Pre-positioning Inventory for Emergency Response

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Based on Duran, Guiterrez, Okwo, Keskinocak

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
- 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 War II

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
- Operates in more than 65 countries

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

- Help communities create plans to deal with emergencies
- Ensure communities receive food, water, shelter, healthcare and other emergency relief supplies when they need them most
- Help communities recover and rebuild after disaster strikes
- In 2001, CARE emergency projects directly assisted more than 7 million people in 26 countries

Responding to Floods in Nepal

- Increase in flash floods due to soil erosion
  - Crops, livestock, homes, schools, roads, drinking water, standing pools
- Response
  - 2.5 tons of food
  - Funds for medicine
- Recovery and mitigation
  - Planting trees
  - Farming methods

Emergency response practice – historical perspective

- Conduct most of the activities **after** the onset of the disaster
  - identify possible suppliers (local and/or international),
  - conduct the procurement process
  - identify potential warehouse sites
  - rent and set up warehouses
- Most of the transportation is outsourced

Emergency response effectiveness

- Response time
- Coverage
- Quality

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

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

• Pre-positioning
  • Faster response
  • Higher availability
	• Warehouse cost
	• Inventory cost

Pre-positioning Inventory

- Goal: Improve the efficiency & timeliness of emergency response
- Evaluate effect of a pre-positioning strategy on response time and cost
  - How many warehouses to open and where?
  - Which items to pre-position, in what quantity, and where?
  - How to replenish warehouses?
- Compare pre-positioning strategies
  - Response time
  - Cost
    - Warehouses
    - Purchasing & storage
    - Transportation costs

Analysis

- Model Input
  - Relief items
  - Supply
  - Demand
- MIP model
  - Given an initial investment, what is the configuration of the network that minimizes the average response time?
- Results
- Recommendations
- Conclusion

Relief Items

- Immediate needs of survivors
- CARE's specifications:
  - Food
  - Water& sanitation kit
  - Hot weather tent
  - Cold weather tent
  - Household kit
  - Hygiene kit

Supply

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

Candidate Warehouse Locations

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

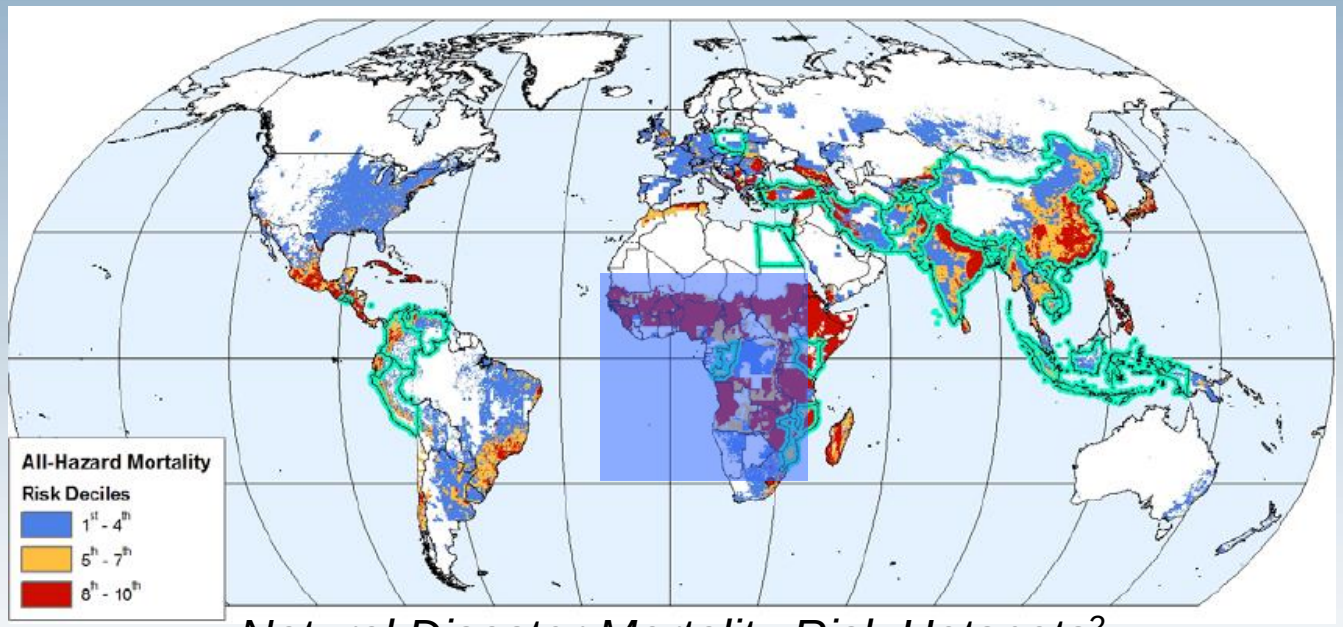
Country	UNHRD	CARE
Cambodia	•	
China, Hong Kong,		•
Denmark		•
Germany		•
Honduras		•
India		•
Italy	•	
Kenya		•
Panama	•	•
South Africa		•
UAE, Dubai	•	•
USA,Miami		•

