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Multi-period dynamic model for emergency resource dispatching problem in uncertain traffic network

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Abstract

After large scale emergencies, rapid and effective emergency resource supply is a very important engineering to ensure the relief activities. Large scale disasters, such as earthquake, floods, often lead to traffic network uncertainty including connectivity uncertainty and travel time uncertainty. In this paper, in view of the connectivity uncertainty, a multi-period dynamic transportation model of variety emergency materials is presented based on CTM network, and a corresponding hybrid genetic algorithm is designed to solve the problem, the numerical example shows the effectiveness of the proposed algorithm.

Keywords: multi-period; dynamic; connectivity reliability; emergency resource dispatch;

1. Introduction

With the development of the society and the inspiration of emergency invents in recent years, such as the 1998 flood, ‘SARS’ in 2003 , ‘Wenchuan’ earthquake in 2008 etc., research on emergency management is becoming more and more popular. Emergency resource dispatching decision is a very important engineering, only rapid and efficient material supply can ensure the relief activities. In many disasters, the connectivity of the network is uncertain, one road (edge) may be blocked caused by damages such as road surface broken, bridge collapse, on the other hand one road may be connected again after reparation. In most situations, the dispatch of relief materials should be considered in uncertain network, and an effective dispatch decision would be very beneficial.

Lots of research work about relief materials dispatching has been down by now. In respect to the variety of the materials, there are both single material dispatching problem[1,2,3] and multi-variety materials dispatching problem [4,5,6].Some of the research aims at minimizing the transiting time in respect to the urgency of the demand [2],while others brought out two or more objection, such as cost, the number of save points and so on. Liu Beilin [3] proposed a model to minimize both the time and the cost of relief materials dispatching. Meanwhile, dynamic dispatching models were proposed by researchers, such as ÖZDAMAR [6] solved the dynamic dispatching problem with multi-supply nodes and multi-demand nodes. Considering demand uncertainty, Ben-Tal[4] tried to dispatch the materials in the method of robust optimization, and Yuki Nakamura[5] studied the dispatching problem with uncertain travel

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time by giving three different kind of shortest path. Liu Xing[7] presented a two stage integer programming method to solve the problem at war time when road maybe destroyed by enemies.

However， rarely seldom researchers considered the connectivity uncertainty. In this article, we proposed a multi-period dynamic dispatching method of variety materials with multi-supply nodes and multi-demand nodes considering the connectivity uncertainty. With the updating of the information, we can renew model input parameters and re-compute dispatching plan, so as to realize the whole rescue schedule in real time. The rest of this paper is organized as follow: the basic hypothesis and multi-period dispatch model is given in section2. In section 3 a hybrid heuristic method is proposed, followed by a 20 nodes example in section 4. Finally, section 5 concludes the paper.

2. Multi-period dynamic dispatch model

A cell transmission model based network was composed by adding dummy nodes, and in this network the travel time between any two adjacent nodes is one unit. Considering the uncertainty of the network after disasters, a multi-period dispatch model was described in this section.

2.1. Basic hypothesis and explanations of symbols

In order to describe the dispatch problem after large scale emergencies, there are some basic hypothesises. The planning of time scale is T periods, and both the demand and the supply are predictable; the dummy nodes added to compose CTM network has no supply or demand; the edges have connectivity uncertainty, and the connected probability is predictable using the information from GIS、GPS, and the connectivity is given by certain rules; the arriving materials amount in the next period can be got by GIS and GPS; the vehicles needn't go back after finished transporting. The meaning of symbols that will be used is listed as bellow:

n： the number of nodes in the network;

V： the number of materials kinds, the Vth kind respect for vehicles;

RN, VN： corresponding to the sets of real nodes and dummy nodes ;

d_{imt}： the predicted demand amount at i for materials m at period t;

s_{imt}： the predicted supply amount at i for materials m at period t;

p_{ijt}： the probability of edge (i,j) to be connected at period t;

a_{ijt}： the connectivity state of edge (i,j) at period t, 1respect for connected and 0 respect for blocked;

b_{ijm}： the arriving amount of material m from j to i in the next period;

g_m： volume of one unit material m;

β： a coefficient of risk tolerance, the tolerance became weaker as β became bigger;

K： the traffic capacity of dummy nodes M： a large enough number;

x_{ijmt} :the amount of material m send from i to j at period t;

$y_{imt} = y^{+}_{imt} - y^{-}_{imt}$： the absent\remaining amount of material m at the end of period t $y^{+}_{imt} \geq 0, y^{-}_{imt} \geq 0$，

$y^{+}_{imt} > 0$ implies demand has been satisfied and the remaining amount is y^{+}_{imt}， $y^{-}_{imt} > 0$ implies the demand haven't been satisfied and the absent amount is y^{-}_{imt};

2.2. Multi-period dynamic dispatch model

This model was proposed considering the urgency and the connectivity reliability. So the objective function is composed by two different parts. The first part is the sum of all the nodes of absent and remaining amount of different materials during different time which applies the effect of the dispatching, and the second part is the risk of the dispatch decision described by the expected amount of delayed materials after some edges are blocked.