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Oil Spill Response Capability Building in China and Her Road Map

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ABSTRACT 299416:

In recent decades, China's strong economic development has brought higher risk of oil spill at sea from ships, oil exploration and land. Accordingly, China government has enacted some new laws and policies such as the compulsory requirements on certain ships calling Chinese ports enter into a preparedness and response contract with a pre-approved response organization, up to now, there are already 137 private oil spill response organizations along the coastline. Also, the port operators are required to invest on oil spill response equipments depending on the result of risk assessment. At the same time, the central government has invested more 20 stockpiles along the sea port and Yangzi River. Nowadays, the amount of clean-up equipments has reached to a historical high level, and the total investment in recent three years is near ten times more than those ten years ago. Therefore, scientific evaluation of the risk and its spatial distribution of oil spill, and development of the reasonable and effective oil spill response capability planning, are the major demands for marine environmental risk management in China. To solve the issues above, a model with oil spill risk evaluation and multi-objective response resources layout is proposed for multi–sources risk. Hopefully, the model will be used to develop the national plan for National Contingency Plan for oil spill capability building in China.

Keywords: Oil spill risk; capability building planning; risk simulation; multi- objective optimization

INTRODUCTION:

In recent years, continuous high-speed development of China's economy has brought increasing demand for the energy, which brings China to be the second largest oil consumption country just behind the United States. China's crude oil import reached 2.71 hundred million tons in 2012, among which more than 90% are transported by sea. According to the statistics data from the Maritime Safety Administration of China, 5200 thousand tons of oil carried by more than 400 ships of oil tankers is shipped in the coastal waters of China per day. At the same time, there is a new climax of development and exploitation in China's coastal areas, as a consequence of which, the offshore oil platforms, coastal oil storage facilities, oil tankers at sea and undersea pipelines have formed the comprehensive sources of

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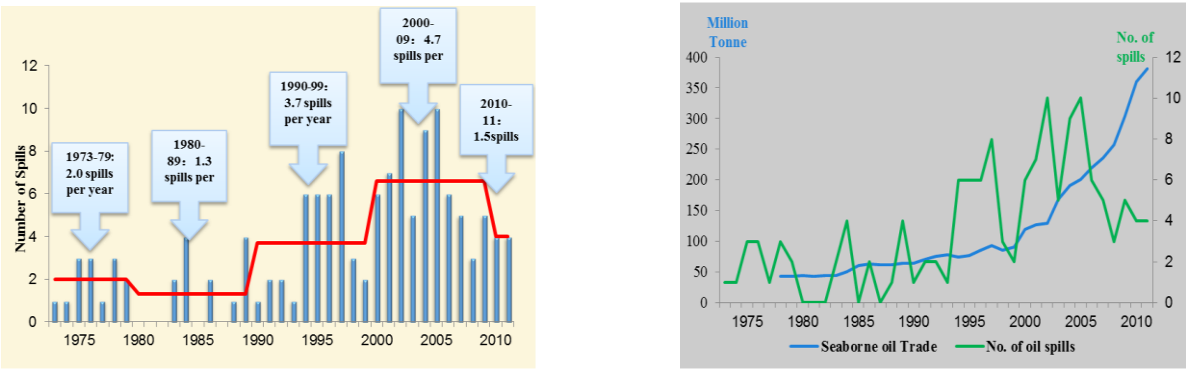
oil spill risks. Oil spill risk situation is not optimistic. Statistics also show that oil spill is in a period of high in China's coastal waters. Figure 1 (a) shows the trends of oil spill occurrences which is more than 50 tons in China’s coastal waters, and the development trend of China’s oil transportation at sea is shown in Figure 1 (b).



(a) Accident statistics of oil spill which is more than 50 tons

(b) Oil transportation and oil spill accident in China’s coastal waters

Fig.1. Ocean exploration and the trend of oil spill accident in China [1]

THE STATUS OF OIL SPILL RESPONSE CAPABILITY IN CHINA:

The National Plan for Waterborne Safety and Rescue System Layout in 2007 gave a road map to build 29 national oil spill response equipment stockpiles/stations. Up to now, 25 oil spill response equipment stockpiles/stations have been built in high-risk of oil spill areas along the Yangtze River and sea ports, and the rest have started the preliminary work. The national of oil spill emergency capability increased significantly in recent years.

