Improving Emergency Supply System to Ensure Port City Safety

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ABSTRACT: To efficiently implement emergency response program to port unexpected incidents, a perfect emergency supply system which including communications supplying, transportation supplying and rescue equipments supplying must be ready-to-used. Considering physical geography, harbor area, possible incident type and incident scale and other factors, using multi-objective fuzzy decision theory to set up emergency supply centers, improving sharing resource mechanism, administrative legislation and other measures are be used to improve port emergency supply system. Shanghai port's practice prove the improve port emergency supply system is effective.

1 INTRODUCTION

In the last two decades, the boom in international trade and the function expanding of port, have led to more vessels to get in and out port water. There has been a strong focus on the relationship between port water unexpected incidents and port authorities, vessels, berth operators, onboard and port workers, terminal operators, owner and operators of different transport modes interacting with the port water area (rail, road, inland navigation). Port water incident is a kind of serious disaster with high consequence. A disaster at port water is an accident which affects the vessel, the berth, the persons on board or berth, the cargo or the environment.

Marine traffic risk has been a core subject in maritime studies, because it is coupled with transport safety, shipping efficiency, distribution reliability and loss prevention (Tsz Leung Yip, 2006). Some coastal countries have undertaken the task of equipping their coastline with the appropriate sea rescue means, following the guidelines of the International Maritime Organization and in accordance with the International Convention of Search and Rescue (IMO, 1974, 1999). Meanwhile, some decision-making methods have also been used in the sea shipping areas. Port water area is much different from sea water in navigation density, width of fairway, type and number of vessels, and other navigation environment. Meanwhile, vessels' berth and anchorage operations, port operations, port and waterway engineering operations, can lead port water accidents.

The port water incidents to which this work refers are those which occur in port water region. The port water region is the water area within the port bound lines. It includes berths' connecting water areas, port fairways, vessel turn around areas and port anchorages.

Although the port authorities do their best to improve the port water's navigational environment, port city safety is still faced with port operation accidents, maritime accidents, and result in personnel injury or death, property loss, as well as severe environmental damages. If effective rescue operation cannot be taken immediately, a great ecological or economic tragedy is unavoidable. Therefore, the port water incident rescue is an emergency operation that requires quick response.

From the technical viewpoint, port water rescue can be defined as an external action aimed at rescuing persons, vessels, public property, and protecting

water area environment from an incident which is immediate and irreversible unless action is taken.

The main activity of the port water emergency rescue services is to attend to incidents that occur in the port water environment. These are services related with the activation of extinguishing a fire, the withdrawal of floating and sinking objects which are dangerous for navigation, separating the unsafe vessel, controlling and clearing up the leakage matters, medical rescue.

When an incident occurs, the authorities in charge the port water area send all of the corresponding reports to the government centre of the port city and to the superior port management department. With this data, official statistics are drawn up, using various parameters related to the characteristics of the vessel and the berth, type of accident and damage incurred. The distribution of the port water rescue resources is planned by using this incident data and the characteristics of the possible locations.

The response time is critical in rescue operations and the rescue charge is very high. The port water rescue activity must be carry out immediately at the time that the emergent rescue centre accepts the official reports. The emergent rescue plan made under time limiting pressure may be not a good one and delay the rescue. The process of planning sea rescue resources and their distribution in the various locations should be carried out according to scientific criteria, both of a technical nature and in terms of cost-effectiveness.

The paper first provides an analysis of the incidents type in the port water area and the relevant rescue resources. Then outline the multi-objective fuzzy decision method based on timeliness and economical efficiency target. At last, describes a practical example of the distribution of a rescue resource and draw some conclusions on the method proposed.

2 INCIDENT TYPE AND THE NECESSARY RESCUE RESOURCES OF PORT WATER AREA

2.1 *Critical characteristics of the port water area*

Vessels passing in and out the water area, vessels' berthing operations, vessels' anchoring operations, port and waterway engineering operations, make the port water area is the busiest navigation area, and bring the port water area's safety faced with more menaces. Port water area's navigation environment is associated with a number of critical characteristics:

- High traffic volumes;
- Wide variation in vessel size and types;

- High portions of speed craft and ferries;
- Close proximity of marine facilities within a small geographic area;
- A high proportion of coastal and inland water craft;
- Active mid-steam operations for cargo movements;
- Lots of port and waterway engineering operations;
- Multiple water approaches to the port and
- Lots of anchoring areas.

