Data-driven optimization of OFDA's disaster response capacity

Phase I Report

Alexander Rothkopf and Jarrod Goentzel

Agenda

- Motivation
- Network analysis preview
- Data analyses
- Phase II suggestions

Motivation

Introduction

Helping people the first days after a disaster with essential items

Disaster relief items in storage

Shipping items into disaster regions

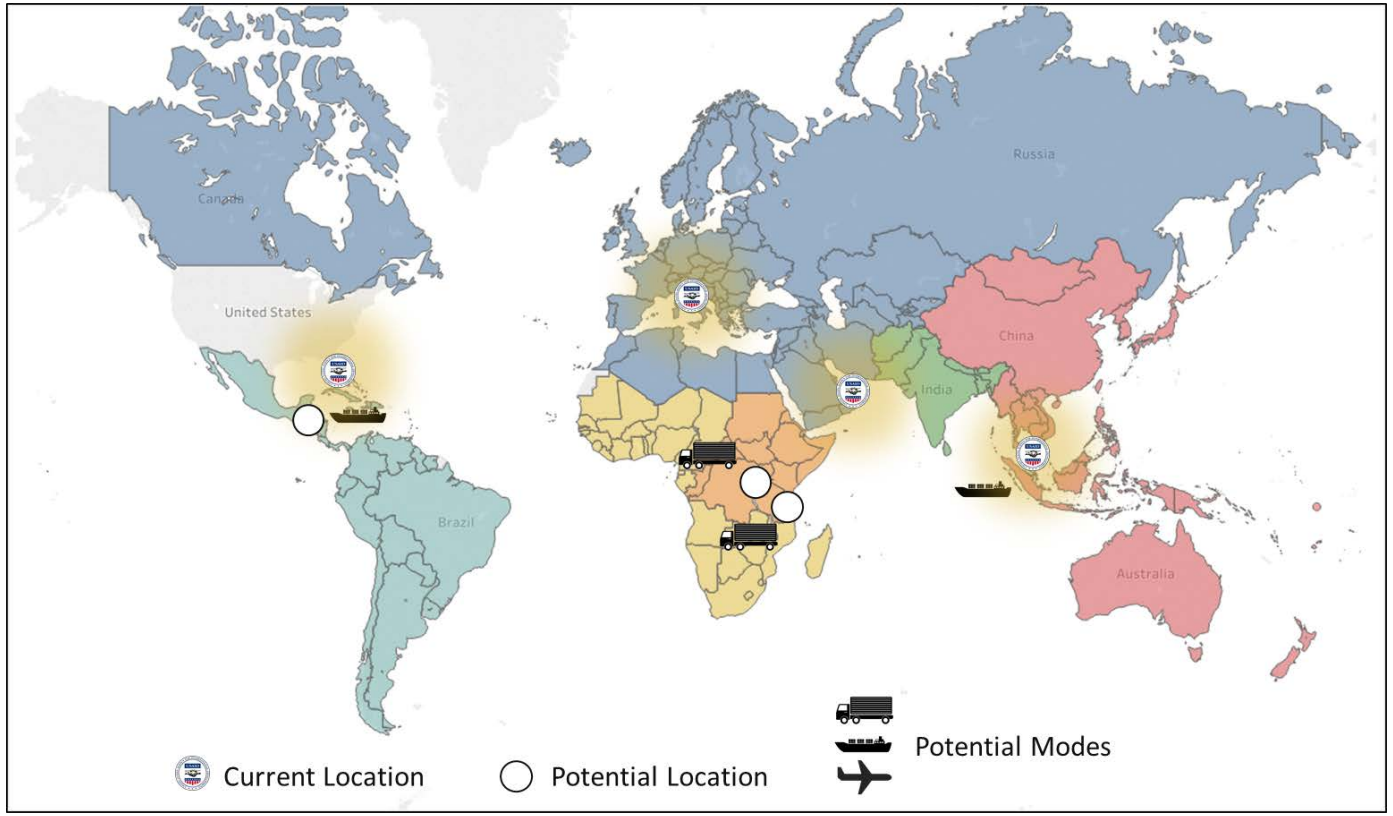
Distributing items to affected population

All pictures from USAID News Photo and other US government sides

Inventory network

OFDA holds a strategic stockpile of key disaster response commodities to support people world wide in crises situations.

Potential Inventory Locations



Research Questions

- How well does the current network perform against a portfolio of disasters?
- Should OFDA redistribute inventory to improve performance, and if so, where should the inventory be located?
- Should OFDA hold more or less inventory?
- How efficient is OFDA's current prepositioning network based on existing costs and capacity?
- What alternative prepositioning strategies should OFDA consider?

Model (i)

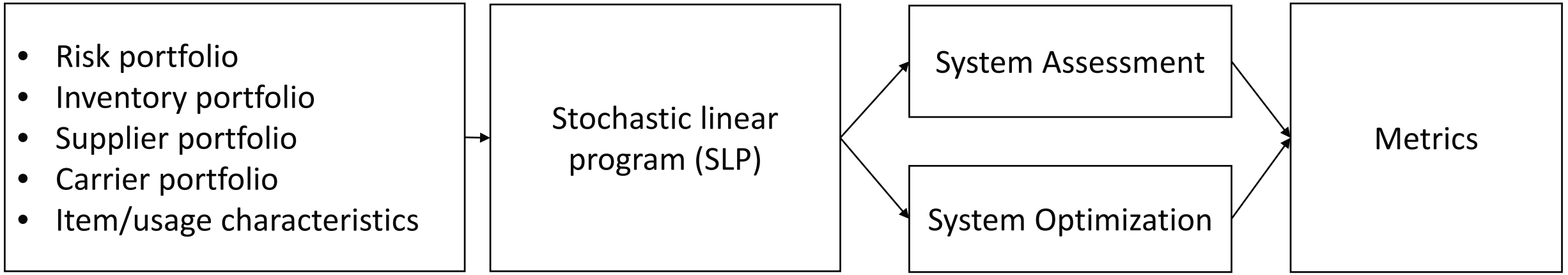
How well does the current setting perform?

Where to position inventory?

Inputs

Model

Outputs

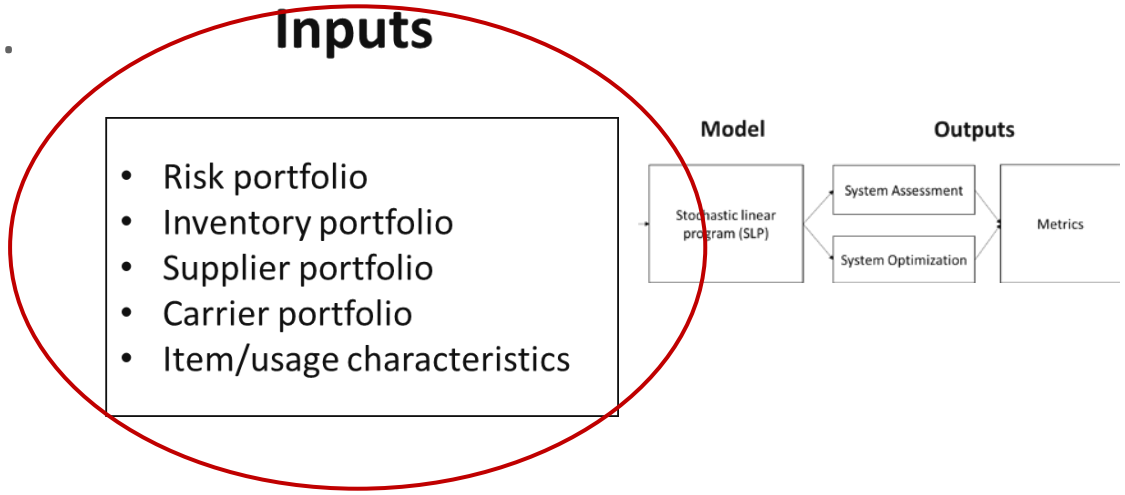


What are recommended procurement strategies to reduce stockout risk?

Model (ii)

Data needs

- To create meaningful recommendations we need data on OFDA's operations (inputs to our model).
- In particular, we need to better understand
  - disasters (location, magnitude, frequency, …)
  - inventory (locations, volumes, storage costs, …)
  - supply (capacity, lead times, costs)
  - transportation (modes, availability, capacity, costs)
  - item use and characteristics.



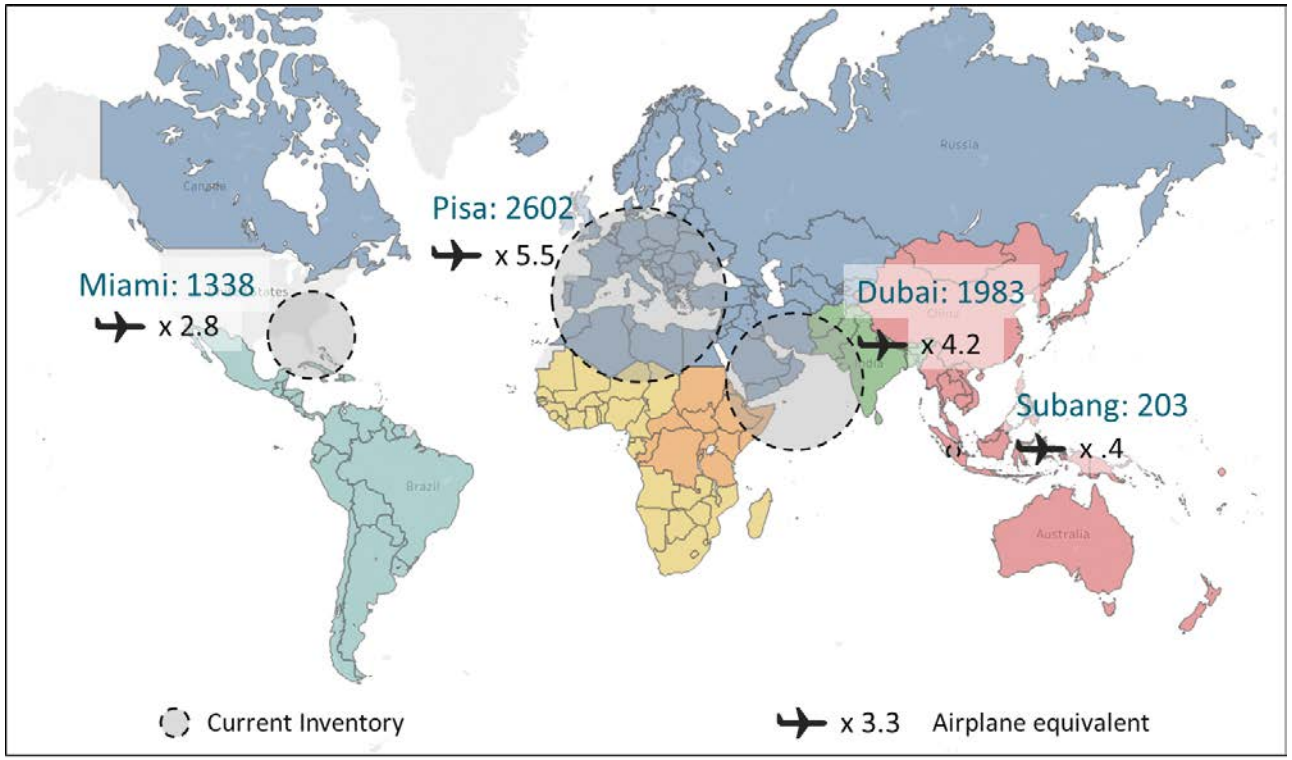
- We combine different datasets from USAID/OFDA and publicly available information to better understand OFDA's operations and identify needs for further data collection.
- Our analysis focusses on disasters that OFDA responded to with its six key commodities from the four warehouses in Miami, Pisa, Dubai, and Subang.

Preview on network analysis

Optimal network design and inventory allocation decision support

Preliminary model

- We create a preliminary* model to evaluate OFDA's current disaster response network and show the capabilities of a more rigorous modelling exercise.
- We assume that a person affected always needs the same mix of the six commodities and convert this product bundle into a cubic meter equivalent (CME).
- We feed information on disasters and need, inventory levels, and (rough) estimates for transportation capacity into the model.
- We minimize time to serve or cost to serve people.

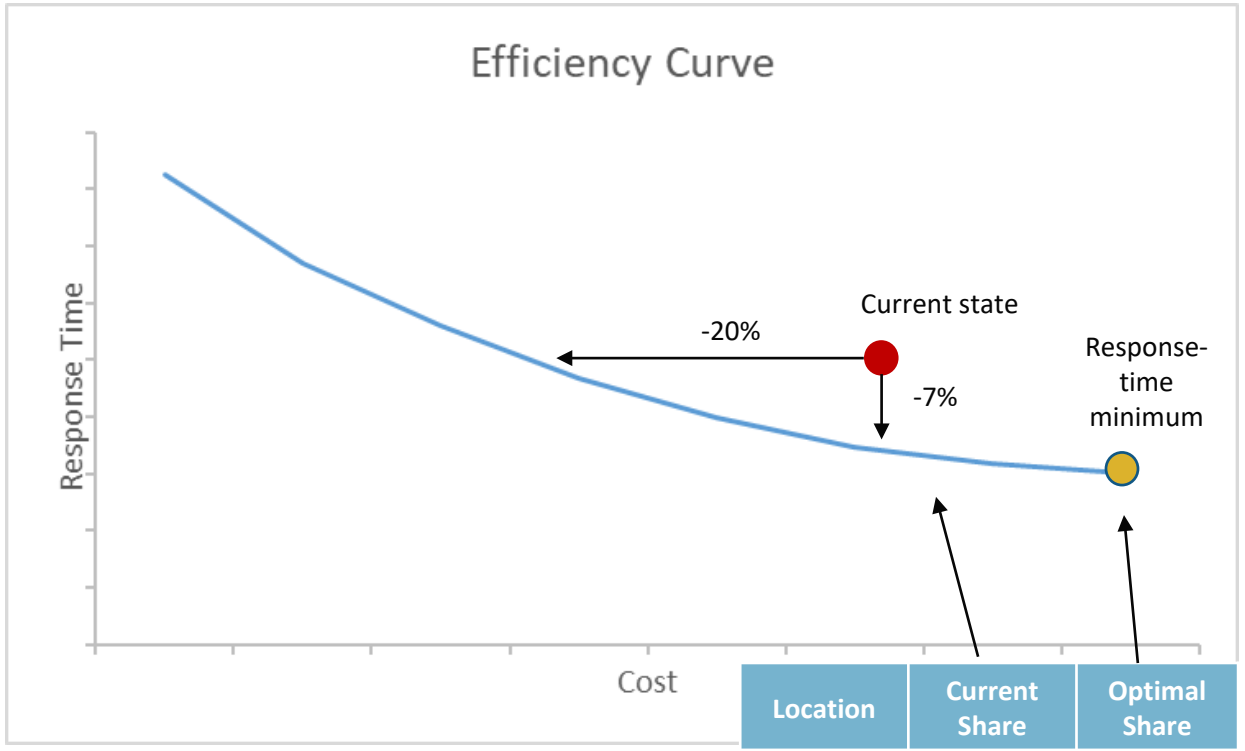


*this analysis is based on a simplified model, not capturing the full complexity of OFDA's operations, and incomplete data in particular on transportation capacity and cost.

How can OFDA balance costs and response-time?

Efficiency curve concept

- Our model allows OFDA to trade off costs and response time to make asset allocation decisions.
- On the right is an exemplary cost-time-efficiency curve.
- Any point on the curve is an efficient allocation.
- The current state is not efficient and optimization saves cost and/or time. For example,
  - with the same response time, OFDA can save 20% in transportation and storage costs through reallocation.
  - with the same budget, OFDA can reduce response time by 7%.