To promote the growth of the professional oil spill response capability, China government has issued the Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels, the Regulation on Emergency Preparedness and Response on Marine Environment Pollution from Ships (i.e. Decree No. 4 of 2011) and other relevant laws in recent years. The laws above require that the ports should have the emergency capability which is commensurate with the risk of pollution from vessels, and that ships should sign agreement with qualified oil spill response origination for oil spill preparedness and response. These policies have contributed to the rapid growth of industries’ capability. Since the implementation of these regulations, there have already been 137 private oil spill response organizations along the coastline. Nowadays, the amount of clean-up equipments has reached to a historical high level, and the total investment in recent three years is near ten times more than that in ten years ago.

The Pipeline Oil Spill in Dalian, 2010 and *the Penglai 19-3 platform Oil Spill* in Bohai Sea, 2011, has caught a great concern from the government and society. Some concerns arising accordingly are whether the capability is enough to tackle the risk of oil spill or whether it is just surplus or waste of money, and then what the next step and direction are for Chinese policy makers to promote the overall capability. Therefore, the state authorities are assembling the national plan for oil spill emergency capacity building, which has great significance to improve the Chinese marine oil spill emergency ability and preserve marine environmental security.

THE OVERALL APPROACH OF OIL SPILL EMERGENCY CAPABILITY BUILDING PLANNING:

Technology route

The Planning is guided by relevant international conventions and national laws, and is based on relevant shipping, offshore oil development and petrochemical industrial layout planning. Combining case studies, model computing, expert advice and other technical method, the oil spill risk areas is identified with consideration of the factors such as accident probability, scale, pollution damage, spatial distribution, etc. To control the risk, the oil spill response capability building plan is presented from four aspects, i.e. the organization, surveillance, equipment stockpiles and strike team. The overall technology route of research is shown in Figure 2.

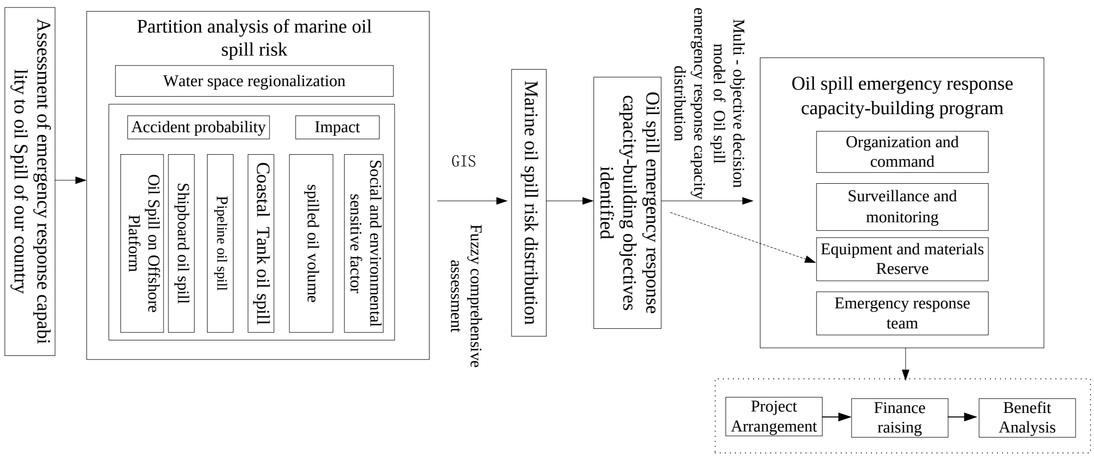


Fig.2. The technology roadmap of oil spill emergency response capacity-building plan

Building contents

The oil spill emergency capability at sea in this plan is the emergency capability to tackle the troubles after the accident, including oil spill emergency monitoring and surveillance, command, equipment and team building four parts. They are shown in Figure 3.