Demand – Affected People

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

Demand - Affected People

- Historical information
  - International Disaster Database[1]



Natural Disaster Mortality Risk Hotspots[2]

- Floods
- Earthquakes
- Windstorms
- Waves
- ~~Droughts~~

  - Risk = Exposure * Vulnerability

1 – EM-DAT: The OFDA/CRED International Disaster Database, Universite Catholique de Louvain – Brussels – Belgium, URL http://www.em-dat.net

2 – Natural Disaster Hotspots: A Global Risk Analysis, Center for Hazards and Risk Research at Columbia University, URL http://www.ldeo.columbia.edu/chrr/research/hotspots/

Demand for Relief items

- Estimate the demand based on historical shipments of CARE
- Historical data from the International Disaster Database (EM-DAT 2007) on the number of affected people affected by natural disasters over the last 10 years.
- “affected” is defined as “ ...[a person] requiring basic survival needs such as food, water, shelter, sanitation . . . “
- Not just demand but base the demand to the number of affected people
- Why?

Demand estimate

- Why?
  - CARE does not have accurate records of past responses in terms of quantity and type of items supplied.
  - CARE usually collaborates with other organizations and only provides aid to portions of affected communities.
    - So even if CARE did have accurate records, we would have to consolidate data from numerous organizations.
  - Third, in the past responses relief items might be over or under supplied to assisted communities.

Demand Estimations

- Collect data for the number of affected people by different disasters over the past 10 years
- Estimate the actual demand quantities for different relief items using
  - the probability of need of different items
  - the number of items required by an affected person.

Demand Estimations

- For the probability
  - Operational guidelines from the International Federation of Red Cross and Red Crescent Societies .
  - The guidelines, based on field experience, provide the likelihood of different needs of people affected by different disasters.
    - The likelihoods are expressed as “high” potential need, “medium” and “low”.
- To determine the number of items required by a person:
  - CARE’s specifications.

Demand - Relief Items

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

	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

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

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

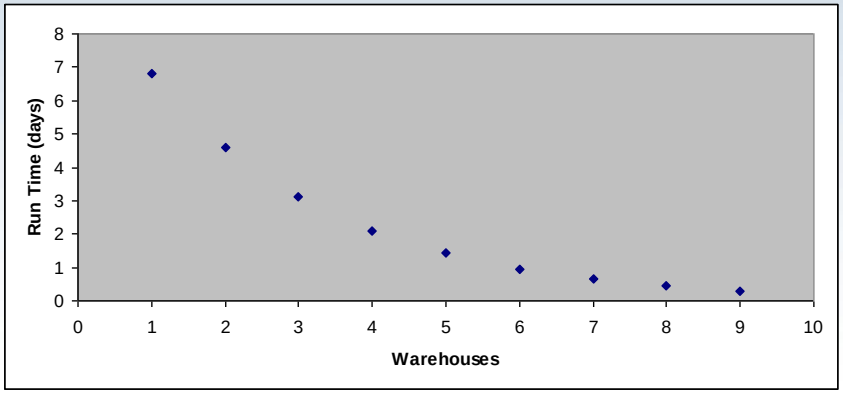
$$dem_{ikl} = \sum_{h \in H} a_{hil} p_{hil} d_{hik}$$

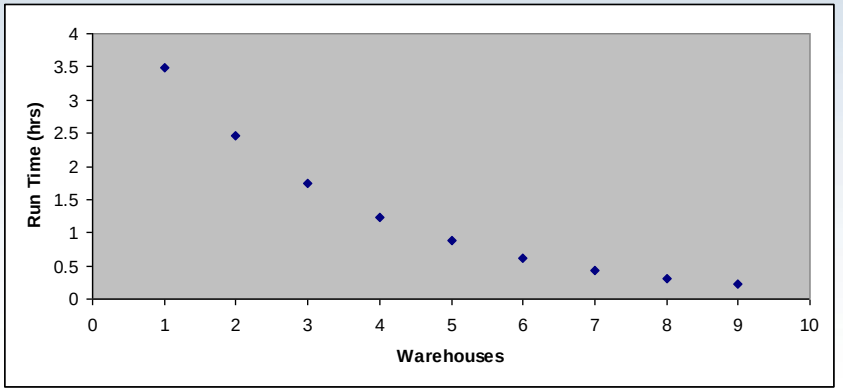
Mathematical Model

- Notes

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.