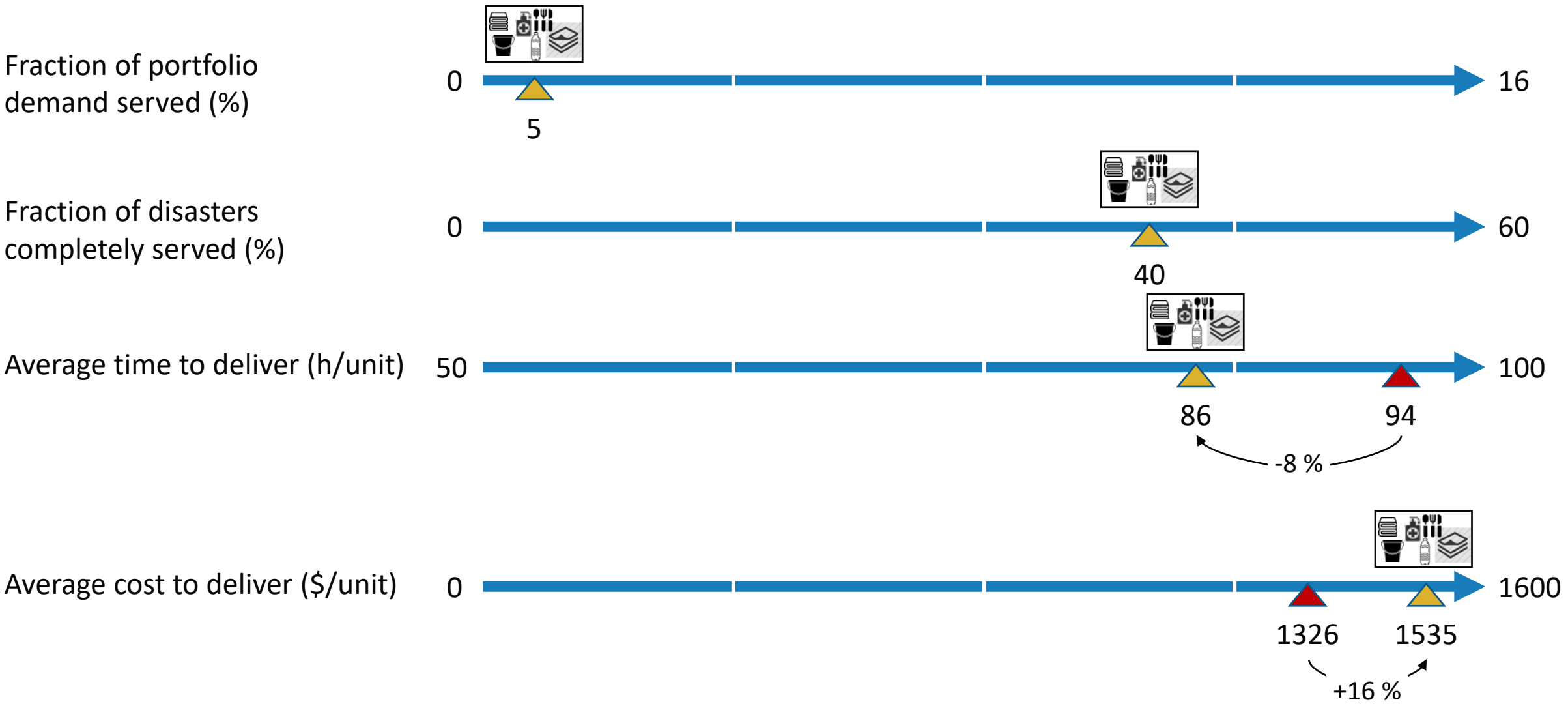


Location	Current Share	Optimal Share
Miami	22%	23%
Pisa	42%	23%
Dubai	32%	31%
Subang	4%	23%

Key questions

1. Should OFDA reallocate inventory to reduce cost while maintaining a sufficient response time?
2. Can OFDA change its network's footprint to further reduce transportation and storage cost?
3. How much inventory should OFDA hold to serve disasters?

Service and effectiveness metrics



MIT Center for Transportation & Logistics

Potential drivers of a reallocation decision

Demand differences and long-haul air freight

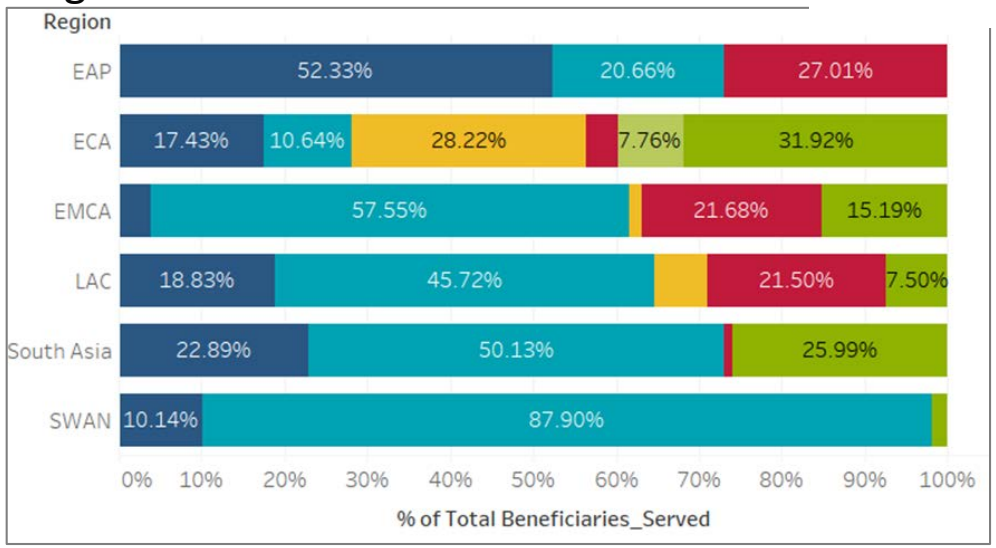
- Should OFDA redistribute inventory, for example
  - to better address regional demand differences,
  - to reduce costs for long-haul air shipments, and
  - to leverage different storage costs?

- Should OFDA increase capacity at a warehouse?
- Is it worth running four warehouse or should OFDA consolidate?
- Quantify the costs of political decisions.

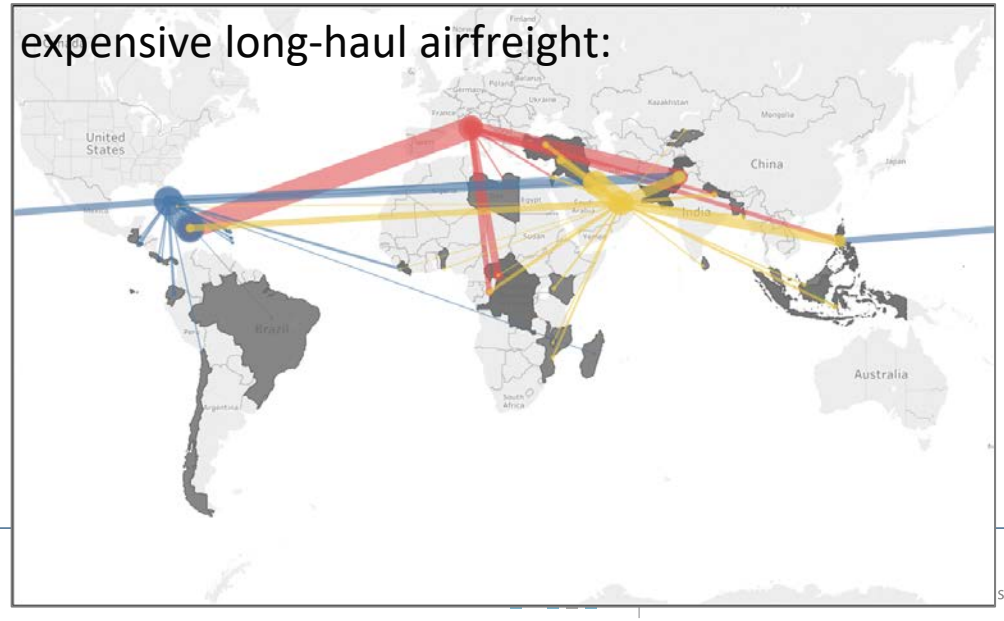
Key challenge

- Reliable data on air freight capacity, availability, and costs.

Regional demand differences:



expensive long-haul airfreight:



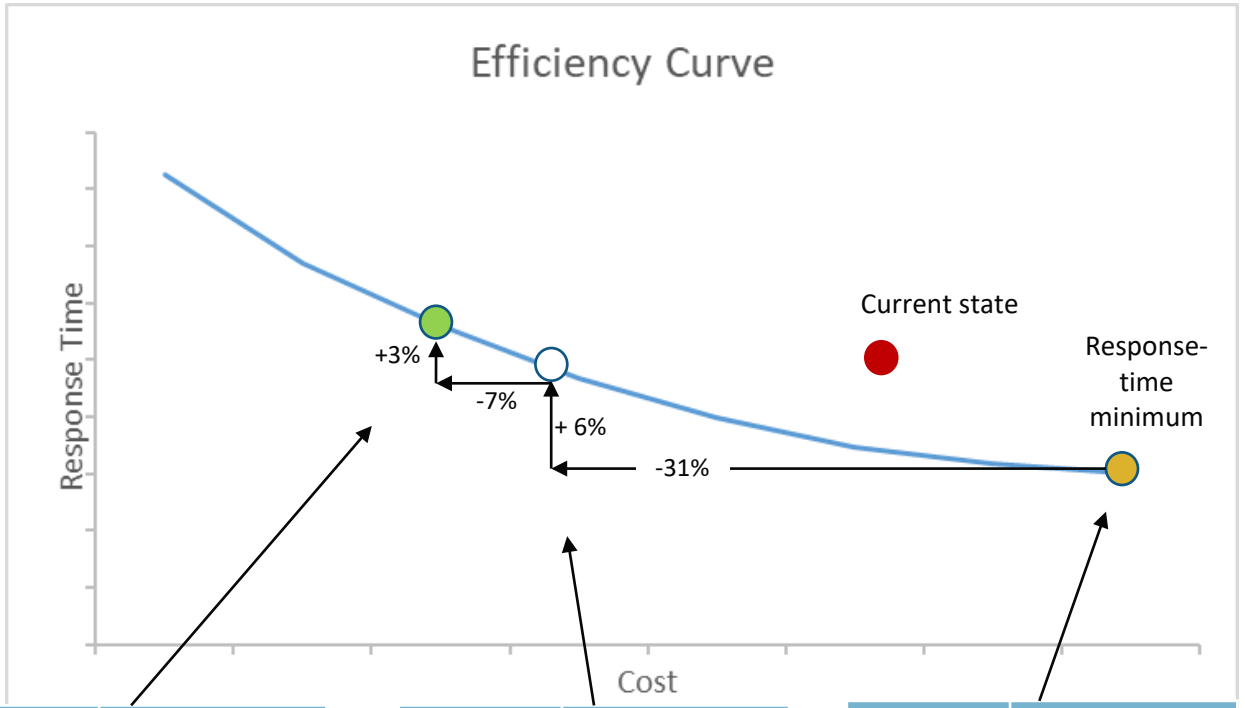
How a model informs OFDA's network decisions

Trade-off analysis

- Suppose OFDA includes WH locations in Africa (e.g. Entebbe, Nairobi, and Mombasa) as options and can use less expensive trucks to serve Central African disasters.
- Truck itself is likely slower than airfreight. However, in a trade-off against costs it becomes relevant and needs to be carefully considered.
- For example, in the chart the preliminary analysis suggests that the network's transportation and storage cost drop by 31% if inventory is consolidated in Pisa and Dubai. This consolidation increases response time by 6%.
- Additionally including Entebbe into the network, transportation and storage costs can drop by another 7%.; in exchange the network's response time increases by 3%.

Key challenge

- Reliable data on transportation capacity, availability, and costs.



Location	Share of CMEs
Miami	0%
Pisa	0%
Dubai	79%
Subang	0%
Entebbe	21%

Location	Share of CMEs
Miami	0%
Pisa	7%
Dubai	93%
Subang	0%
Entebbe	0%

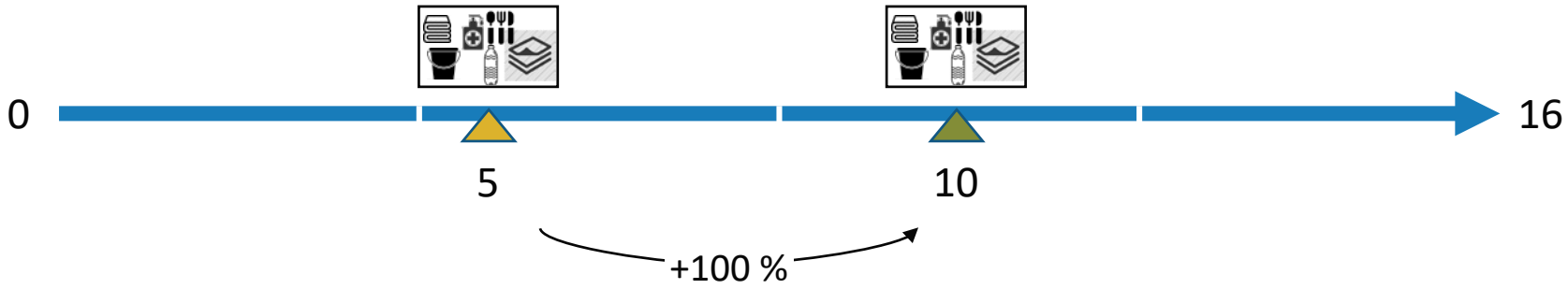
Location	Share of CMEs
Miami	23%
Pisa	23%
Dubai	31%
Subang	23%
Entebbe	0%

Inventory level decisions

How much should OFDA invest in inventory?

- Current working capital is (approx.) 6.5 Mio USD.
- Suppose OFDA invests another 6.5 Mio USD.
- Our preliminary model suggests that it doubles the portfolio demand served.
- Our model also provides a recommendation where to allocate the new inventory.

Fraction of portfolio demand served (%)



Fraction of disasters completely served (%)

MIT Center for Transportation & Logistics

What is next?

- Our preliminary analysis showed that OFDA's operations are complex
- ➢ Model refinement necessary
- ➢ Reliable data on transportation capacity, availability, and cost

Expected Outcomes:

- Based on a rigorous, data-driven analysis, we develop recommendations on
  - how much inventory OFDA should hold,
  - how OFDA should (re-) allocate the inventory in the network,
  - if OFDA should change its network footprint and the modes of transportation.
- ➢ Reduce OFDA's cost while maintain a sufficient response time.

Data analyses

OFDA's global disaster response portfolio

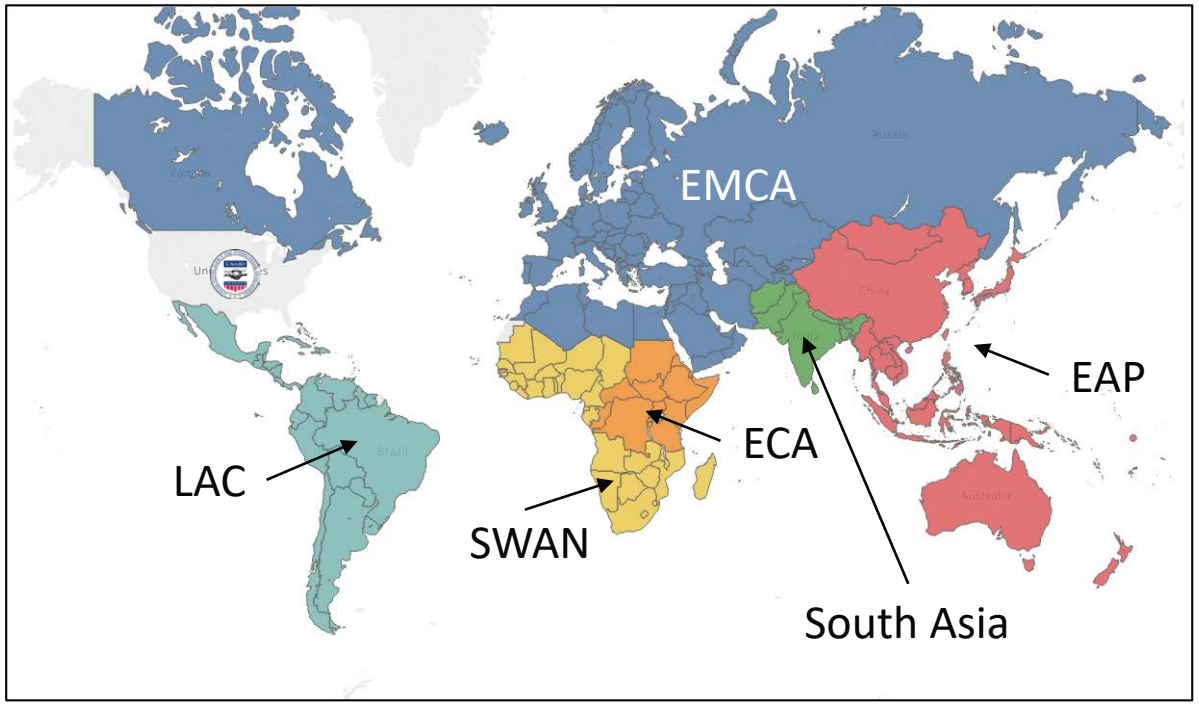
Region
- EAP
- ECA
- EMCA
- LAC
- South Asia
- SWAN

USAID/OFDA's disaster portfolio

- USAID/OFDA responds to disasters on a global scale.
- They partition the globe into six regions (see chart on the right).
- Disasters fall into one of two brought categories – natural and complex.

