Effects and Mitigation of Natural Hazards in Retail Networks

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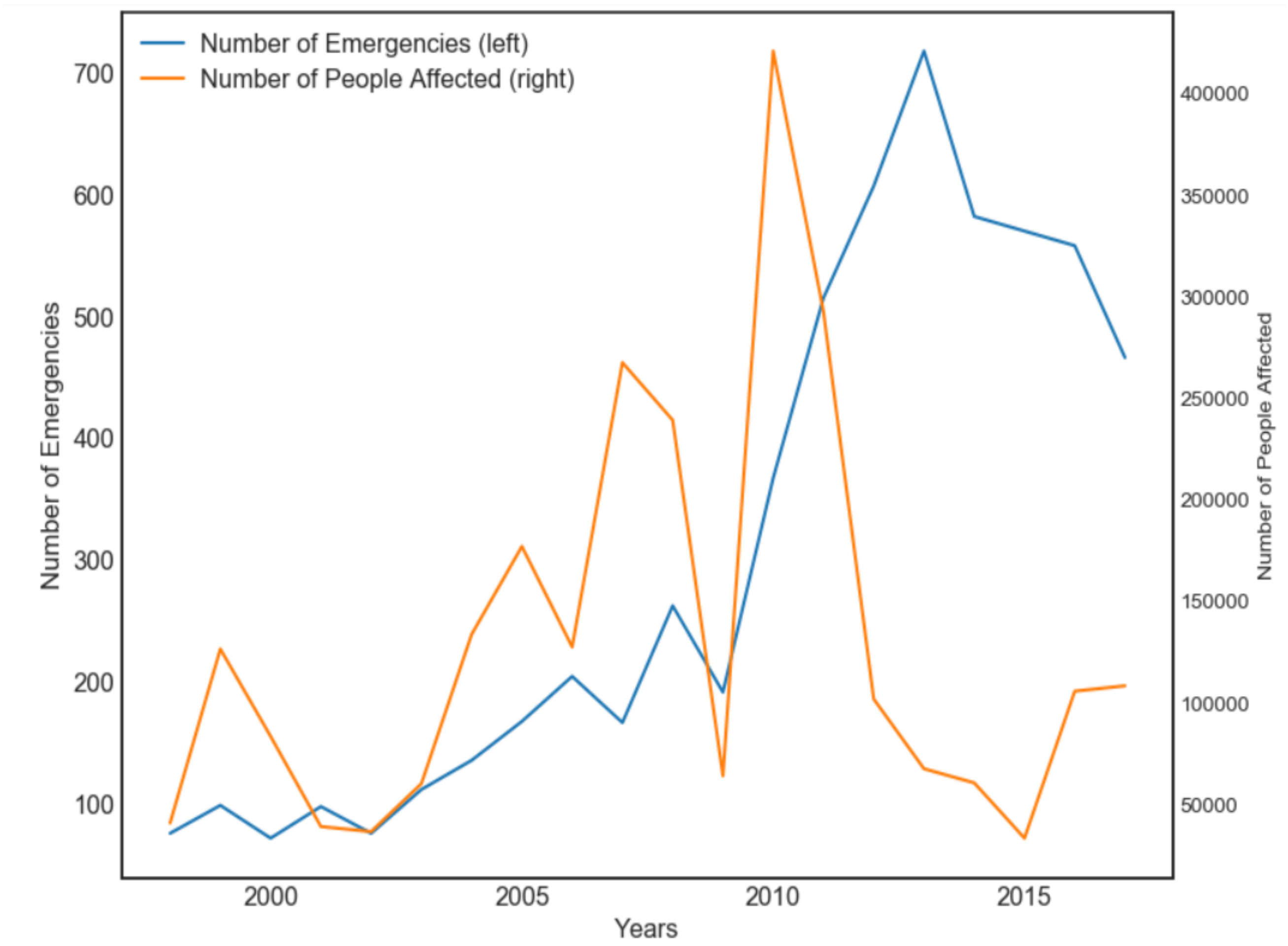
logyca

Motivation



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Motivation

If I give you $100,000 to invest in resilience,

What do you do?

Context

Available data:

- Daily sales and inventory of a major retailer in Colombia (> 500 POS)
- 20 years of historical data of natural emergencies in Colombia

Objectives:

- Understand the effects of natural hazards in retail sales
- Provide a framework to invest against the effects in retail networks

Methodology to Invest in Resilience

1. What is the **frequency**, **impact** and **location** of natural hazards?
2. What are the **effects** in sales for different products?
3. What are the possible **investments** for resilience?
4. What is the **risk profile** of the organization?
5. What is the **future cost** from the investments

