Optimization Of Urban Emergency Supplies Distribution Paths for Epidemic Outbreaks

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Introduction

In the aftermath of an epidemic breakout, hospitals located across a city need a lot of emergency supplies, such as oxygen, disposable protective gear, and food. The solution to the general Vehicle Routing Problem(VRP) is no longer relevant due to the features of frequent logistical operations and a significant quantity of information, short transportation distance, high timeliness requirements, multiple forms of transportation, and tiny batches. It has become a pressing issue for humanitarian logistics to figure out how to effectively distribute urban emergency supplies during an epidemic outbreak while also ensuring the equitable distribution and prompt delivery of such commodities.

In contrast to other VRP variations that attempt to reduce distribution costs, the distribution of emergency supplies under the effect of epidemics must also take the prudence of emergency supplies distribution and the timeliness of transportation into account. The best distribution route for emergency supplies must be chosen based on the demand-urgency of various hospitals for various emergency supplies in order to allocate supplies properly under multi-dimensional restrictions, such as time windows and heterogeneous vehicles.

Problem Statement

The problem is to find an optimal solution in which we can efficiently distribute urban emergency supplies in an epidemic outbreak and find the fair distribution and timely delivery of such emergency supplies to the hospitals, also accounting for the urgent need of these supplies, proper utilization of each vehicle and lowering the transportation cost.

Problem Formulation

In this problem we have certain emergency supplies which are required by different hospitals. We have a set of vehicles of varying capacity which will transport these supplies to the hospitals.Our task is to find a route for all the vehicles carrying emergency supplies simultaneously, maximizing the objective function and satisfying a given set of constraints.

Objective function comprises of three components-

1. Vehicle Utilization (τ) - Each vehicle should be utilized to its maximum capacity. This factor is formulated as the ratio of weight(or volume) of a vehicle used to its maximum loading weight(or volume).

$$Vehicle\ Utilization\ (\tau)\ =\ \frac{Weight(or\ volume)\ used}{Maximum\ loading\ weight(or\ volume)}$$

2. Vehicle Transportation cost - Overall vehicle transportation cost should be minimized. This formulated as

   $$Vehicle\ Transportation\ Cost\ (F_a) = Freight\ per\ unit\ time\ * \ Total\ time\ taken\ by\ each\ vehicle$$

3. Demand Urgency Factor (γ) - This factor is to maximize the demand urgency value of emergency materials delivered before the latest delivery time required by the hospital, indicating that the higher the demand urgency, the higher the priority of distribution

So, our final objective function becomes

$$Max\ f = \frac{(Vehicle\ Utilization) * (Demand\ Urgency\ Factor)}{Vehicle\ Transportation\ Cost}$$

Proposal

I. Implementation and Comparison of Algorithms

We will implement algorithms like DE-IMOV (Multiverse optimizer algorithm based on differential evolution), MVO (Multiverse optimizer), DE(Differential Evolution), and compare and analyze their results.

II. Trying different objective functions

A. Function 1

$$Max\ f = \omega_1 * \tau + \omega_2 * \gamma - \omega_3 * F_a$$

B. Function 2

$$Max\ f = \omega_1 * \tau + \omega_2 * \gamma + \frac{\omega_3}{F_a}$$

III. Hyperparameters tuning

Changing the number of universes of MVO, number of iterations, average vehicle speed, number of vehicles etc.

References

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