EMPLOYING HELICOPTERS IN THE MODELLING OF LAST MILE DISTRIBUTION SYSTEM IN LARGE-SCALE DISASTERS

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CURRENT SITUATION

- After a catastrophe, transport infrastructure, is often damaged.
- Transport capacity is extremely limited or non-existent.
- Managing transportation becomes even more complex due to chaotic conditions.
- Agility is crucial and time is a critical factor in the decision-making process.

CURRENT SITUATION

The use of helicopters in air transport operations:

- Expensive
- Complex
- Requires a well-structured planning-process

IMPROVEMENT

Minimize the mission time to perform the transport task in the last mile distribution:

- To victims in isolated regions
- Considering aeromedical evacuations as well
- In a network composed of multiple hub
- multiple products and heterogeneous fleet
- With specific restrictions for helicopters after catastrophic situations

IMPROVEMENT

Proposed model expands the restrictions when considering:

- The speed of the vehicles
- Availability of fuel and helicopters consumption
- Budget availability for the mission
- Physical compatibility between helicopters and the places
- The possibility of the aircraft returning from the demand point to base, transporting victims who need medical assistance

EXACT METHOD

In catastrophes, helicopters

- usually travel from an origin to one single destination,
- where it delivers supplies,
- and return back to the origin.

Consequently, it can be modelled as a transportation problem,

- aiming to minimize the total time of service,
- considering multiple depots (hub), products, demand points, and heterogeneous fleet.

