Pre-positioning Inventory for Emergency Response

By Bahar Yetis Kara

CARE International Overview

- (Cooperative for Assistance and Relief Everywhere, Inc.)

- One of the world's largest private international humanitarian organizations
  - more than 12,000 staff
  - in over 100 countries

- Founded in 1945 to provide relief to survivors of World War II

  - 22 American organizations worked together to provide "care packages" to the survivors of World

> **"**
>
> *We received a CARE package every few months, beautifully wrapped. Every time a package came, it was like Christmas. I still remember the excitement, as we had to wait until our father came home from work before we were allowed to open them.*
>
> *Bernd Kadritzke, Germany*

CARE International Overview

- Mission: serve individuals and families in the poorest communities in the world

Strengthen capacity for self-help

Provide economic opportunity

Influence policy decisions at all levels

Address discrimination in all its forms

Deliver relief in emergencies

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CARE Overview - Development

- Hunger
  - Focus on young children
- Education
  - YouTube - Imagine This- India ‿
- Health
  - Training, nutrition, education, health services
  - HIV/AIDS – education, testing, treatment, caring for orphans
  - YouTube - Imagine This- Nepal

CARE Overview - Development

- Economic development , empowerment of women

  - YouTube - The Girl Effect

- Agriculture and natural resources

- Water

  - Build and maintain clean water systems and latrines

CARE overview: Emergency Relief

- In 2022, CARE projects directly assisted more than a million people in 38 countries

Preparedness	Help communities create plans to deal with emergencies
Response	Ensure communities receive food, water, shelter, healthcare and other emergency relief supplies when they need them most
Recovery & mitigation	Help communities recover and rebuild after disaster strikes

Emergency response practice – historical perspective

- Conduct most of the activities **after** the onset of the disaster
  1. identify possible suppliers (local and/or international),
  2. conduct the procurement process
  3. identify potential warehouse sites
  4. rent and set up warehouses
- Most of the transportation is outsourced
- Criteria
  - Response time
  - Coverage
  - Quality

Direct Shipments vs Pre-positioning

• Local Suppliers
    • Stimulate economy
    • Low transportation cost
	• Low quality
	• Lower availability

• Global Suppliers
    • Higher availability
    • Higher quality
	• Slower response
	• Higher transportation cost

Direct Shipments vs Pre-positioning

- Local Suppliers
  - Stimulate economy
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  - Low quality
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  - Slower response
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- **Pre-positioning**
  - **Faster response**
  - **Higher availability**

  - **Warehouse cost**
  - **Inventory cost**

Pre-positioning

- CARE and most humanitarian organizations have relied historically on local suppliers. *In fact, CARE has never pre-positioned*

- When there is a large scale disaster, local supplies run out and supplies have to be imported from unanticipated locations and transported by unanticipated systems

- Pre-positioning can significantly reduce response time because it may eliminate *the slow procurement process* during the initial stages of the response

Goal

- Given an initial investment, what is the configuration of the network that minimizes the average response time?

Pre-positioning Inventory

- Objective: Improve the <u>efficiency</u> & <u>timeliness</u> of emergency response
- Decisions
    - How many warehouses to open and where?
    - Which items to pre-position, in what quantity, and where?
    - How to replenish warehouses?
- Evaluate pre-positioning strategies
    - Response time
    - Cost
        - Warehouses
        - Purchasing & storage
        - Transportation

Analysis

- Model Input
  - Demand locations
  - Potential warehouse locations
  - Possible disaster types
  - Relief items
  - Supply
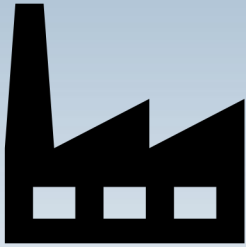 - Demand (depends on disaster type)

Relief Items

- Immediate needs of survivors

- CARE's specifications:

  - Food

  - Water& sanitation kit

  - Hot weather tent

  - Cold weather tent

  - Household kit

  - Hygiene kit

Option1:

