Supply Policies for the Time of Rapid-onset Disasters

Mahyar Eftekhar

October 13, 2021

Associate Professor of Supply Chain Management
W.P. Carey School of Business, Arizona State University
22,400 natural disasters were recorded that left more than 14 billion affected people who needed immediate assistance (Ref: Ritchie & Roser).
Responding to rapid-onset disasters is logistically more complicated.

**Challenge:** Humanitarians are unable to preplan an effective and efficient demand coverage, due to the unknowns e.g., when? where? how many?
Responding to rapid-onset disasters is logistically more complicated.

The first stages of disaster response are the most chaotic period.
Responding to rapid-onset disasters is logistically more complicated.

**Primary goals:** (i) quick response, and (ii) securing enough supply of life-saving items (e.g., water, sanitation, and food).
Two common models

**Proactive policy:** Prepositioning inventory at strategic locations

**Advantages:** enough time to buy and store the selected relief items, at a low purchase price, with assurance of quality.

**Challenge:** demand uncertainty
Two common models

Reactive policy: Using local supply

Advantages: more precise demand estimation, culturally accepted products, and stimulation of the local economy

Challenge: supply uncertainty
Other factors: Total landed cost

Proactive is more expensive than reactive:

(Based on internal audit of four organizations CRS, CARE, Mercy Corps, and WVI.)
Other factors: Total landed cost

Reactive is more expensive than proactive:

Price gouging, due to the lack of supply, might be an example.
• Donors’ preference:

→ USAID requires humanitarians to supply items from suppliers of the donor country (encouraging prepo stock).

→ The EU requires humanitarians to procure goods from suppliers in the country of operations (encouraging reactive supply).
Question

**Optimal level of prepo** either as the **main** source of supply, or as **backup**?
We solved this question for different settings:

- Single-relief item (e.g., a kit of essential items)
  - Reactive policy is prioritized
  - Proactive policy is prioritized

- Multi-relief item (i.e., a subset of items are distributed at each event)
  - Reactive policy is prioritized
  - Proactive policy is prioritized
  - Reactive for some items, and proactive for others
A cycle starts from the end of an emergency operation, and ends when next disaster occurs.

Uncertainty: time to next disaster, demand magnitude, amount of local supply, and amount of emergency fund.
A high-level expected cost during a cycle is

\[
C(x) = E \left[ \sum_{j \in \mathcal{N}_L} \left( iT_x + \alpha_j y_j^* (D, Q, R, T, x) + \min \left\{ x_j, \left( D_j - y_j^* (D, Q, R, T, x) \right)^+ \right\} \right) \\
+ \sum_{j \in \mathcal{N}_P} \left( iT_x + \alpha_j y_j^* (D, Q, R, T, x) + \min \left\{ x_j, D_j \right\} \right) \\
+ v_j \left( D_j - x_j - y_j^* (D, Q, R, T, x) \right)^+ \right] 
\]
Optimal prepo level and key players

Optimal prepo level

A general policy to determine optimal prepo level can be calculated using high-level data. See our papers:


Key elements to structure a model

Our results show that two key factors identify the model one should choose to identify optimal prepo level: total landing price of an item, and the total budget available.
Why landing price matters?

Because it changes our objective cost function.
Why **total budget** matters?

Because our key tradeoff is how to efficiently spend the budget.
High-level insights: Key elements

4-dimensional tradeoff

- the cost of insufficient prepo
- the cost of excess local fund

2-dimensional tradeoff

- the cost of insufficient prepo
- the cost of excess prepo

Budget below a threshold
Budget above a threshold
High-level insights: Key elements

Total budget and item price lead to completely different policies. A few examples:

<table>
<thead>
<tr>
<th>Directional impact of [variable, if increasing]</th>
<th>Reactive (Local supply is cheaper)</th>
<th>Proactive (Prepo is cheaper)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sufficient budget</td>
<td>Insufficient budget</td>
</tr>
<tr>
<td>Disaster frequency</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Shortage cost</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Holding cost</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Average local supply</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Uncertainty of emergency funds</td>
<td>Unaffected</td>
<td>🔼</td>
</tr>
<tr>
<td>Average emergency funds</td>
<td>Unaffected</td>
<td>🔼</td>
</tr>
<tr>
<td>Volatility of disaster frequency</td>
<td>Unaffected</td>
<td>🔼</td>
</tr>
<tr>
<td>Cash inflow</td>
<td>Unaffected</td>
<td>🔼</td>
</tr>
<tr>
<td>Cost of local supply</td>
<td>Unaffected</td>
<td>🔼</td>
</tr>
<tr>
<td>Initial budget</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Cost per unit of prepo</td>
<td>🔼</td>
<td>🔼</td>
</tr>
<tr>
<td>Demand or supply uncertainty</td>
<td>If critical</td>
<td>🔼</td>
</tr>
<tr>
<td>Effective approximate solution</td>
<td>We found simple approximate solution.</td>
<td>We have not been able to find it.</td>
</tr>
</tbody>
</table>
Ex. Why can't we have a determined direction when *budget is limited*?
Ex. Why can’t we have a determined direction when *budget is limited*?

When budget is limited, we need **more information or a clear strategy** to determine optimal prepo level.
High-level insights: Structured decisions

To be more strategic,

- design inventory models based on your internal preferences; proactive or reactive.
- narrow down the list of items you deliver.
- for each region, categorize items based on their comparative prices, criticality, and likelihood of shortage in local market.
- historical data can certainly help to tailor policies with lower error.
- if completely flexible between reactive and proactive but access to limited budget, assign emergency budget to the less critical items.
- etc.
### High-level insights: Structured decisions

<table>
<thead>
<tr>
<th></th>
<th><strong>High local price</strong></th>
<th><strong>Low local price</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High shortage cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low shortage cost</strong></td>
<td></td>
<td><strong>High shortage cost</strong></td>
</tr>
<tr>
<td><strong>Low shortage cost</strong></td>
<td></td>
<td><strong>Low shortage cost</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Low emergency fund</strong></th>
<th>Close to Upper Bound</th>
<th>Close to Upper Bound if D-Q correlated</th>
<th>Close to Lower Bound if independent but close to Upper Bound if correlated</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>High emergency fund</strong></th>
<th>Close to Upper Bound</th>
</tr>
</thead>
</table>
High-level insights: Scope

<table>
<thead>
<tr>
<th>Regional or global system</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ If prepo is the main source of supply (i.e., proactive policy), a <strong>global</strong> inventory model can be developed.</td>
</tr>
<tr>
<td>→ If prepo is backup (i.e., reactive policy), a <strong>regionally-tailored</strong> model should be considered.</td>
</tr>
</tbody>
</table>
High-level insights: Emergency fund

Is emergency fund useful?

→ If proactive, emergency fund is almost always less efficient than pre-disaster investment.

→ If reactive, emergency fund might be efficient in some conditions.
Prepo planning?

We welcome opportunities to collaborate with humanitarians in order to transform our Excel-based calculator to a simple online platform through which all humanitarians will be able to find optimal prepo of different relief items, without any cost!
Further collaboration?

On a range of “global health and humanitarian” supply chain topics, including

→ inventory management
→ asset management
→ distribution models and LMD
→ equity
→ field experiments to evaluate policies

Email: eftekhar@asu.edu