

Zero Hunger Lab

Optimal Humanitarian Depot Locations

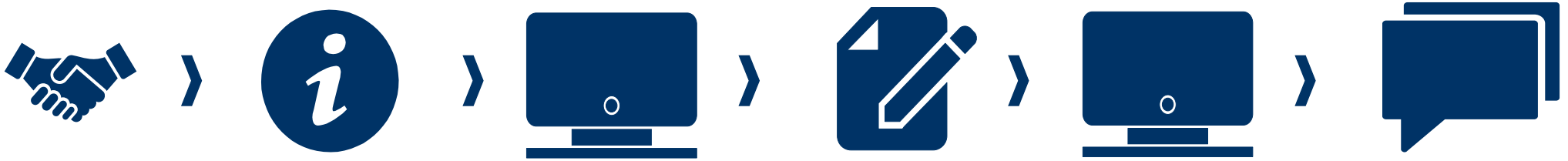
Joris Wagenaar, Valentijn Stienen, Dick den Hertog, Hein Fleuren

June 2022

Tilburg University

Understanding Society

Outline



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Introduction

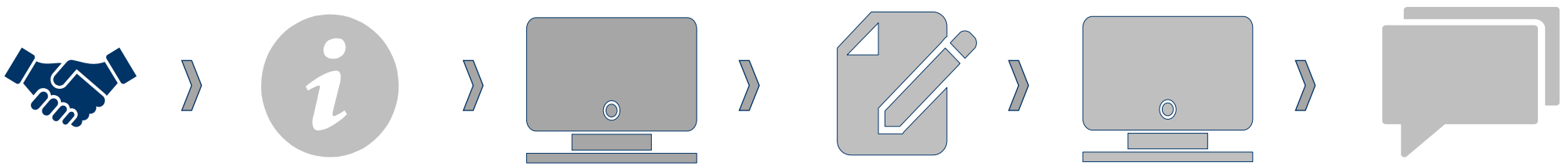
Nominal approach

Intermediate results

Robust approach

Conclusion and discussion

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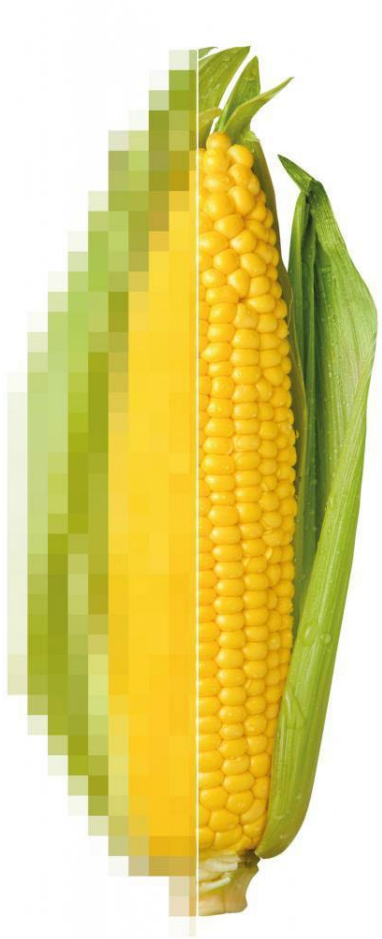
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Hunger - Bytes for bites



Hunger remains one of the world's most challenging problems. According to the United Nations, as many as 811 million people will go to bed hungry tonight and every ten seconds a child dies somewhere in the world due to hunger and malnutrition.

Zero Hunger Lab uses data science to help ensure global food and nutrition security. We call this *bytes for bites*.

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With Data Science we can make an impact

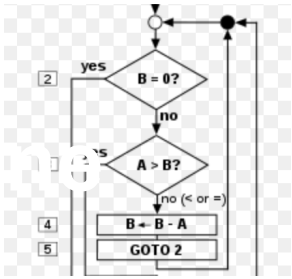




Data



Algorithms







Solutions / Advise



Better decisions

Emergency relief

Sustainable development

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Current research

Healthy, Sustainable and Affordable Diets

- Project ENHANCE with WFP, Johns Hopkins and Cap Gemini
- Sustainability becomes very important
- But also: is healthy really affordable?



