Bi-objective optimal planning for emergency resource allocation in the maritime oil spill accident response phase under uncertainty

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ABSTRACT

Emergency resource allocation is an important issue in emergency response to marine oil spill accident. This paper addresses an emergency resource allocation problem which involves multiple relief resource center and one accident point. To solve this problem, a bi-objective model is constructed to minimize the disposal time and the disposal costs. Due to the existence of uncertainty in different aspects involved in the emergency response to the marine oil spill, we also incorporated into the model some fuzzy parameters. An algorithm based on the non-dominated sorting genetic algorithm 2 and the differential evolution algorithm, was presented to obtain the Pareto set. The technique for order preference by similarity to ideal solution method was employed to reach a final compromise solution. A case was studied to demonstrate the effectiveness of the proposed model and the hybrid algorithm, which can support the decision making in the process of the oil spill emergency disposal.

KEYWORDS

Resource allocation, maritime oil spill accident, bi-objective model, uncertainty, fuzzy programming, NSGA-2.

ACM Reference format:

GECCO '19 Companion, July 13–17, 2019, Prague, Czech Republic
ACM ISBN 978-1-4503-6748-6/19/07.
https://doi.org/10.1145/3319619.3326780

1 INTRODUCTION

Due to the complexity of the marine environment, marine oil spills occurs frequently and the emergency management is extremely important to the safety of the human beings and the marine environment once the accident occurred. Moreover, the decision support for the emergency management plays an important role in selecting and implementing effective emergency response operations.

Ali Bozorgi-Amiri et al [1] established a novel robust optimization model which contemplates the different sources of uncertainty, including the demand uncertainty, the supply uncertainty and the cost uncertainty about the procurement and the transportation. Najafi, et al [2] proposed a multi-objective, multi-mode, multi-commodity, and multi-period stochastic model to manage the logistics of the commodities and the injured people in the earth earthquake response. Abounacer et al [3] built a three-objective location-transportation model which contains minimizing the total transportation duration, minimizing the numbers of agents needed or operated and minimizing the non-covered demand points within the affected area. CL Hua, X Liu, and YK Hua[4] formulated a bi-objective robust emergency resource allocation model which tries to maximize the efficiency as well as the fairness under different sources of uncertainties and proposed a novel decision method to assist decision-makers to identify their most preferred solution. Although these studies provided insight into various disaster recovery efforts, the uncertainty in the course of disaster response has not been well take into account but the oil spill response involves a lot of uncertainty. This study aims to construct a fuzzy multiple objective model, which considers the uncertainty of the transport time and the demand for emergency supplies.

2 EXPERIMENTAL SETUP

To obtain decision-makers' most preferred allocation plan, we propose a novel emergency resource allocation decision method which consists tree steps: (1) establish a bi-objective model to describe the reality; (2) develop a hybrid algorithm to search the Pareto frontier of the proposed model; (3) employ TOPSIS to reach a final compromise solution.

Firstly, we have established a bi-objective emergency resource allocation model which tries to minimize the emergency response time as well as cost under uncertainty. Emergency response time is divided into the disposal time and the delivery time. The disposal time mainly depends on the efficiency and the quantity of the resources and the delivery time mainly depends on the speed of each supply point and the distance between the supply point and the accident point, on account of the complexity and variability of the marine environment, the delivery time is uncertain and expressed as a triangular number. Emergency response cost include the transportation cost and the material cost. As the model we constructed is an uncertain linear programming model that includes triangular fuzzy numbers and random variables, we have to employ the fuzzy set theory and the stochastic programming to transform the uncertainty numbers into deterministic numbers.

Secondly, we established a hybrid algorithm that mixed the NSGA-2 and DE. NSGA-2 is one of the most popular multi-objective algorithm and it can effectively maintain the diversity of the Pareto frontier by using the methods of non-dominant sorting and sharing variables. Meanwhile, the differential evolution (DE)[5] algorithm based on the intelligent optimization algorithm of the group search, with a simple structure and high performance, has attracted more and more attention in the scientific research and the practical engineering application. We have combined the advantages of both algorithm to obtain more efficient solver for our model.

Finally, TOPSIS was employed to reach the final compromise solution from Pareto solutions. TOPSIS is a multi-attribute decision-making method proposed by C.L.Hwang and K. Yoon[6]. The core of this method is to rank different schemes by comparing the proximity to the ideal scheme. In order to compare the performance of the proposed algorithm to such a ready-made algorithm, we have used LINGO software to get the results based on fuzzy programming which transformed the multi-objective model into single objective.

