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Allocating emergency resource for leakage of dangerous chemicals at sea by fuzzy programming

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Abstract

In this study, we propose a fuzzy programming model that considers a single accident site and multiple emergency rescue bases. Various resource constraints, such as volume and weight capacity at the emergency rescue bases, are considered. Rescue funding availability is also integrated into the model. The results from a numerical example show that the model is mathematically valid and practically feasible. The proposed model can be used to provide insightful decision support information to liquid chemical leakage rescue effort.

Keywords: *emergency resources allocation; emergency bases; liquid bulk chemicals;leakage accident; fuzzy programming*

1 Introduction

In recent years, the volume of liquid bulk chemicals transported by sea is growing rapidly. This growth has led to increased number of accidents that are associated with liquid chemical delivery at sea. Large chemical leaking accidents happened in the US, France, Kuwait, Iran and many other countries. In 2010, BP spill caused another world's largest accidental leakage of oil into water and polluted the marine environment and damaged natural resources (Robertson et al., 2010).

Although emergency resource allocation is a very important environmental and safety issue, the published research regarding this problem is limited. Furthermore, most of the models are developed to handle overland emergency resource allocation problems that are not always appropriate to be applied to the maritime situation. This research deals with the challenge of maritime emergency rescue resource allocation issues. Specifically, we will exam the constraints in delivering rescue services, the allocation of different resources, and the configuration of emergency rescue-based networks.

2 Literature

The published literature on emergency rescue resource allocation is limited. A few studies that devote to this topic have focused on the cost-benefit analysis of resource allocation, and the design and configuration of emergency rescue sites in a single region or at a multiple level of a geographic area.

Using cost-benefit analysis method, It developed an allocation model to protect risk resources [1,2]. James et al studied the allocation problem of security sensors for air contaminants [3]. Tie el al analysed the key factors that affect resource layout and quantified an index about emergency resource guarantee cost and rescue efficiency [4]. Having considered regional dispersion and demand distribution, Zhang and Huang proposed a multi-objective model to analyse multi-supply and multi-demand zones during disaster rescue [5]. Zhang et al. proposed a two-level resource allocation model after they evaluated the need for emergency resources in each disaster area at two levels [6].

Most of the above mentioned published articles are not specifically dealt with maritime emergency issues. The following section proposes a multiple objective goal programming model to effectively allocate resources to manage liquid bulk chemical spill and pollution, and mitigate accident consequences.

3 Problem description

This paper studies the problem of resource allocation of one demand node and multiple supply nodes. We assume that emergency rescue resources can be dispatched from multiple neighboring emergency land bases if accident occurs at any point.

We also assume that available funding and investment in emergency rescue are limited. The objectives are (i) to minimize the travel time from the emergency rescue base to the disaster center; and (ii) to minimize the cost of emergency rescue resource allocation.

4 Emergency rescue resource allocation

4.1 Parameters

$w_i(s)$: Influence coefficient of scenario s that affects resource needed at demand point i;

q_{is}^{e}: Leakage amount of liquid chemical e at demand point i at scenario s;

p_{is}^{e}: Probability of a leakage accident occurred at demand point *i* at scenario *s*, and $\sum_{s} p_{is}^{e} = 1$;

p_{isq}^{e}: Probability of leakage amount *q* of dangerous chemical e at demand point *i* in scenario *s*, and $\sum_{q} p_{isq}^{e} = 1$.

k_{m}^{e}: The demand for emergency resource *m* when one unit of chemical e leaks into sea.

When an amount of q_{is}^{e} has leaked into the sea, the demand for emergency resource *m* at demand point *i* can be described as follows:

$$d_{mi}(q_{is}^{e}) = k_{m}^{e} \cdot w_{i}(s) \cdot p_{is}^{e} \cdot p_{isq}^{e} \cdot q_{is}^{e}$$

I: Set of demand points, $i \in I$

J: Set of supply points, emergency rescue bases, $j \in J$

M: Set of type of emergency rescue resources, $m \in M$

t_{ji}: Time needed to dispatch resources from emergency base *j* to demand point i

V_{j}: Maximum volume of emergency rescue resources stored at emergency base j

G_{j}: Maximum weight of emergency rescue resources stored at emergency base j

v_{m}: Unit volume of emergency rescue resource m

ξ_{mj}: Minimum weight of emergency rescue resources m allocated to emergency base j

c_{m}: Unit cost of resource m

C: Total funding for all of the resources allocated at emergency base j

4.2 Decision variables

$x_{mij}(q_{is}^{e})$: The amount of resource m dispatched from emergency rescue base j to demand point i when q_{is}^{e} has leaked into sea at demand point i

q_{mj}: The amount of resource m allocated to emergency rescue base j

4.3 Objective function

$$Min \quad t = \sum_{i}\sum_{j}(e^{p_i u_i} \cdot t_{ji}\sum_{m}\sum_{e}\sum_{s}\sum_{q} p_{is}^{e} \cdot p_{isq}^{e} \cdot x_{mij}(q_{is}^{e})) \tag{1}$$

Equation (1) means that the total dispatching time is minimized.

$$Min \quad C = \sum_{m}\sum_{j} c_m q_{mj}, \quad \forall j \in J, m \in M \tag{2}$$

Equation (2) means the distribution cost is minimized.

