Location and supply of humanitarian aid distribution points

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Abstract: This article concerns the location of points to distribute humanitarian aid to the population. In such situations, it isn't possible to make every single home visited by relief teams. Instead, people are required to get to specific distribution points in order to get the survival goods provided that these points are not far from their domiciles (usually within walking distance). Meantime, these distributions points need to be supplied from a set of prefixed humanitarian distribution centers using a heterogeneous and capacitated fleet of vehicles. We model this situation as a generalization of the covering tour problem by introducing the idea of split delivery, and we propose a heuristic approach to solve it. Numerical experiments on random generated data show first that only very small instances can be solved efficiently using the mathematical formulation, and second that the proposed heuristic produce high quality solutions and tackles instances of practical size in reasonable computing times.
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1. Introduction and Problem definition

Given the growing number of natural disasters in recent years and the enormous damage that they have caused, the interest of the scientific community in problems of logistics management in situations of emergency has literally exploded in the last three years. For example, in 2007 was published a special issue of the Journal of Transportation Research Part E containing six papers devoted to emergency logistics. Since then, others scientific journals and reviews have also chosen emergency logistic or humanitarian relief as their main target.

Humanitarian crises are vast and extremely complex situations, and although a small part in the general crises management scope, humanitarian logistics are difficult to design and manage. Yet, humanitarian logistics is a broad field, which may include tasks like establishment of a rescue command center, collection of information about the disaster area, identification of appropriate sites for shelters, determination of the best evacuation routes, transportation for evacuation and delivery of relief material, installation of medical and fire-prevention and emergency construction facilities. These activities may therefore involve both inflow and outflow of goods and people [1]. This paper focuses in the inflow logistics and concerns the distribution of survival goods (food, water, drugs) to the people in the disaster area. Distribution networks of humanitarian help are often compared to classical industrial distribution networks by replacing suppliers by collection points out of the disaster area and permanent warehouses by public sites which are temporary adapted to store and handled goods. The last link in the industrial chain (the retailers) is here replaced by mobile distribution booths that are located at any parking lot or major streets intersections.

To formalize things, let assume that a distribution network composed of a set of given distribution centers has been deployed on the affected area. Each distribution center is then responsible of the needs for a given region, and this work focuses specifically in the segment of the distribution chain between a DC and the customer assigned to him. Let then assume that in the targeted region there are a set of potential distribution points or booths, and a set of customers. Several products are distributed simultaneously and each customer has different demands for each of the available, non interchangeable, products. Customers need to move a distance shorter than the covering distance to reach her closest booth, which will be supplied from one or several distribution centers in order to completely satisfy the demand of the customers that have been assigned to it. Supplying of booths is done by a given fleet of heterogeneous vehicles. Moreover, the demand of each customer may be split over different vehicles or booths. The problem consists in electing where to locate these booths and how to supply them from the distribution center using at its best the available vehicle fleet.

This problem is very difficult to solve efficiently. The location of such distribution points is not trivial[2]. First, since people in the neighborhood move to these booths to receive the survival goods, we must ensure that they are close enough (let's say, a walk distance). It follows that one would wish to locate as much booths as possible to reduce their average distance to customers. On the other hand, booths require consequent human and material resources for their operation which would be very "expensive". In fact, nobody wants to bring into the sinister zone more people (drivers, policemen, technicians) than necessary because, despite of the potential risk to their own lives, they require also food, water and increasing need for coordination. Nevertheless, booths are supplied from distribution centers (DC's) by trucks. These trucks are limited in number and in their capacity. Clearly the location and the size of booths are strongly related to the design of trucks routes [3]. For example, choosing to deploy few booths may reduce the length of routes and increase the loading and unloading operations efficiency, but also increases the average distance that customers will walk to get their supplies. But locating plenty is not better for the inverse reasons. Also, routes design requires electing which DC will supply each booth and therefore the capacity and the location of the DC's influence routes length.

In this context, the goal of this paper is to provide a tool supporting decision makers in the design of the downstream part of the distribution chain. To this end, we aim at proposing a model encompassing the location of booths (number and size) and the supplying operations (allocation of truck routes) given a DC deployment. We introduce the coverage idea to model the fact that during distribution, a customer place does not need to be visited provided that a mobile booth is located within a cover distance and therefore the customer can go and get his supplies at the closest booth.

2. Solution Approach

The proposed approach to solve the problem includes several neighborhoods and mechanisms, aiming at avoiding the search to be trapped by local optima. The local search procedure has been embedded into a multi-search scheme so that, for a given number of times, a solution is constructed and improved iteratively. The goal of this mechanism is to increase the robustness of the method with respect to the initial solution as well as to improve its ability to explore non-visited regions of the solution space.

3. Computational Results

Numerical experiments on random generated data show first that only very small instances can be solved efficiently using the mathematical formulation, and second that the proposed heuristic produce high quality solutions and tackles instances of practical size in reasonable computing times.

4. References:

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