Dutch Food Banks – Forecast & Logistics

- Forecast how many people might need the food banks
- Look at the best investments in transport and storage
- How to optimally divide food over the 171 food banks



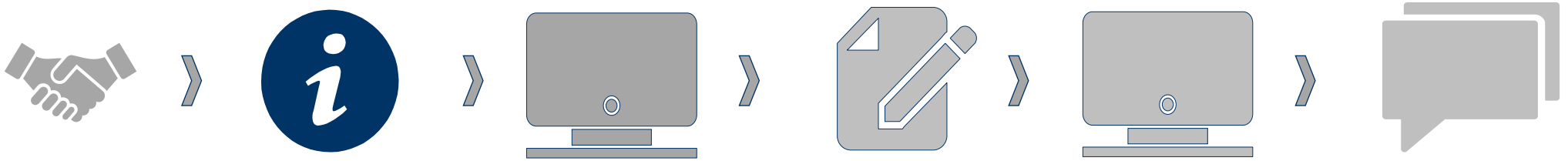
Child Growth Monitor - Welthungerhilfe

- With a mobile app try to detect malnutrition for children as early as possible
- Zero Hunger Lab works on the Machine Learning in the app



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ZHL

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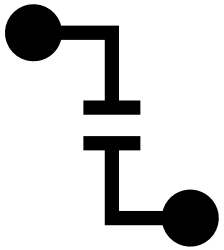
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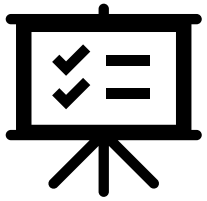
Use of math to aid during disasters



Minimizing expected travel time in disaster situations



Critical infrastructure recommendations



Prepositioning relief items



Determine optimal HLSP depot locations

Use of math to aid during disasters

Minimizing expected travelling in disaster situations

Critical infrastructure recommendations

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Determine optimal HLSP depot locations