Key questions

- Where did USAID/OFDA serve disasters in the past?
- How many disasters did they serve and when?
- Which commodities did they supply?
- How much does OFDA spent per beneficiary?
- How does the mix of disaster categories change over time, if at all?
- Does USAID/OFDA's mandate change in regions?
- ….

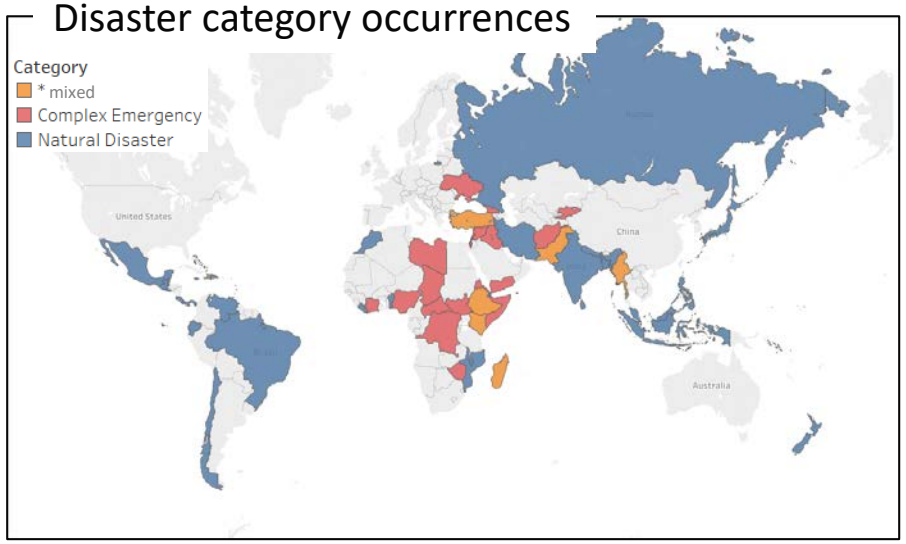


OFDA's global disaster response foot print

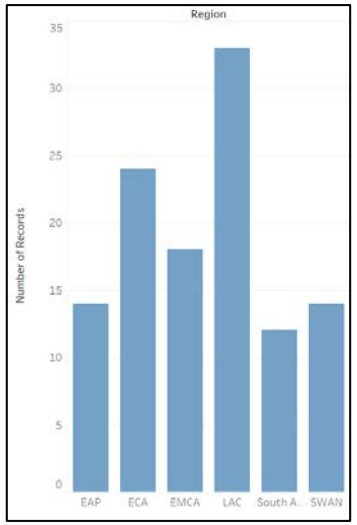
Where do OFDA's disaster response activities take place?

- OFDA responded to 116 disasters since 2000 with commodities.*
- The charts show OFDA's global response foot print in terms of number of disasters (right), total affected population (lower right), and disaster category mix (lower left).
- As expected, OFDA responds to many disasters with many people affected in East Africa and the Middle East.
- A lot of LAC disasters instances with comparatively small total affected population (TAP).
- Most complex disasters are in Africa and the Middle East.

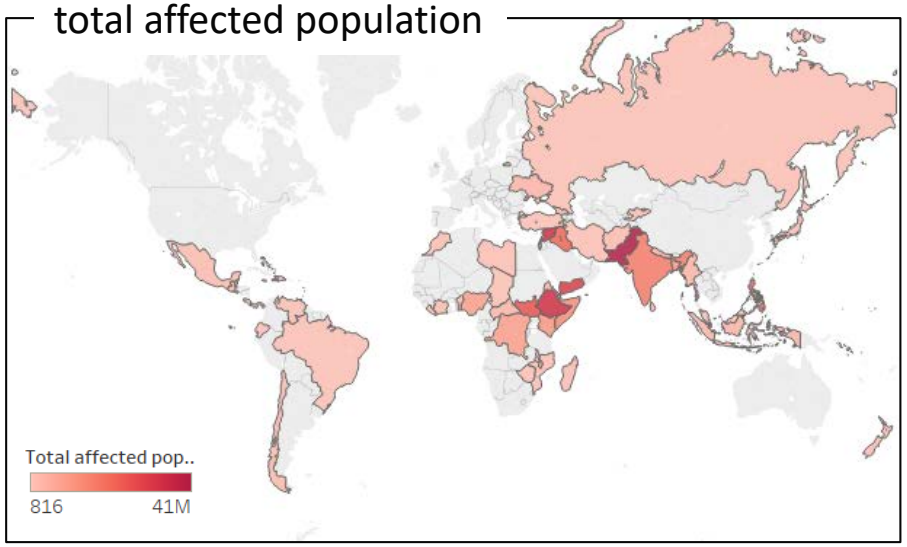
Disaster category occurrences

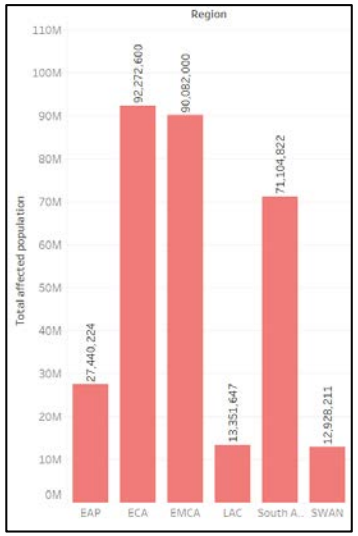


# of disasters



total affected population





© 2018 MIT Center for Transportation & Logistics

*Shipment data is only available for 49 distinct disasters, and shipment cost data is only available since 2014, i.e. 36!

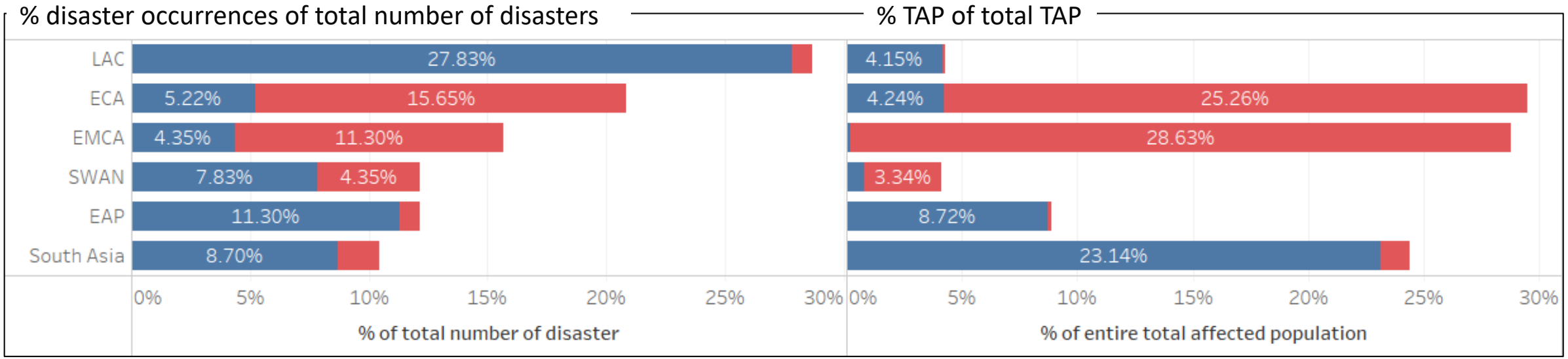
MIT Center for Transportation & Logistics

OFDA's disaster mix

Category
Complex Emergency
Natural Disaster

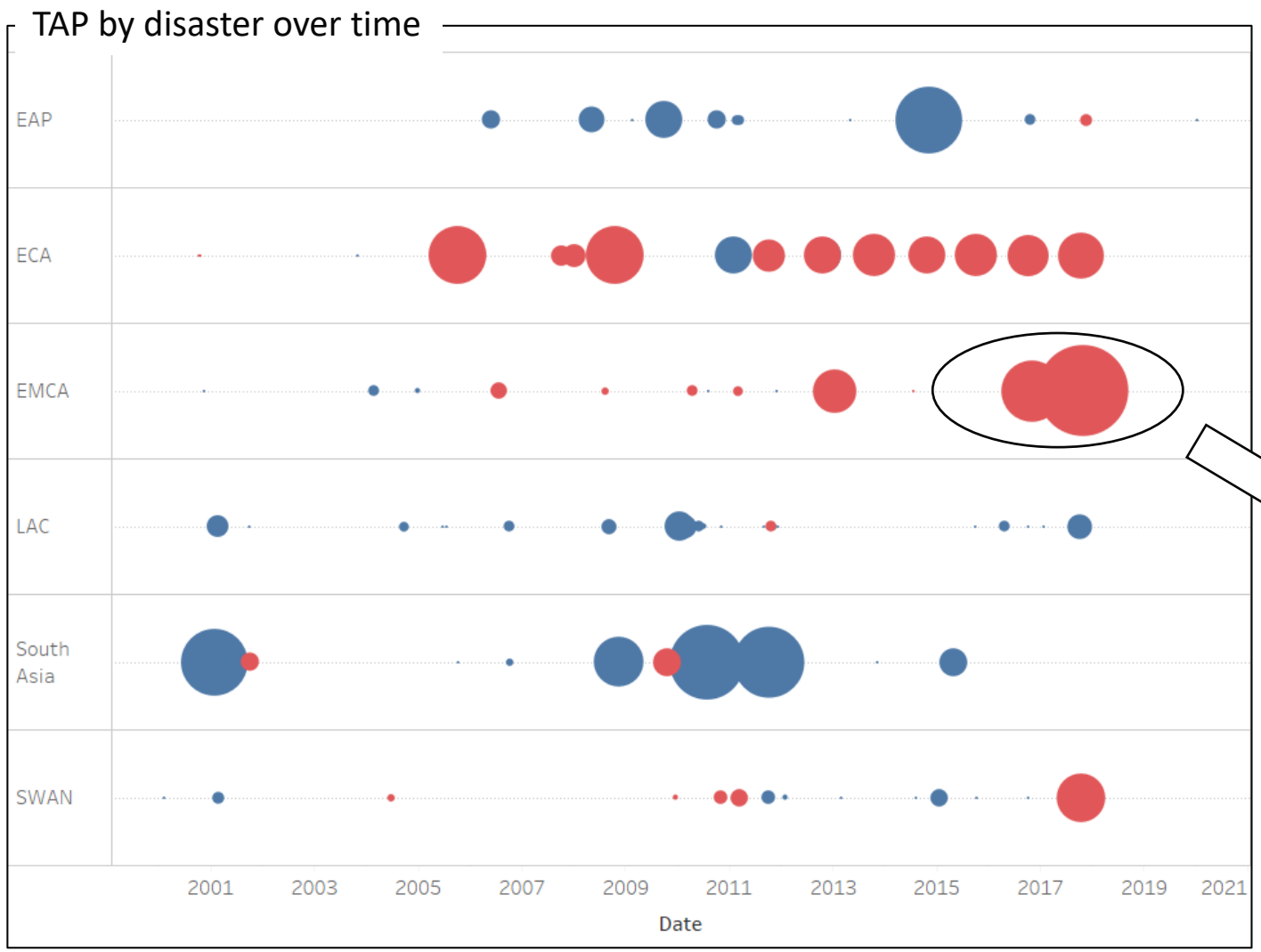
How are disasters and TAP distributed across the disaster categories?

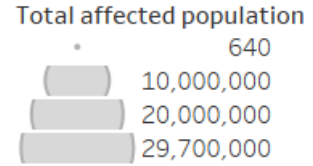
- The chart on the bottom left shows how many disasters (as a percent of the total number of disasters) in each region and what category they are.
- Latin America (LAC) has the highest number of disasters and the highest number of natural disasters.
- ECA and EMCA have the highest number of complex emergencies.
- The chart on the bottom right shows the number of people affected (as a percent of the total number of people affected).
- Notably, Latin America (LAC) has the lowest number of people affected, whereas South Asia, Middle East, and East Africa together make up 75% of TAP.
- South Asia has the lowest number of disasters, but the highest number of TAP in natural disasters.



MIT Center for Transportation & Logistics

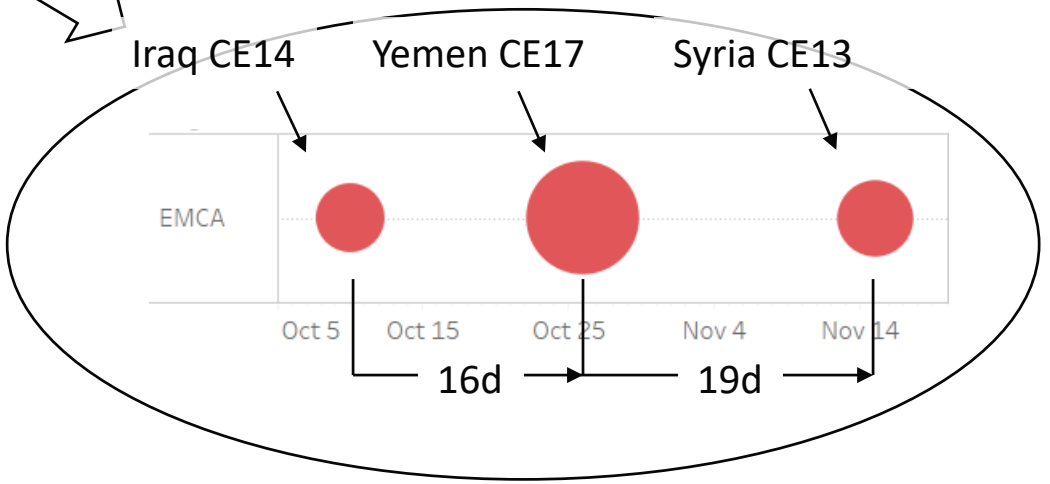
Disaster timeline





When did OFDA respond to disasters?

