Optimizing emergency responses: developing operations research tools for Flood response in Bangladesh

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Abstract:
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1 INTRODUCTION

2 METHOD

2.1 Optimization model (VRP-TW)

Conceptual Model

1. Objective: **maximizing coverage** of shelter (demand) points
2. DV: no. of vehicles (# of drone, helicopter, truck), capacity of these vehicle
    a. Vehicle level: x_ijk, from where to where
    b. Routing level: road selection (disrupted, non-disrupted routes)
3. Input parameters: packages.
    a. Disrupted vs non-disrupted networks
4. Constraint
    a. Travel each demand points only once
    b. Capacity constraints: for each vehicle

c. Travelling distance: helicopter (max coverage), every vehicle (truck refuel), other practical limits
d. Time-window

Table 1 Notations of the model

Decision variables		Input parameters	
x_{ijk}	Binary variable indicating if vehicle k traveled from warehouse i to demand point j	d_{ij}	Distance from warehouse i to shelter j
y_j	Continuous variable (need discussion) for proportion of population in shelter points covered	q_j	Demand in shelter j
		Q_k	Capacity of vehicle k
		R_k	
		A_i	Availability in warehouse j

Add the model ++ (for now, lets build simpler model with minimalistic structure, and complete the web app so that we can see the crude output from the model). The objective is to maximize the number of shelters covered (1) (maybe proportion of population is a better metric++). Each shelter must be covered at least once (2). Vehicles cannot exceed their capacity (3). Drone and trucks must stay within their range (*4*) (defining, and getting data on these ranges can be challenging++). Boundary conditions for decision variables (5).

$$\text{Maximize } Z = \sum_j y_j \qquad (1) \quad \text{Objective function}$$

$$\sum_i \sum_k x_{ijk} \geq y_j \quad \forall j \qquad (2) \quad \text{Coverage Constraint}$$

$$\sum_j q_j x_{ijk} \leq Q_k \quad \forall i\, \forall k \qquad (3) \quad \text{Capacity Constraint}$$

$$\sum_j d_{ij} x_{ijk} \leq R_k \quad \forall k \qquad (4) \quad \text{Range of vehicles}$$

$$x_{ijk} \in \{0,1\}, \quad y_j \in \{0,1\} \qquad (5) \quad \text{Boundary condition}$$

2.2 Data:

2.2.1 Summary of the case study (present situation)

As of today (Aug 25, 2024), more than 500,000 people have taken refuge in around 3,500 shelters in the 11 flood-hit districts, where nearly 750 medical teams are on the ground to provide treatment (ReliefWeb

2024; Paul 2024). Most affected communities are from Feni, Noakhali and Khagracchari districts; 193,864 people are in 3170 shelters.

1.

Working on:

1. Collecting GIS map & .json/.shp files of flood impacted regions ++

Some useful links (ref. everyone):

1. https://protirodh.net/flood (you need to drag the map to the right). Note: view is different in Safari vs Chrome.
2. http://biwta.port-log.net/live/Map.php
3. Flood Forecasting & Warning Centre http://www.ffwc.gov.bd
4. Water level data