Responding to a disaster

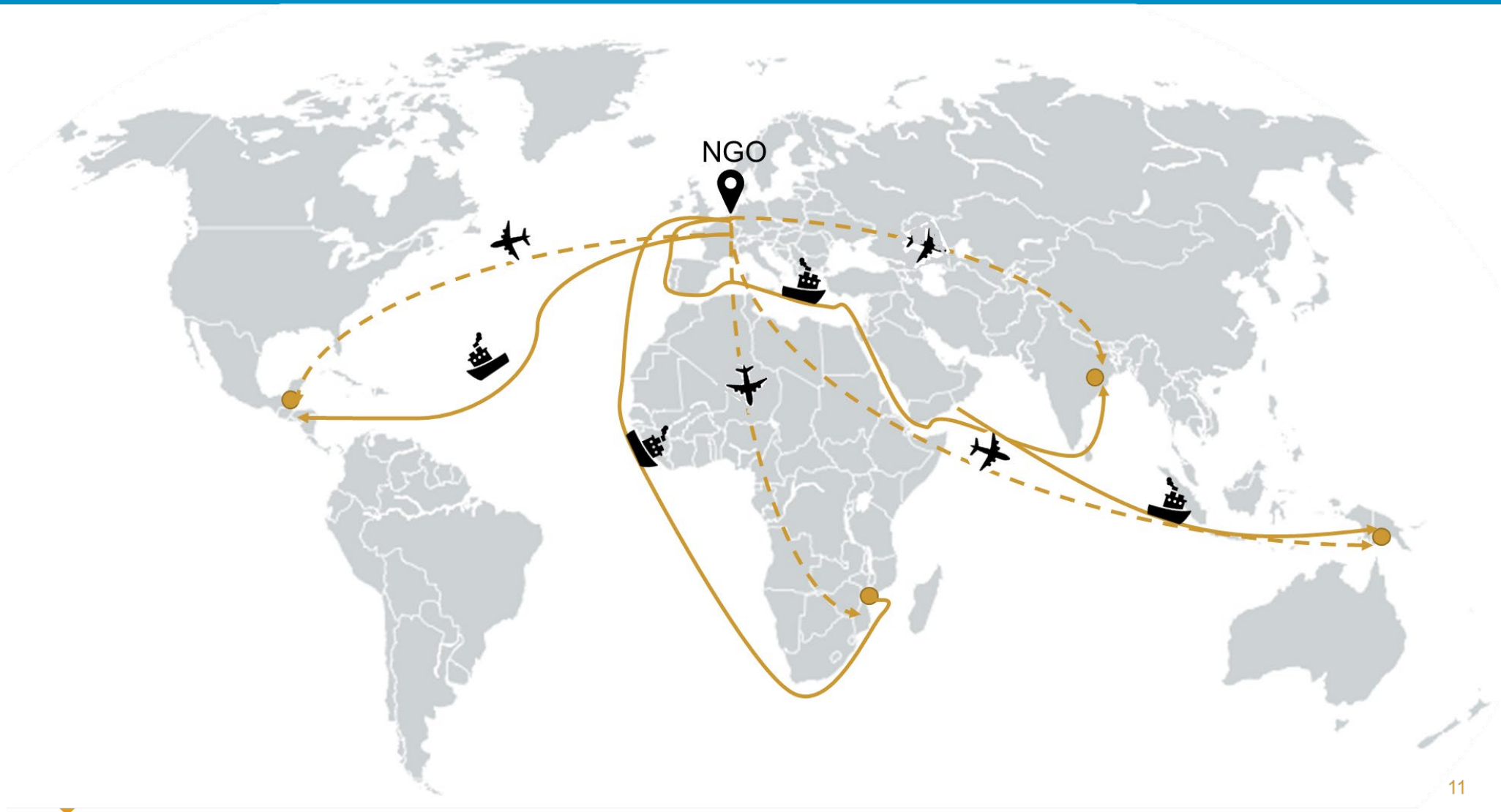


Immediate response

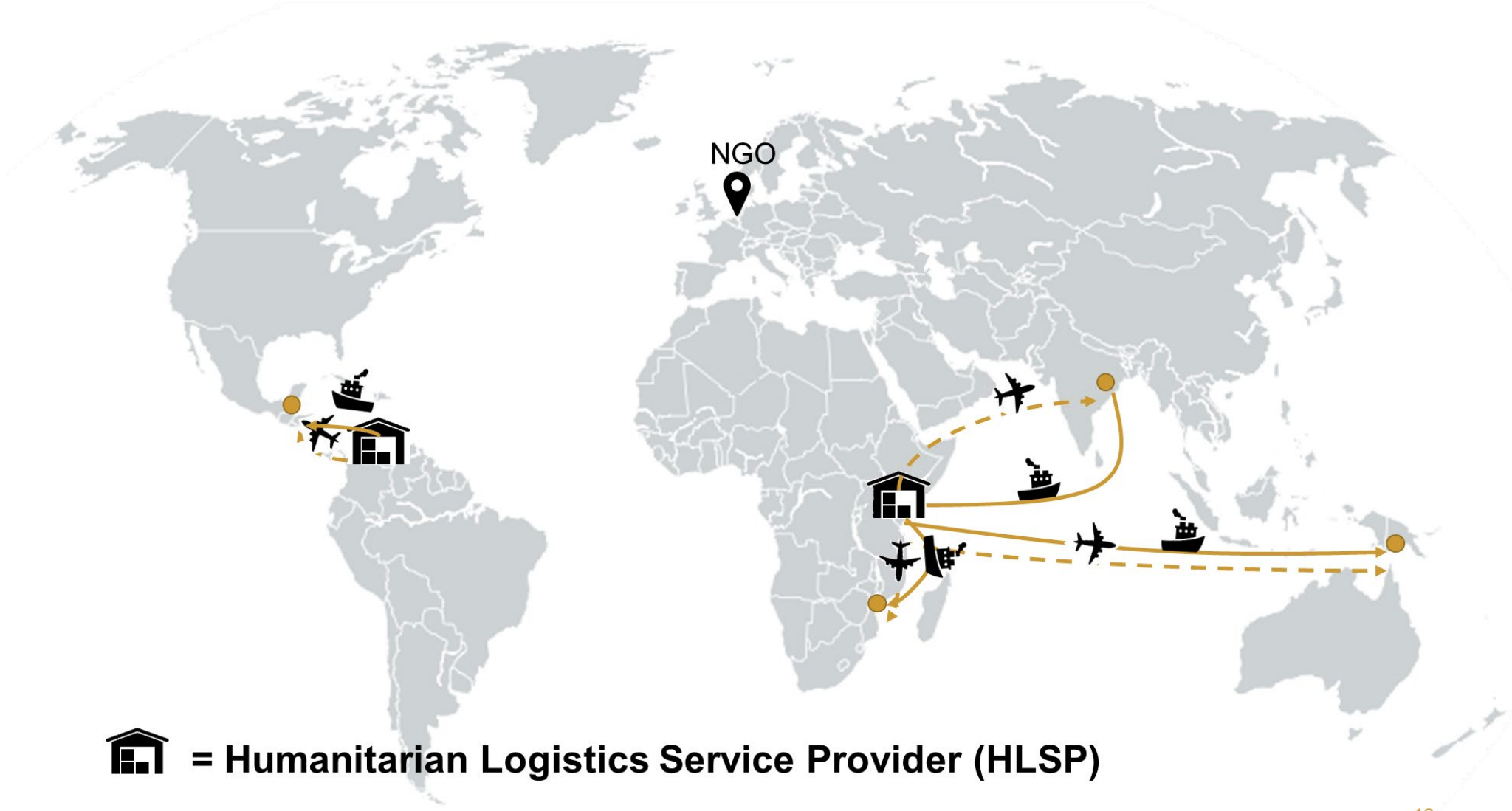


Recovery phase

Example



Hubs



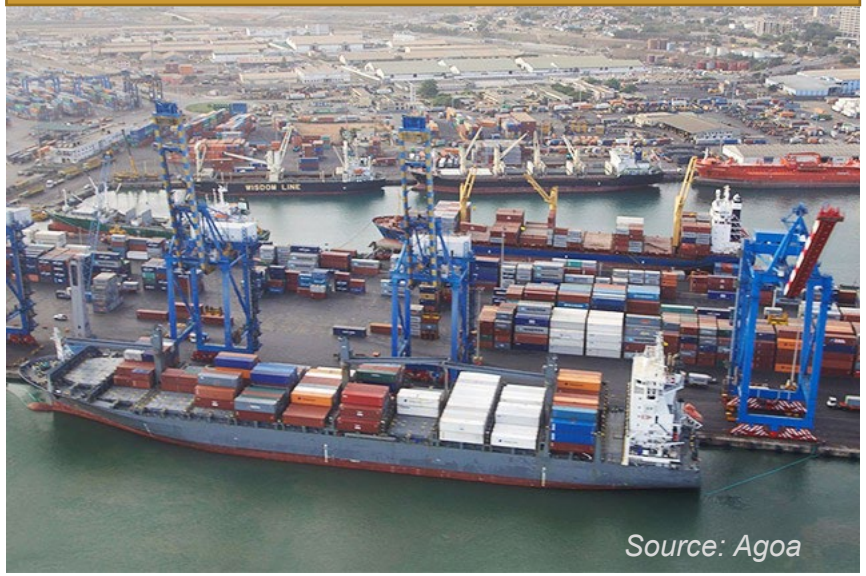
Where to establish hubs?



Restrictions

Hubs should be established at locations close to a:

Large harbor



Large airport



Potential Hub Locations

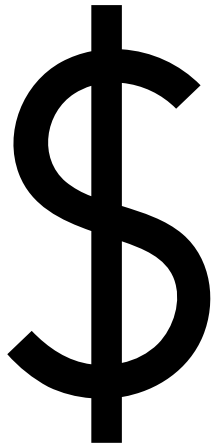


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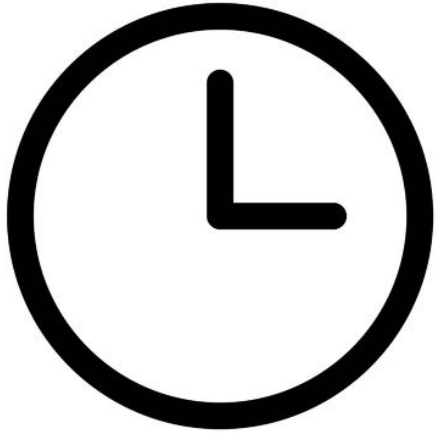
Objectives

An optimal network of hubs aligns with two main objectives:

