

# Supply Policies for the Time of Rapid-onset Disasters

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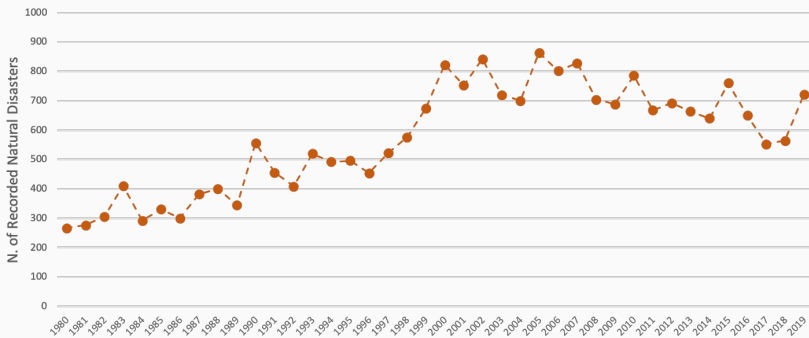
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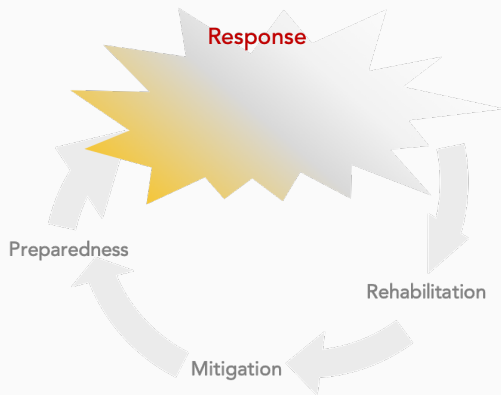
# Background

**22,400 natural disasters** were recorded that left more than **14 billion affected people** who needed immediate assistance (Ref: Ritchie & Roser).



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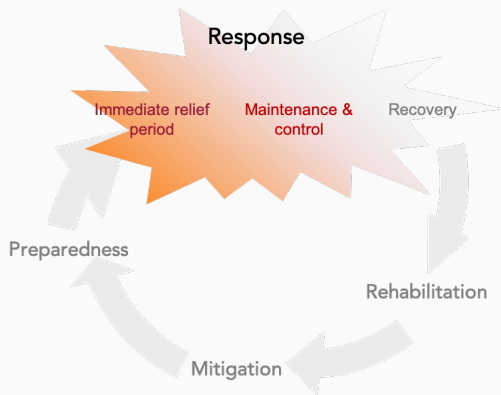
Responding to rapid-onset disasters is logistically more complicated.



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

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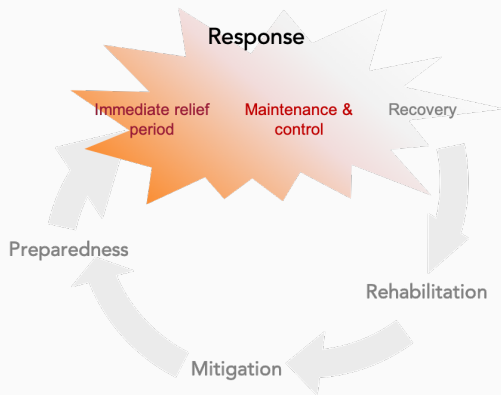
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The first stages of disaster response are the most chaotic period.

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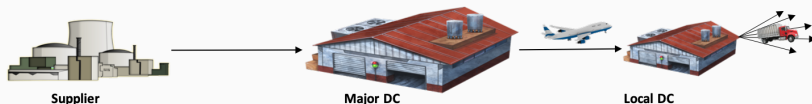
Responding to rapid-onset disasters is logistically more complicated.



**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).

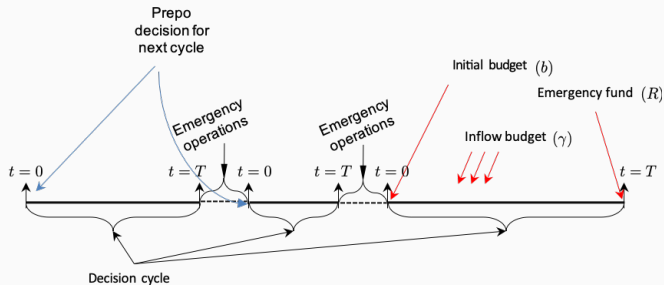


Optimal level of prepo either as the **main** source of supply, or as **backup**?

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

# 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

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



## 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

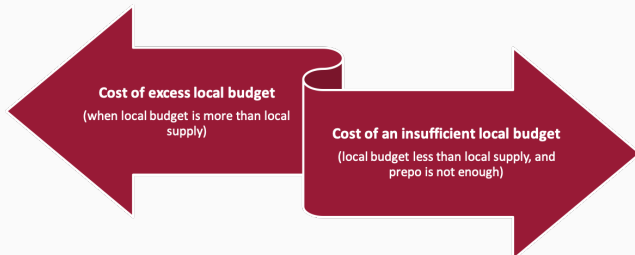
Why **landing price** matters?

Because it changes our objective cost function.