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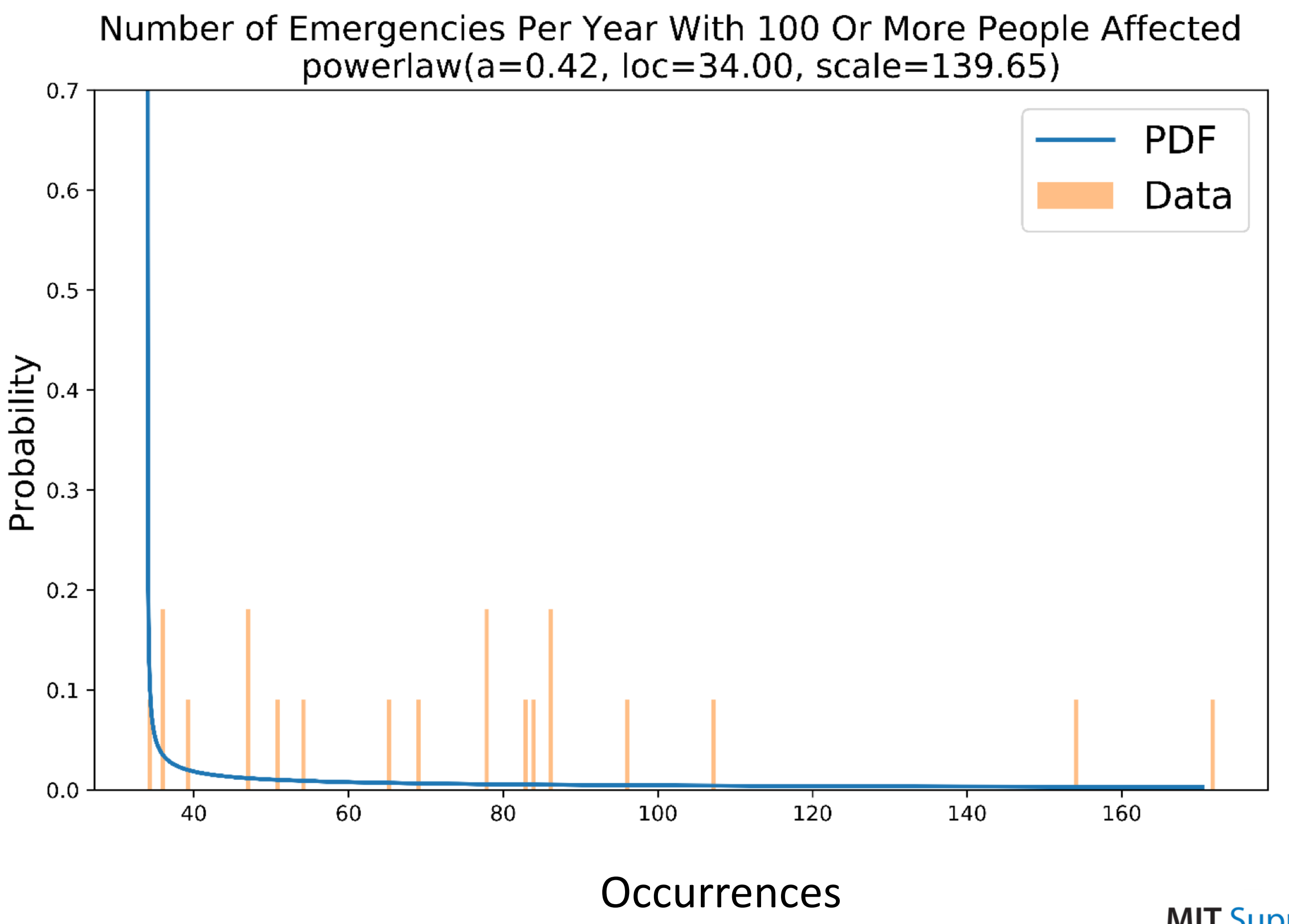
1. Natural Hazards

Frequency of Natural Hazards

- 166 natural emergencies per year
- 75 natural emergencies per year affecting > 100 people
- Power Law Distribution



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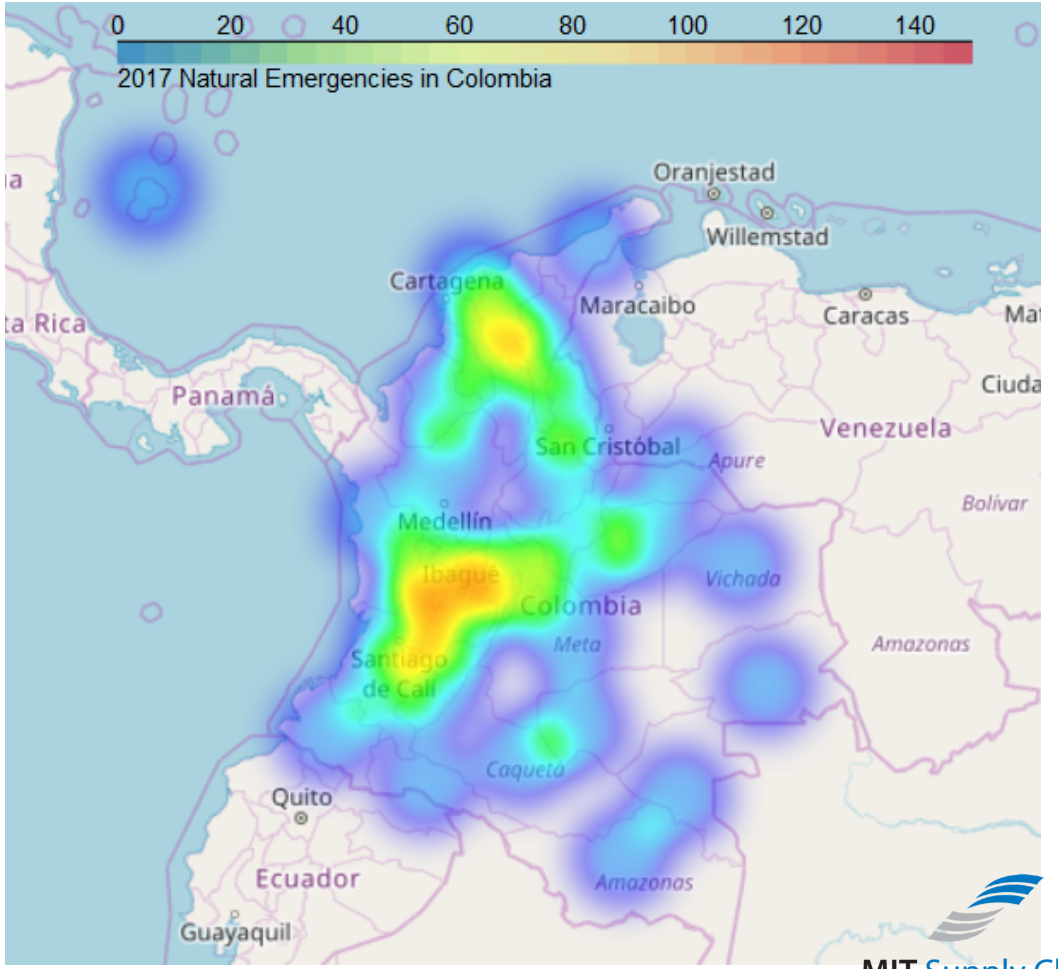
Location of Natural Hazards