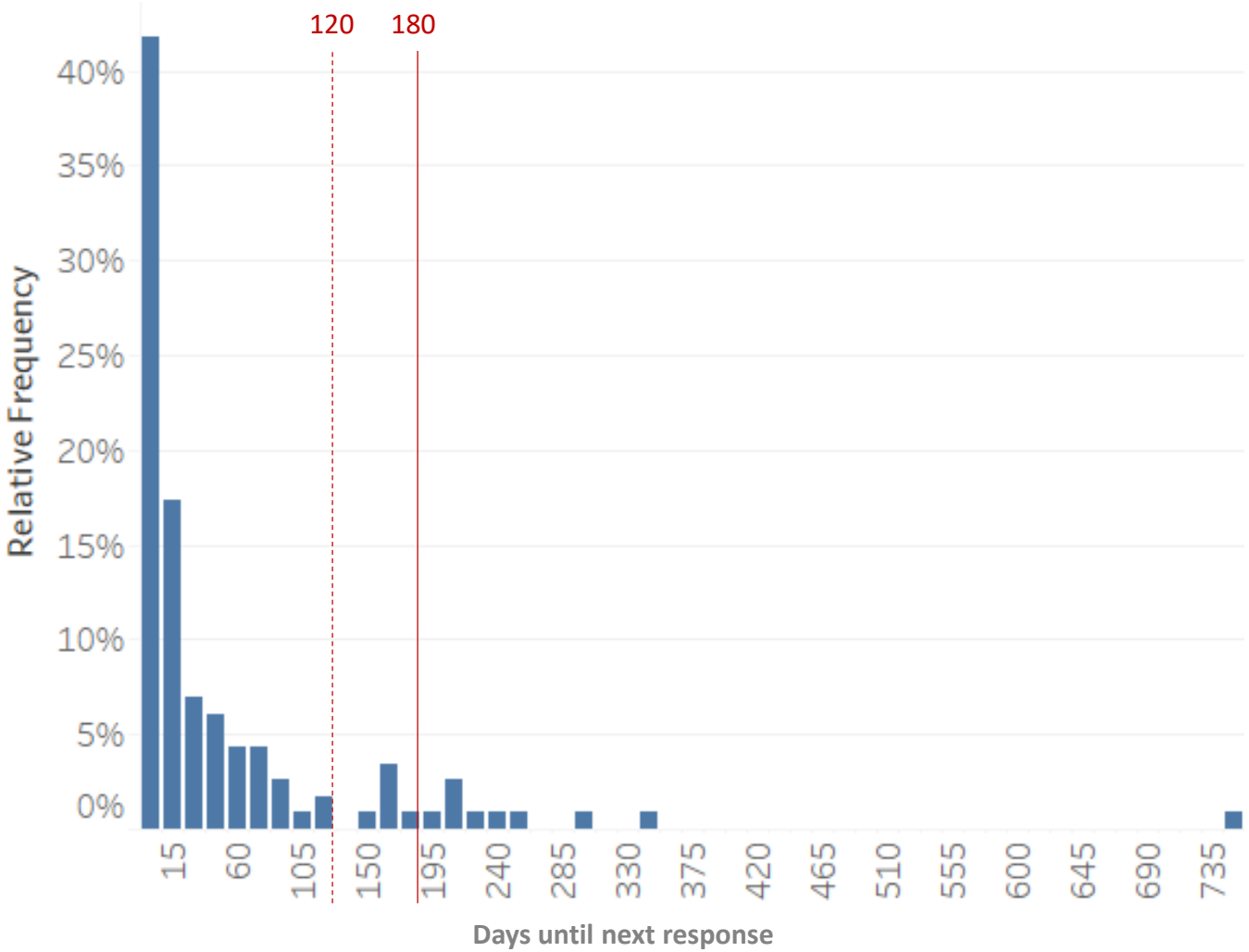
- The chart shows disasters and TAP over time and also indicates the disaster category.
- The number and size in particular of complex disasters are increasing in recent years.
- This puts more stress onto OFDA's response capacity and demands careful planning against a portfolio of potential risks.



Disaster frequency

How frequently is OFDA responding to a disaster?

- The chart shows the percentage of all disaster responses that happen within a certain timeframe. For example, 42% of disasters are followed by the next event in between 0 and 14 days.
- 60% of the responses are followed by the next response within 30 days.
- 86% of the responses happen within 120 days.
- 91% of the responses happen within 180 days.
- Therefore, almost all disaster responses are followed by at least one other response within the supply lead time window of 120 (red dashed line) to 180 (red solid line) days.

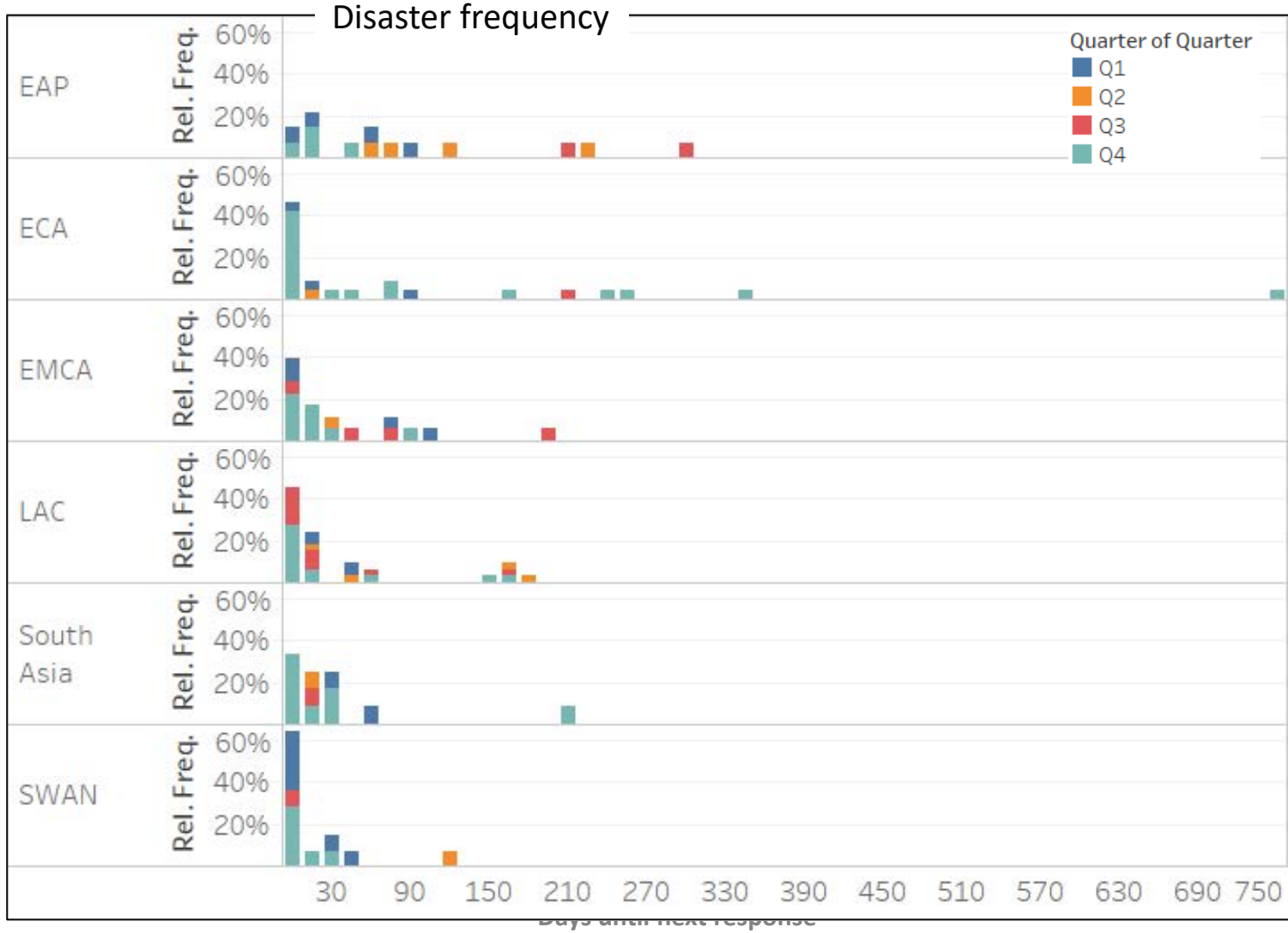


MIT Center for Transportation & Logistics

Indications for disaster seasonality in OFDA's responses

Does disaster frequency differ among regions, does OFDA face seasonality in their mandate?

- The chart shows the percentage of all disaster responses in a given region that happen within a certain timeframe. For example, 40% of disasters in LAC are followed by the next event within 14 days. Colors indicate different quarters.
- Regions show different disaster response timing!
- EAP offers pretty evenly distributed response timing.
- ECA shows strong seasonality in Q4, i.e. many disasters happen within 14 days.
- EMCA shows some seasonality in Q4 and Q1.
- LAC shows strong seasonality in Q3 and Q4.
- South Asia shows some seasonality in Q4.
- SWAN shows strong seasonality in Q4 and Q1.



MIT Center for Transportation & Logistics

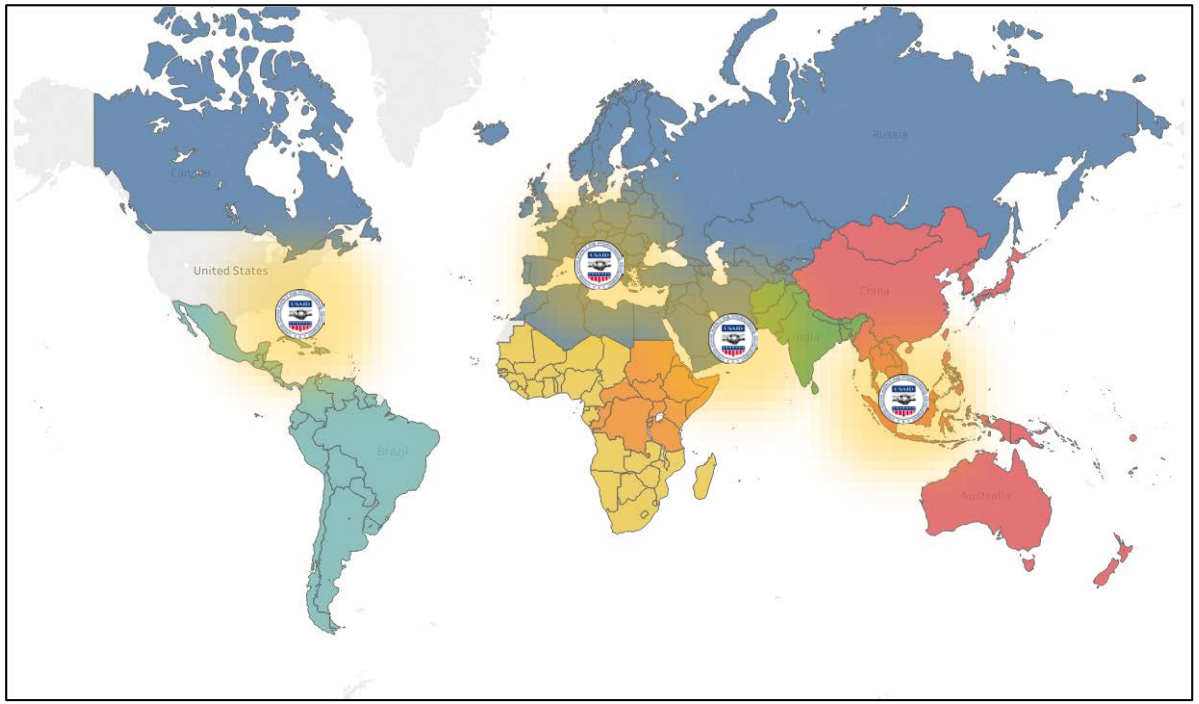
OFDA's warehouse operations

OFDA's warehouses

- OFDA currently operates four warehouses (see on the right)
  - Miami (FL)
  - Pisa (I)
  - Dubai (UAE)
  - Subang (MY)
- Core commodities are blankets, buckets, hygiene kits, kitchen sets, plastic sheeting, water.

Key questions

- How much volume does OFDA ship from each location?
- Which regions and disasters does OFDA serve from each WH?
- How much does OFDA ship of each commodity?
- Do different disasters request different commodity types from WHs?
- …



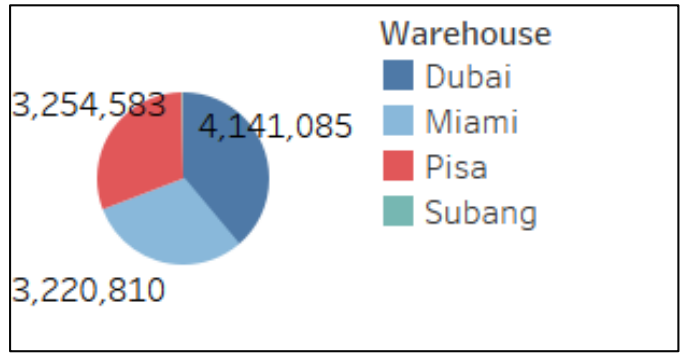
MIT Center for Transportation & Logistics

Warehouse shipment volumes

How much does OFDA ship from each warehouse?

- The chart on the right shows the number of beneficiaries served by warehouse.
- Dubai accounts for approximately 40%, Pisa 30%, and Miami 30%.
- Subang is new and therefore underrepresented (only one shipment).
- Recall that any shipment analysis is working from a limited data set. Data is representing OFDA operations since 2009.

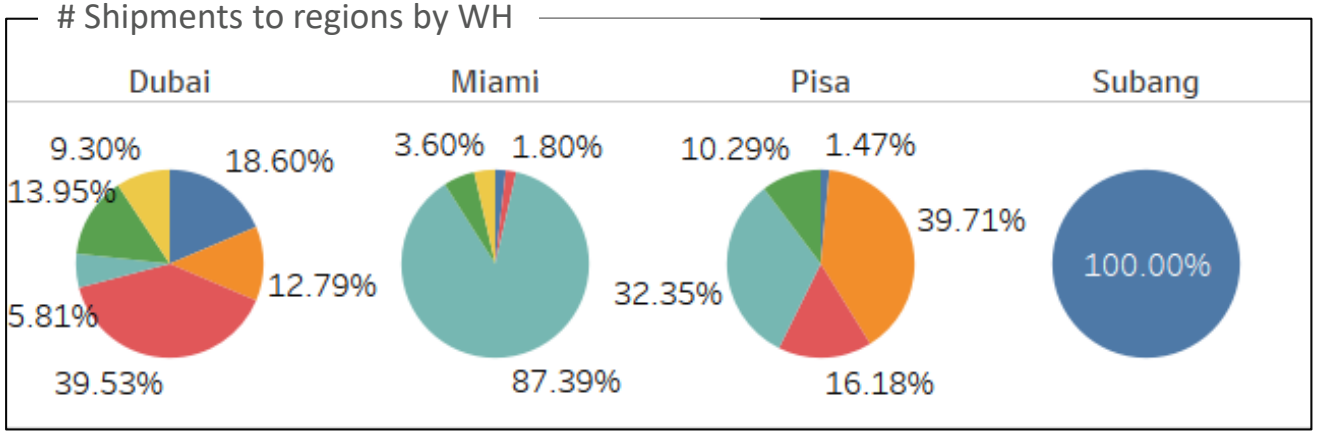
Beneficiaries served by warehouse



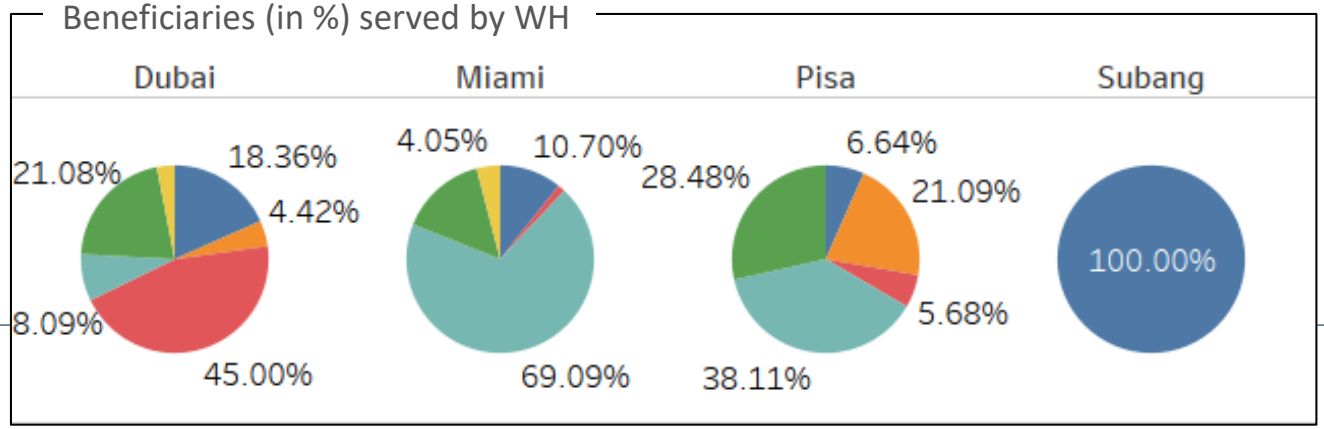
How much does each warehouse ship to each region?

- The charts on the right show the number of shipments and the beneficiaries served (in percent) from each WH to one of the six regions OFDA serves.
- Dubai and Pisa do not show a substantial regional preferences.
- Miami mostly serves LAC: 88% of shipments and 69% of quantity goes to LAC.