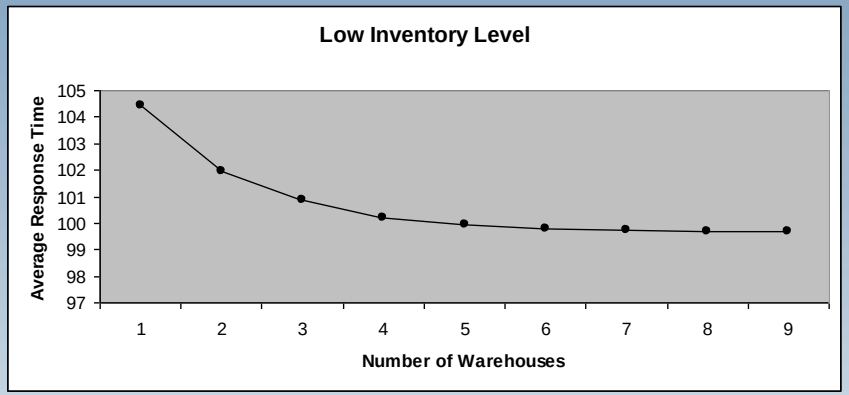
Results

- 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
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
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
Kenya			X	X	X	X	X	X	X
Panama		X	X	X	X	X	X	X	X
South Africa									
UAE, Dubai								X	X

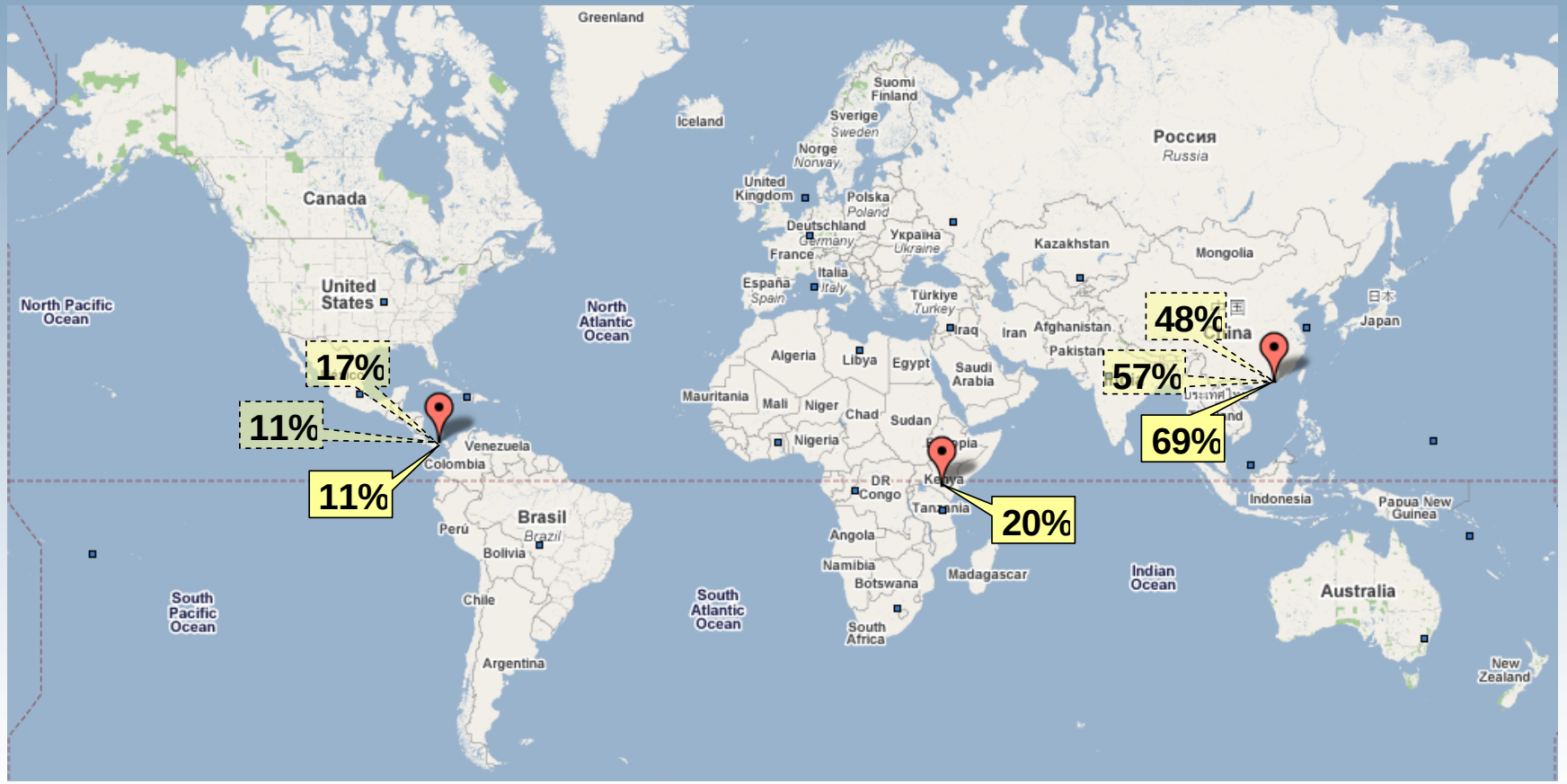
Optimal Locations and Inventory Allocation