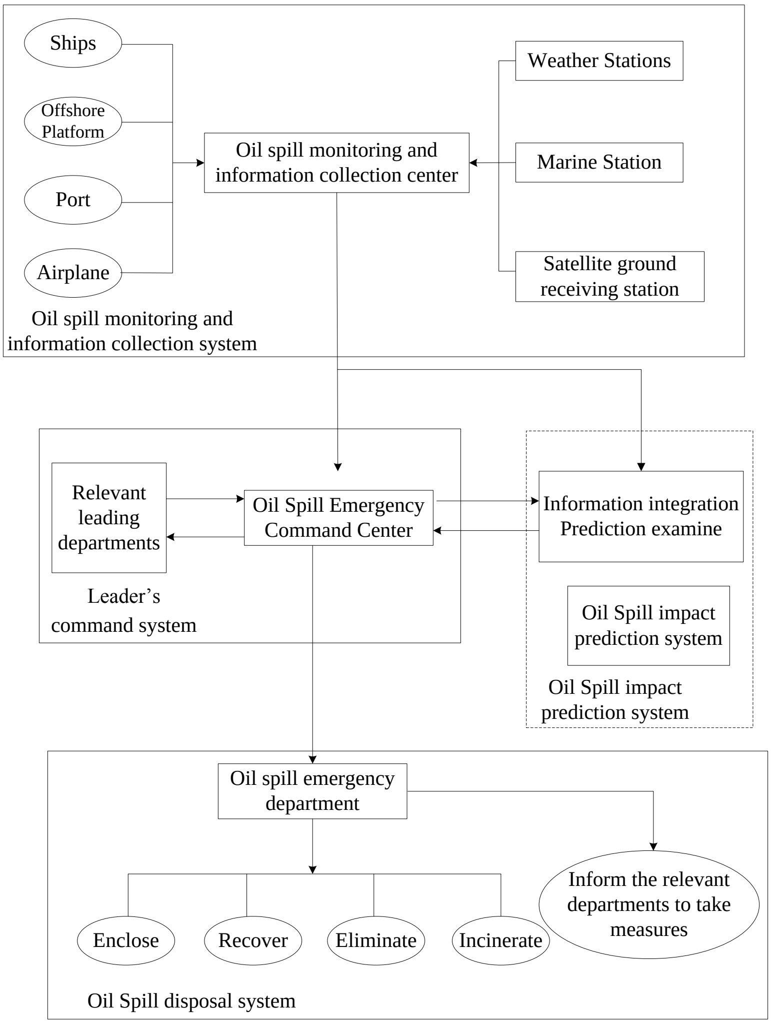


Fig.3. The main contents of planning building

Oil spill risk analysis [2-8]

Oil spill risk assessment normally consists of two components: accident probability and its consequence. To evaluate oil spill accident probability, we have to analyze the occurrence possibility of the four kinds of marine oil spill accidents, i.e. oil spill from ships offshore platform, oil pipelines and coastal storage tanks. The consequences of the oil spill accident are evaluated based on the amount of spills caused by different types of accidents as well as the social and environmental sensitive factors affected by oil spill.

To assess oil spill risk, mathematical statistics, GIS and comprehensive evaluation methodologies are used. First of all, water areas are divided into spatial grid cells according to its geographic information. Then, combined with the distribution of potential pollution sources and environmental sensitive resources targets, the oil spill risk of each grid cell and its pollution damage by the accident are comprehensively evaluated. Finally, the distribution of oil spill risk in China's coastal water could be drawn with the application of GIS. The technology route of oil spill risk analysis is shown in Figure 4.

