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# Multi-stage multi-objective engineering evaluation method for the ability of the emergency resources reserve system

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**Abstract**

Emergency Plans play an important role in engineering emergency management. Evaluating the ability of the current resources reserve system is the first step of developing Emergency Plans, while the demand of affected areas are always different for different kinds and levels of the disasters. In this paper, we will present a multi-stage multi-objective evaluation model. Based on satisfaction function of resource, we consider both the amount and arriving time of resource arrived at each affected area. Because of the dynamic rescue process, the transportation scheme is multi-stage and we divide the emergency rescue period into three stages. Then a heuristic algorithm is proposed for the evaluation model. Computational results show both the model and algorithm are helpful when evaluating the ability of reserve resource system.

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Keywords: emergency resources serve system; engineering evaluation; multi-stage; multi-objective

## 1. Introduction

In recent years, many kinds of disasters either natural or human-made occurred frequently. Whether the SARS outbreak in 2003, south snowstorm and Wenchuan earthquake in 2008, or Japan's magnitude 9.0earthquake and the tsunami caused by the nuclear explosion, and so on, all these disasters lead to heavy loss of human lives and properties. In order to prepare for the respond of disasters, and relieve the loss of the disaster, Emergency Plans are indispensable. Before developing Emergency Plans, evaluation of the ability for the current resource reserve system of the region is essential.

There are lots of researches on the layout of emergency resources and lots of better results. Lei Fang[1] puts forward a new nonparametric DEA model for resources allocation, to evaluate the performance of resources utilization during the emergency system according to the total relative efficiency. Qian Wang et al. [2] study a budget constrained location problem in which they simultaneously consider opening some new facilities and closing some existing facilities. The objective is to minimize the total weighted travel distance for customers subject to a constraint on the budget for opening and/or closing facilities and a constraint on the total number of open facilities desired. Mohan R. Akella[3] et al evaluating the reliability of automated collision notification systems in emergency management by models. Meiwen Wu et al.[4] provide four indexes about coveting and fire area of fire stations in a city to evaluate layout of fire stations in the city. And analyzed the indexes in detail, gave the related mathematic models. Yingying Yu et al. [5] propose a loss function based on time, resource supply and demand to evaluate the loss under a given resource distribution when different degrees of emergencies will occur. And an optimization

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model is developed to adjust the current resource location and allocation when the loss is not accepted. To solve the evaluation problem of sites-setting for short wave air-to-ground communications, Wen Wu et al.[6] gave two evaluating indicators, coverage degree and coverage efficiency. And Grid scanning algorithm and Monte Carlo method are used respectively to calculate the two evaluating indicators. Libo Xi et al.[7] according to the task of military materials support system and formulating ride of evaluating index system, set up index system for military material support ability, studied BP network model to evaluate material support ability. In order to evaluation the allocation planning and service level of passenger stations in comprehensive transportation terminal, and to optimize the planning schemes, Yuan Tian[8] established a synthetic evaluation system by AHP theory based on planning harmony, the need of transportation terminal, the impact to environment and convenient transportation terminal. Meanwhile, the fuzzy evaluation was used in setting up the traffic impact system to appraise it. Based on the features of emergency logistics, Xiaolan Shi et al[9] establishes a hub-and-spoke-based dynamic network in the light of the idea of grading, step by step, with hub and ascription and brings forth a tripartite start-up mode according to the development tendency of emergency. Li Zhuang et al[10] discussed the evaluation criteria for the distribution of the fixed shelters in urban disaster, including main assessment points and the specification technical requirements, etc. And taking Qingdao as an example, analyzed the current problems of the fixed shelter's layout. Aiming at the design discipline about optimizing earthquake relief transport, Pan Qiu et al[11] set up a model by introducing the theory minimum cost max-flow, and discussed the application of the theory into earthquake relief transport.

The remainder of this paper is organized as follows. We present the multi-stage multi-objective evaluation model in section2. Then a heuristic algorithm is proposed in section3. Finally, computational results are shown in section 4and draw a conclusion in section 5.

## 2. Multi-stage multi-objective evaluation model

After an emergency, emergency resources need to be transported to the affected areas from storage directly or indirectly. Especially in the initial stage the demand is greater than the supply, so rational scheduling of the limited emergency resources to achieve maximum aid effectiveness is very necessary. In this paper, we study in the rescue period, the ability of emergency resources (tents) reserve system.

Considering 3 stages, storages set *I*, affected areas set *J*, Hubs set *M*, and each Hub collects emergency resources from other storages that belong to the same administrative district (municipal). Main Hubs set *K* (Main hubs choose from the hubs which is convenient and nearly to the affected areas), $M \subset I,\ K \subset I,\ M \cap K = \Phi$ . The aim of emergency rescue is to transport tents to affected areas from storages directly or indirectly, made the utility of tents achieve to the maximum. In our model the central and the provincial storages are considered as the county storages, if the disaster is not serious enough to start the central or the province storage, they will not be considered, and omit the Save Points. After simplification, transportation network $G(V, A)$, $V$: vertices (storages, Hubs, Main Hubs), $A$: directed arcs set that from storages to Hubs or Main Hubs, Hubs to Main Hubs, Main Hubs to the affected areas.

### *2.1. Model assumptions :*

1) Information system is reliable, and we can obtain every resource supply point and the demand of each affected area in every stage.
2) Relevant people can effectively evaluate the disaster weight coefficient of the affected area depends on casualties, economic losses of the affected area.
3) The satisfaction function of affected area: suppose demand point *d*, supply point *s*, the waiting time $[l, u]$, arrival time *t*; For a affected area, the satisfaction depends on both the amount and arriving time of resource:

When $t < l$, $g(t) = 1$; when $t > u$, $g(t) = 0$; when $t \in [l, u]$, let $g(t) = \left(\frac{u - t}{u - l}\right)^k$. When $S > D$, $w(S) = 1$; When $S < D$, $w(S) = \frac{S}{D}$. The expression of Satisfaction: $f(S, T) = w(S) * g(T)$

### *2.2. Parameters*

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