Supply Policies for the Time of Rapid-onset Disasters

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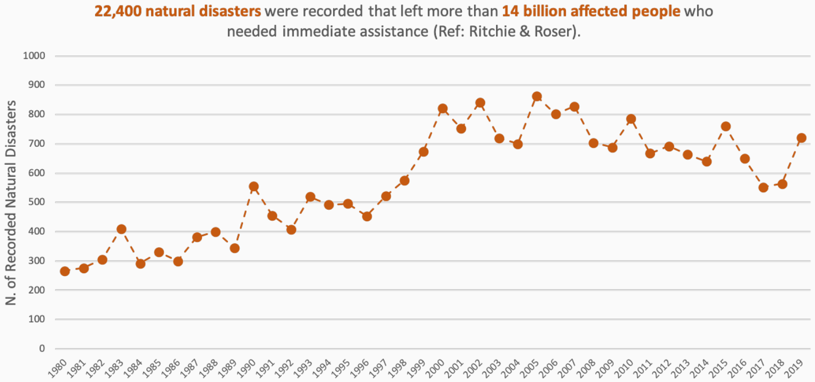
Background


22,400 natural disasters were recorded that left more than 14 billion affected people who needed immediate assistance (Ref: Ritchie & Roser).
N. of Recorded Natural Disasters
0
100
200
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600
700
800
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1980
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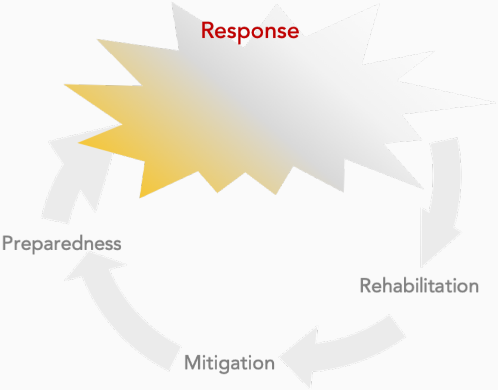
Background

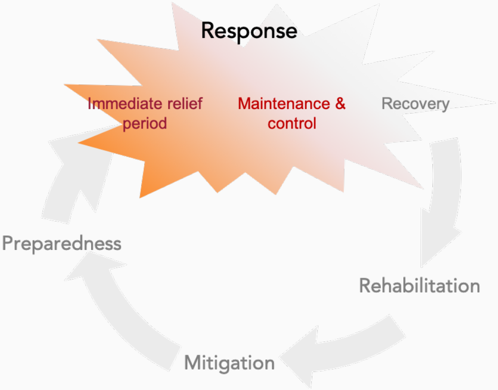
Responding to rapid-onset disasters is logistically more complicated.



Challenge: humanitarians are unable to preplan an effective and efficient demand coverage, due to the **unknowns** e.g., when? where? how many?

Background

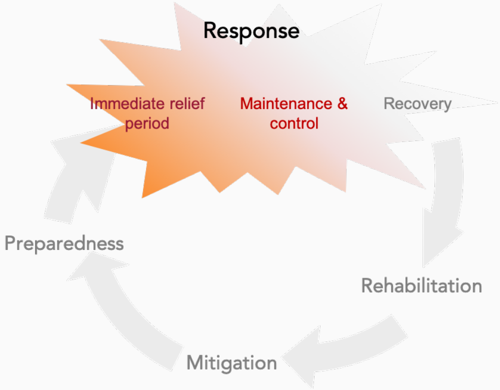
Responding to rapid-onset disasters is logistically more complicated.



The first stages of disaster response are the most chaotic period.