- Not uniformly distributed
- Average of 15 natural emergencies per region
- Range between 5 and 43 emergencies



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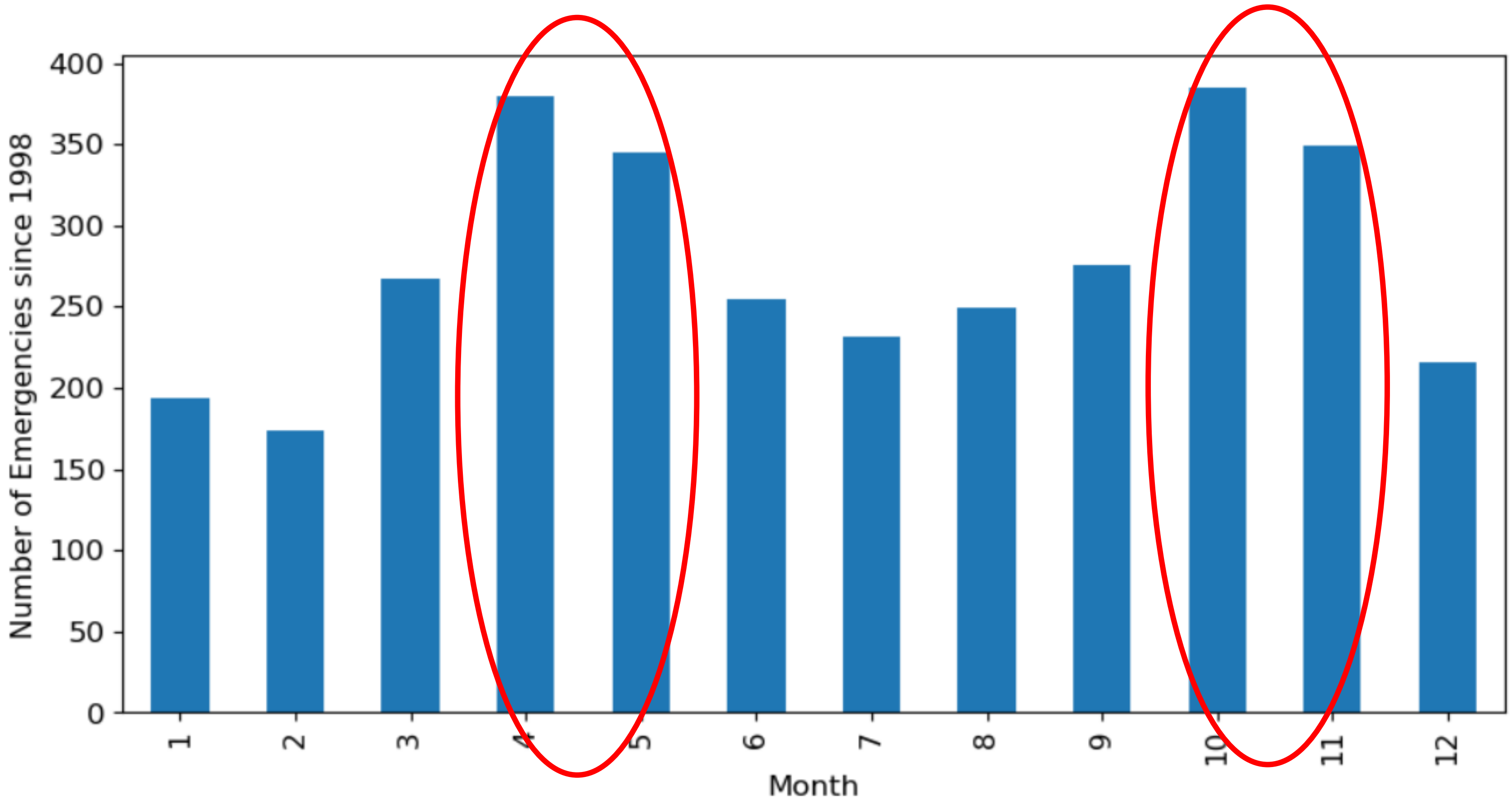
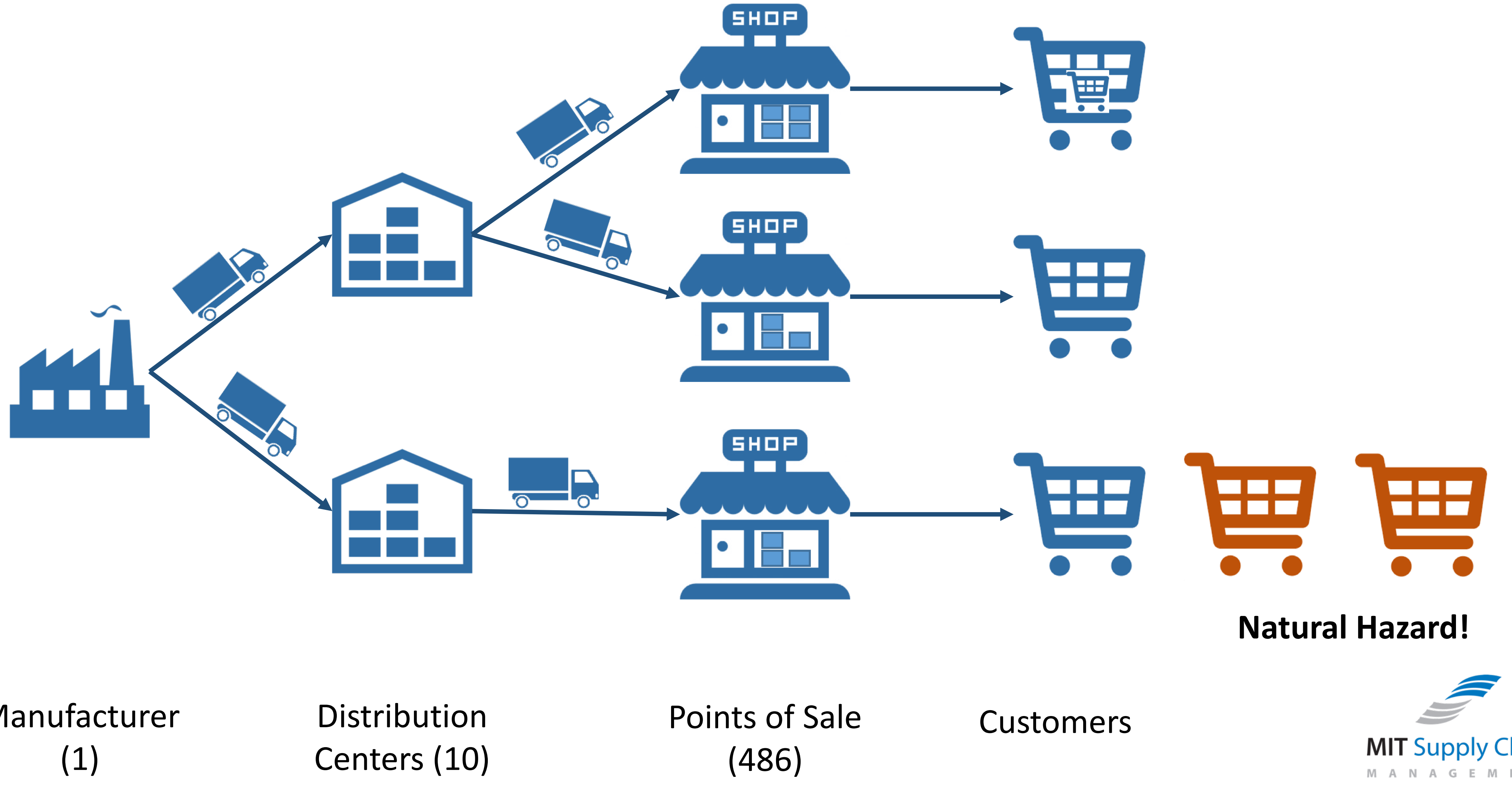
Seasonality of Natural Hazards