Above characteristics are disadvantageous in port water area. The following are several advantageous key characteristics:

- Good navigation traffic control of vessel activity;
- Perfect navigation system and
- A high level of reporting of port water area incidents.

2.2 *Incident types in the port water area*

The causes of port water area incident can be various, such as design defects of vessel, navigation traffic events, port operation accident, port and waterway engineering operation failure, badly weather and other disadvantageous factors. The direct impacts of the disaster may include oil/chemical spills, raw sewage discharges, cargo losing, fairway blocks, port paralysis, crews and workers casualties, with indirect impacts such as ecology disaster.

Table 1 illustrates the accident types and the possible consequences of each kind of accident.

Table 1 Incident types and the possible consequences

Type of incidents	Possible consequences
Vessel accidents	Fire/explosion
	Danger cargo falling
	Gas/liquid leakage
	Collision/contract
	Stranding/grounding
	Foundering/sinking
	Capsized/list
	Man overboard
	Structural failure
	Others(e.g., machinery failure)
Port operating accidents	Fire/explosion
	Danger cargo operation failure
	Gas/liquid leakage
	Damage to equipment
	Capsized/list
	Damage to wharf
Heavy nature damage	Fire/explosion
	Danger cargo falling
	Gas/liquid leakage
	Damage to equipment
	Capsized/list
	Damage to vessel
	Damage to wharf

Each kind of incident needs the suitable rescue resources to effectively carry out emergency response.

2.3 *The point of determining how to response the incident*

Port water incident rescue gains great attention from decision-makers and researchers. On reporting an incident, it always covers the precise location, the latest condition, and the physical parameters (type, construction, and size) of the disaster vessel, the berth, the fairway, the nature and quantity of the cargo, as well as the nature of the damage, in particular any harmful and poisonous substances. Therefore, port water area incident rescue is a necessary and complicated subject.

At the point of determining how to response the port water incident, some factors must be taken into account which is decisive in the process of distributing port water rescue resources. These factors consist of:

1 Characteristics of the incident, the wharf, the fairway, the vessel and the damage produced.
2 Types of the incidents and establishment of a scale of severity.
3 Risk source and sensitive area analysis.
4 Distribution of resources such as tug-boats, fire-fighting boat, oil-absorbing ship, rescue boats, cleaner vessel, helicopters, with a definition of their radius of action.
5 Placement of rescue resources assigning indicators of suitability to every possible incident location.
6 With shorter response time.
7 Cost-effectiveness.

3 METHOD FOR ASSIGNING PORT WATER RESCUE RESOURCES

In the port environment, rescue resources distribution is one of the most important parts of the port emergency response plan. In China, work on the emergency support system is managed by port authorities and the Ministry of Maritime Safety Administration. When the authorities draw up the emergency response plan, they firstly carry out hazards identification and evaluation, and study on sensitive areas according to port function zone.

The efficient assignment of port rescue resource requires, on the one hand, various port operation areas to be interrelated with areas in which accidents are concentrated and on the other hand, a planning process to be developed in which information on the past and present, as well as predictions on the future, are handled. The information is about vessels' information (type, size, performance, loading condition and, manning), port water's navigation environment (traffic flow, hydrological condition, meteorological conditions and, channel condition), and service at port (pilotage service, vessel traffic service, berth condition, and port operations).

Thus, the method to be applied in assigning rescue resources combines aspects of models for the location of port activities with elements of planning, such as port areas planning and port functions planning. A general methodology based on gravitational models to optimize distribute sea rescue resources has been applied to assign 'sea rescue boats' (Azofra, 2007). To overcome limited time pressure, while retaining minimum rescue project duration, a rescue plan for the maritime disaster rescue is obtained with the application of heuristic resource-constrained project scheduling approach (Liang Yan, 2009).