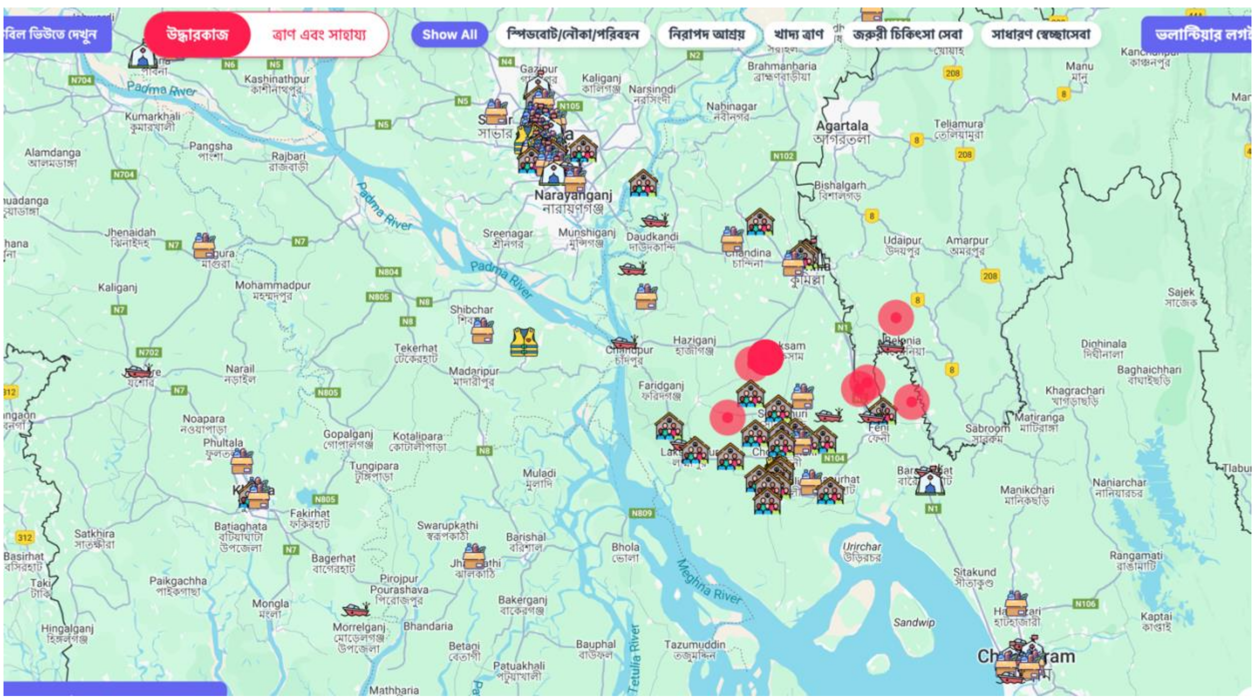

Figure 1 Affected regions in Bangladesh (Source: protirodh.net 2024)

2.2.2 Data needed for the optimization model

Table 2 Metadata and database schema

Category		*Specifics*	*Data points/ type*

Affected region	Road Network Data	Traffic Data: Real-time or historical traffic patterns, congestion data, and road closures. Accessibility: Information on road conditions, including roads that may be flooded or inaccessible.	
		Shelters: Locations of emergency shelters and their capacities. Hospitals: Locations, capacities, and current status (operational or flooded). Locations of communication towers, especially in areas with poor signal coverage.	Geolocation of shelters (& their capacity) Note: Current occupancy in this shelters are location of demand points for our model.
Supplier		**Depots/Warehouses**: Locations of resource storage facilities.	Geolocation of depot
	Resource Data	Resource Type: Types of resources available for distribution (e.g., food, water, medical supplies). Stock Levels: Current stock levels of each resource at different locations. Resource Requirements: Demand for resources at various locations.	
Affected people (demand)			

Hypothetical table summarizing some of the GIS data elements, shown in Table 3. We may not be able to obtain or produce such precise information for our problem, but this can be a good starting point for our data collection.

Table 3 Hypothetical datatable (for our brainstorming), produced using ChatGPT

Data Type	Attributes	Example Values
Road Network	Road ID, Type, Condition, Traffic Level, Closure Status	R123, Highway, Good, High, Open
Bridges	Bridge ID, Location, Condition, Flood Risk	B456, (38.8977, -77.0365), Fair, High
Elevation	Location, Elevation (m)	(38.8977, -77.0365), 50
Flood Zones	Zone ID, Flood Risk Level, Last Flooded Date	FZ789, High, 2024-08-20
Shelters	Shelter ID, Location, Capacity, Occupancy	S101, (38.8977, -77.0365), 200, 150
Hospitals	Hospital ID, Location, Status, Bed Capacity	H202, (38.8977, -77.0365), Operational, 100
Population Density	Location, Density (people/km²)	(38.8977, -77.0365), 2000
Weather	Location, Temperature (°C), Rainfall (mm), Wind Speed (km/h)	(38.8977, -77.0365), 25, 50, 10
Resource Stock	Resource ID, Type, Location, Stock Level	R303, Water, Depot 1, 5000 liters

