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Research on Emergency Supply Plan in Disaster Relief

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Abstract. The determination of material supply plan in the disaster relief process has an important impact on the later relief work, the goal of this research is to Build a mathematical model to draw up a plan of emergency supply to meet the demand for resources during the disaster rescue process. In this paper, the integer programming model is established with the longest material supply time as the target and the material demand in the disaster area as the constraint. The model shows great flexibility and was applied as an example of a hurricane in Puerto Rico.

Keywords: Integer Programming; supply plan; lingo; hurricane.

1. Introduction

The attack of extreme weathers can cause severe damage to a region such as casualties, Houses collapsed, loss of power, traffic jams. Demands for medical supplies and lifesaving equipment will strain health-care clinics, hospital. Making a reasonable rescue plan is a complicated process, the quantity and types of supplies, the location of the base, and the route of supply must be considered carefully before the rescue.

In 2017, the worst hurricane to ever hit the United States territory of Puerto Rico, knocked down 80 percent of Puerto Rico's utility poles and all transmission lines, resulting in loss of power to essentially all of the island's 3.4 million residents. The electrical power and cell service outages lasted for months across much of the island, and longer in some locations. Widespread flooding blocked and damaged many highways and roads across the island.

Thus, a proper supply plan is the key to manage the event, in this case, the government need to provide medical supplies to 5 hospitals in Puerto Rico using 3 ISO containers. In order to prevent the shortage of resources, this model find a supply strategy to distribute the medical supplies evenly in 3 containers to avoid the situation in which one of the containers has run out supplies in advance and other containers are still remaining many supplies.

2. Problem Description

Three different medical packages referred to as MED1, MED2, and MED3 are needed by 5 different hospitals (see table 1). The government will use International Standards Organization (ISO) standard dry cargo containers to carry the medical supplies. The length, width and height of an ISO container is 19’3”, 7’8” and 7’ 10”. And the medical supplies will be delivered by rotor wing drones. The government needed to figure out a plan for 3 containers supplying 5 hospitals.

Table 1. Emergency Medical Package Configuration/Dimensions

Emergency Medical Package Configuration		
Package ID	Weight (lbs.)	Package Dimensions(in.) (L × W × H)
MED 1	2	14 × 7 × 5
MED 2	2	5 × 8 × 5
MED 3	3	12 × 7 × 4

Table 2. Anticipated Medical Package Demand

Location Name	Latitude	Longitude	Requirement	Quantity	Frequency
Caribbean Medical Center	18.33	-65.65	MED 1	1	Daily
			MED 3	1	Daily
Hospital HIMA	18.22	-66.03	MED 1	2	Daily
			MED 3	1	Daily
Hospital Pavia Santurce	18.44	-66.07	MED 1	1	Daily
			MED 2	1	Daily
Puerto Rico Children's Hospital	18.40	-66.16	MED 1	2	Daily
			MED 2	1	Daily
			MED 3	2	Daily
Hospital Pavia Arecibo	18.47	-66.73	MED 1	1	Daily

3. Nomenclature

Table 3. Nomenclature

Symbol	Definition
$Zi(A,j)$	The number of MED i supplied by container A to point j.
V	Volume of each container using ISO standard.
Vn	Volume of MED n.
$MEDnx$	Daily MED n consumption of Container x.
T_A,T_B,T_C	Time of container A, B, C running out of medical supply

4. Mathematical Formulation

The drone's flying distance is about 52.7km, according to the location of the hospital, we can draw approximate location of three container. Three containers from left to right are marked as A, B and C. The intersection of the lines represents the hospital. Piont1, Point2…Point5 represent Caribbean Medical Center, Hospital HIMA…Hospital Pavia Arecibo (follow the order from top to bottom of the first column in table 2). $z_1(A,1)$ represents the amount of MED1 supplied from container A to point 1. $z_2(B,5)$ represents the amount of MED2 supplied from container B to point 5, others are similar.

