 2) the law of distribution of random variables/events is not known, which is typical for conditions of uncertainty, when the researcher deals with poorly studied phenomena.

Thus, in the first case, obtaining quantitative estimates of the probability is not difficult. In the second case, if the law of distribution of random values/events is not known, then for convenience of calculating probability estimates, they assume that random values have a beta distribution. The choice of this law cannot be strictly justified. It has a density function resembling Gauss's law, but left and right bounded.

The beta (β) distribution considered in the context of our task is chosen so as to calculate the value of the probability of the occurrence of a random e vent and the dispersion according to the formulas:

$$P_{ож}=P_{min}+4P_{НВ}+P_{max}6,$$

Dispersion $\delta 2$ is calculated by formula:

$$\delta 2=(t_{max}-t_{min}26),$$

The minimal, most probable and maximal values of probability have been determined by experts. The opinion of experts was based on the analysis of data on cases of the main engine and steering failures on the "JHON-N"-type vessels. The probability estimates regarding the flow and wind were determined taking into account the wind rose analysis for the considered season/month of the year, current maps, and location data. Synoptic maps and weather forecasts of coastal hydrometeorological stations were analyzed in the short term. The signs “and”, “or” are used when in between one event to the next. In the case of the “and” sign, the probability estimates of events are multiplied, and in the case of the “or” sign, the estimates are added up [2]. The probability estimates of the occurrence of events can be determined by the method of fuzzy numbers, but this method is more time consuming and requires to perform a large number of calculations, and also yields approximate results.

3. Conclusion

The analysis of a fault tree reveals that the risk of the ship running aground is not too great (the frequency of the occurrence of the event is within (10-1 ÷ 10-2), that is, we have a case of a critical event, and the risk will be lower than the acceptable level as long as the necessary dafety measures are undertaken. As a safety measure, it is possible to recommend setting the course of the ship at such a distance from dangers (if possible) that in the event of failure of the ship, the ship could drift on clear water for 18-20 hours (the time required for repairs). The main task of the captain is to take all possible measures to keep the hip on a deep water until the rescue ship arrives. It is necessary to develop and implement a plan of measures aimed at reducing the risk of grounding.

When developing a plan, it is necessary to be guided by the principles: necessity, rationality, realizability, and “do not harm”. The first concern of the captain is the safety of people. The crew must stay on the vessel until the vessel is a safer place to be than any other means. In the case under consideration, the large-tonnage vessel aground does not pose any danger to the crew.

In the situation under consideration, the following measures can be suggested:

1. To agree with the insurers and shipowners on the question of the vessel/tug-rescuer and the time of its arrival at the scene of the accident. To cennect the ships that are in the area of accident.
2. To drop both anchors to reduce drift rate.
3. To drop 9 shackles of one anchor when ship is accessing the depths of 100-120 m.
4. To drop another anchor (if necessary) when accessing the depths of 70-100 m.
5. To prepare the rescue means for the case of leaving the ship by the crew.
6. To perform an analysis of hydrological and meteorological information on the area, as well as available weather forecasts. On the basis of the analysis, to determine the prognostic estimates of the development of drift rate of the ship, including drift with anchors on the ground (for the case when the ground does not hold).
7. To ensure continuity of control, obtaining information about the state of the ship and the environment, its analysis and correction of management decisions.
8. To secure sustainable interconnection and interaction with a rescuer ship.

In the instant case, if the ship is thrown onto rocky ground, there is a high probability of holes in the bottom of the ship, which poses a threat of spillage of fuel and petroleum products into the sea. It should be noted that in the considered area of the accident, it is not possible for the crew to localize the fuel spill zone. The captain of the ship must give relevant information about oil pollution to the relevant authorities in accordance with the requirements of normative acts in force.

Thus, the scenario and the event tree reflect the dynamics of the development of ES. In the case of ship landing on sand/stone ground, two main outcomes are possible: 1) constructive destruction of the ship, that is, loss of the vessel in case of heavy weather conditions (westerly winds over 20 m/sec.); 2) if the damage to the hull is limited to holes in the bottom of the vessel and the weather allows rescue operations, then the decision to raise the vessel from the ground is taken by the shipowner jointly with the insurers.

4. References

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