Background

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

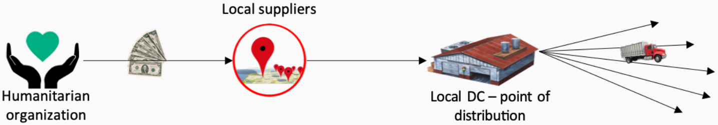
Proactive policy: Prepositioning inventory at strategic locations

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

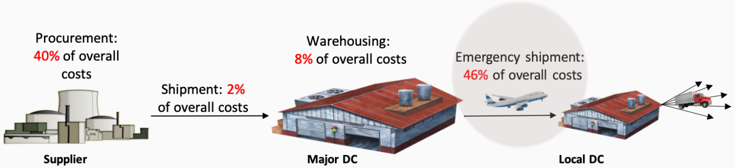


Advantages: more precise demand estimation, culturally accepted products, and stimulation of the local economy

Challenge: supply uncertainty

Other factors: Total landed cost

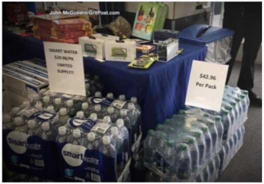
Proactive is more expensive than reactive:



(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.

Other factors: Donors' policy

- 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

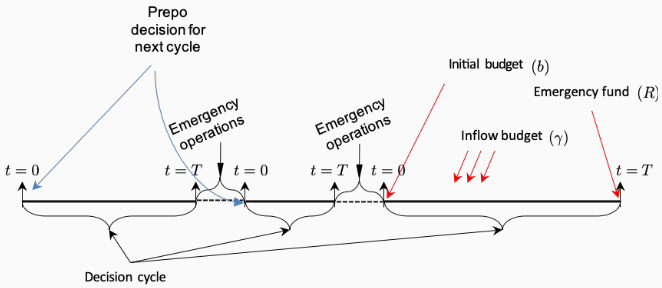
Optimal level of prepo either as the main source of supply, or as backup?

Scenarios

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

Decision cycle



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.

Cost function

A high-level expected cost during a cycle is

$$C(\mathbf{x}) = \mathbf{E}\left[\begin{array}{l} \sum_{j \in N_L} \left(\begin{array}{l} iTx_j + \alpha_j y_j^*(\mathbf{D}, \mathbf{Q}, R, T, \mathbf{x}) + \min\left\{x_j, \left(D_j - y_j^*(\mathbf{D}, \mathbf{Q}, R, T, \mathbf{x})\right)^+\right\} \\ +v_j\left(D_j - y_j^*(\mathbf{D}, \mathbf{Q}, R, T, \mathbf{x}) - x_j\right)^+ \end{array} \right) \\ + \sum_{j \in N_P} \left(\begin{array}{l} iTx_j + \alpha_j y_j^*(\mathbf{D}, \mathbf{Q}, R, T, \mathbf{x}) + \min\left\{x_j, D_j\right\} \\ +v_j\left(D_j - x_j - y_j^*(\mathbf{D}, \mathbf{Q}, R, T, \mathbf{x})\right)^+ \end{array} \right) \end{array}\right].$$

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:

- Eftekhar, M., J-S. J. Song, S. Webster. Pre-Positioning and Local-Purchasing for Emergency Operations Under Budget and Supply Uncertainty. *Manufacturing & Service Operations Management*. Articles In Advance.
- Eftekhar, M., S. Webster. Inventory Policies for Relief Operations: A Mix of Reactive and Proactive Alternatives. Earlier version available at: SSRN: https://ssrn.com/abstract=3694817.

High-level insights: Key elements

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.

High-level insights: Key elements

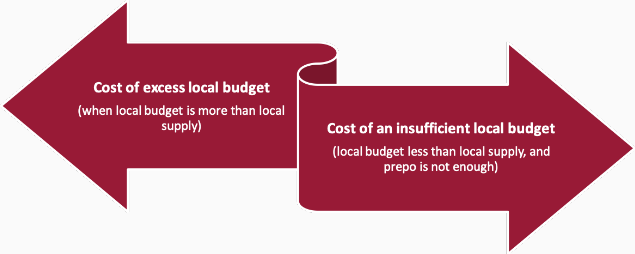
Why **landing price** matters?

Because it changes our objective cost function.

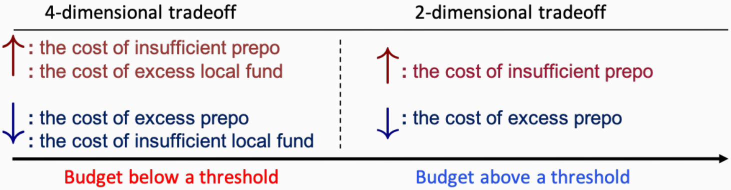
High-level insights: Key elements

Why **total budget** matters?