3 Warehouses, Low Inventory Level

Optimal Locations and Inventory Allocation

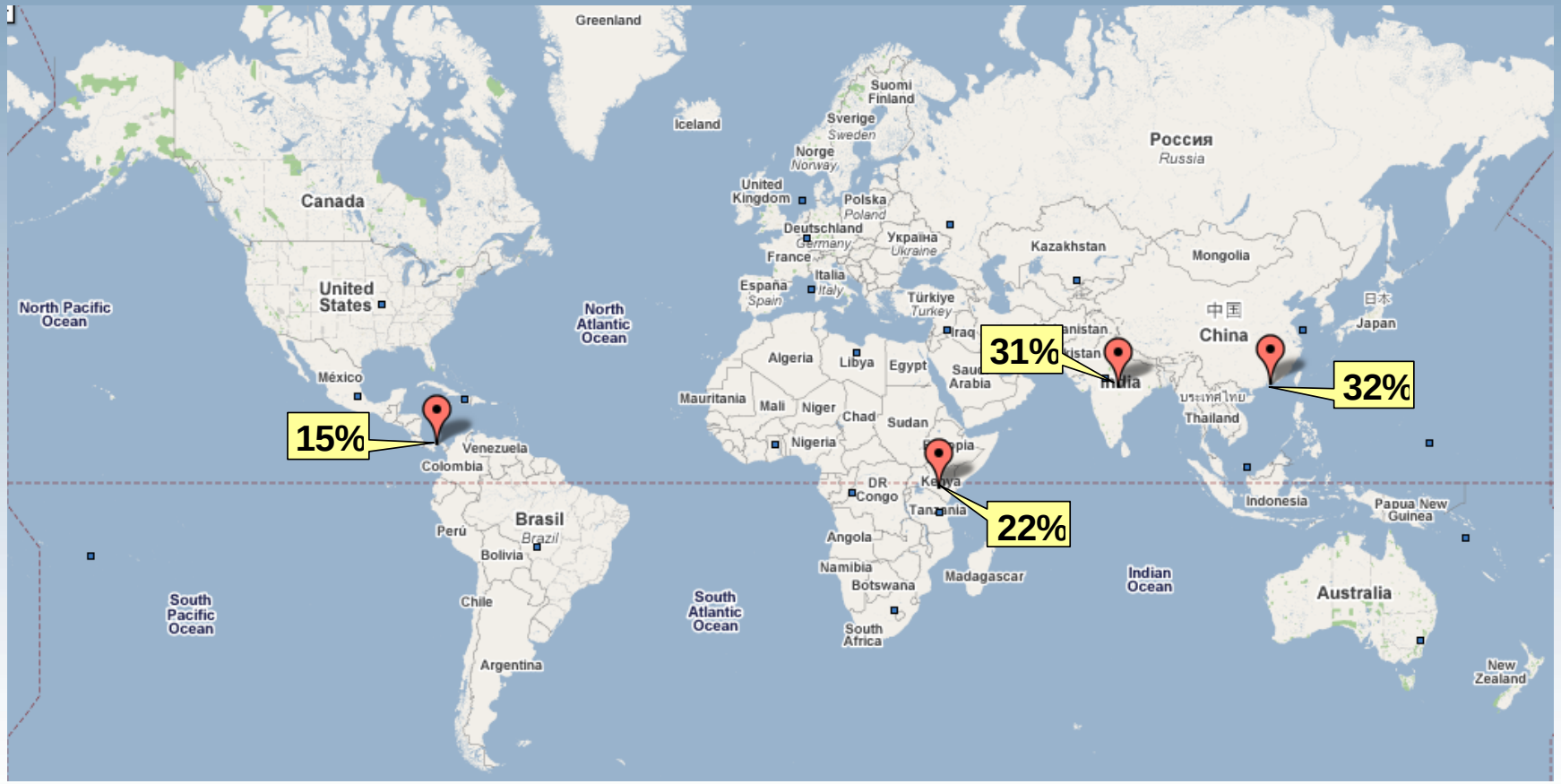
3 Warehouses, Medium Inventory Level

Optimal Locations and Inventory Allocation