2. Impact on sales

Retail Network



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Impact on Sales

Products analyzed:

- Beer
- Family Pasta
- Coffee
- Personal Care

Results:

- People drink 21% less beer
- People eat similar pasta
- People drink 120% more coffee
- People buy 18% more personal care

$$\Delta sales = \frac{sales\ after\ emergency\ -\ regular\ sales}{stdv\ of\ regular\ sales}$$

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3. Resilience Options

Two ways to Invest in Resilience

Additional Buffer Stock

- Purchased at the beginning of the planning period
- Allocated for each region
- Consumed only when emergencies occur

Real Options Contract

- Optional fixed capacity purchased to the supplier
- Executed only after a declared emergency and non-refundable if there is no emergency
- Price based on discount from product cost

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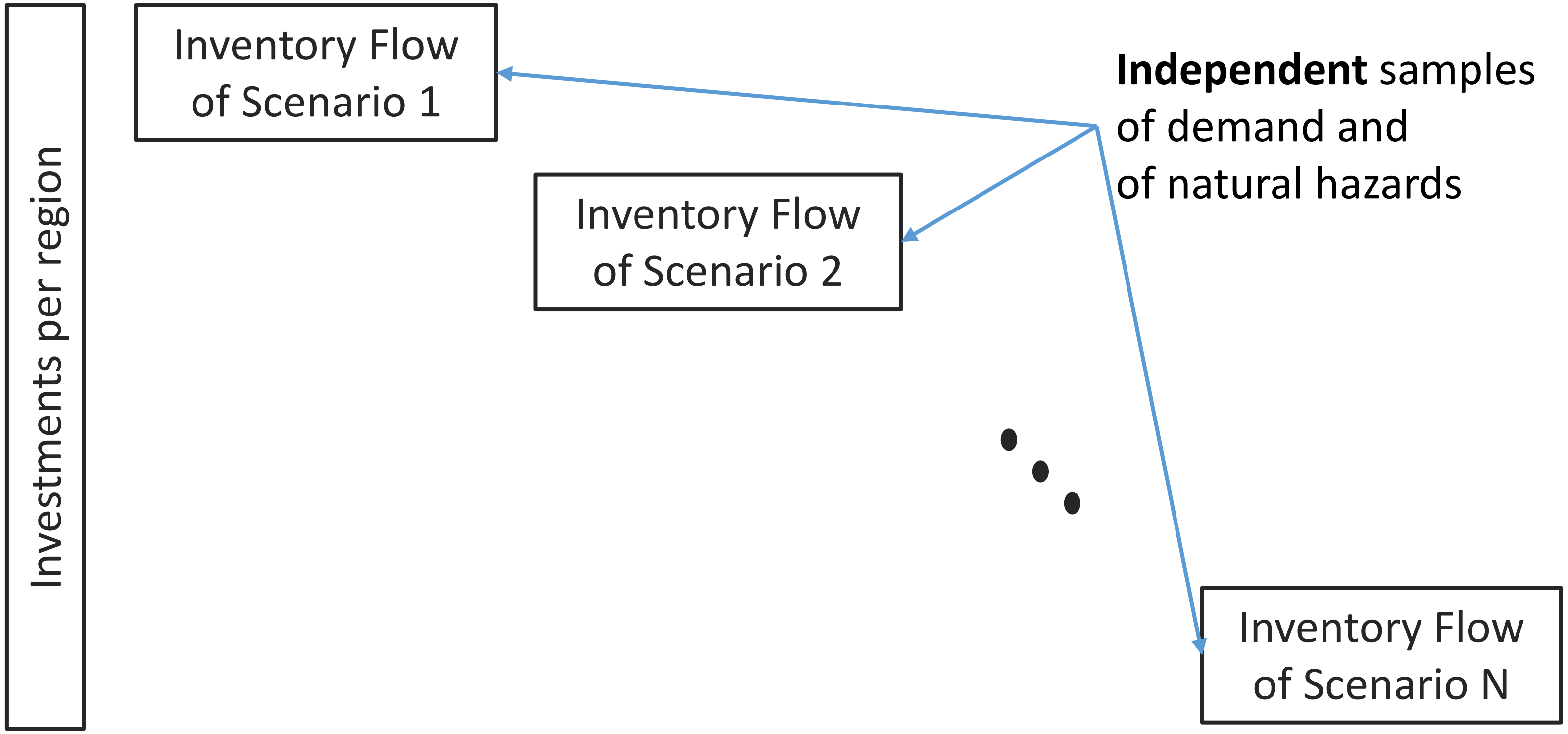
Resilience Investment Model (RIM)