Transportation cost



Maximum response time



Current UNHRD Hub Locations



Research Objective

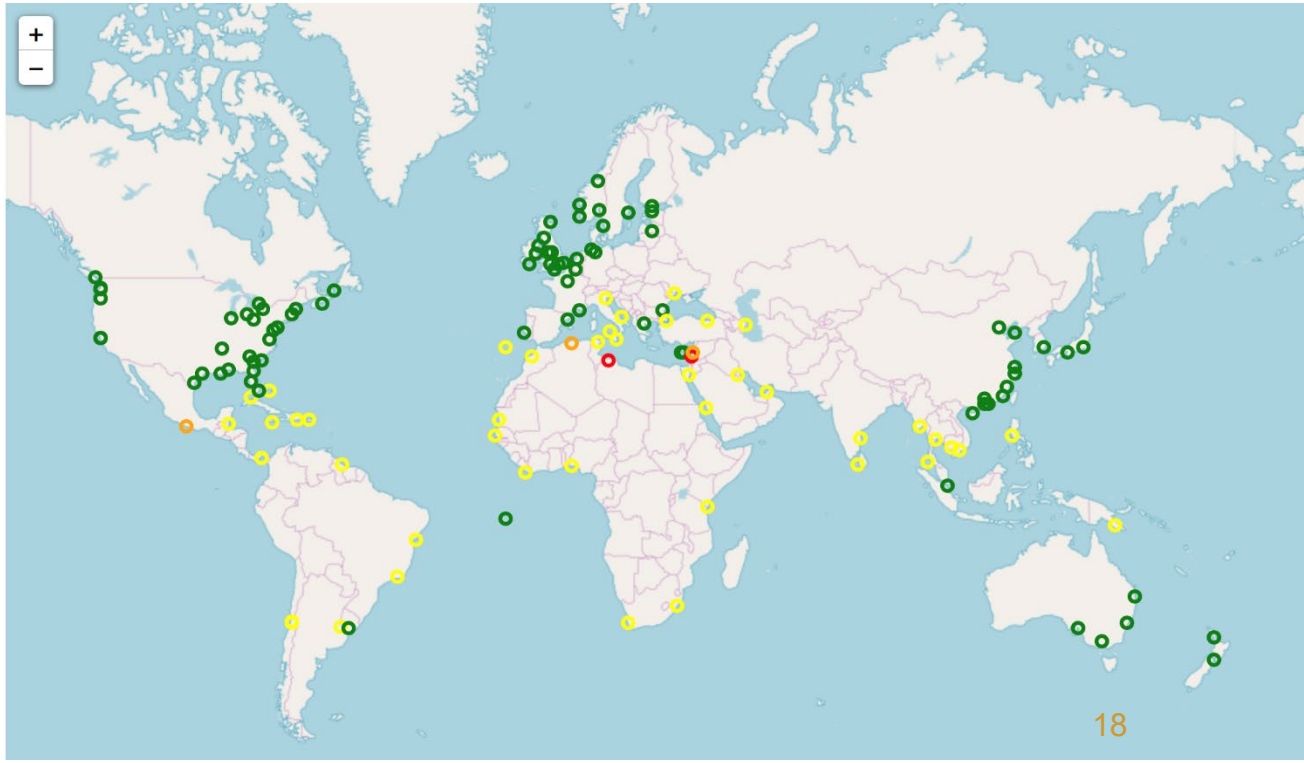
"Based upon historical data we try to find the optimal distribution of UNHRD depots."

Objectives:

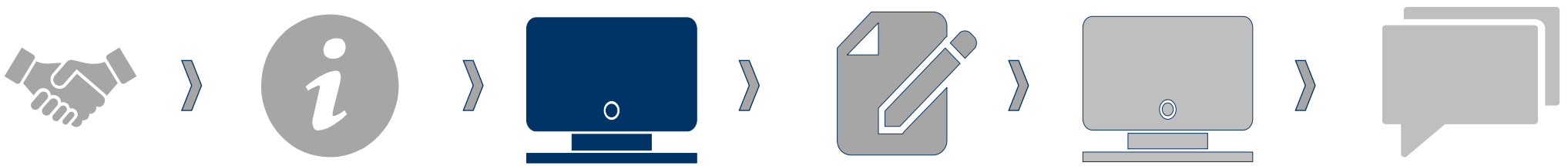
- Minimizing the maximum response time (transportation time). Time it takes to deliver goods from one of the open depots to the disaster site, using aircraft and trucks)
- Minimizing costs.