After disaster:

Supplier
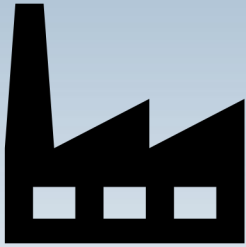
Demand node

Option1:

After disaster:

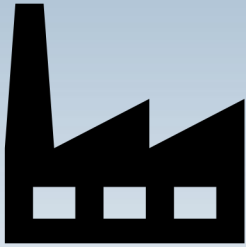Supplier → Demand node

Option2:

Before disaster:

Supplier   Warehouse   Demand node

Option2:

Before disaster:
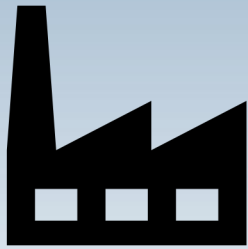
Supplier   Warehouse   Demand node
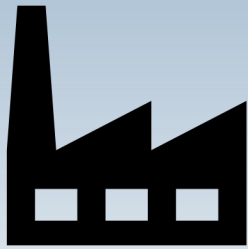
Option2:

After disaster:
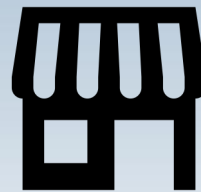
Supplier   Warehouse   Demand node

Candidate warehouse locations

- United Nations Humanitarian Response Depot (UNHDR, www.unhrd.org)
  - is a Network to deliver humanitarian relief items worldwide within 24/48 hrs.
  - The Network provides storage, logistics support and services to
    - UN humanitarian agencies,
    - international humanitarian organizations,
    - governmental and non-governmental organizations,
  - thus reinforcing capacity for humanitarian emergency response.

Candidate warehouse locations

Other locations identified by CARE

Locations where CARE is considering to open a warehouse, possibly in collaboration with other humanitarian organizations

Country	UNHRD	CARE
Cambodia	•	
China, Hong Kong,		•
Denmark		•
Germany		•
Honduras		•
India		•
Italy	•	
Kenya		•
Panama	•	•
South Africa		•
UAE, Dubai	•	•
USA, Miami		•

Supply

- Existing suppliers
    - Direct shipment
    - Replenishment
- 12 candidate warehouse locations

Candidate Warehouse Locations

Demand Locations

- Demand points geographic location
  - Human Settlements Database[4] ~ 55,000 settlements
- Aggregation - 2 cases:
  - Country level (225 demand points)
  - Regional level (22 demand points) – UN sub regions

Demand Locations – Regional Aggregation

4 – Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI), the World Bank; and Centro Internacional de Agricultura Tropical (CIAT), 2004. Global Rural-Urban Mapping Project (GRUMP), NY: CIESIN. Columbia University. URL http://sedac.ciesin.columbia.edu/gpw

Demand Locations and Candidate Warehouse Locations

Demand – Affected People

- Historical information
  - International disaster database
- Natural disaster hotspots
  - Floods
  - Earthquakes
  - Windstorms
  - Tsunamis
  - Etc
- 233 events in the last 10 years

Instances: Collect data over the past 10 years

- Each instance represents simultaneous disasters at different locations
    - **Number of affected people** at each location for each disaster type in each instance
        - *Historical data from the International Disaster Database (EM-DAT 2007)*
    - **Probability of requesting** a relief item per person at each location for each disaster type
        - *Operational guidelines from the International Federation of Red Cross and Red Crescent Societies*
    - **Amount requested** for a relief item per person at each location for each disaster type
        - *CARE's specifications*

Demand Estimations

- Estimate the actual demand quantities for different relief items using

  - the probability of need for different items per person

  - the number of items required by an affected person

  - number of people affected

Demand - Relief Items

- p_{hil} : likelihood that a person affected by disaster type h in demand location i will require item l

- The likelihoods are expressed as "high" potential need, "medium" and "low".