Data Type	Attributes	Example Values
Resource Requirement	Location, Resource Type, Required Quantity	(38.8977, -77.0365), Food, 1000 kg
Communication Towers	Tower ID, Location, Signal Strength	C404, (38.8977, -77.0365), Strong

2.2.3 Dataset of our case-study

Table 4 Dataset of flood-affected region

Population density of Bangladesh source link; link2

3 RESULT & DISCUSSION

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The flood severity plot in Figure 2 is semi-hypothetical (I have manually put the severity after reading some local newspapers). Population density plot in Figure 3 (need to fix color++)

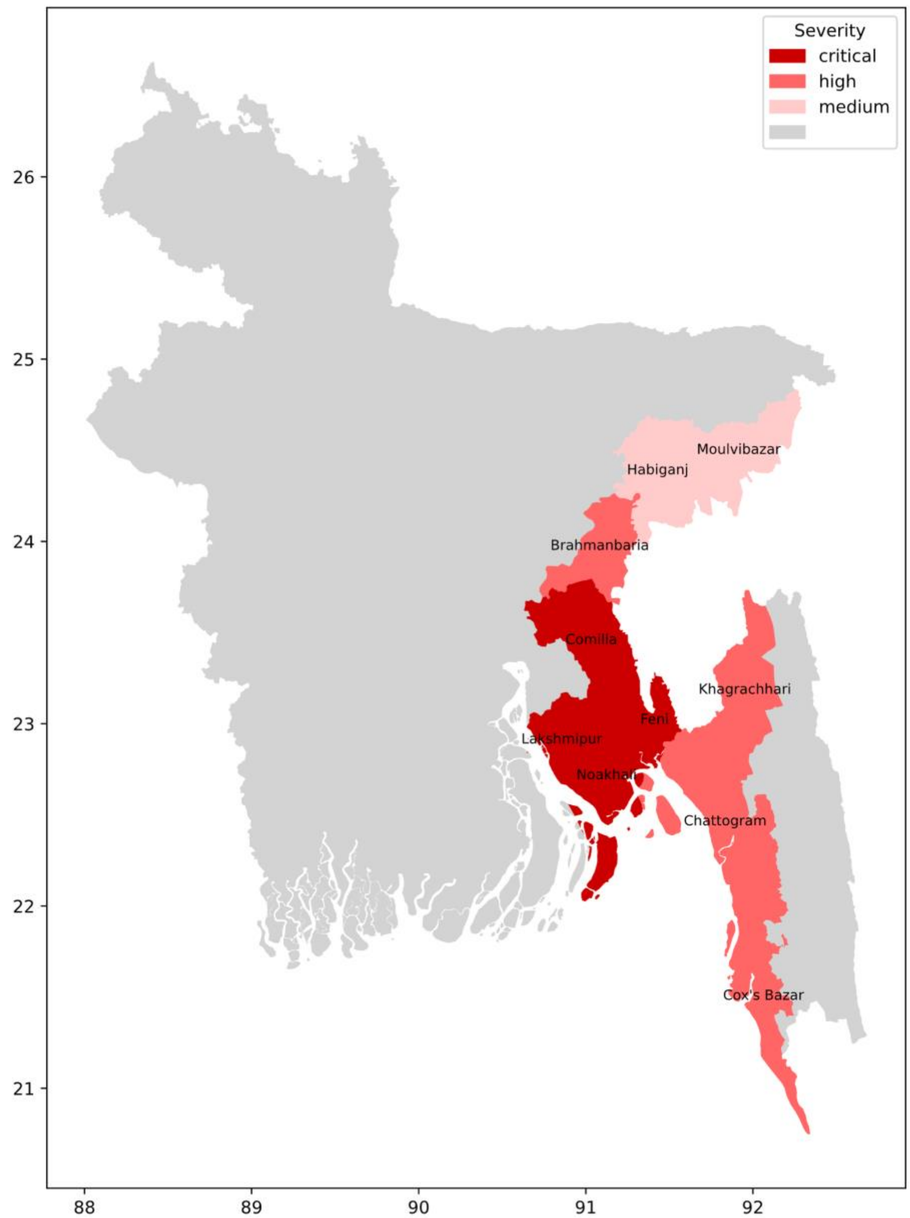

Figure 2 Floor severity in affected districts