Scenarios:

- Greenfield situation: How to optimally locate 6 hubs anywhere in the world.
- Expansion situation: We are allowed to add one hub to the current network.



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Introduction

Nominal approach

Intermediate results

Robust approach

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Input

Input regarding disasters:

- UNHRD → Actual disasters on which UNHRD responded in last two years
- Disaster is represented by number of affected people

Input regarding hubs:

- All cities with a large airport and harbor → Potential Hub locations
- Hubs are assumed to have infinite capacity

Objective:

- *Assign disasters to opened hubs to minimize costs and transportation time*

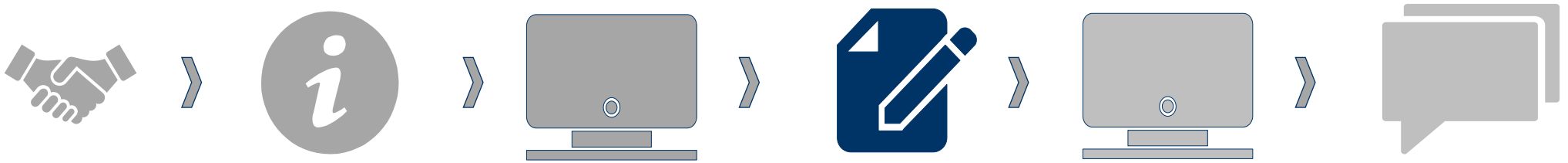
Mathematical model

$$
\begin{aligned}
\text{minimize} \quad & \sum_{h\in\mathcal{H}}\sum_{c\in\mathcal{C}} a_c c_{hc} x_{hc}, & \\
\text{s.t.} \quad & \textstyle\sum_{c\in\mathcal{C}} x_{hc} \le |\mathcal{C}| y_h, & \forall h \in \mathcal{H}, \\
& \textstyle\sum_{h\in\mathcal{H}} x_{hc} = 1, & \forall c \in \mathcal{C}, \\
& \textstyle\sum_{h\in\mathcal{H}} y_h \le n, & \\
& y_h = 1, & \forall h \in \mathcal{H}^f, \\
& \textstyle\sum_{h\in\mathcal{H}} t_{hc} x_{hc} \le T, & \forall c \in \mathcal{C}, \\
& x_{hc} \ge 0, & \forall h \in \mathcal{H},\ c \in \mathcal{C}, \\
& x_{hc} \in \mathbb{R},\ y_h \in \{0,1\}, & \forall h \in \mathcal{H},\ c \in \mathcal{C}.
\end{aligned}
$$

Important notes

- Objective: minimize transportation costs and maximum response time simultaneously
- Trade-off between the two → Pareto front