$$\textit{minimize}\ \frac{1}{N}\sum_{\textit{scenarios}}(\textit{transport cost} + \textit{inventory cost} + \textit{lost sales}) + \frac{1}{N}\textit{Risk of scenarios}$$

s.t.



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4. Risk Profiles

Risk Profiles

They are **preferences** of the decision maker over the possible future costs of an investment

They **shape** the distribution of future outcomes

Profiles used (You, Wassick & Grossman (2008):

- **Risk Neutral:** No preference for large deviations
- **Variance Minimization:** Minimize the dispersion of future costs
- **Variability Index:** Minimize scenarios with cost over average
- **Probabilistic Financial Risk:** Minimize any scenario above a cost target
- **Downside Risk:** Minimize deviations over a cost target

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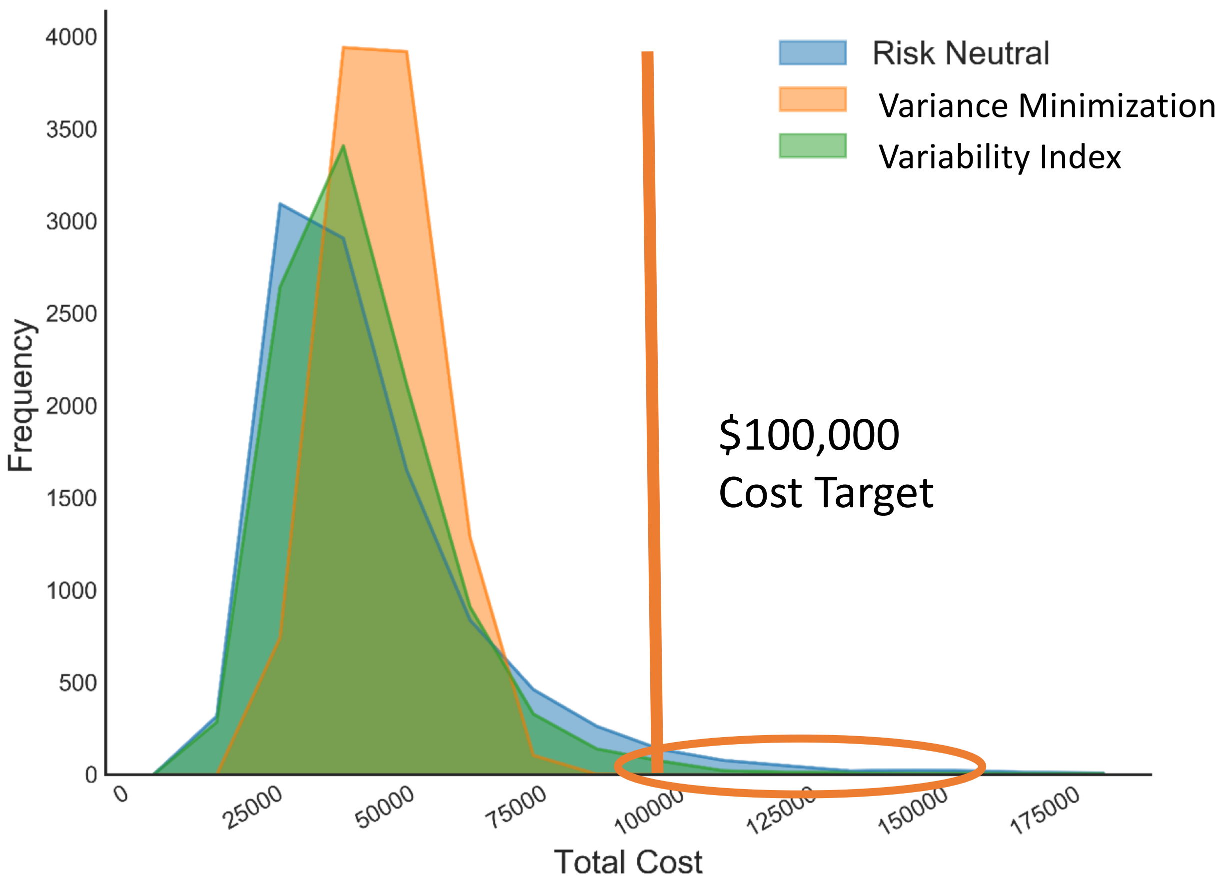
Risk Profiles (Example)