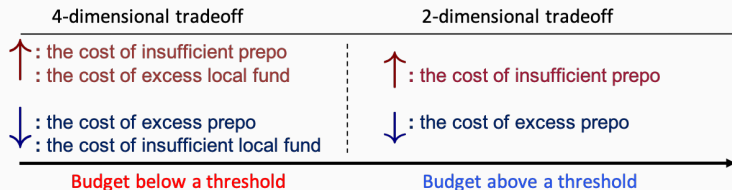
# High-level insights: Key elements

Why **total budget** matters?

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



# High-level insights: Key elements



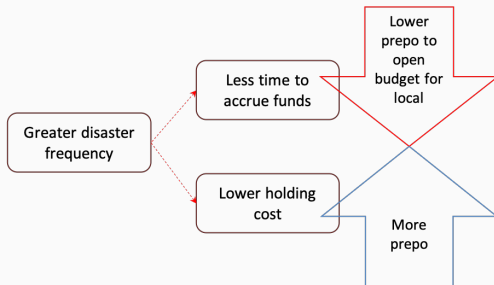
# High-level insights: Key elements

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 <b>approximate solution</b>	We found simple approximate solution.		We have not been able to find it.	

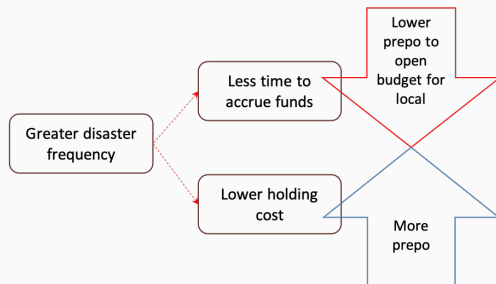
# High-level insights: Key elements

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



# High-level insights: Key elements

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

	<b>High local price</b>		<b>Low local price</b>	
	<b>High shortage cost</b>	<b>Low shortage cost</b>	<b>High shortage cost</b>	<b>Low shortage cost</b>
<b>Low emergency fund</b>	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	
<b>High emergency fund</b>	Close to Upper Bound			



## 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!

The screenshot shows an Excel spreadsheet titled "2 items - gen model w ASP v7 - 13 (info changed) - Saved". The ribbon includes "Analytic Solver" and "Data Mining". The spreadsheet content is as follows:

**10** We assume random inflow of cash at the time of disaster is proportional to demand, i.e.,  $k = \alpha \cdot D$  where  $\alpha$  is the total DEMAND in terms of the cost of demand in stock supply, and  $k$  is the fraction of this demand received in donations.

**11**

**12** To solve for a single item, set the min and max demand for 1 item to 0 and 0.0001 (i.e., miniscule demand will item will not have prepo and will not affect cost)

**13**

**14**

**15**

**16** Parameter values

Item number	1	2	Total	Sensitivity	min	max	base case
Initial budget (b)	100	100	100	100	100	4300	700
Cash inflow rate ( $\gamma$ )	300	300	300	300	300	400	400
Carrying cost rate (per 5-year) ( $\delta$ )	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Prepo to local cost ratio ( $\alpha$ )	0.95	0.50					
Shortage cost ( $\nu$ )	2.00	7.00					
Disaster frequency (R/year) ( $L/\mu_s$ )	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Disaster cash as a % of demand ( $\beta$ )	0.90	0.90	0.90	0.90	0.90	0.90	0.90

**17** **2.5-point or uniform flow, high parameters (if needed)**

	Low demand	High demand
Mean demand ( $\mu_s$ )	14	4
Demand variance ( $\sigma_s^2$ )	7000	2000
$\beta$ (demand = high)	40%	40%
Low supply	0	0
High supply	6450	1000
$\beta$ (supply = high)	60%	60%

**18** Full correlated uniform ( $\beta = \text{yes}$ , 0 = no)?

**19** **2.5-point or uniform flow, high parameters (if needed)**

	Mean demand ( $\mu_s$ )	Demand variance ( $\sigma_s^2$ )	Mean local supply ( $\mu_s$ )	Local supply variance ( $\sigma_s^2$ )
Mean demand ( $\mu_s$ )	10.00	10.00		
Demand variance ( $\sigma_s^2$ )	4.00	4.00		
Mean local supply ( $\mu_s$ )	6.00	6.00		
Local supply variance ( $\sigma_s^2$ )	2.00	2.00		

**20** **Prepo quantity constraint**

	1	2	Total
Initial budget limit on prepo (b)	100	100	100
Cash inflow limit on prepo ( $\gamma$ )	500	500	500
Upper limit on total prepo quantity	100	100	100

**21** **Sensitivity** ----- sensitivity inputs -----

**22** base case can be any number or your best guess but it is for document

**23** things that you want to be fix should not change from min to max

**24** Note:

**25** For uniform & perfect negative correlation, supply for realized demand is given below:

$$Q_s = \left( \frac{D_s - d_s}{D_s - D_s} \right) (Q_s - Q_s)$$

$$\alpha \beta = \min \left( \frac{i}{(1/\mu_s)(\gamma - 1)} \right)$$

**26** **Mean-supply correlation matrix**

	D1	D2	S1	S2
D1	1.00	0.00	-1.00	0.00
D2	0.00	1.00	0.00	0.00
S1	-1.00	0.00	1.00	0.00
S2	0.00	0.00	0.00	1.00

**27** Analysis Report **General model**

# 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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