Shipments to regions by WH



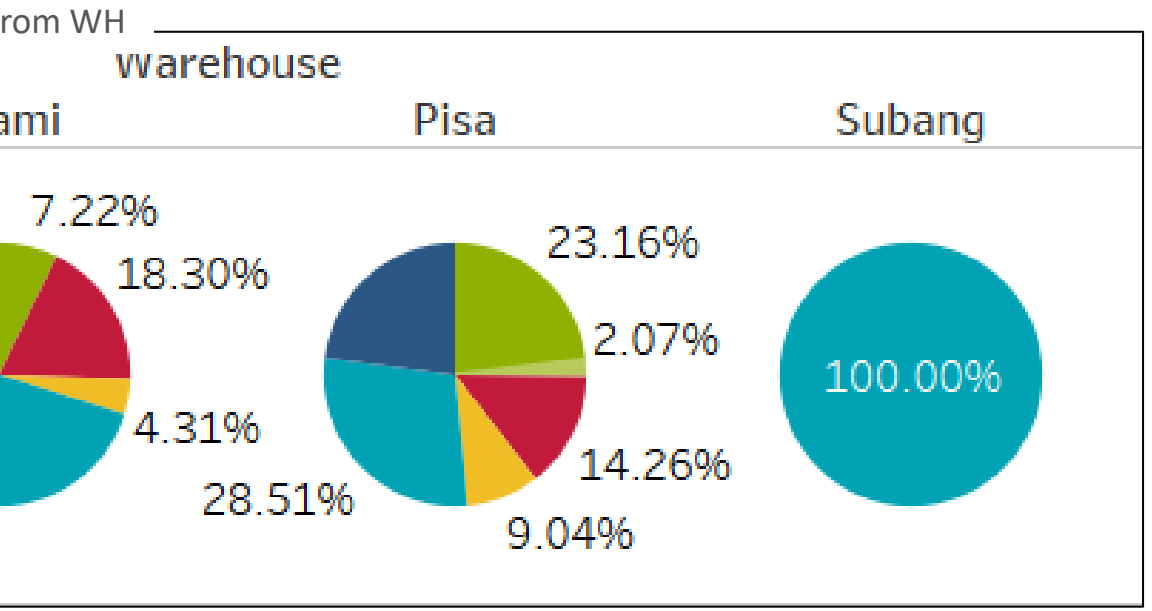
Beneficiaries (in %) served by WH



Commodities dispatched from WH

Does OFDA prefer to ship products from certain WHs?

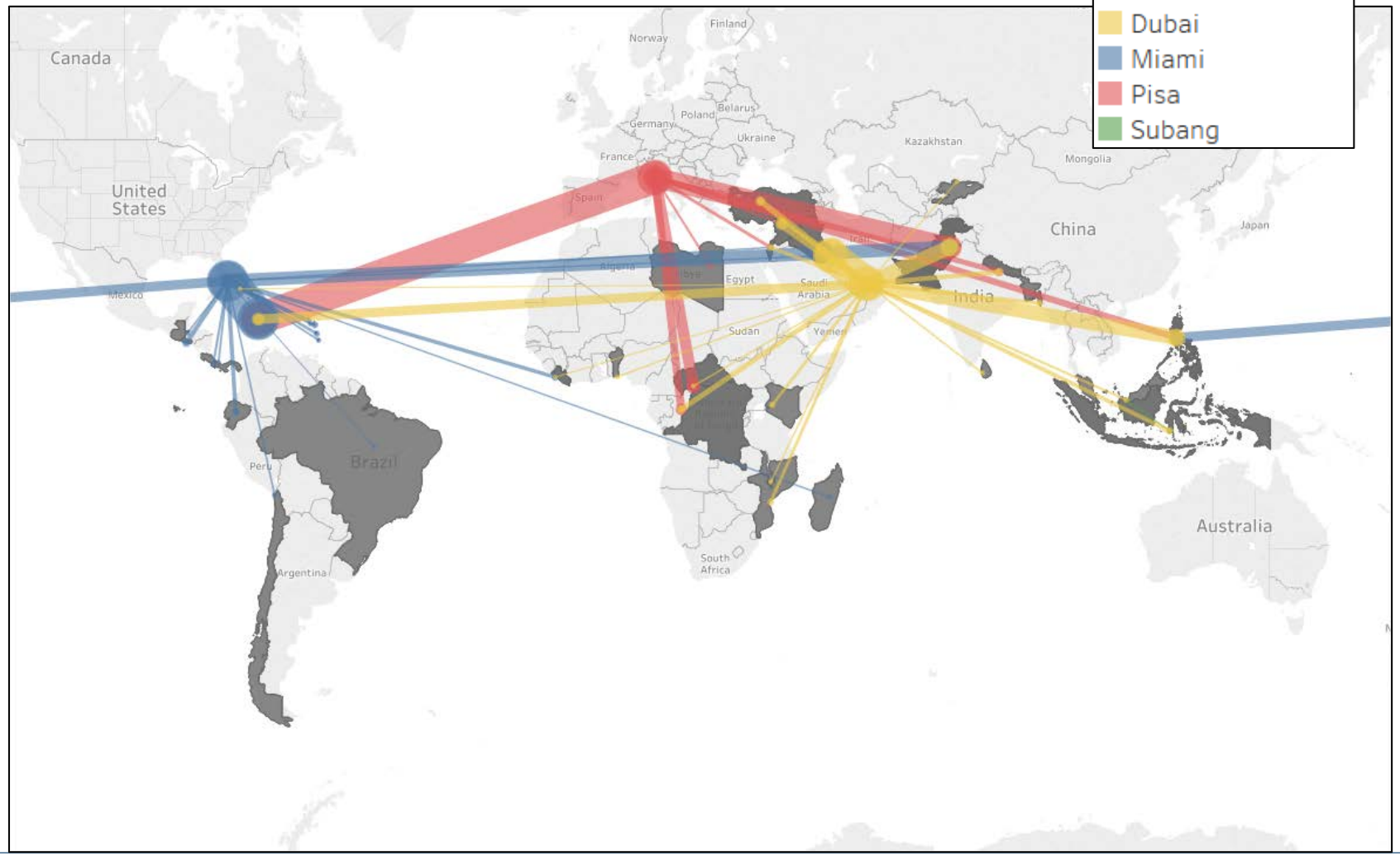
- The chart on the right shows the beneficiaries served (in %) by warehouse and commodity.
- Dubai and Miami have an almost identical mix.
- Pisa reaches less beneficiaries with plastic sheeting to the proportional benefit of the other categories.
- Subang is a new location had only one shipment of plastic sheeting, yet.



OFDA's shipments across the globe

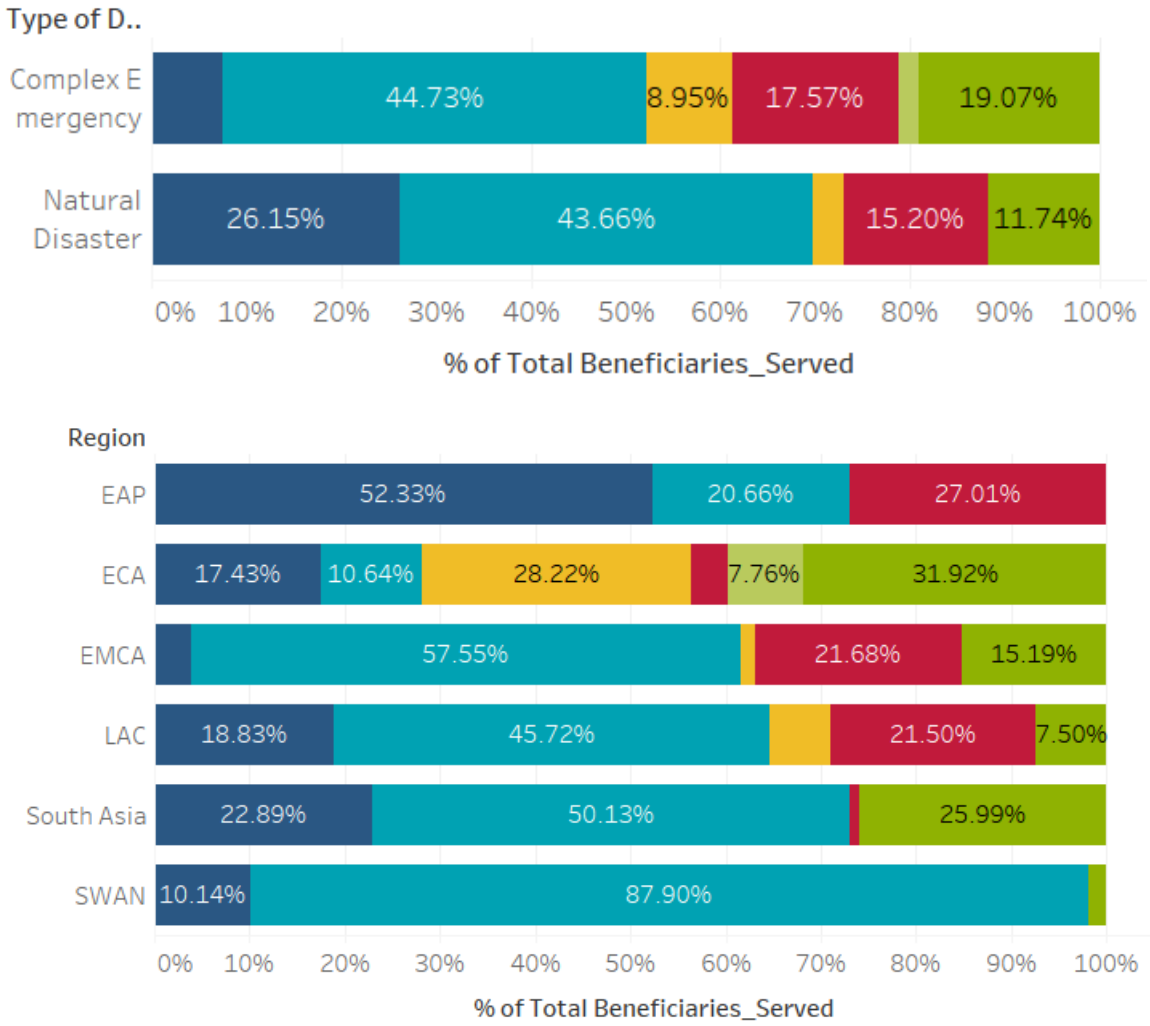
How does OFDA's network look like geographically?

- The chart on the right shows the shipment originating in one of the four WHs and the beneficiaries served in each country.
- No WH is dedicated to a specific region!
- In particular, Dubai, and Italy are serving all regions frequently.
- Miami is somewhat more focused towards LAC but does respond to other regions too.



MIT Center for Transportation & Logistics

Disasters have different commodity requests



Is the mix depending on the type of disaster or the region?

- Charts show the percent of beneficiaries served.
- OFDA tracks two disaster types. Clearly the commodity mix shipped to each disaster type does not substantially differ.
- The six geographic regions seem to indicate some differing needs. Notably:
  - Buckets are only required in East Africa (ECA).
  - South Asia, East Asia, and SWAN do not require hygiene sets.
  - South Asia and SWAN do not require hygiene kits.
  - EAP received more than 50% water.
  - EMCA, LAC, South Asia, and SWAN receive plastic sheeting.

© 2018 MIT Center for Transportation & Logistics

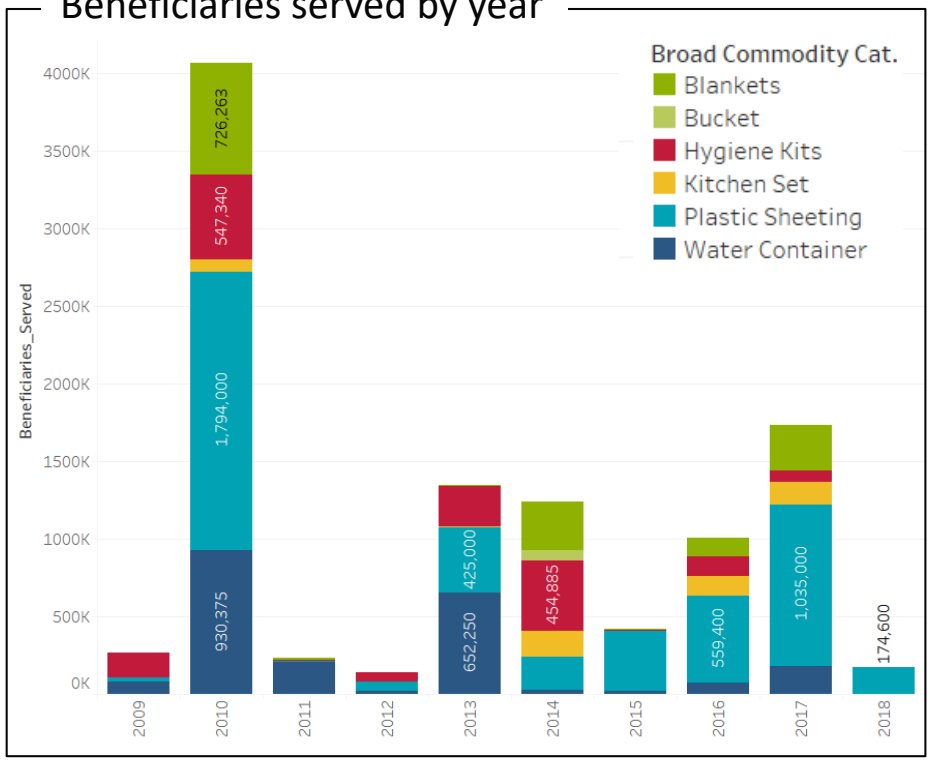
MIT Center for Transportation & Logistics

Disasters have different commodity requests (ii)

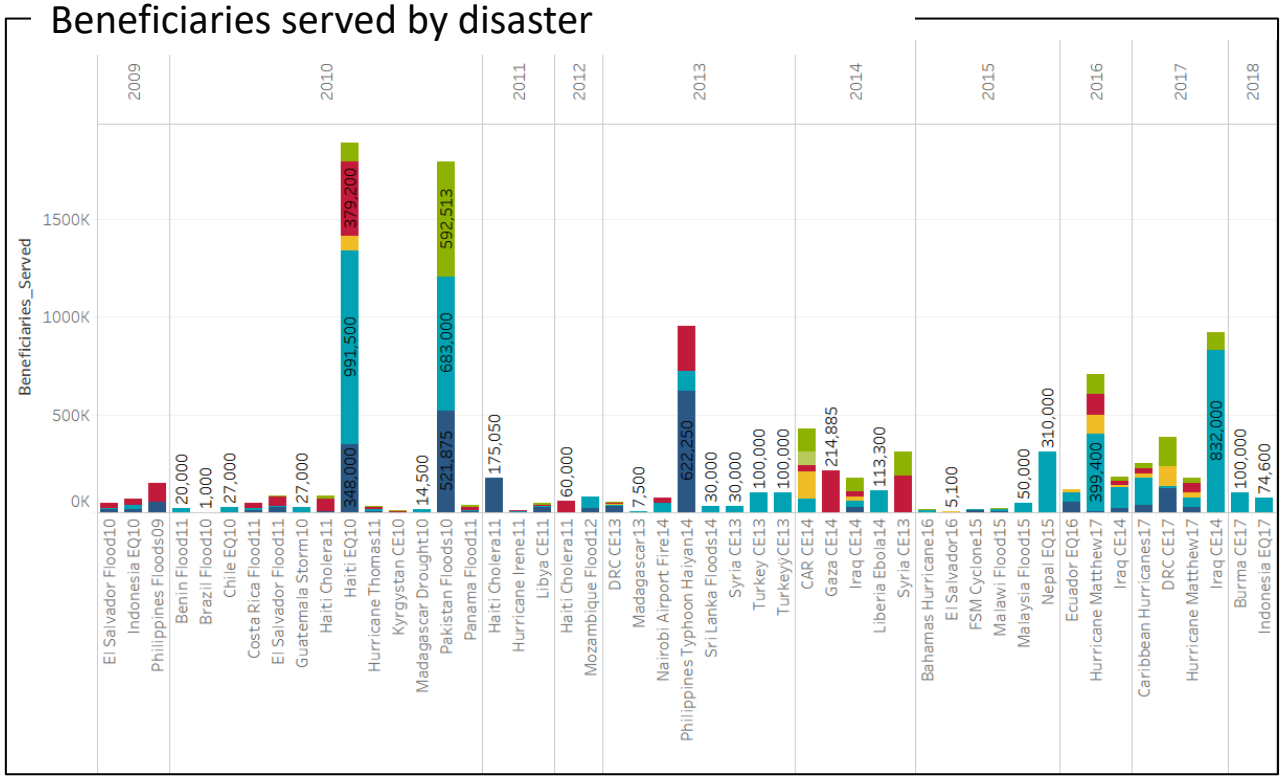
How does the quantity of each commodity change over time and by disaster*

- Charts show the beneficiaries served by commodity over the years (left) and by disaster (right).
- Across years overall shipment quantities fluctuate substantially in total.
- Naturally, the quantities are driven by different disasters that USAID/OFDA responds to.