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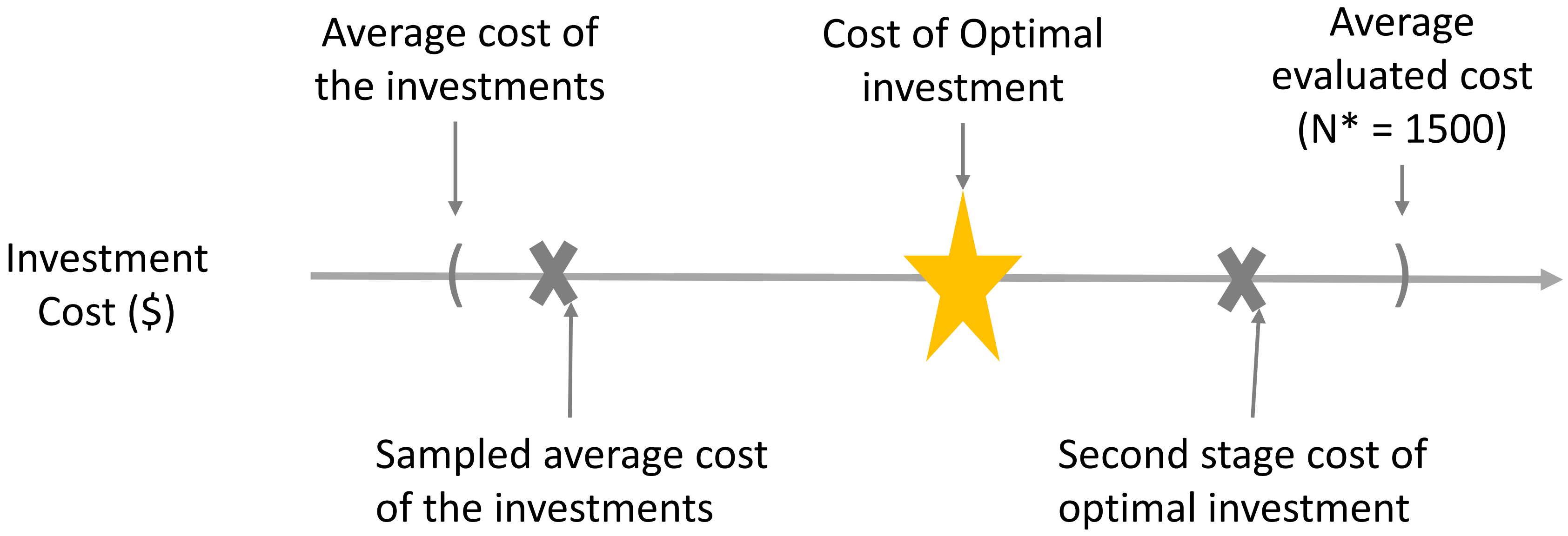
5. Future Costs

Selected Investments

We want the investment with sampled cost closer to the optimal cost

This investment will maximize the Value of the Stochastic Solution

VSS = Cost of Stoch. Solution – Cost of Mean Value Solution



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RIM Results

PROFILE	REGIONS INVESTED	% ACQUIRED STOCK	% OPTIONS CONRACT
NEUTRAL	14	10.3%	89.7%
VARIANCE REDUCTION	13	12.4%	87.6%
VARIABILITY INDEX	11	3.4%	96.4%
PROB. FINANCIAL RISK	17	0.6%	99.2%
DOWNSIDE RISK	14	11.9%	87.8%

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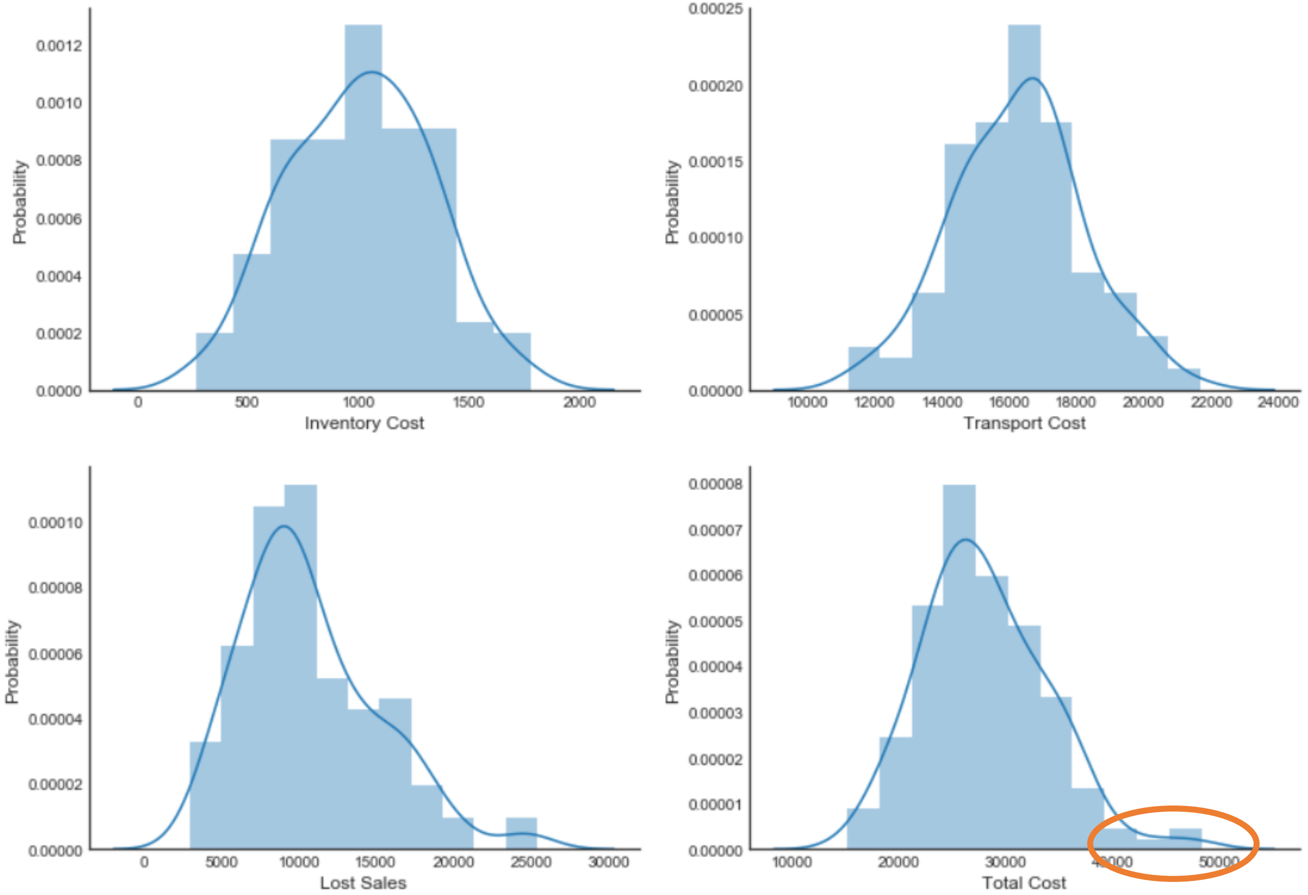
Future Costs – Risk Neutral