Because our key tradeoff is how to efficiently spend the budget.



High-level insights: Key elements



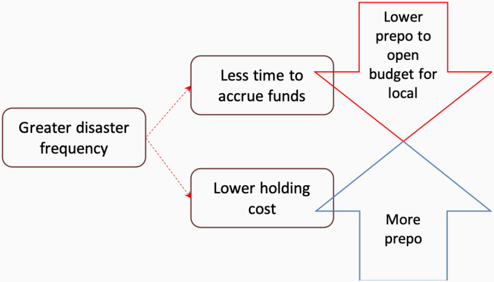
High-level insights: Key elements

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

Directional impact of [variable, if increasing]	**Reactive** (Local supply is cheaper)		**Proactive** (Prepo is cheaper)	
	Sufficient budget	Insufficient budget	Sufficient budget	Insufficient budget
Disaster frequency	↗	↗ ↘	↗	↗ ↘
Shortage cost	↗	↗	↗	↗
Holding cost	↘	↘	↘	↘
Average local supply	↘	↘	↘	↘
Uncertainty of emergency funds	Unaffected	↗ ↘	Unaffected	↗ ↘
Average emergency funds	Unaffected	↗ ↘	Unaffected	↗ ↘
Volatility of disaster frequency	Unaffected	↗ ↘	Unaffected	↗ ↘
Cash inflow	Unaffected	↗	Unaffected	↗ ↘
Cost of local supply	Unaffected	↗ ↘	↗	↗ ↘
Initial budget	↗	↗	↗	↗ ↘
Cost per unit of prepo	↘	↘	↘	↗ ↘
Demand or supply uncertainty	If critical ↗	↗ ↘	↗	↗ ↘
Effective **approximate solution**	We found simple approximate solution.		We have not been able to find it.	

High-level insights: Key elements

Ex. Why can't we have a determined direction when *budget is limited*?



High-level insights: Key elements

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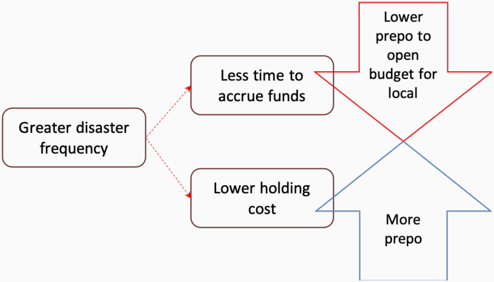


When budget is limited, we need more information **or** a clear strategy to determine optimal prepo level.

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

	High local price		Low local price	
	High shortage cost	Low shortage cost	High shortage cost	Low shortage cost
Low emergency fund	Close to Upper Bound	Close to Upper Bound if D-Q correlated	Close to Lower Bound if independent but close to Upper Bound if correlated	
High emergency fund	Close to Upper Bound			

High-level insights: Scope

Regional or global system

→ If prepo is the main source of supply (i.e., proactive policy), a global inventory model can be developed.

→ If prepo is backup (i.e., reactive policy), a regionally-tailored model should be considered.

High-level insights: Emergency fund

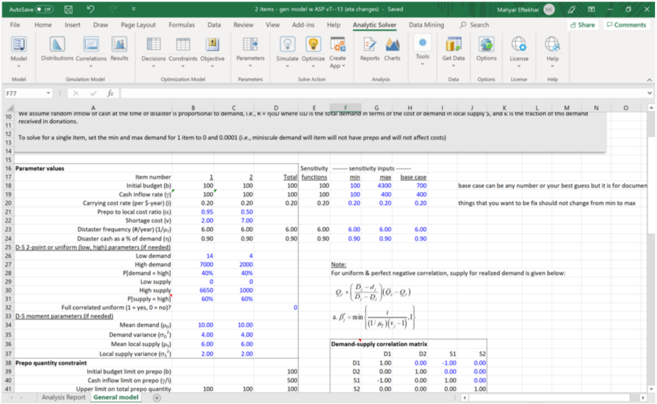
Is emergency fund useful?

→ 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

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