Beneficiaries served by year



Beneficiaries served by disaster



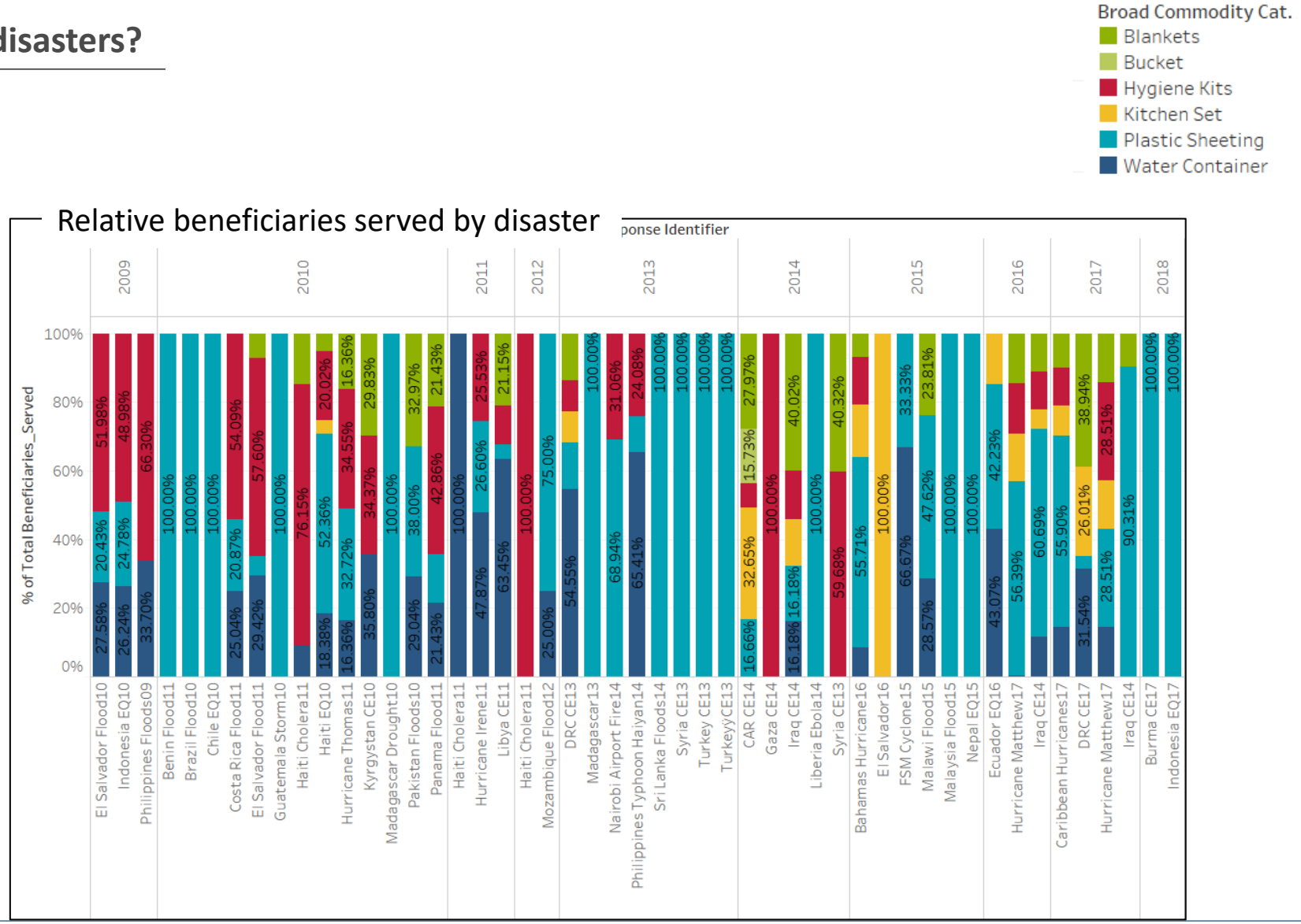
*commodity analysis is based on incomplete shipment data, representing only ca. 50% of the entire disasters served since 2000; therefore absolute values are not representative of OFDA ops.

MIT Center for Transportation & Logistics

Disasters have different commodity requests (iii)

Does the commodity mix change across disasters?

- The chart shows the percentage of beneficiaries served per disasters.
- The commodity mix (per disaster) substantially changes across disaster.
- Some disasters need only one category, others need a mix of commodities. This is largely driven by the needs on the ground.
- It seems that hygiene kits and water is less often requested. Kitchen sets seem to be more important.
- This could be driven by the change in disasters OFDA responded to (Slide 12).

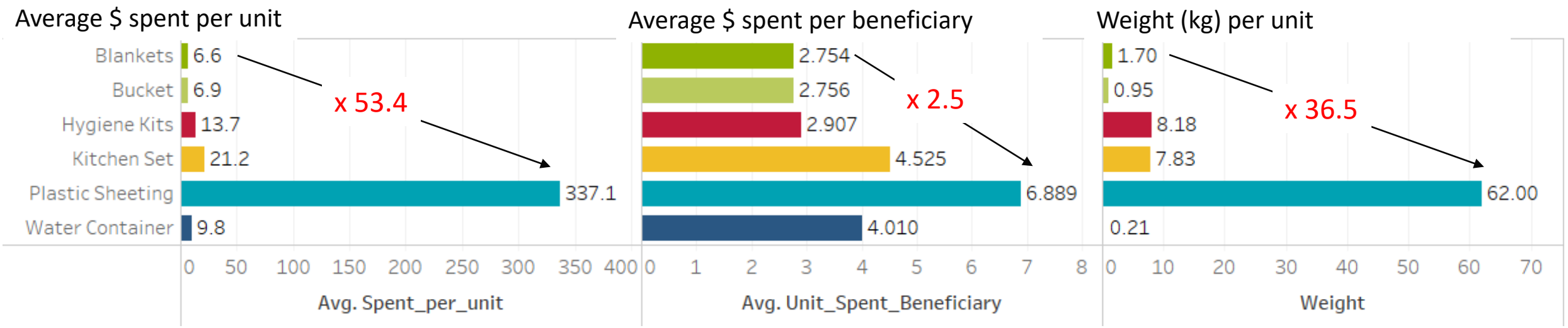


MIT Center for Transportation & Logistics

Commodity procurement cost

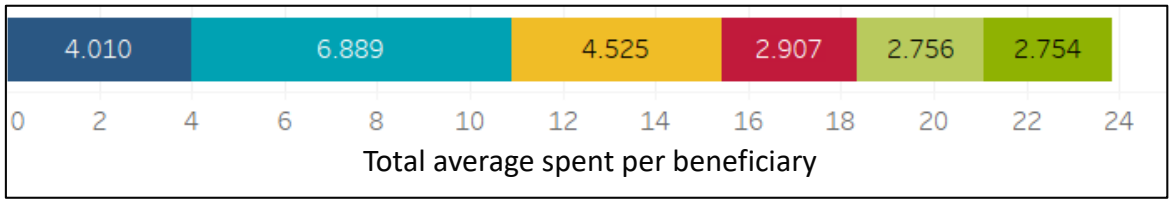
How much does OFDA pay per unit and per beneficiary?

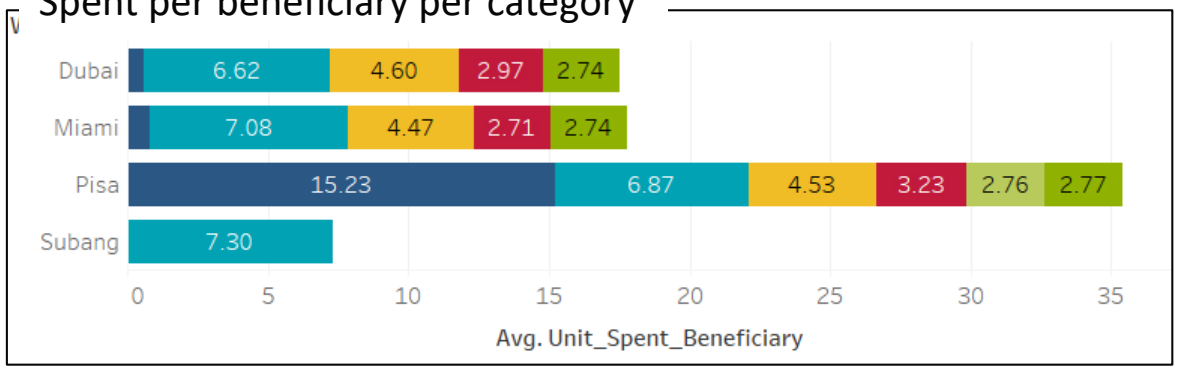
- The left hand chart shows average spent per unit.
- Blankets are the cheapest commodity per unit. Plastic sheeting is the most expensive being 53-times more expensive than blankets.
- Middle chart shows the average spent per beneficiary.
- Most cost-effective to reach a beneficiary are blankets, buckets, and hygiene kits at less than $3/beneficiary.
- Most expensive is plastic sheeting at $6.9. Meaning OFDA could serve 2.5 times the beneficiaries using cost-effective commodities (if possible).
- The right hand chart shows weight per unit.
- Assuming that transportation cost are proportional to weight the cost effectiveness of blankets, buckets, & water containers is even more substantial.

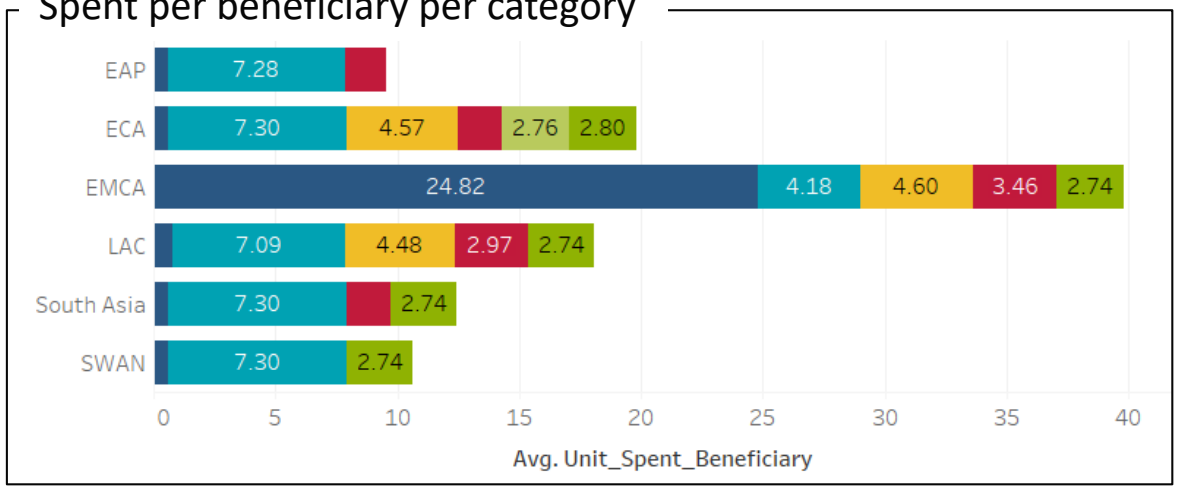


MIT Center for Transportation & Logistics

Commodity cost-effectiveness







How much does OFDA spent on commodities?

- The upper left hand chart shows the total spent per beneficiary and commodity.
- The total is $23.8. About 29% of the total spent is for plastic sheeting.
- The middle left hand chart shows the commodity spent per beneficiary originating in each warehouse.
- The lower left hand chart shows the commodity spent per beneficiary originating to each region.
- Highest spent served from Pisa.
- Largest spent goes to EMCA. About 50% of the spent in EMCA is for water.
- EAP has to lowest spent and it is very focused on plastic sh. (no kitchen sets, no blankets).
- Lowest spent regions (EAP, South A., SWAN) do not need kitchen sets.

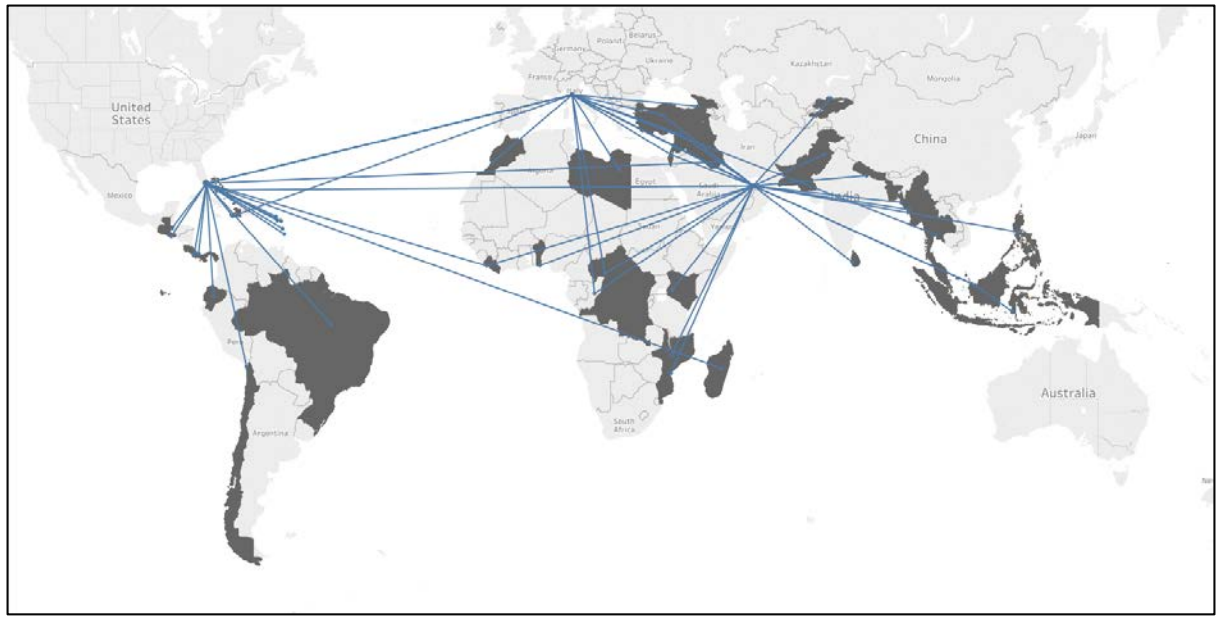
OFDA's use of transportation capacity

OFDA's operations

- OFDA transports commodities to disaster regions to fill requests from the field.
- OFDA uses air, sea, and trucks and chooses the mode balancing response time and transportation costs.