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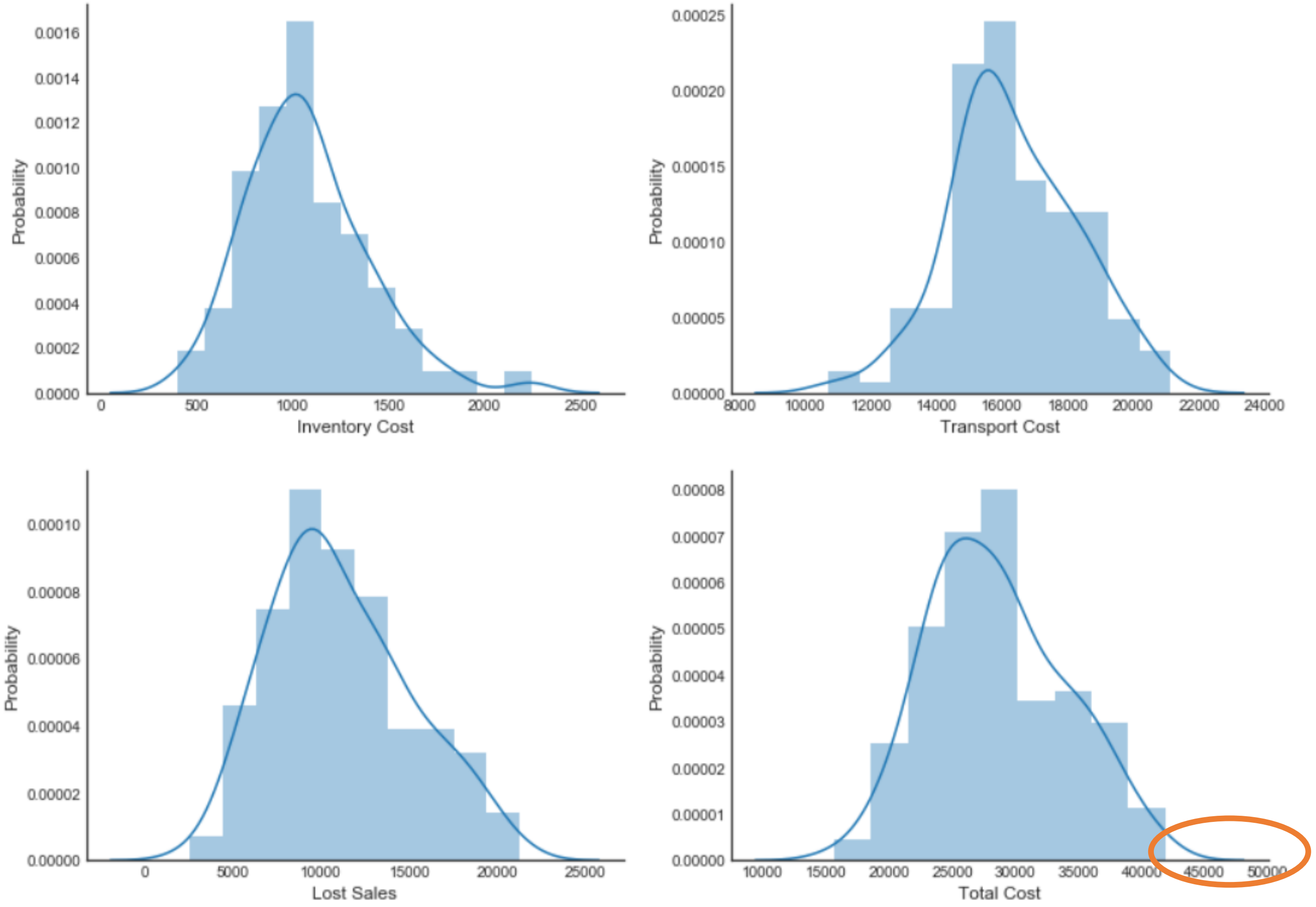
Future Costs – Variance Minimization