	Earthquakes	Floods
Water and Sanitation		
Distribution, storage, processing	H	H
Personal hygiene	H	M
Insect and rodent control	M	H
Food and Nutrition		
Short term distribution	H	M
Supplementary/curative feeding	L	M
Agriculture	L	H
Shelter and Household Stock		
Emergency shelter	L,C	L
Fuel for dwellings	L	M
Kitchen utensils	H	M

Potential Emergency Needs[3]

3 – Disaster Preparedness Training Manual. International Federation of the Red Cross and Red Crescent Societies. URL http://www.ifrc.org/WHAT/disasters/dp/manual.asp

Summary

- 22 demand points (N)

- 12 potential locations (M)

  - Flight distances (d_{ij})

- Disaster types (H)

- 233 disaster instance (K)

  - Equal probability (p_k)

- 6 relief items (L)

  - H, L, M requirement

Summary

- Expected demand for relief item l at location i at disaster instance k: (dem_{ikl})

  - d_{hik}: number of affected people at regional demand location i by disaster type h in demand instance k.

  - p_{hil}: probability of supply l being required at regional demand location i by a person affected by disaster type h.

  - a_{hil} : quantity of relief item l required by a person affected by disaster type h in demand location i

$$dem_{ikl} = \sum_{h \in H} a_{hil} p_{hil} d_{hik}$$

Mathematical Model

- Notes

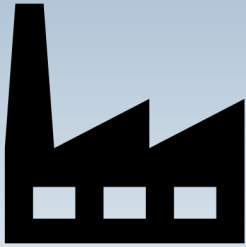Option2:

Before disaster:

Supplier   Warehouse   Demand node

$$y_j$$

Option2:

Before disaster:
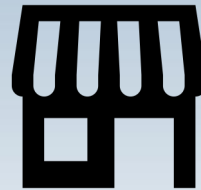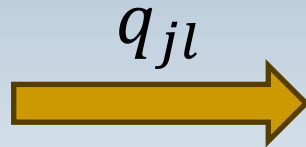
| Supplier | q_{jl} | Warehouse | Demand node |

Option2:

After disaster: (instance k)
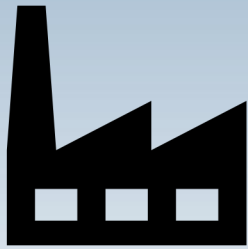
Supplier   Warehouse $\xrightarrow{x_{ijkl}}$ Demand node

Option1:

After disaster: (instance k)
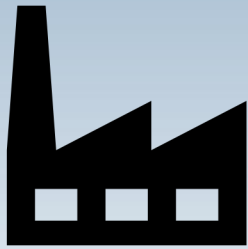
$$\bar{x}_{ikl}$$

Supplier   Demand node

Run Times

- Large Model – Country Level
    - 225 demand points
    - 12 candidate warehouse locations
    - 7 items
    - 233 time periods
    - 4,770,771 variables
    - 386,633 constraints