We tun two objective to one objective,

$$\min F = k_1 Z_1 + k_2 Z_2 \tag{3}$$

Where k_1 and k_2 are non-negtive integers and $k_1 + k_2 = 1$.

4.4 Constraints

$$x_{mij}(q_{is}^{e}) \prec= q_{mj}, \forall j \in J, i \in I, m \in M, s \in S, q \in Q, e \in E \tag{4}$$

Equation（4）shows that an accident can be supplied only there are some resources are storaged in the base. And supply quantity is not over the storage quantity.

$$\sum_{j} x_{mij}(q_{is}^{e}) \succ= d_{mi}(q_{is}^{e}), \forall i \in I, j \in J, m \in M, s \in S, q \in Q, e \in E \tag{5}$$

Equation (5) shows that the supply quantity is to meet the requirement in the accident point.

$$\sum_{m} q_{mj} v_m \le V_j, \forall j \in J \tag{6}$$

Equation(6) shows the supplied quality to a base is not over the warehouse volume capacity.

$$\sum_{m} q_{mj} \le G_j, \forall j \in J \tag{7}$$

Equation(7) shows the supplied quality to a base is not over the warehouse weight capacity.

$$\mathrm{v}\,\xi_{mj} \le q_{mj}, \forall j \in J, m \in M \tag{8}$$

Equation (8) shows the lower limit to resources distributed to a base.

$$q_{mj}, x_{mij}(q_{is}^{e}) \ge 0, \tag{9}$$

5 Using the Template

Only 2 chemical liquids are considered that are e_1 and e_2. 2 accident scene are s_1 and s_2. The leakage quantity is 50 tun. $p_{is_1}^{e_1}=0.4$ 、 $p_{is_2}^{e_1}=0.6$ 、 $p_{is_1}^{e_2}=0.4$ 、 $p_{is_2}^{e_2}=0.6$, $|J|=3$, $|I|=3$,3 resourced are m_1 , m_2 .Set $k_{m_1}^{e_1}=50$ 、 $k_{m_2}^{e_1}=0.3$ 、 $k_{m_3}^{e_1}=0$, $k_{m_1}^{e_2}=50$, $k_{m_2}^{e_2}=0.3$, $k_{m_3}^{e_1}=0.05$, $V_1=V_2=V_3=10000$, $G_1=G_2=G_3=10000$, $v_{m_1}=0.1$, $v_{m_2}=10$, $v_{m_3}=3$, $c_{m_1}=0.025$, $c_{m_2}=12$, $c_{m_3}=50$. $\zeta_{m_1 1}=\zeta_{m_1 2}=\zeta_{m_1 3}=3$, $\zeta_{m_2 1}=\zeta_{m_2 2}=\zeta_{m_2 3}=3$, $\zeta_{m_3 1}=\zeta_{m_3 2}=\zeta_{m_3 3}=3$

Table1-Transportation time from a base to a requirement point 1,2,3,4,5,6

	1	2	3	4	5	6
1	1.01	0	1.63	2.39	3.23	1.99
2	2.11	2.38	2.42	0.16	0.85	1.17
3	2.97	6.32	7.56	5.23	6.16	3.01

Table 2- Transportation time from a base to a requirement point 7,8,9,10,11,12,13

	7	8	9	10	11	12	13
1	2.05	4.20	5.06	4.97	1.36	1.67	1.46
2	0.96	1.82	3.18	4.18	2.19	3.54	0.66
3	3.38	7.13	3.12	0	0.82	3.31	1.18

Table 3- Datas of $w_i(s)$ and $e^{p_i u_i}$ （$i=1,2,3,4,5,6$）

$w_i(s)$	**1**	**2**	**3**	**4**	**5**	**6**
s_1	1.0	1.2	1.2	1.2	1.2	1.2
s_2	2.0	2.4	2.4	2.4	2.4	2.4
$e^{p_i u_i}$	1.70	3.67	3.67	3.67	3.67	1.27

Table 4-Datas of $w_i(s)$ and $e^{p_i u_i}$ (i = 7,8,9,10,11,12,13)

$w_i(s)$	**7**	**8**	**9**	**10**	**11**	**12**	**13**
s_1	1.0	1.0	1.0	1.0	1.1	1.1	1.2
s_2	2.0	2.0	2.0	2.0	2.2	2.2	2.4
$e^{p_i u_i}$	1.7	3.67	1.7	2.8	1.3	2.9	1.3

$k_1 = k_2 = 0.5$. Solving result is shown in Table 5.

Table 5-Solving result

	m_1	m_2	m_3
O_1	3000	22	3
O_3	3000	22	5
O_6	3000	18	2

Value of objective function is 678.

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