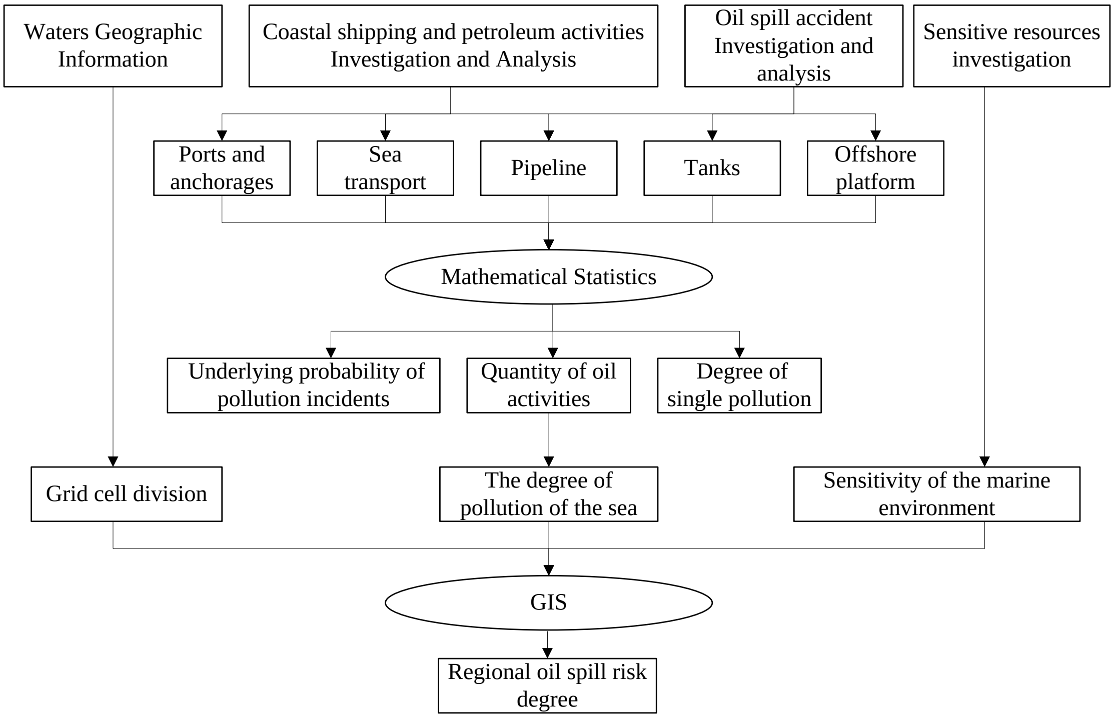


Fig.4. The technology route of calculation of oil spill risk index

The grid cell division of water areas

The key to divide water areas are the method of division and size of grid cell. According to the geography position and size of the water areas, China's coastal waters are divided to different size of grid cells in order to fully reflect the spatial distribution characteristic of offshore activities and the time-space requirements for oil spill response. The grid cells are divided to four types, i.e. coastal area, near shore area, offshore area and far-sea area. In this study, in consideration of the characteristic of nature environment and other factors which influence the oil spill accident probability, China's costal waters are divided to Bohai Sea, Yellow Sea, East China Sea and South China Sea.

Oil spill pollution index

Oil spill pollution index in each grid cell is given by the following steps. First, spatial distribution of historical oil spill accidents and the amount of oil spill are obtained from the statistic data of oil spill accident caused by the four kinds of oil spill sources. Then, with consideration of the meteorological and hydrodynamic conditions, the amount of oil spill accidents in current and future, pollution scope and extent are comprehensively analyzed and assigned to the corresponding grid cell based on the oil spill risk situation and the future trend. Finally, oil spill pollution index of each grid cell is calculated by adding the single pollution index of the four kinds of oil spill sources.

(1) Amount of oil spill

On the base of the statistic data of shipping routes and ship types from AIS, the risk level in shipping routes is analyzed using the GIS technology by input of the annual average amount of oil spill from ships. Then, based on the position and scale of sub-sea pipelines, storage tanks and oil platforms, the risk levels of these facilities are comprehensively calculated by GIS technology. Finally, combined with the annual average amount of oil spill of each sources, the risk level in the grid cell is obtained.

(2) Pollution consequences

The level of pollution consequences is expressed by considering the factors such as the amount of oil spill, probability of pollution, maximum thickness of oil film and the arrival time of oil to sensitive resources. The level of pollution in each grid cell is graded by oil spill trajectory model.