- Many historical disasters included → Computation time increases



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Introduction

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Intermediate results

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UNHRD case

- Disasters between January 2017 and April 2019

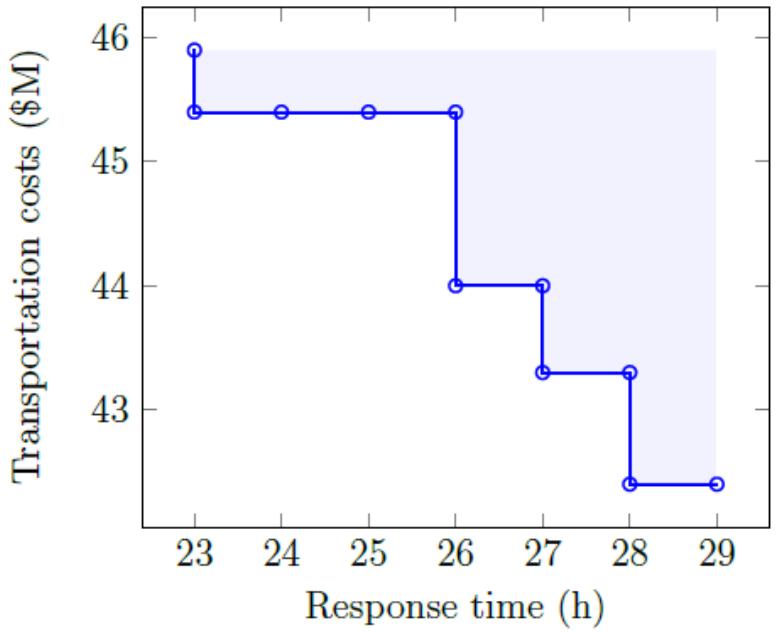
- Greenfield and Expansion situation

Greenfield situation

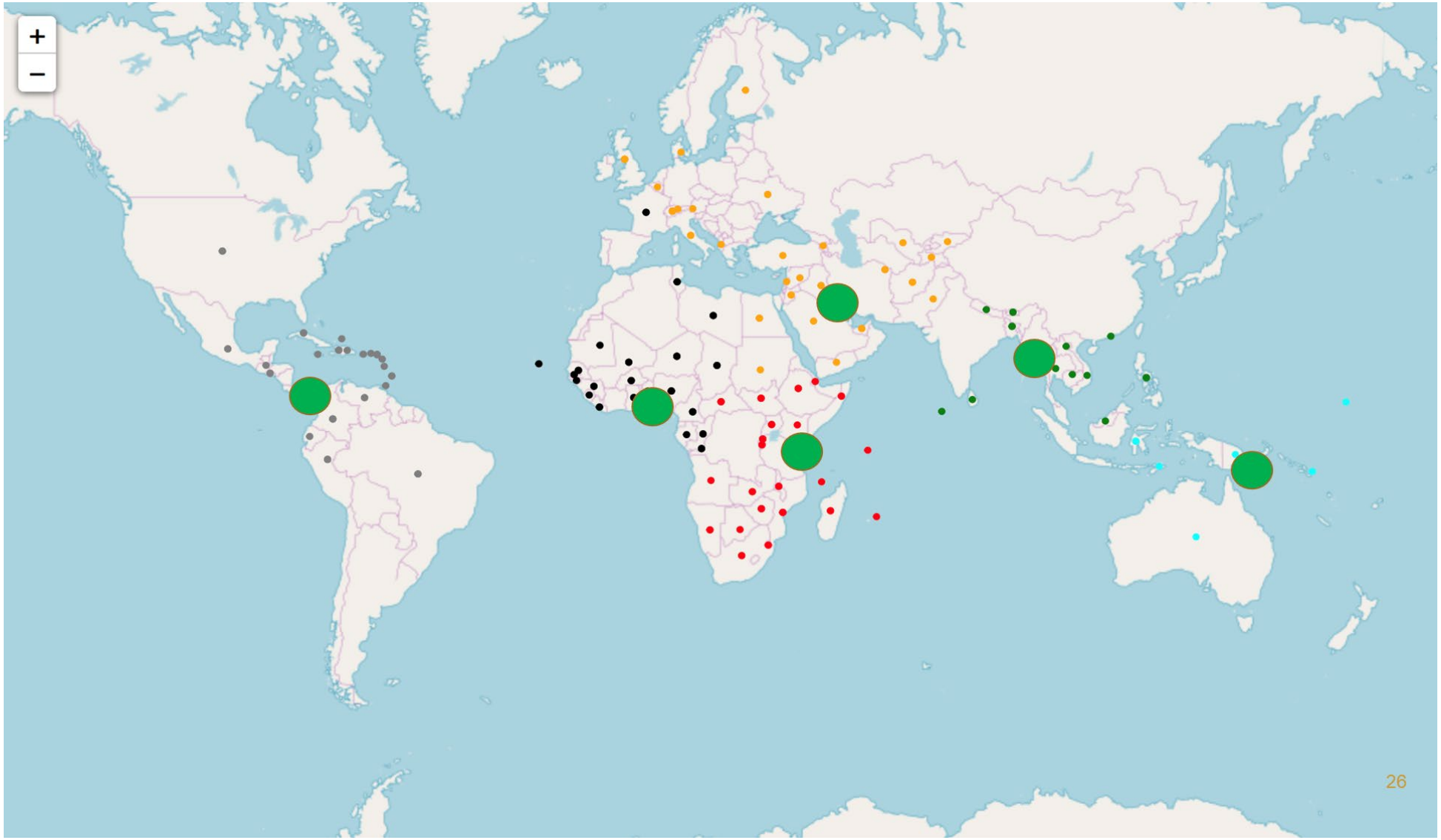
1. Find extreme points:
   - Minimizing the maximum response time -> Minimizing transportation costs.
   - Minimizing the transportation costs -> Minimizing the maximum response time.