- Small Model – Regional Level
    - 22 demand points
    - 12 candidate warehouse locations
    - 7 items
    - 233 time periods
    - 466,562 variables
    - 55,540 constraints
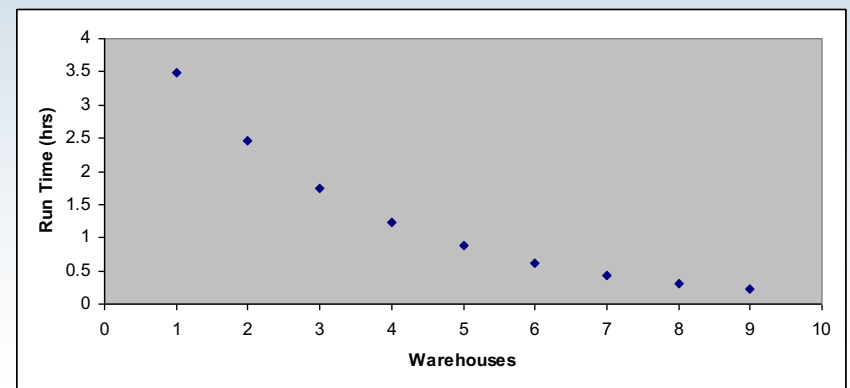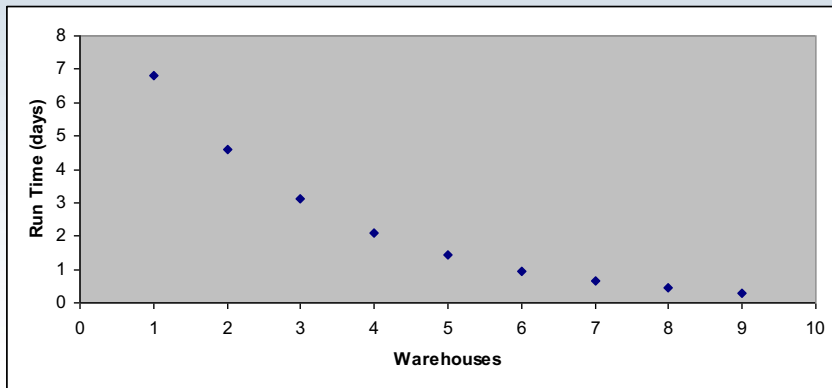
Results

- Two types of budget:

  - the number of warehouses to open

  - the inventory amount to keep throughout the pre-positioning network.

  - Both of these constraints are always binding because the model assumes that demand can be satisfied faster from the pre-positioning warehouses than with direct shipments from the suppliers.

Results

- Number of warehouses: 1-9 warehouses
- 3 levels of inventory to store (Q)