EXACT METHOD

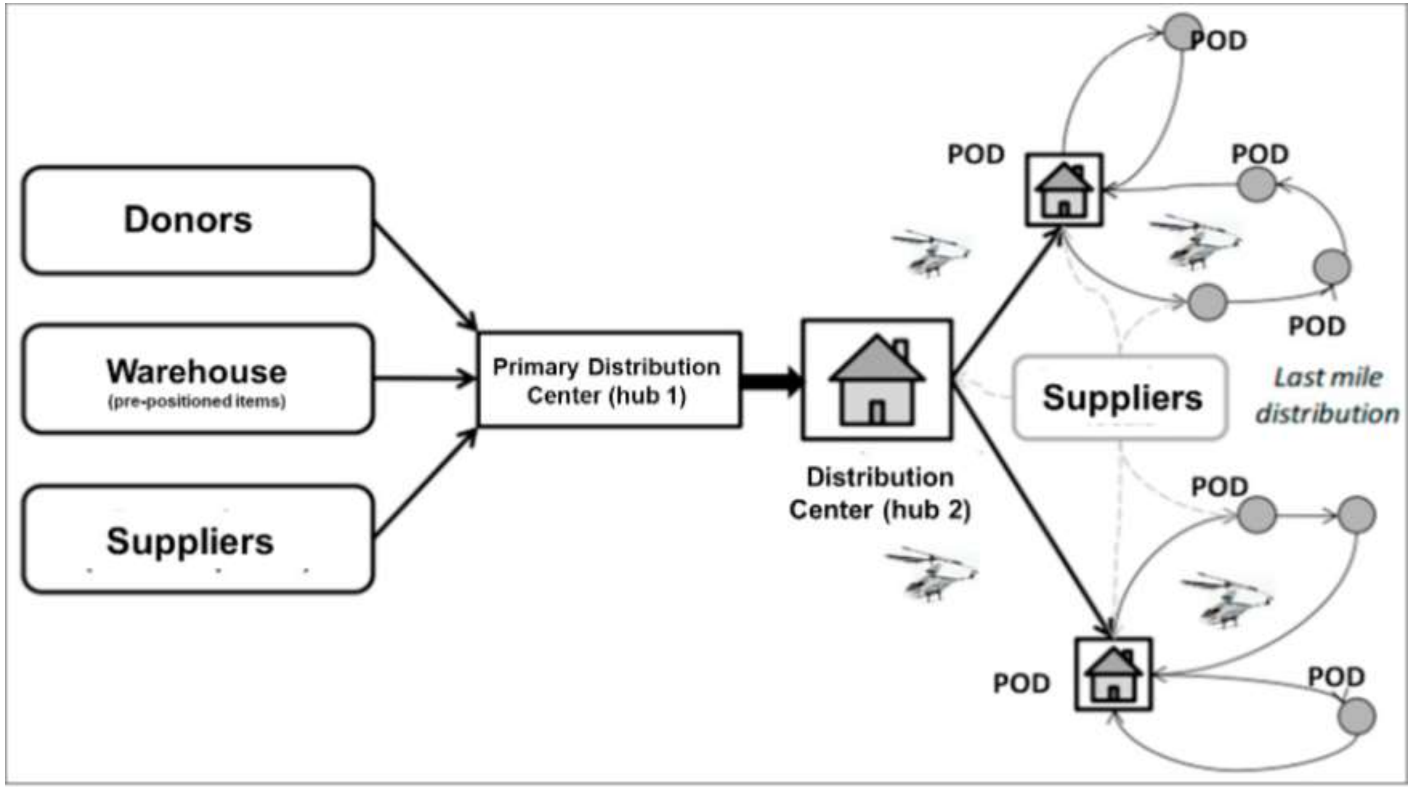

Fig. 1. Physical flow of resources in the humanitarian supply chain
Source: Balcik et al. (2008).

EXACT METHOD

INDEX SETS

D	set of hub 2, $d = \{1,2, \ldots, i\}$
C	set of POD, $c = \{1,2, \ldots, j\}$
P	set of supply types, $p = \{1,2, \ldots, a\}$
H	set of vehicle types, $h = \{1, 2, \ldots, m_d\}$
K	set of vehicles type h available, $k = \{1, 2, \ldots n_{dh}\}$
V	set of trips made on the assessed day, $v = \{1,2, \ldots, r\}$

EXACT METHOD

PARAMETERS

DEM_{cp}	quantity of supplies p required at the POD c, in units.
NVR_c	number of victims to be transported from PODc, in units.
ZPH_c	conditions of the landing zone at the PODc, where {1,2,3,4}
$DISP_{dp}$	availability of supplies type p in hub 2 d, in units.
$COORD_d$	co-ordinates of hub 2 d.
$COORD_c$	co-ordinates of POD c.
$DIST_{dc}$	distance between hub 2 d and PODc, in km
T_{dch}	travel time between hub 2 d the POD c using vehicle type h, in hours
PU_p	volume of a unit of supply p, in kg
VU_p	volume of a unit of supply p, in m^3
CAT_h	Category of vehicle type h, in {1,2,3}
VEL_h	cruising speed of vehicle type h, in km/h
$CAPW_h$	transport capacity for vehicle type h, in tonnes
$CAPV_h$	transport capacity for vehicle type h, in m^3

EXACT METHOD

PARAMETERS

$CAPPAX_h$	transport capacity of people of vehicle type h, in units
$CTHV_h$	cost of one hour of flight of vehicle type h, in monetary unit
α_{ph}	time for loading/unloading a unit of supply o in a vehicle type h, in hours/unit
τ_{hc}	approach time of vehicle type h at PODc, in hours/unit
λ_h	time for embark/disembark of victims in a vehicle type h, in hours/unit
MJ_h	maximum daily journey for each k-th vehicle type h, in hours
$CCOMB_h$	fuel consumption for each vehicle type h, in liters/hour
n_{dh}	Number a vehicle types h available at hub 2.
$DCMB_d$	availability of fuel in the hub 2d, in liters
$MHVD_h$	maximum availability of flight hours for vehicles type h
ORC	maximum budget availability for air operation, in monetary units

EXACT METHOD

DECISION VARIABLES

X_{dckhc}	decision variable; defined as 1 if the delivery of hub 2 (d) to PODc occurs using the k-th vehicle type h in trip number v; 0 if it occurs otherwise.
QT_{dcpkhv}	quantity of supplies p transported from hub 2 (d) to the PODc by the k-th vehicle type h in trip number v.
$QEVAC_{dckhv}$	number of victims transported from POD c to hub2 d using k-th vehicle type h in trip number v..

