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Emergency material collecting model of sudden disasters with fuzzy collecting time

Huang Xing

School of Economics and Management, Southwest University of Science and Technology, Mianyang City 621010, China

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ABSTRACT

The paper looked the Hub-and-Spoke emergency material collecting network with double level Multi-hub as the research target to reality the decision optimization of emergency material collecting under the sudden disaster. The paper set the double goals for the collecting time and costs with the major constraint conditions of the fuzzy collecting time and the system time according to the primary characters of disasters, and the paper constructed the Multi-hub, double goals of programming model with some constraint conditions, including the capacity limited of each hub spot, the total time of the collecting system and the ownership of each demand point. The author used the improved Particle Swarm Optimization (PSO) algorithm to solve the model, which can effectively reality the optimal goals, including the node-line distribution between the emergency material response points and each hub center, the emergency material quantity and the range of each hub center. Finally, the case showed that the improved PSO is superior to the standard PSO. The improved PSO has a clear advantage, such as a perfect iteration speed, a shorten collecting time and small collecting costs, etc. So the model can make a decision to the emergency material collecting of sudden disaster.

1. Introduction

The frequent sudden disasters in recently years showed that an outbreak disasters, which posed great challenges to emergency material collecting, usually triggers a rapid expansion of the demand in the disaster area. The low efficiency, high cost emergency material collecting might cause more casualties and property damaged, moreover, might lead to the secondary disasters. Therefore, it has become a hotspot being continuously studied in the field of emergency logistics about how to collect emergency materials with high efficiency and low cost after the disasters.

According to the relevant data, the loss was caused by emergency material shortage or failure emergency material provision in time contributes to 15–20% of total loss in the natural disasters or man-made disasters [1]. For example, in the economic loss from SARS ($17.9 billion), the loss was caused from poor performance of emergency logistics and failure of timely emergency material provision about $3 billion or so. Typically, this situation is much worse for earthquake disasters and it showed that the emergency supplies management is a critical problem in the emergency logistics research field. The chief problem is the emergency material collecting, which is both a challenge of emergency management practices and is a frontier subject in the research field of emergency logistics.

According to the analysis above, the emergency material collecting is a chief decision tusk in the emergency logistics field, and is also a critical problem, which need be solved by the rescue decision departments and the command organization. The emergency decision departments will be confronted with the many optimization decision problems with the many uncertain factors of the disaster situation after the disasters, such as the construction and optimization of the dynamic emergency logistics network, the collection and distribution of the uncertain demands, the adjustment of the hub nodes under the dynamic network, etc. However, these problems will be resolved difficulty attribute to many constraints, for example, the uncertain demands, the fuzzy collecting time(Note: Compared with the certain number, the fuzzy number is uncertain, such as interval number, triangular fuzzy number, and so on), the capacity limitation of hub nodes, the distribution of the disaster relief points, etc. In all those problems, the emergency material collection need be focused firstly under the hub-and-spoke network environment at the early stage of sudden disaster (Note: Hub-and-spoke network is a centralized transportation system, which based on the central station of large logistics hub. Compared with the traditional logistics network, the hub-and-spoke network will be identified as one or more nodes in the logistics center, and the nodes are connected to each other by the central station). So the paper will focus on the study of the issue.

E-mail address: huangxing6213@126.com

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2. Literature review

Firstly, research on the network flow, route selection, logistics location and distribution of logistics network. For example, Lee H [2] has carried on the thorough research to the logistics network flow and he has studied the network flow problem with a large number of algorithms, including the increased intercept orbit algorithm of Ford-Fulkerson, blocking flow algorithm of Dinic, pushing and labeling algorithm of Goldberg and so on. James K [3] used the Shapley value method of game theory to solve effectively the vehicle carrying problems of logistics network. Tang C S [4] discussed a kind of common logistics network, which is composed of three types of nodes including consumer markets, factories, warehouses, while he also studied the logistics facilities location and logistics network structure design of centralized and decentralized optimization and decision problems. Bertsmasd [5] constructed a multi-objective planning model for logistics network optimization with many impact factors, including product consumption, product manufacturing and transportation, etc., of logistics network costs and network operation. Ju Songdong [6] researched the composition of the logistics network system, and he thought that the logistics network mainly was consisted of three sub networks, such as logistics information network, logistics infrastructure network and logistics organization network. Pan Kunyou [7] structured the hub-and-spoke logistics network of the central towns, with some principle constraints of the shortest running time of the logistics network, Maximum coverage of the network and the multi hub distribution of network structure, along the Yangtze River in Anhui province, China. Bian Wenliang [8] focus on some researches about the relationship of logistics network nodes and how to constraint the nodes with the development of the whole logistics network change dynamically.