3.1 *Problem statement*

In the port emergency response plan, according to the characteristic of unexpected incident, the degree and the development, the scale of severity is classified into four grades: particularly serious (Grade I), grave (Grade II), severely (Grade III) and general (Grade IV). The particularly serious incident needs the nation to start the emergency response plan and dispatch domestic each kind of rescue resources, or even receive overseas support resources. The general incident can be deal with the port enterprise by self-prepared resources. The Grade III incident only needs the port authority to use resources of one rescue center. The grave incident needs more resources than one rescue center, so that several rescue centers need to take part in the rescue activity.

Here only the rescue resources distribution of the grave incident is discussed, that is to solve how to use more than two rescue centers to deal with unexpected incident. To the port city, the emergency resources candidate storages are those areas where many berths are concentrated. Port operation areas, port fairway and anchorages are those areas where need resources. To improve port city's safety and competitiveness, the port areas are planed scientifically according to the types of unload cargoes and berthing vessels. Berths with the same function are centralized in one area, so that vessels entering and outgoing the port area are the same. So that the possible incidents in the area are the same and the needed resources are regular. The locations of all of the rescue resources do not necessarily have to coincide and an incident at port water area may or may not require the presence of one or several means of sea rescue.

3.2 Multi-object decision models

The evaluation of location should be performed taking into account several factors of the accidents: their number, type, scale of severity and, considering that any accident should be responded to immediately, the distance between the place where the accidents takes place and the location of the resource to be used. Moreover, for any possible location (port zone, harbor enterprise) its suitability or capacity should be assessed (fire fighting, sewage cleaning and other rescue installations available).

The response time is critical in rescue operations. This will depend on the technical characteristics of the means of rescue used (speed and operability), on the distance to be covered and on the weather conditions at the time of the rescue. However, once the resource to be used is identified, the only controllable parameter is distance. Thus, for the purposes of the present work, it is assumed that time is proportional to distance.

Storage and usage rescue resources have to pay quite a large amount of money. On the one hand, to keep the resource storage into use need a vast cost, this is a flat-rate fee. On the other hand, sending resource from the storage point to demand points need fee which is related to means of delivery and transmission distances. Considering the economic target, the number of storage point to be used should be as small as possible.

The decision of distribution rescue resources is one kind of multi-objective problems. The targets of the decision are that the response time is short and the number of storage point to be used is small.

Provided that one port city has port areas as $B_1, B_2, \cdots, B_p$. The possible needed resources in the port areas are $X_1, X_2, \cdots, X_m$. Supposed that the port has n candidate resource storages $A_1, A_2, \cdots, A_n$. The flat-rate fee of each storage and the weights of the two criterions (timeliness and economic) are known. The weights of the two criterions can be gotten by using Analysis Hierarchy Progress (AHP) according to incident type and characteristic of the port area. The most proper decision is that the rescue resource support scheme based on an overall consideration of timeliness and economic factors. For one kind of incident, the rescue resources' support scheme has two targets as follow:

– The target function of economic

$$C = \sum_{i=1}^{n} \sum_{j=1}^{p} C_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{p} X_{ij} SC_i \qquad (1)$$

where C_{ij} is the costs of resources transmitted from storage $i (i=1, \cdots n)$ to the demand point j

$(j = 1, \cdots p)$; SC_i is the flat-rate fee of each storage i $(i = 1, \cdots n)$. X_{ij} is the criteria be used to judge whether the resource is transmit from storage i $(i = 1, \cdots n)$ to the demand point $j (j = 1, \cdots p)$. If the resource is transmit for storage i to the demand point j, $X_{ij} = 1$, else, $X_{ij} = 0$. And there is a relation: $X_{ij} = \mathrm{sgn}(C_{ij})$.

– The target function of timeliness

$$T = \max(\sum_{i=1}^{n} \sum_{j=1}^{p} X_{ij} \times T_{ij}) \quad (2)$$

where T is the timeliness target. T_{ij} is the time that the resource send form storage $i (i = 1, \cdots n)$ to the demand point $j (j = 1, \cdots p)$. If there are more than one storage to attend the rescue activity, the timeliness target is the time of the scheme with the longest time.

– The general objective
  Use the Linear Weighted Technique (LWT) to get the general objective:

$$S = \min(\lambda_1 T + \lambda_2 C) \qquad (3)$$

where $\lambda_1 + \lambda_2 = 1, \lambda_1 > 0, \lambda_2 > 0$. λ_1, λ_2 can be get by using Uncertainty AHP (WANG Zesheng 2007) based on incident type and incident degree.