(3) Comprehensive pollution index

For each grid cell, the single pollution index of four kinds of oil spill sources are put together to get the comprehensive pollution index. Then, three indicators are introduced, the pollution probability, the maximum thickness of oil film and the shortest arrival time, to calculate the comprehensive pollution index. The formulas are as follows:

$$C_{ij} = \sqrt{P_{ij} \times H_{ij}^{'} \times T_{ij}^{'}} \tag{1}$$

$$H_{ij}^{'} = (H_{ij} - \min(H_i)) / (\max(H_i) - \min(H_i)) \tag{2}$$

$$T_{ij}^{'} = \begin{cases} (\max(T_i) - T_{ij}) / (\max(T_i) - \min(T_i)) & T_{ij} \neq 0 \\ 0 & T_{ij} = 0 \end{cases} \tag{3}$$

where C_{ij} is the oil spill pollution index in grid cell j caused by the oil spill source i; P_{ij} is the oil spill pollution probability in grid cell j by the oil spill source i; H_i is the maximum thickness of oil film in grid cell j by the oil spill source i; T_i is the shortest arrival time of the oil film to the grid cell j from the oil spill source i; $H_{ij}^{'}$ is the standardized maximum thickness of the oil film; $T_{ij}^{'}$ is the standardized shortest arrival time.

The maximum thickness of the oil spill film $H_{ij}^{'}$ and the shortest arrival time $T_{ij}^{'}$ calculated from the oil spill numerical model should be positive and negative standardized to make them in 0~1. On this basis, the characteristic of pollution index for each oil spill source could be compared and added to get the apprehensive pollution index.

Oil spill risk index

Oil spill risk index represents the degree of oil spill pollution to the environment, and it is the comprehensive results of the oil spill pollution index and sensitive level of environmental protection target.

The sensitive environmental protection targets at sea are divided into five levels according to the importance of environmental protection targets and its sensitivity to oil spill pollution. The valuation by geometric sequence is assigned to each grid cell.

Oil spill risk index is introduced to represent the oil spill risk to the spatial geographical grid cell. The index is comprehensively calculated by probability of relative accident, oil spill pollution index and marine environmental sensitivity. Based on above, the description of risk distribution and the comparison of risk in each grid cell could be achieved.

(1) Oil spill risk index

The formulation of oil spill risk index is as follows:

$$R_{ij} = p_i \times C_{ij} \times S_j \tag{4}$$

where R_{ij} is the oil spill risk index in grid cell j by the oil spill source i; p_i is the relative probability of accident by the oil spill source i, that is the source coefficient. It could be obtained from the historical statistic data of different accident types; C_{ij} is the oil spill pollution index in grid cell j by the oil spill source i; See the formula 3; S_j is the environment sensitivity of the grid cell j.

(2) Oil spill risk index of single source

The oil spill risk indexes of each oil spill source in every grid cell are superposed to obtain total oil spill risk index of each oil spill source.

$$r_i = \sum_{i=1}^{n} R_{ij} \tag{5}$$

where r_i is the total value of oil spill risk index of a certain oil spill source; R_{ij} is the oil spill risk index in grid cell j by the oil spill source i.

(3) The comprehensive oil spill risk index of multi types of oil spill source

The oil spill risk indexes of each oil spill source in corresponding grid cell are superposed to obtain comprehensive oil spill risk index of multi types of oil spill source.

$$O_j = \sum R_{ij} \tag{6}$$

where O_j is the comprehensive oil spill risk index of a certain grid cell.

The oil spill risk is divided into five levels, i.e. high risk, mid-higher risk, medium risk, mid-low risk and low risk, based on the planning need. Then, the distribution of oil spill risk could be drawn.