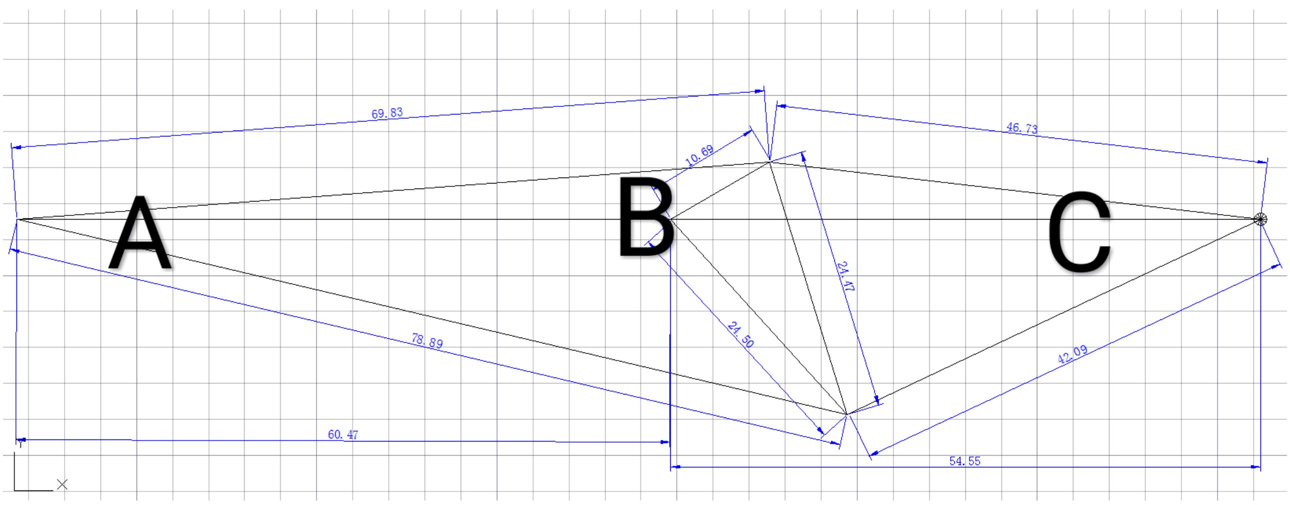

Fig. 1 locations of containers and hospitals

According to the constraints given in the problem, the following equations can be listed:

$$\begin{cases} z_1(A,5)=1 \\ z_1(C,1)=1 \\ z_3(C,1)=1 \end{cases} \tag{1}$$

Container A and B cannot deliver medical supplies to Point 1, Container C cannot deliver medical supplies to Point 4 and 5, the following equations can be listed:

$$\begin{cases} z_1(A,1)+z_2(A,1)+z_3(A,1)=0 \\ z_1(B,1)+z_2(B,1)+z_3(B,1)=0 \\ z_1(C,4)+z_2(C,4)+z_3(C,4)=0 \\ z_1(C,5)+z_2(C,5)+z_3(C,5)=0 \end{cases} \tag{2}$$

According to the demands of tasks, the following equations can be listed:

$$\text{Point 1: } \begin{cases} z_1(A,1)+z_1(B,1)+z_1(C,1)=1 \\ z_3(A,1)+z_3(B,1)+z_3(C,1)=1 \end{cases} \tag{3}$$

$$\text{Point 2: } \begin{cases} z_1(A,2)+z_1(B,2)+z_1(C,2)=2 \\ z_3(A,2)+z_3(B,2)+z_3(C,2)=1 \end{cases} \tag{4}$$

… …

The goal is to find the optimal allocation of deliveries to make the rescue last the longest time.V_1 represents the volume of MED1, V represents the volume of an ISO container, MED_{1A} represents the amount of MED1 consumed per day of container A. Suppose the container A is filled with MED1, MED2, MED3 in A certain proportion . T_A represents the time of container A running out of medical supply, others are similar. So, we get:

$$\mathrm{Max}[\min(T_A, T_B, T_C)] \tag{5}$$

$$\begin{cases} T_A = V/(V_1 MED_{1A} + V_2 MED_{2A} + V_1 MED_{3A}) \\ T_B = V/(V_1 MED_{1B} + V_2 MED_{2B} + V_1 MED_{3B}) \\ T_C = V/(V_1 MED_{1C} + V_2 MED_{2C} + V_1 MED_{3C}) \end{cases} \tag{6}$$