  - high : 100%
  - medium : %50
  - low: 25%

  of the average demand per instance

Results

- Response time vs {number of warehouses, inventory level}
- 3 levels of inventory

Results

- Optimal warehouse locations

Low Inventory Level

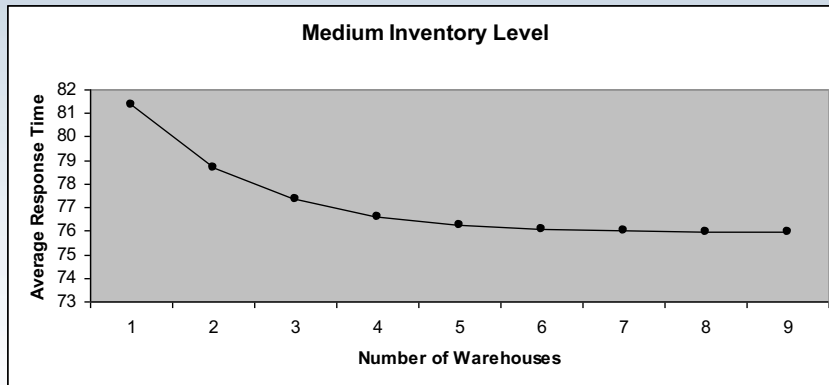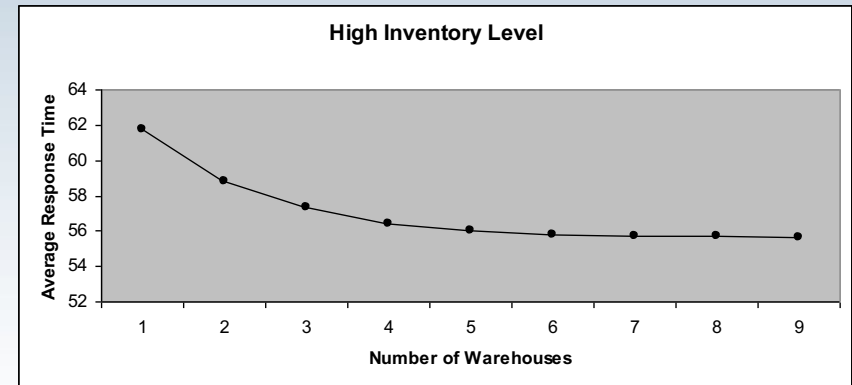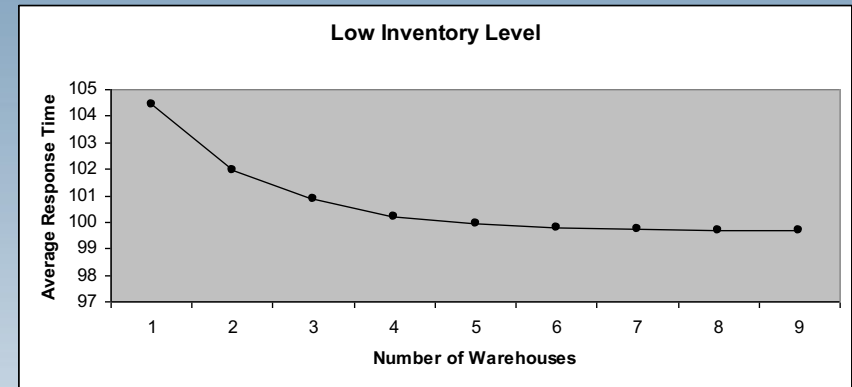| Warehouses	1	2	3	4	5	6	7	8	9
Cambodia						X	X	X	X
USA, Miami							X	X	X
Denmark									
Germany									
Honduras									X
Hong Kong			X	X	X	X	X	X	X
India	X	X		X	X	X	X	X	X
Italy				X	X	X	X	X	X
Kenya				X	X	X	X	X	X
Panama		X	X	X	X	X	X	X	X
South Africa									
UAE, Dubai			X					X	X