Multi-objective optimization layout model of oil spill response resources [9-17]

Multi-objective optimization layout model of oil spill response resources are described as Figure 5 shown. All the places that could be built as response resources stockpiles are set as the candidate stations, and generally they are only located at coastal area in order to facilitate transportation and clean-up at sea. Whereas, the locations at sea which have a certain level of risk and need response resources are called as risk demand locations. Assuming that there are M candidate stations of oil spill resources stockpiles and N risk demand locations, the distance between each candidate station and oil spill risk demand location is labeled as D(M,N). The risk value of each risk demand location is R_i, and the risk grade value of is λ_i.

Each candidate stations can be built C_i resources stockpiles and the cost of them is Q_i. The service radius of resources stockpile itself is d, and the risk demand location within the service radius should be covered. Response resources layout issues are expected to select appropriate places in candidate stations to build resources stockpiles and the places should meet the following objectives: (1) All the risk demand locations are fully covered. (2) It should be with the fastest response reaction, which means the total distance between stockpiles and all of the risk demand location is shortest. (3) Define the overall capability of stockpiles as that the sum of capability of each risk demand location could get, and give priority to demand locations with high-risk. It means that these high-risk demand locations get the maximum service of the response capability. (4) The total cost for constructing the stockpiles shall be kept at as minimum level as possible.

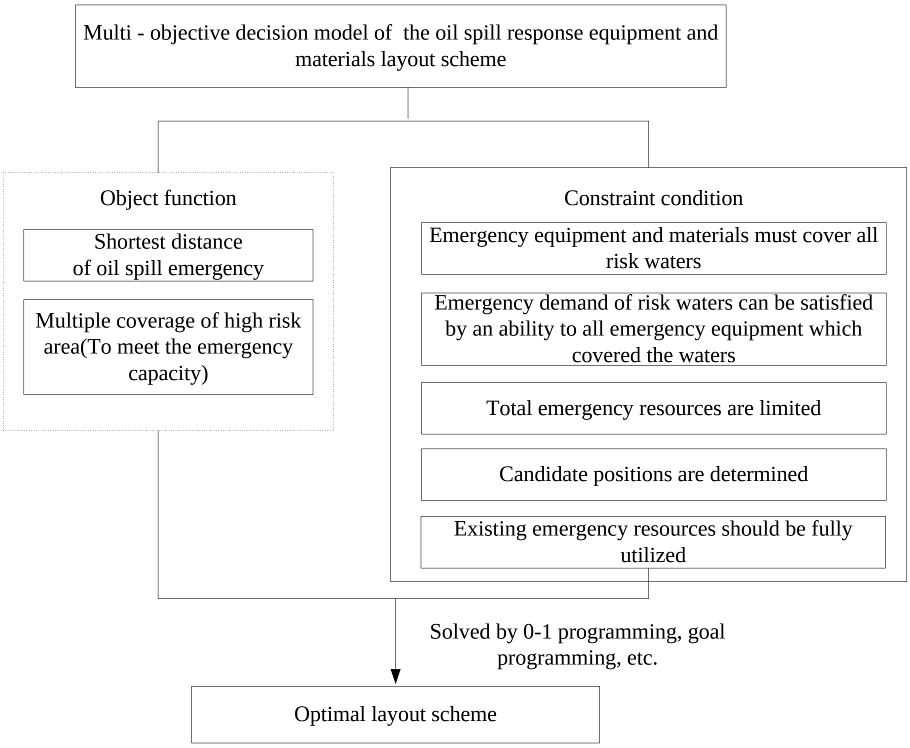


Fig.5. The technology route of Multi-objective decision model

CONCLUSIONS:

In this study, the oil spill pollution index and risk index are calculated to represent the distribution of oil spill risk by oil spill risk evaluation numerical model with consideration of factors such as location and scale of oil spills. In order to reduce the pollution damage of oil spill accident, multi-objective optimization layout model of oil spill response resources is used to get the spatial layout of oil spill response resources stockpiles. The model is based on the timeliness, effectiveness and economy of emergency management. At last, the response vessels, equipments and other resources could be assigned according to the characteristics of different regions. The technology route and methodology described in this paper will be applied to the National Contingency Plan for oil spill capability building in China. It is hopeful that the National Plan could be promulgated and implemented to promote the overall capability of oil spill response in China.

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