$$\begin{cases} MED_{1A}=z_1(A,1)+z_1(A,2)+z_1(A,3)+z_1(A,4)+z_1(A,5) \\ MED_{1B}=z_1(B,1)+z_1(B,2)+z_1(B,3)+z_1(B,4)+z_1(B,5) \\ \vdots \\ MED_{3C}=z_3(C,1)+z_3(C,2)+z_3(C,3)+z_3(C,4)+z_3(C,5) \end{cases} \tag{7}$$

z1, z2, z3 are limited to integers, tasks of delivery can be figured out by Lingo. The result is as follow:

A gives 1 MED 1 to Point 5, 1 MED 1 to Point 4, and 1 MED 2 to Point 4; B gives 1 MED 1 to Point 2, 1 MED 1 to Point 3, and 2 MED 1 to point 4; C gives 1 MED 1 and 1 MED 3 to Point 1, 2 MED 1 and 1 MED 3 to Point 2, 3 MED 2 to Point 3.

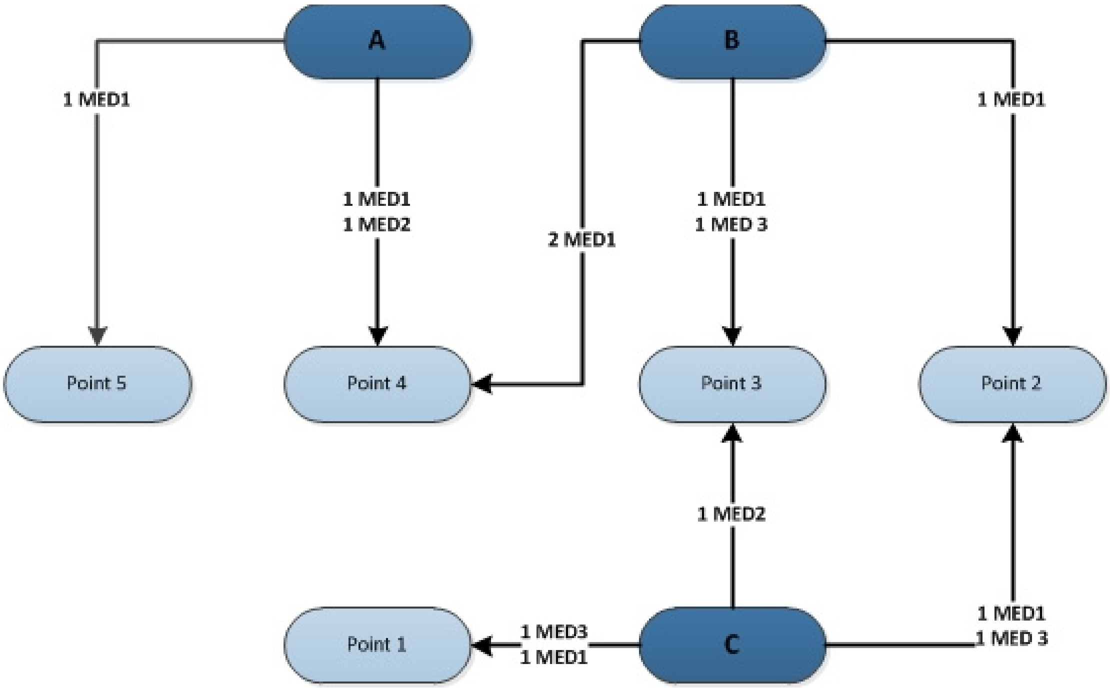

Fig. 2 plan of medical supplies

5. Conclusion

If the packing configuration for each of up to three ISO cargo containers follows the result above, considering other things carried by containers, the medical supplies is sufficient for three months, which means the model is works quite well in practice.

The strength is that the model is easy to adjust to different situations, since the objective function and constraints can be adjusted according to the actual situation. But the weakness is also obviously that it does not take into account the payload of drones and bin packing problem of 3 containers. Adding more constrains may be my future work.

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