Medium Inventory Level

Warehouse	1	2	3	4	5	6	7	8	9
Cambodia						X	X	X	X
USA, Miami							X	X	X
Denmark									
Germany									
Honduras									X
Hong Kong			X	X	X	X	X	X	X
India	X	X		X	X	X	X	X	X
Italy				X	X	X	X	X	X
Kenya				X	X	X	X	X	X
Panama		X	X	X	X	X	X	X	X
South Africa									
UAE, Dubai			X					X	X

High Inventory Level

Warehouse	1	2	3	4	5	6	7	8	9
Cambodia						X	X	X	X
USA, Miami							X	X	X
Denmark									
Germany									
Honduras									X
Hong Kong			X	X	X	X	X	X	X
India	X	X		X	X	X	X	X	X
Italy				X	X	X	X	X	X
Kenya			X	X	X	X	X	X	X
Panama		X	X	X	X	X	X	X	X
South Africa									
UAE, Dubai								X	X

Optimal Locations and Inventory Allocation

3 Warehouses, Low Inventory Level

Optimal Locations and Inventory Allocation
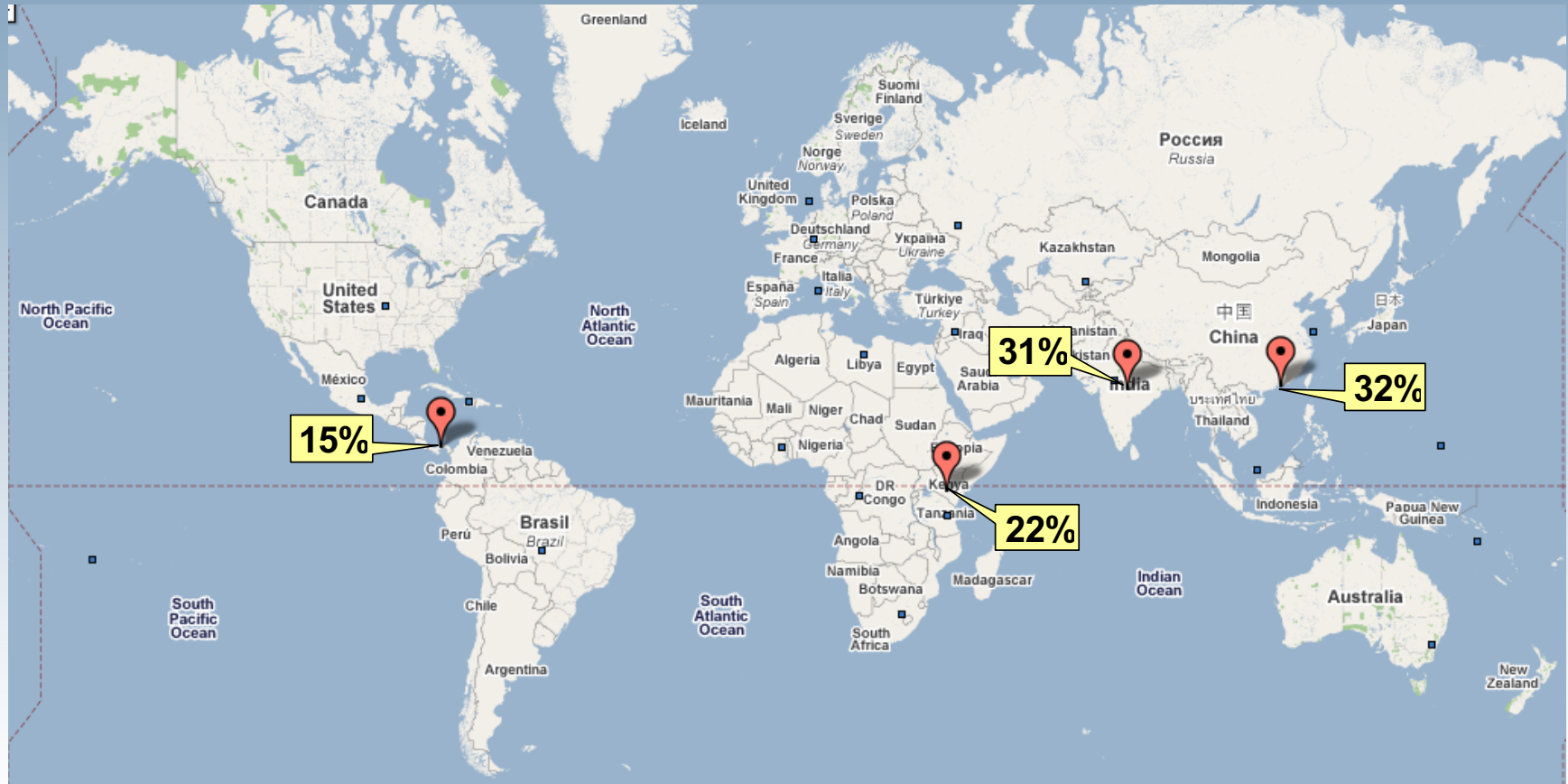

3 Warehouses, Medium Inventory Level

Optimal Locations and Inventory Allocation

3 Warehouses, High Inventory Level

Optimal Locations and Inventory Allocation

4 Warehouses, Low Inventory Level

Recommendation

Low Inventory Level

Warehouses	1	2	3	4	5
Hong Kong			X	X	X
India	X	X		X	X
Italy					X
Kenya				X	X
Panama		X	X	X	X
South Africa					
UAE, Dubai			X		

Recommendations

- Based on the recommendations,

- in collaboration with other humanitarian organizations,

- CARE decided to establish 3 warehouses:

  - first pre-positioning facility in Dubai in 2008

  - second and third one in Panama and Cambodia, respectively, in 2009.

Recommendations

- CARE has pre-positioned more than one million sachets of water purification kits in each of the facilities.

- Most recently, water purification tablets in Panama warehouse were used during the response to the 2010 Haiti Earthquake (Esterl and Mckay 2010).

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