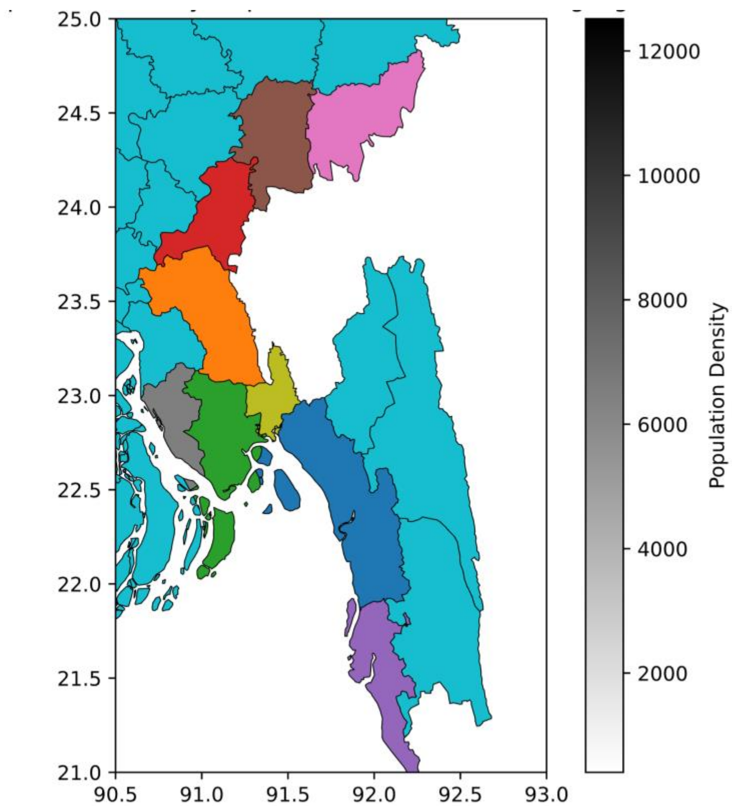

Figure 3 Population density

3.1 Optimization network and analysis of relief distribution

The mathematical model is implemented using Gurobi, with variables x for routes and y for shelter coverage.

3.2 Web application (think about a name)

How this web app can be useful, and what is typical inputs and outputs of the app++ . Input of the web application (from user): newly available relief amount

Expected output:
Screenshot from app, and tabular output (for stakeholders)

Anylogic, and AIMMS platform (they have some amazing tabular format output for easy interpretation) can be useful reference to build the app.