Form the function (1) and (2), it is easy to see that the decision variable is X_{ij}.

4 EXAMPLE OF THE MULTI-OBJECT DECISION MODELS: ASSIGNING A RESCUE RESOURCE

The Port of Shanghai faces the East China Sea to the east, and Hangzhou Bay to the south. It includes the heads of the Yangtze River, Huangpu River (which enters the Yangtze River), and Qiantang River. The Port of Shanghai is a critically important transport hub for the Yangtze River region and the most important gateway for foreign trade. The port of Shanghai includes 5 major working zones as shown in Fig 1.

The possible main types of accidents occurring in each zone are shown in Table 2.

Table 2 Port zone area and possible accidents

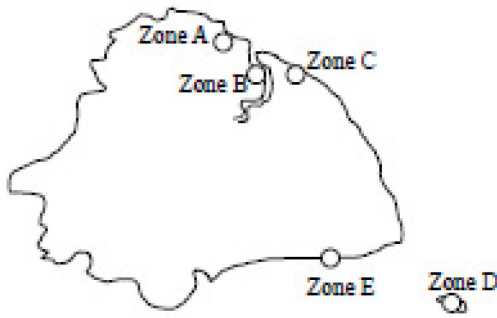| Port zone area	Possible accidents
Zone A	Collision/ Man overboard
Zone B	Collision/ Grounding
Zone C	Collision/ Damage to wharf
Zone D	Collision/ Damage to equipment
Zone E	Fire/explosion/Gas/liquid leakage

Fig 1 Port zone area

The distances between every zone are shown in Table 3.

Table 3 Distances between every zone (kilometer)

Zone	A	B	C	D	E
A	0	10	30	150	100
B	10	0	15	140	90
C	30	15	0	120	70
D	150	140	120	0	50
E	100	90	70	50	0

The supporting provided that every zone area is the candidate storage, the flat-rate fees of each storage are as shown in Table 4.

Table 4 The flat-rate fee of each storage (ten thousand Yuan RMB)

Zone	A	B	C	D	E
Fee	20	20	20	25	23

The costs of one kind of resource (for example for liquid leakage) transmitted form zone $i(i = 1, \cdots 5)$ to zone $j(j = 1, \cdots 5)$ are shown in Table 4.

Table 5 Transmitting costs between zones (ten thousand Yuan RMB)

Zone	A	B	C	D	E
A	0	0.3	0.5	2	1.5
B	0.3	0	0.4	1.8	1.2
C	0.5	0.4	0	1.7	1.1
D	2	1.8	1.7	0	1
E	1.5	1.2	1.1	1	0

To response liquid leakage accident in port areas, the timeliness is very strong. Set up $\lambda_1 = 0.8, \lambda_2 = 0.2$, by using the above multi-objective model, get that Zone A and Zone E are the best point to set up storage.

5 CONCLUSION

The principle on which a port city should take decisions about the supply center of port rescue resources should be based on highly objective criteria. At present, when assigning rescue resources, a wide variety of technical factors are taken into account (e.g. water area of the port to be covered, traffic flows and types of traffic, danger involved in these traffics and port operations, accident rates, port facilities). By using these factors it is possible to weigh the suitability of a candidate location. In fact, however, political factors often affect and the process of determining the supply center of rescue resources. Although it is the most subjective factor, it usually has the greatest weight in taking the final decision.

When assigning port rescue resources, it is necessary to use a holistic viewpoint of the problem. This vision is essential if the problem involves management of port water rescue resources. In practice, the management of all port rescue resources of a port city is interdependent, regardless of how they are distributed.

The proposed model is for individual allocation of port rescue resources supply center. The method presupposes that these resources supply center will be assigned one by one, but this does not imply that a previous assignment will not condition a later one. Therefore, once a given resource has been assigned, it must be considered in an interdependent way with the other resources located along the same zone of the port. In this context, it should be pointed out that the assignment of a resource to a location would lead to a reduction of the suitability factor of the rest of the possible locations near the selected location.

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