3 RESULTS

We have assumed an oil spill case and got the following results. Firstly, as we can see in Figure 1, the evolutionary curve of standard NSGA-Ⅱ algorithm and hybrid algorithm has a similar shape and a similar evolutionary trend. Besides, the slope at the beginning of the curve is relatively large but small at the end, which means that the cost of money can be lower a lot by increasing the cost of time a little bit when the time is relatively small. Secondly, comparing the performances of standard NSGA-Ⅱ algorithm and hybrid algorithm, and it can be seen clearly from Figure 1 that the hybrid algorithm based on NSGA-Ⅱ and DE has longer evolutionary curve than standard NSGA-Ⅱ algorithm. Besides, Pareto solutions in diversity and convergence of hybrid algorithm is superior to standard NSGA-Ⅱ algorithm. Finally, based on LINGO, we can find that the quality of LINGO solution is equivalent to hybrid algorithm and better than standard NSGA-Ⅱ algorithm, however, LINGO software can only get one solution only and cannot easily adjust the relative weight of time and cost according to the preferences of decision-makers. Instead, genetic algorithm can get many feasible solution for decision-makers to choose and can easily adjust the relative weight, so the performance of the hybrid genetic algorithm is much better than LINGO software.

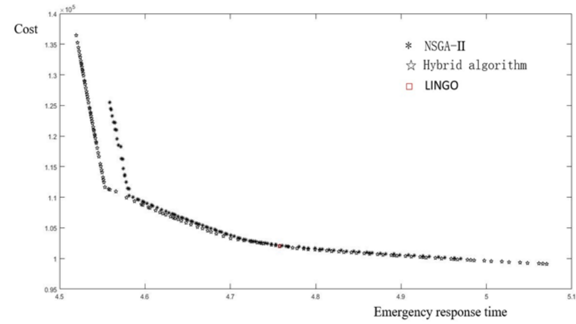

Figure 2: Pareto sets of different algorithms and LINGO solution.

4 CONCLUSIONS

The emergency materials scheduling problem is an important aspect of the oil spill disposal. However, it is a complex problem due to the large number of variables that need to be included throughout the process. The distribution model has to reflect the real condition as closely as possible, as well as faithfully interpreting decision maker's requirements and goals. However, in these procedures, there is a high level of uncertainty in the form of imprecise data due to the inaccurate needs of the decision makers or the changing environment. In this paper, it was assumed that the emergency response time and the needs of emergency resources are more sensitive to uncertainty. This paper introduced a fuzzy programming and random variables to characterize those uncertainty and establish a multi-objective model which minimizes the emergency response time and costs. The LINGO software and the hybrid algorithm based on NSGA-Ⅱ and DE are introduced to solve this problem. Finally, an example is used to verify the effectiveness of the proposed model and algorithm.

However, this paper only considers the problem of emergency materials allocation at single accident point. In actual conditions, oil spill accidents often lead to secondary disasters so that there are multiple accidents at the same time, and the situation will be more complicated. Therefore, the next research direction of this paper is to consider the emergency materials scheduling problem under the condition of multiple accidents.

REFERENCES

[1] Ali Bozorgi-Amiri, MS Jabalameli, SMM AI-E-Hashem (2013) A multi-objective robust stochastic programming model for disaster relief logistics under certainty [J]. OR Spectrum 8:1-30.
[2] M Najafi, K Eshghi, W Dullaent (2013) A multi-objective robust optimization model for logistics planning in the earthquake response phase [J]. Transportation Research Part E 49(1): 217-249.
[3] R Abounacer, M Rekik, J Renuaud (2014) An exact solution approach for multi-objective location-transportation problem for disaster response [J]. Computer & Operation Research 41: 83-93.
[4] CL Hua, X Liu, and YK Hua (2016) A bi-objective robust model for emergency resource allocation under uncertainty [J]. International Journal of Production Research 54(24):7421-7438.
[5] Strorn R, Price K. Differential evolution- a simple and efficient heuristic for global optimization over continuous spaces[J]. Journal of Global Optimization, 1997, 11(4):341-359.
[6] Baykasoglu A, Golcuk I. Development of a novel multiple-attribute decision making model via fuzzy cognitive maps and hierarchical fuzzy TOPSIS[J]. Information Science, 2015, 301:75-9.