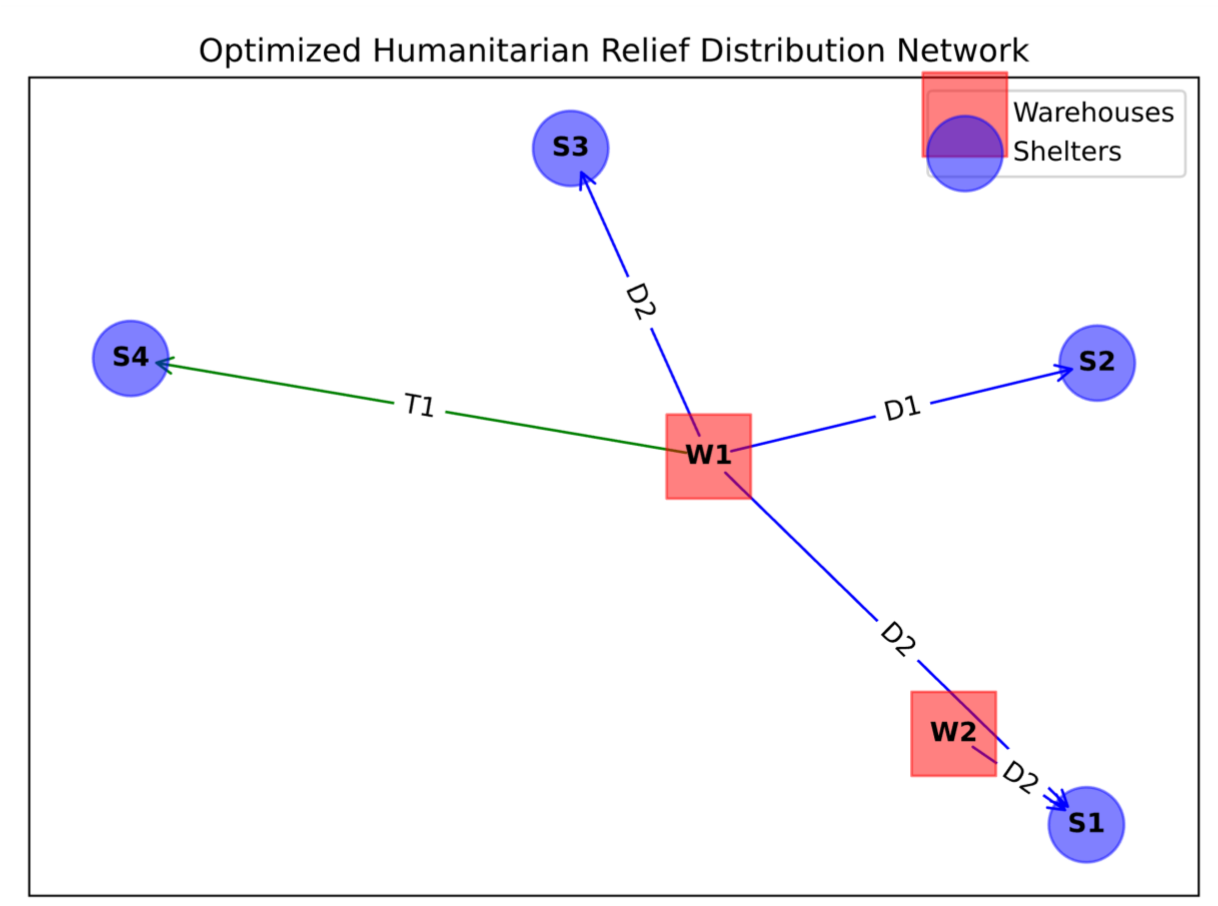

Figure 4 Optimized relief distribution network (will add GIS map, and data for Feni++)

3.3 Challenges, Limitations, and future works

Challenges (Brainstormed with Riad):

1. Most Bangladesh Army base locations are NOT open-source

Emergency response in Bangladesh is often at community level (getting data at national level is almost impossible, partly due to security reasons)

4 CONCLUSION

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SUPPLEMENTARY RESOURCES

https://github.com/tanmoyie/Optimizing-flood-reponse-in-Bangladesh

AUTHORS' CONTRIBUTION

Md Mahbubar Rahman: original research idea, optimization model development, solution algorithm; ***Tanmoy Das:*** optimization model development, data curation and analysis; ***Riad Alam:*** Domain experience, data collection; ***Hafizur Rahman:*** model deployment, validation

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