A Goal Programming for Dispatching Chemical Relief Materials on Sea

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ABSTRACT

Liquid chemical spill or leakage at sea pollutes sea environment, damages natural resources, and does harm to the health of local residents. In this research, we provide a goal 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. ¹

KEYWORDS

Relief Resource, Emergency Bases, Liquid Bulk Chemicals, Leakage Accident.

INTRODUCTION

In recent years, the volume of liquid chemical resources transported by sea is growing fastly. This growth has led to increased number of accidents that are associated with liquid chemical delivery at sea. Liquid chemical leak and spills happen due to releases of liquid chemical from vessels, wells, tankers, offshore platforms, etc. Cleanup and recovery from a liquid chemical spill or leakage are challenging projects.

Although emergency resource allocation plays an important role, the published research regarding this problem is limited. In addition, most of the models are

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developed to handle overland emergency resource allocation problems of land-carriage, and these researches can not 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.

MATHEMATICAL MODEL

Parameter

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

$a^e_{is}$: Leakage amount of liquid chemical $e$ at demand point $i$ at scenarios;

$b^e_{is}$: Probability of a leakage accident occurred at demand point $i$ at scenario $s$, and for dangerous chemical $e$;

$c^{e}_{isq}$: Probability of leakage amount $q$ of dangerous chemical $e$ at demand point $i$ in scenario $s$, and

$r^e_m$: The demand for emergency resource when one unit of chemical $e$ leaks into sea.

When an amount of $q^e_i$ has leaked into the sea, the demand for emergency resource at demand point $i$ can be described as follows:

$$\theta_{mi}(a^e_{is}) = r^e_m \nu_i(s)a^e_{is} a^e_{isq} b^e_{is}$$

(1)

We take $\theta_{mi}(q^e_i)$ as a random variable because it is influenced by so many uncertain factors.

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, $m \in M$
\( I_j \): Time needed to dispatch resources from emergency base \( j \) to demand point

\( V_j \): 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

\( \varepsilon_{mj} \): Minimum weight of emergency rescue resource small located to emergency base \( j \).

**Decision Variables**

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

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

**Models**

Our objective is to minimize the sum of surplus of dispatched resources, inadequate of volume and weight limit.

\[
\text{Min} T = \sum_i \sum_j \sum_m \sum_e \sum_q d_{mjx}^{(1)e-} + \sum_m \sum_j \sum_d d_{mj}^{(2)+} + \sum_m \sum_j \sum_d d_{mj}^{(3)+} 
\]  

(2)

\[x_{mij}(q^e_{is}) + \sum_m \sum_i \sum_s \sum_e d_{mj}^{(1)e-} - \sum_m \sum_i \sum_s \sum_e d_{mj}^{(1)e+} \leq q_{mj}, \quad \forall j \in J, i \in I, m \in M, s \in S, q \in Q, e \in E \]  

(3)

\[
\sum_j x_{mij}(q^e_{is}) = \theta_{mi} (q^e_{is}), \quad \forall j \in J, i \in I, m \in M, s \in S, q \in Q, e \in E
\]  

(4)

\[\sum_m q_{mj} V_m + \sum_m d_{mj}^{(2)+} + \sum_m d_{mj}^{(3)+} \leq V_j, \quad \forall j \in J
\]  

(5)

\[\sum_m q_{mj} + \sum_m d_{mj}^{(3)-} - \sum_m d_{mj}^{(3)+} \leq G_j, \quad \forall j \in J
\]  

(6)

\[\varepsilon_{mj} \leq q_{mj}, \quad \forall j \in J, m \in M
\]  

(7)

\[q_{mj}, x_{mij}(q^e_{is}) \geq 0 \text{ and integer, } \forall j \in J, i \in I, m \in M, s \in S, q \in Q, e \in E
\]  

(8)
EXAMPLE PROBLEMS

We have designed an example problem to illustrate the model. Let’s assume there are two types of liquid chemical e1 and e2, two scenarios s1 and s2 of accidents that occur at every demand point, three emergency rescue bases (|J|=3), thirteen demand points (|I|=13), and three types of emergency resource (|M|=3). Leakage amount of dangerous chemical of each type at any demand point in any scenario is 50 (i.e. $q_{i1}^{e1} = q_{i2}^{e1} = q_{i1}^{e2} = q_{i2}^{e2} = 50$). We set the probability of chemical leakage ( $p_{i1}^{e1} = 0.4$, $p_{i2}^{e1} = 0.6$, $p_{i1}^{e2} = 0.4$ and $p_{i2}^{e2} = 0.6$), demand parameters ( $k_{m1}^{e1} = 12$, $k_{m2}^{e1} = 3$, $k_{m3}^{e1} = 5$, $k_{m1}^{e2} = 15$, $k_{m2}^{e2} = 3$, $k_{m3}^{e2} = 8$).

<table>
<thead>
<tr>
<th>TABLE I. TRANSPORT TIME.</th>
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<tbody>
<tr>
<td><strong>Supply (j)</strong></td>
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<tr>
<td><strong>Demand (i)</strong></td>
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<td>3</td>
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Based on the problem setting, we can see that the value of the objective function of three cases is different. Case 1 puts more weight on the time to respond to the liquid leakage accident; Case 2 highlights the balance between the time to respond to liquid leakage accident and the funding capacity; and Case 3 puts more emphasis on funding capacity and investment. Each objective value decreases as its weight increases. These findings indicate that the model in section 4 not only is mathematically valid, but also is able to provide decision support information to make rescue decision for real emergency situations. $j \rightarrow m_1 : 998$. $j \rightarrow m_2 : 79$. $j \rightarrow m_3 : 135$. The objective value is 13.33.

REFERENCES