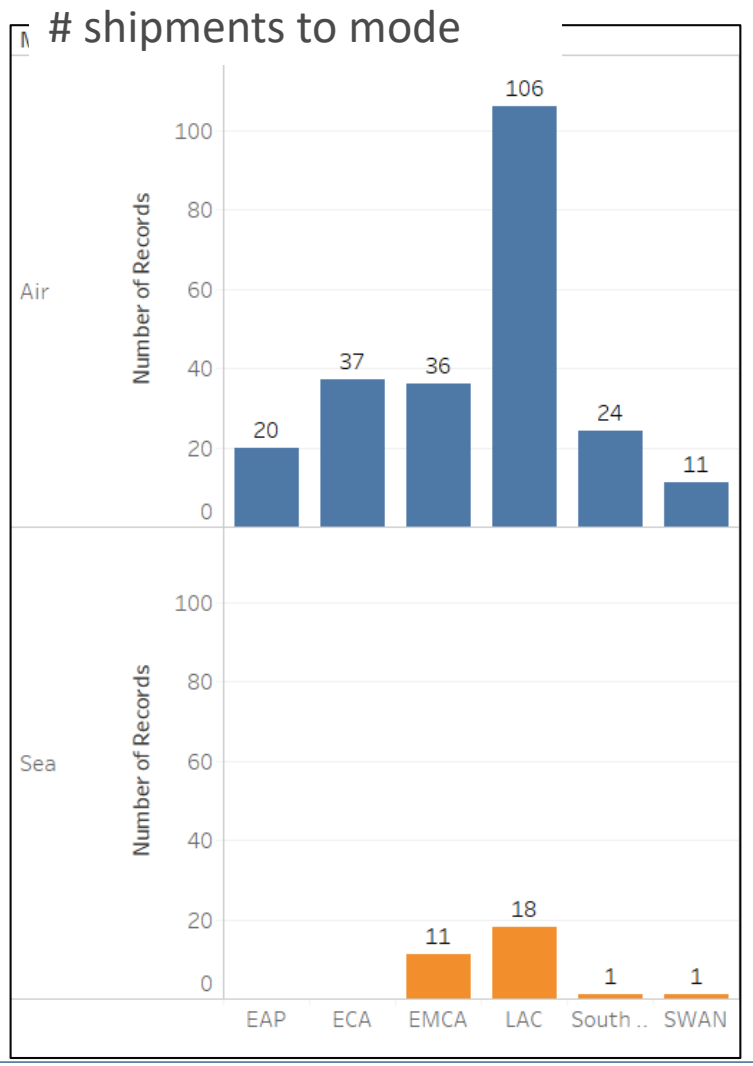
Key questions

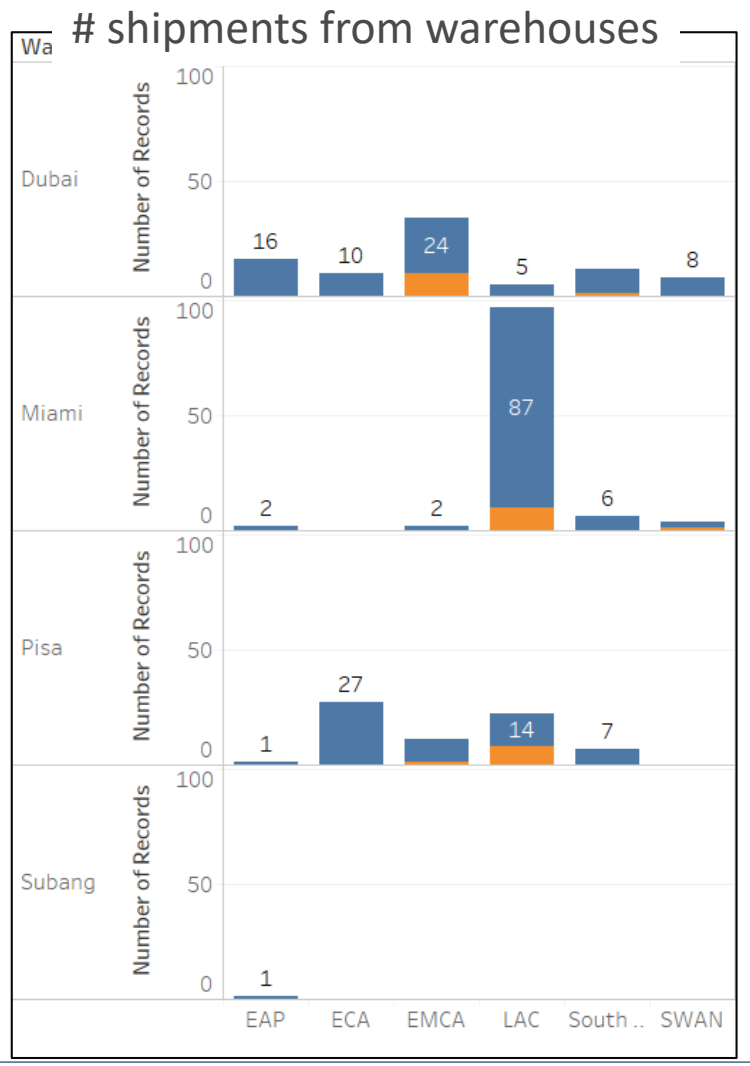
- Which modes of transportation does OFDA actually use?
- Are there warehouse and disaster region preferences?
- Does the model mix change over time?
- Are there preferences to ship certain commodities on certain modes?
- How frequently does OFDA send shipments?
- How much does OFDA pay for transportation services?
- What are the main cost drivers?



MIT Center for Transportation & Logistics

Modes of transportation



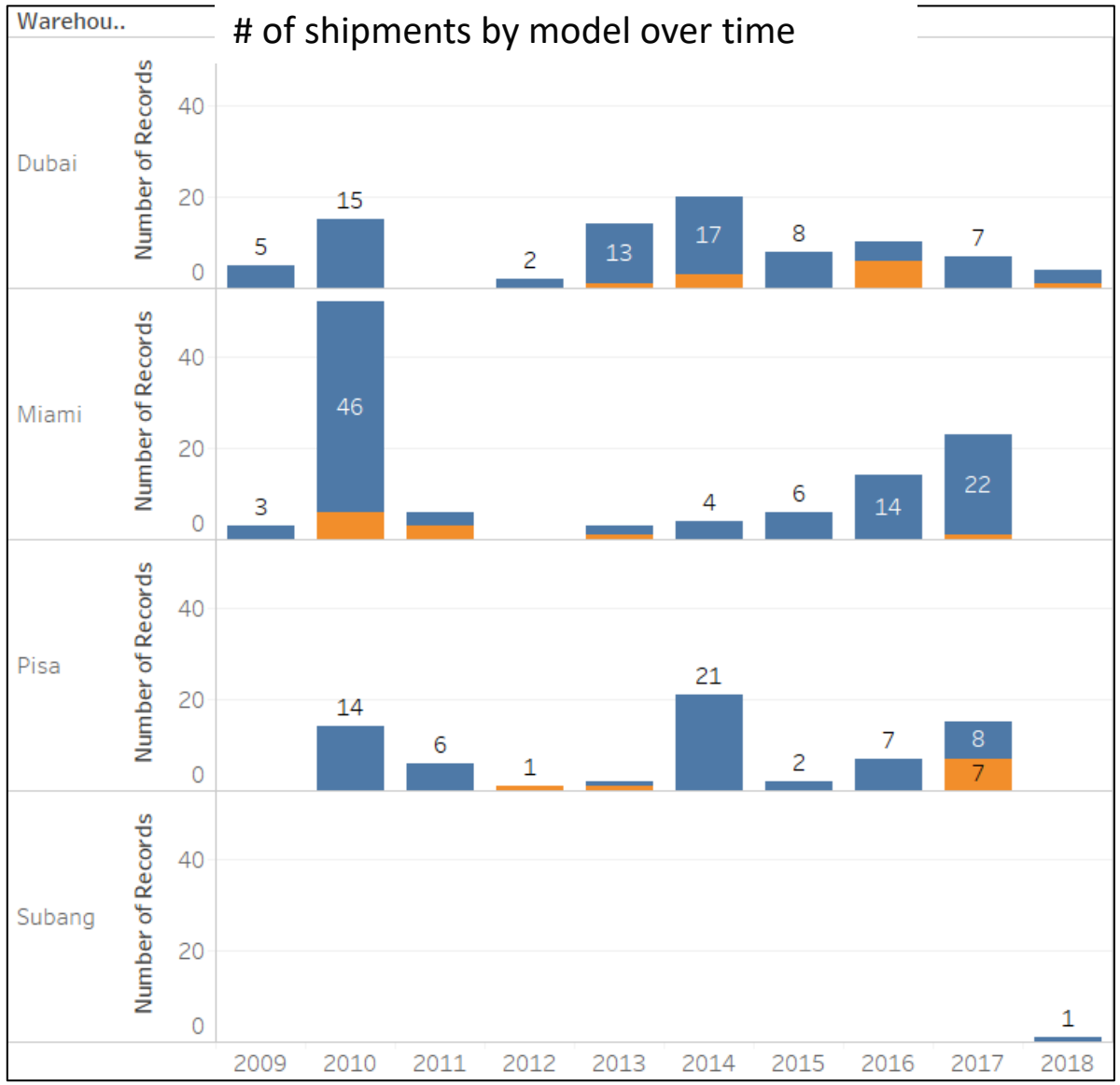


Do regions and warehouses have mode preferences?

- Charts show the number of shipments by mode to regions.

- Two modes of transportation are used, i.e. air and sea.
- Air is used from all WHs to access all regions.
- Air is used most often.
- Sea is sometimes used for Middle East, Latin America, and (rarely) South Asia.

Modal mix over time



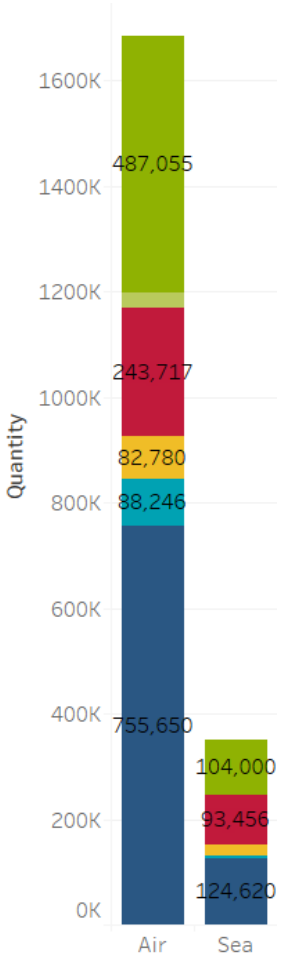
How does the model mix change over time?

- Chart shows the number of shipments from warehouses over time.
- Some indication for less shipments from Dubai and more shipments from Miami.
- There is no apparent trend in modal mix.

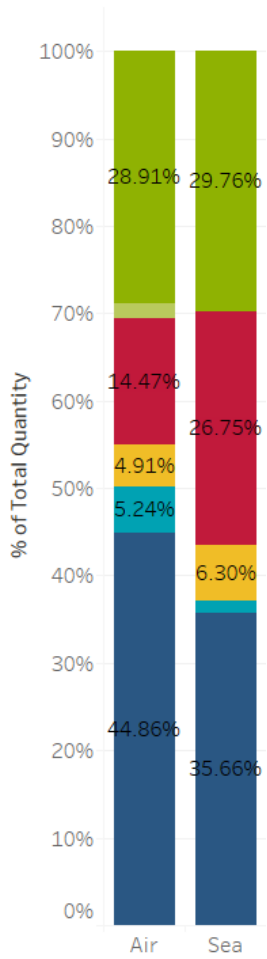
MIT Center for Transportation & Logistics

Modes vs. quantity and commodity type

Absolute quantity (kg)



Relative quantity (kg)



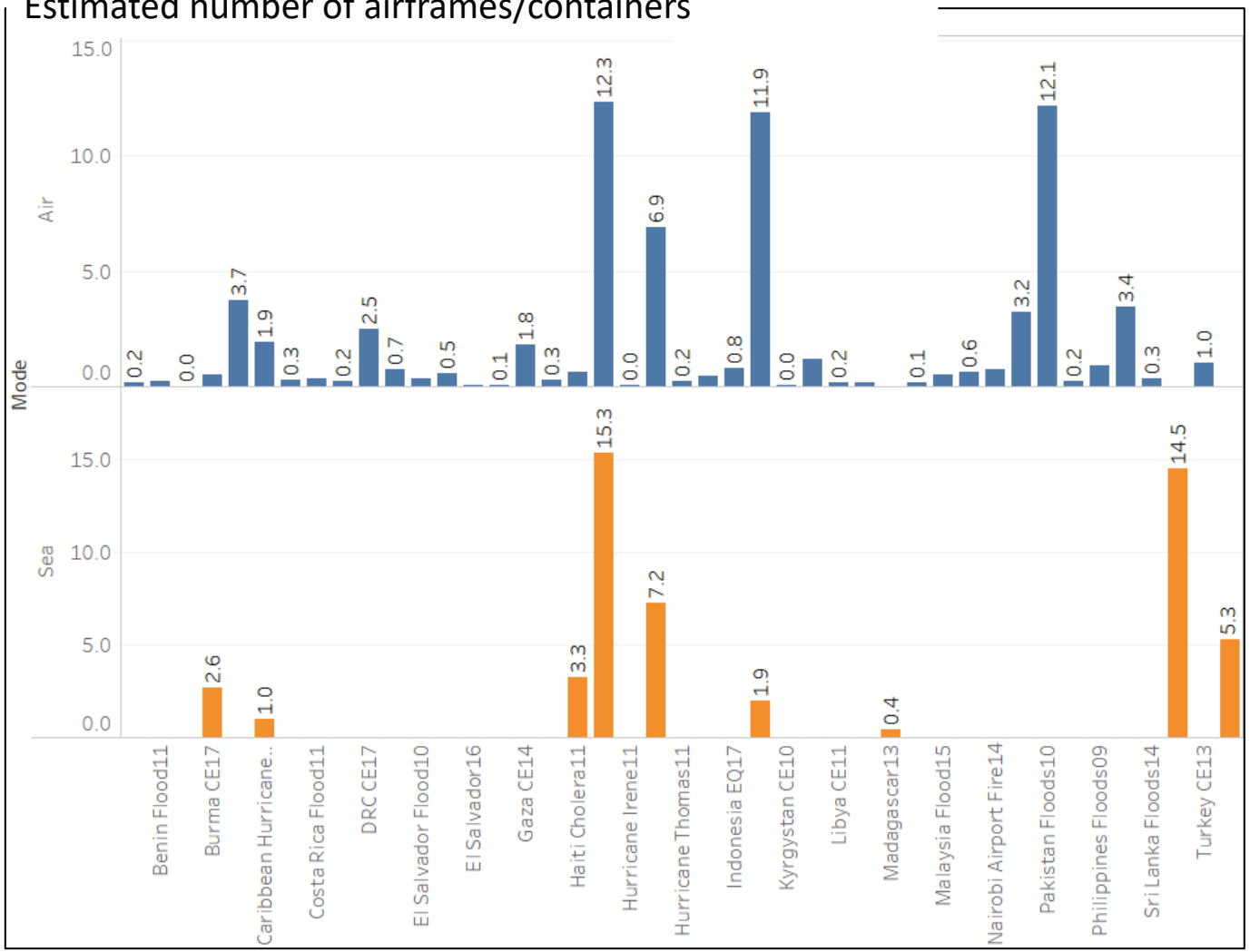
How much is shipped with a specific mode?

- Charts show shipment quantity per commodity for each mode.

- Most shipments are via air.
- There is no clear preference to ship commodities via a specific mode.

MIT Center for Transportation & Logistics

Number of airframes/containers



How many airframes /containers are sent in response to a disaster?

- The chart estimates shipment quantities in number of vessels. To do so, shipment quantity (kg) is converted into airframes (110t capa.) and containers for sea freight (21.6t capa.).

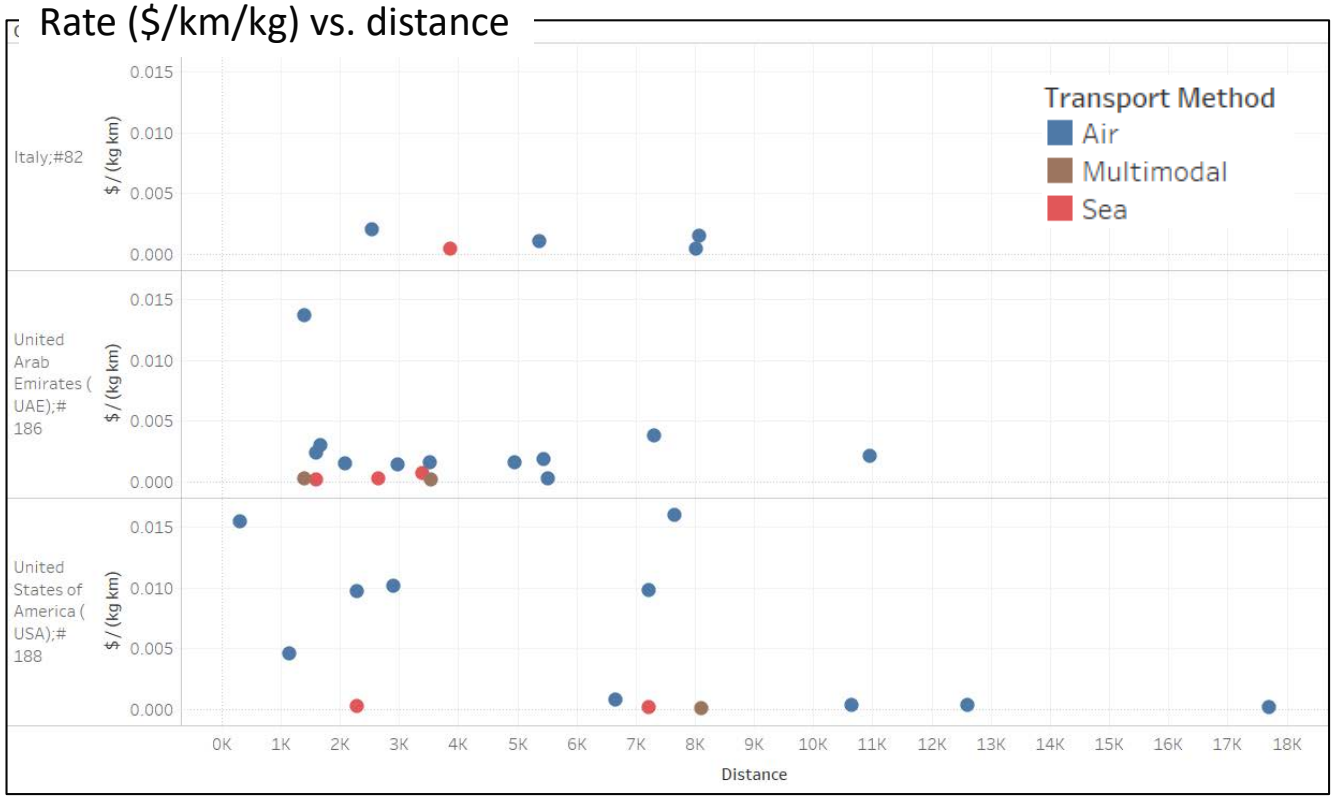
- There is a substantial number of airfreights with smaller volumes.
- Sea freight are generally smaller quantities.