EXACT METHOD

MODEL

$$Min\ Z = \sum_{d=1}^{i}\sum_{c=1}^{j}\sum_{h=1}^{m_d}\sum_{k=1}^{n_{dh}}\sum_{v=1}^{r} D_{dchkv}$$

$$D_{dchkv} = (2.T_{dch} + \tau_{hc}).X_{dckhv} + \sum_{p=1}^{a}\left(\alpha_{ph}.QT_{dcpkhv}\right) + \lambda_h.QEV_{dckhv}$$

EXACT METHOD

CONSTRAINTS

supply limitation of products (supplies) p to the availability of each product type;

$$\sum_{c}\sum_{k}\sum_{h}\sum_{v} QT_{dcpkhv} \leq DISP_{dp}, \qquad \forall d, p$$

guarantee the supply of the demand for products p at POD c;

$$\sum_{d}\sum_{k}\sum_{h}\sum_{v} QT_{dcpkhv} \geq DEM_{cp}, \qquad \forall c, p$$

guaranteeing that trip v respects weight limit (carry by vehicle types h);

$$\sum_{p} PU_{p}.QT_{dcpkhv} \leq CAPW_{h}.X_{dckhv}, \qquad \forall d, c, k, h, v$$

EXACT METHOD

CONSTRAINTS

guaranteeing that trip v made with vehicle type h leaves hub 2 for POD;

$$\sum_{d}\sum_{c}\sum_{k}\sum_{h} X_{dckhv} = 1, \qquad \forall v$$

guaranteeing that, in each trip v, the volume limit carried by vehicle type h is respected;

$$\sum_{p} VU_p . QT_{dcpkhv} \leq CAPV_h . X_{dckhv}, \qquad \forall d, c, k, h, v$$

ensuring that the victims that required aeromedical evacuation for medical purposes are transported

$$\sum_{d}\sum_{k}\sum_{h}\sum_{v} QEVAC_{dckhv} = NRV_c \qquad \forall c$$

EXACT METHOD

CONSTRAINTS

guaranteeing that, in each trip v, the limit of passengers carried by vehicle type h is respected;

guaranteeing that the vehicles have their maximum working day respected;

$$\sum_{c}\sum_{v} D_{dchkv} \leq MJ_h, \qquad \forall d,k,h$$

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characteristics of the helicopter landing area (ZPH);

$$CAT_h . X_{dchkv} \leq ZPH_c, \qquad \forall d,k,h,v,c$$

guaranteeing that the vehicles have their maximum working day respected;

$$\sum_{c}\sum_{v} D_{dchkv} \leq MJ_h, \qquad \forall d,k,h$$

EXACT METHOD

CONSTRAINTS

guaranteeing that the fuel limit available on hub 2 is respected;

$$\sum_{c}\sum_{k}\sum_{h}\sum_{v} CCOMB_h.(2.T_{dch} + \tau_{hc}).X_{dckhv} \leq DCOMB_d, \qquad \forall d$$

guaranteeing that the budget limit is respected;

$$\sum_{d}\sum_{c}\sum_{k}\sum_{h}\sum_{v} CLHV_h.(2.T_{dch} + \tau_{hc}).X_{dckhv} \leq ORC$$

statement that X_{dckhv} is a binary variable;

$$X_{dckhv} \in \{0,1\}, \qquad \forall d, c, k, h, v$$

statement that QT_{dcpkhv} is a non-negative real variable (R+)

$$QT_{dcpkhv} \in R^+, \qquad \forall d, c, k, h, v$$

statement that $QEVAC_{dcpkhv}$ is a non-negative integer variable (Z+);

$$QEVAC_{dcpkhv} \in Z^+, \qquad \forall d, c, k, h, v$$

EXACT METHOD

Table 4. Mean results of the simulations for the number of demand points

POD		20	40	60
Number of variables		29.210	58.410	87.610
Number of restrictions		29.577	58.837	88.097
Average processing time (seconds)		62,70	223,61	> 3.599
Average load carried (kg)		34.458	70.499	103.910
Average number of people transported (pax)		242	487	778
60 seconds	Gap %	0,36	0,84	1,79
	Optimal solution	9	3	0
120 seconds	Gap %	0,36	0,53	0,92
	Optimal solution	9	9	0
600 seconds	Gap %	0	0,41	0,75
	Optimal solution	10	4	0

ADDITIONAL EXAMPLE

- **A Drone Fleet Model For Last-mile Distribution in Disaster Relief Operations (**Boualem Rabta, Christian Wankmüller, Gerald Reiner)
  - helicopters is not applicable in this situation, alternative means of transport have to be considered.
- **Planning helicopter logistics in disaster relief** (Linet Ozdamar)
  - The objective aims at minimizing the total mission time