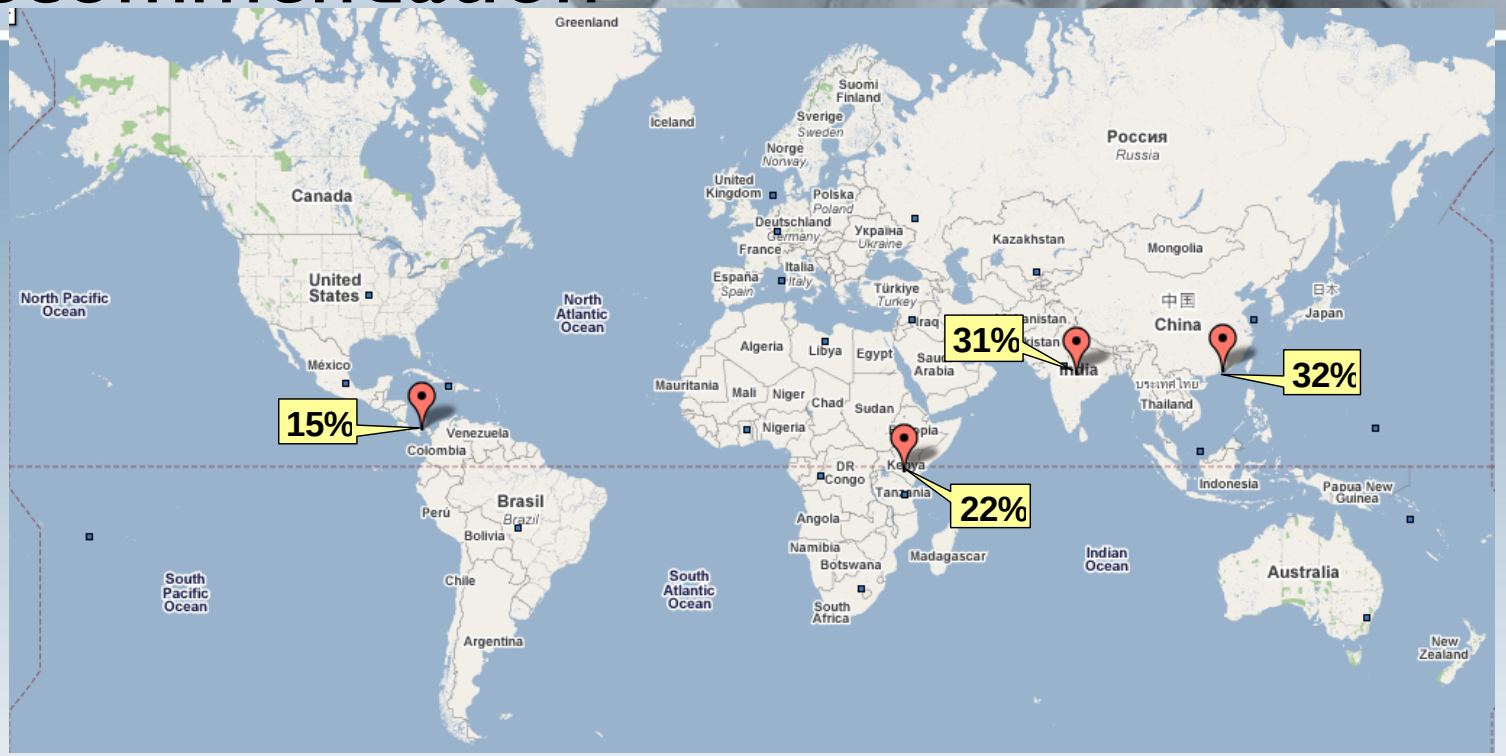
3 Warehouses, High Inventory Level

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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