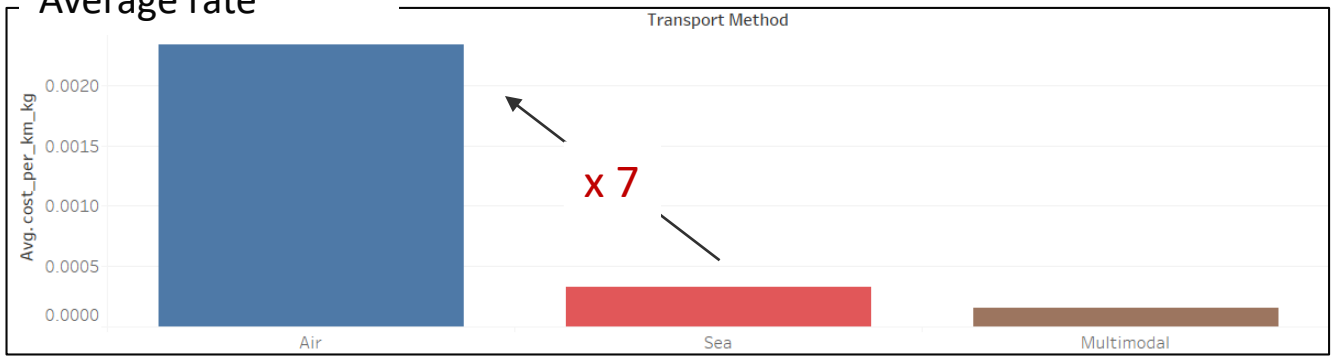
MIT Center for Transportation & Logistics

Shipment costs

How much does OFDA pay for shipment

- We do not have sufficient data to provide a holistic and empirically founded picture.
- The chart on the upper right shows OFDA's shipment rates ($/km/kg) from three WHs depending on distance.
- Long hauls appear to be less expensive then short hauls.
- Air, which is used mostly by OFDA, is on average seven-times more expensive than sea (see lower right chart).
- Multi-model is less expensive than individual modes.





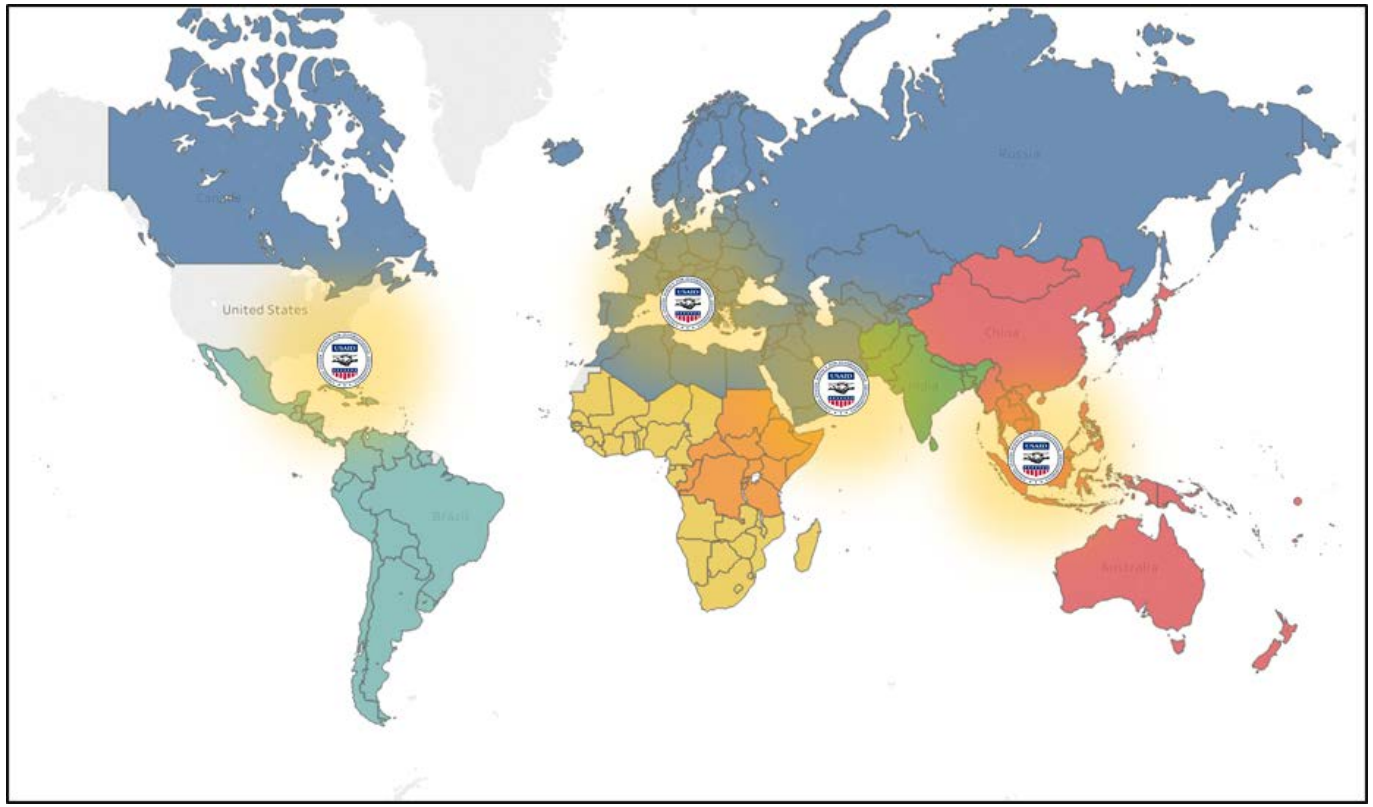
MIT Center for Transportation & Logistics

Summary data needs

Refining our initial questions.

OFDA holds a strategic stockpile of key disaster response commodities to support people world wide in crises situations.

Potential Inventory Locations



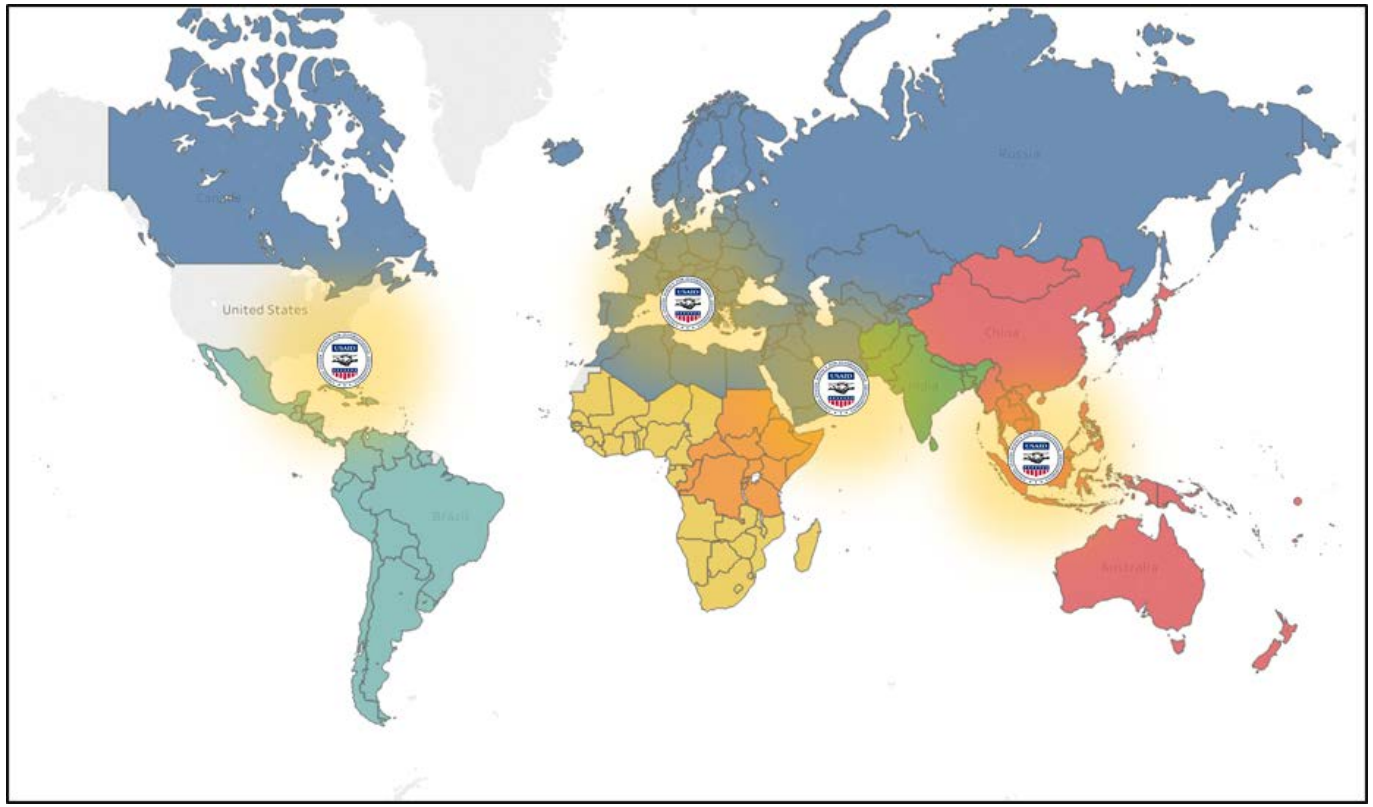
Research Questions

- USAID/OFDA faces a mix of complex emergencies and natural disasters that are distributed across the world and vary in occurrence and size over years.
- The complexity of OFDA's operations raises multiple questions:
  - How many warehouse locations should OFDA maintain?
  - What inventory levels of different commodities should OFDA hold at different locations to reduce cost and ensure responsive service to people in need?

Refining our initial questions.

OFDA holds a strategic stockpile of key disaster response commodities to support people world wide in crises situations.

Potential Inventory Locations



Research Questions

- How is the network depending on transportation capacity availability and cost? E.g.
- Should OFDA focus on air transport or should OFDA consider regional WHs that open access to less expensive modes of transportation (ship, truck) while maintaining/improving responsiveness?
- How does lower vendor lead times improve logistics and warehousing cost?

How we plan to approach the problem in Phase II

How we approach these questions:

- USAID/OFDA continues to engage with the Humanitarian Supply Chain Lab (HUSCL) @MIT.
- HUSCL will create a tailored model that can answer the questions raised before for USAID/OFDA and its partners.
- USAID/OFDA and HUSCL will look for partners who are willing to participate in our study and share data.
- In particular, we are looking for information on
  - transportation capacity and cost.
  - partners WH locations and inventory levels.

How partners can benefit:

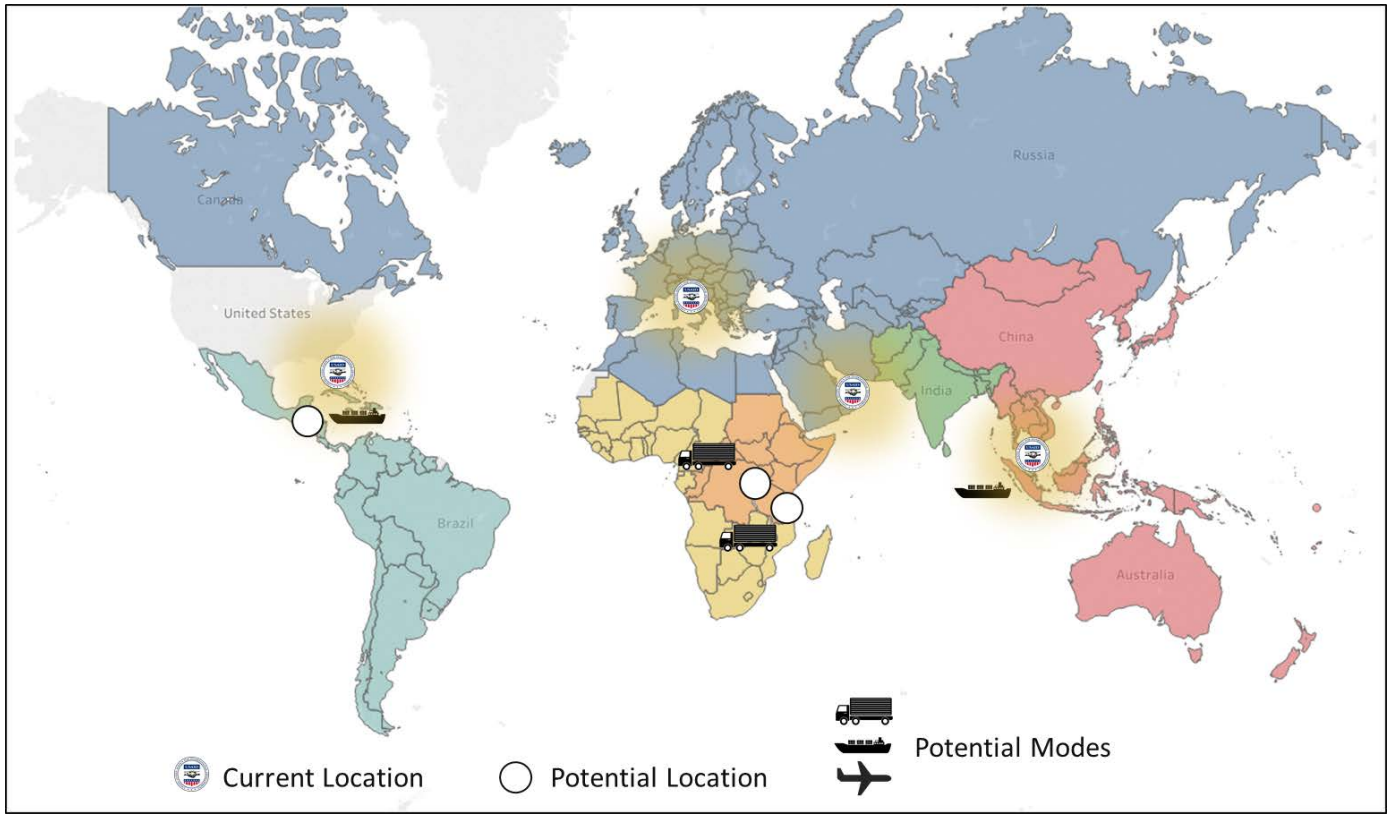
- Get access to our project's findings on inventory locations and transportation capacity.
- Coordinate our efforts to become more responsive.
- Lower costs of operations.

Intended model insights

We intend to explore with the model

1. How much inventory should OFDA carry in its network to trade off working capital req. and potential stock outs.
2. Where in its current network OFDA should locate the inventory to balance storage/transportation costs with response-time.
3. How, if at all, should OFDA change its global networks footprint to reduce storage/ transportation costs, e.g. by exploiting less expensive means of transportation.

Potential Inventory Locations



Thank you for your attention!