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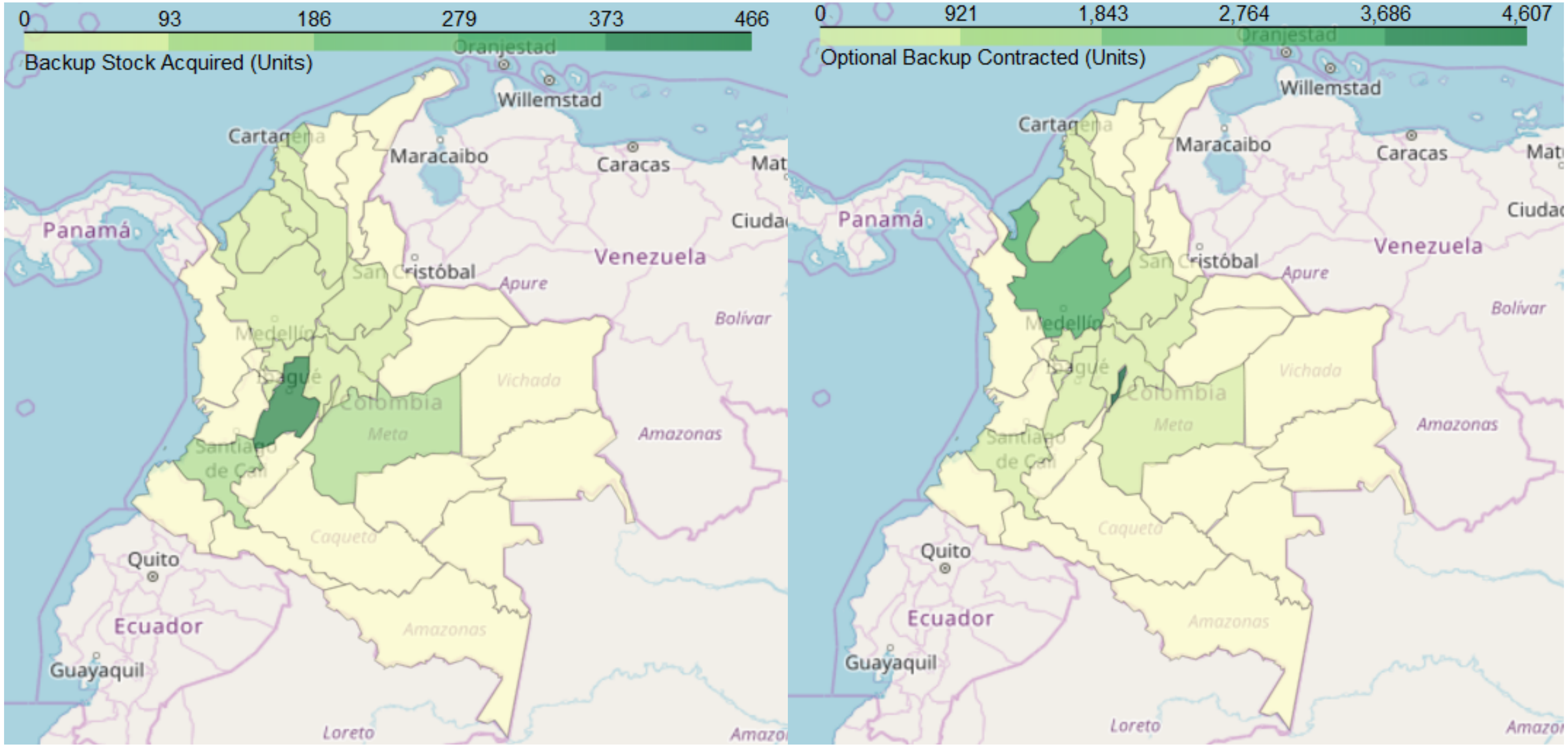
Distribution of Investments



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Key Insights

1. There is a variety of effects of natural hazards per product category
2. Risk neutral profile produce worst-case scenarios 15% worse than risk averse profiles with only 2% lower cost
3. The budget available needs to be high enough to mitigate the variability generated by natural hazards
4. Real options contracts provide a risk sharing strategy between manufacturers and retailers.

Thank you

Q&A

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$$minimize\ \mathbb{E}(Q(\omega, y)) + \mathcal{R}(Q(\omega, y))$$

$$\sum_{r \in R} (\theta * c * z_r + c * v_r) \leq L$$

$$z_r - \theta \sum_{k \in K} (k * \mu_r * y_{r_k}) = 0, \forall\ r \in R$$

$$b^{\omega}_{r(i)it} + x^{\omega}_{ijt} - x^{\omega}_{j'it} = 0, \forall\ t \in [0, T], \forall\ i \in I_d, \forall\ j \in I_p, \forall\ j' \in I_s, \forall\ \omega \in \Omega$$

$$\delta^{\omega}_{it} + \delta^{\omega}_{it-1} + x^{\omega}_{ijt} - x^{\omega}_{j'it} = 0, \forall\ t \in [0, T], \forall\ i \in I_p, \forall\ j \in I_d, \forall\ j' \in I_c, \forall\ \omega \in \Omega$$

$$x^{\omega}_{ijt} + u^{\omega}_{it} \geq d^{\omega}_{jt}, \forall\ t \in \forall t \in [0, T], \forall\ i \in I_p, \forall\ j \in I_c, \forall\ \omega \in \Omega$$

$$\xi^{\omega}_{r(i)it} + b^{\omega}_{r(i)it} + x^{\omega}_{ijt} + u^{\omega}_{it} + u'^{\omega}_{it} = (1 + \gamma^{\omega}) * d^{\omega}_{jt}, \forall\ t \in \Phi^{\omega}_i, \forall\ i \in I_p, \forall\ j \in I_c, \forall\ \omega \in \Omega$$

$$x^{\omega}_{ijt} + x^{\omega}_{j'it} \leq m_i, \forall\ t \in [0, T], \forall\ i \in I_d, \forall\ j \in I_p, \forall\ i' \in I_s, \forall\ \omega \in \Omega$$

$$\delta^{\omega}_{it} \leq m_i, \forall\ t \in [0, T], \forall\ i \in I_p, \forall\ \omega \in \Omega$$

$$\sum_{t=0}^{T} \xi^{\omega}_{r(i)it} \leq v_r, \forall\ r \in R, \forall\ i \in I_p, \forall\ \omega \in \Omega$$

$$b^{\omega}_{r(i)it} \leq\ 0, \forall t \notin \Phi^{\omega}_i, \forall i \in I_p, \forall\ \omega \in \Omega$$

$$b^{\omega}_{r(i)it} \leq\ z_r, \forall t \in \Phi^{\omega}_i, \forall i \in I_p, \forall\ \omega \in \Omega$$

$$x^{\omega}_{ijt} \geq 0, \forall\ i, j \in I, \forall\ t \in [0, T], \forall\ \omega \in \Omega$$

$$u^{\omega}_{it}, u'^{\omega}_{it}, \delta^{\omega}_{it} \geq 0, \forall\ t \in [0, T], \forall\ i \in I_p, \forall\ \omega \in \Omega$$

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