Secondly, research on the building and application of the hub-and-spoke network in emergency logistics. The hub-and-spoke emergency logistics networks have a wide range fields including the selection of hub points, the distribution of the non hub point, the analysis of the operation environment and reward to hub-and-spoke networks, expanding application of hub-and-spoke network, the coordination and interaction of regional hub-and-spoke network systems, etc. Zhang Yi [9] accorded to the structure characteristics of the hub-and-spoke networks and considered many objective conditions, including the administrative division of logistics network, road traffic, geographical environment, economic development and other objective conditions, etc, while he studied on the distribution relationship of hub points and other non hub points for all determined sites after the comprehensive evaluation (the evaluation accorded to some indexes, such as the site function, the site size, transportation conditions, ability of collecting and distributing, etc). Wang Han [10] studied the synergy of Intercity multi-hub emergency logistics networks on the basis of System Dynamics. Ge Chunjing [11] built the optimal choice model of single distribution networks under the bypass constraints, while the model made up for the bypass disadvantage of hub-and-spoke networks.

Thirdly, research on the optimization of the emergency supplies collecting networks. To solve the continuous supply of emergency resources, Liu Chunlin [12] discussed the combination optimization problems of the rescue points to reality the optimal goal of earliest emergency response time. Pan Yu [13] researched on the uncertain time from the numerous relief points to the demand points of emergency materials in the collecting systems to solve the problems of the continuous consumption with varieties of emergency supplies. He Shoukui [14] researched on the least response number of emergency material points under the constraint condition of the emergency time and the number of emergency materials. Han Jingti [15,16] uses the fuzzy optimization theory and multi-objective programming method to construct a multi objective emergency material collection model with the shortest time, the lowest cost and the high reliability.

Fourthly, research on the models of emergency supplies collection. Most of the authors build he models of emergency material collection to base on the theory and methods of operations and the main tools included mathematical programming, network flow models and modern intelligent optimization technology. Zografos et al. [17] used the linear programming method to optimize the four major functions of the traffic emergency logistics decision system for the six countries Europe. Chang et al. [18] put forward a two-stage model of location-allocation for the affect areas to base on the goal of the shortest transportation distance under the background of flood disaster. Chen [20] and Liu [19] put forward the optimal model of between the travel choice of multi time segment road network and congestion charging.

According to the literatures mentioned above, most researchers focused on the conventional logistics networks, while some scholars tried to introduce the hub-and-spoke network to the emergency logistics; furthermore, they also researched the dynamic optimization of networks to accord to the change of emergency situation. Especially, they deeply studied the network structures, flow distribution and the coordination of emergency participants with many uncertain conditions. However, at present, most literatures assumed that demand quantity and collecting time are known in advance. Actually, it is now thought that this was not so and it just provided a good idea for the paper. And there were some shortcomings in the literatures to choice the methods, such as these methods focused on the determination information. However, these methods were less concerned with uncertain information. In this paper, the fuzzy processing method will be used to deal with the uncertainty of the disaster information, because the fuzzy method can comprehensive the risk preferences of decision makers from the pessimistic, normal and optimistic. So the fuzzy constraint processing method will be more intuitive and reasonable, and fit the decision characteristics of the emergency. The innovation contents of this paper are as follows:

(1) When the collecting time is fuzzy number, the paper will solve the optimal decision problems of emergency material collecting network with some constraint conditions, such as the demand time of emergency material limited and the limited capacity of the multi-hub centers, etc. In total, this paper will make the decision problem more close to the reality of sudden disaster.

(2) The paper built the multi-objective programming model, and designed the algorithm of Simulated Annealing-Particle Swarm Optimization (SA-PSO). This model and algorithm will improve the efficiency of emergency materials, reduce the cost of emergency materials, accelerate the convergence velocity of the model and greatly reduce the running time of the model.

3. Question description and hypotheses

According to the emergency situation early, the several inputs are given as follows: the set of emergency material response sites $A = \{ i|i = 1, 2, \dots, n\}$; the set of emergency material hub centers $H = \{ p|p = 1, 2, \dots, l\}$; the set of emergency material demand points $D = \{ j|j = 1, 2, \dots, m\}$; the set of emergency material categories $K = \{ k|k = 1, 2, \dots, g\}$; the emergency material demand at each demand point; the time limited of emergency material demand; the capacity limited of emergency material hub centers; the fuzzy number of collection time from emergency material response sites to emergency material hub centers and its unit cost;