	Lower bound	Upper bound
Maximum response time	23h	28h
Transportation costs	$42,392,308	$45,421,838

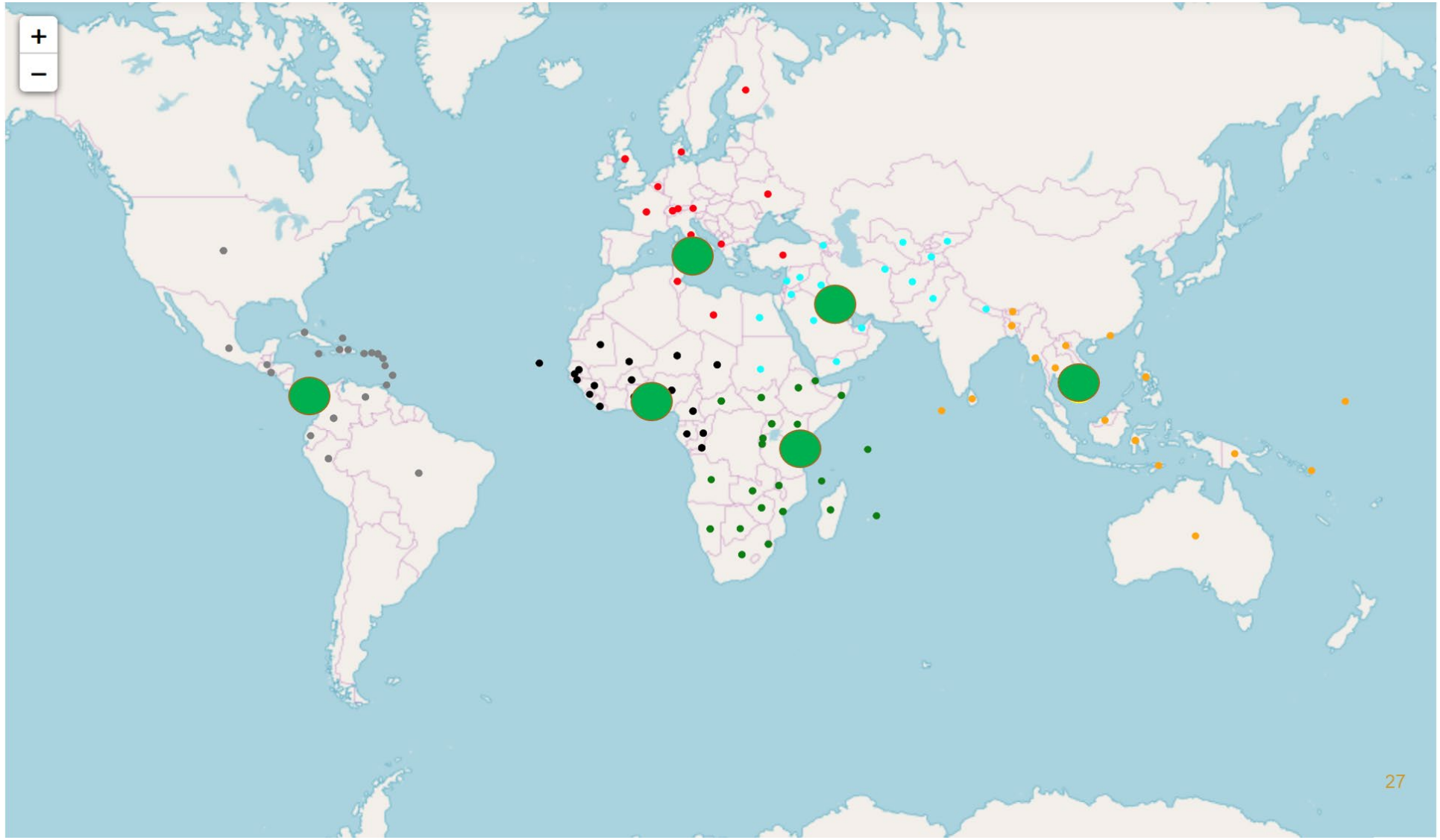
2. Find Pareto front using integer maximum response times.



Maximum response time 23 hours

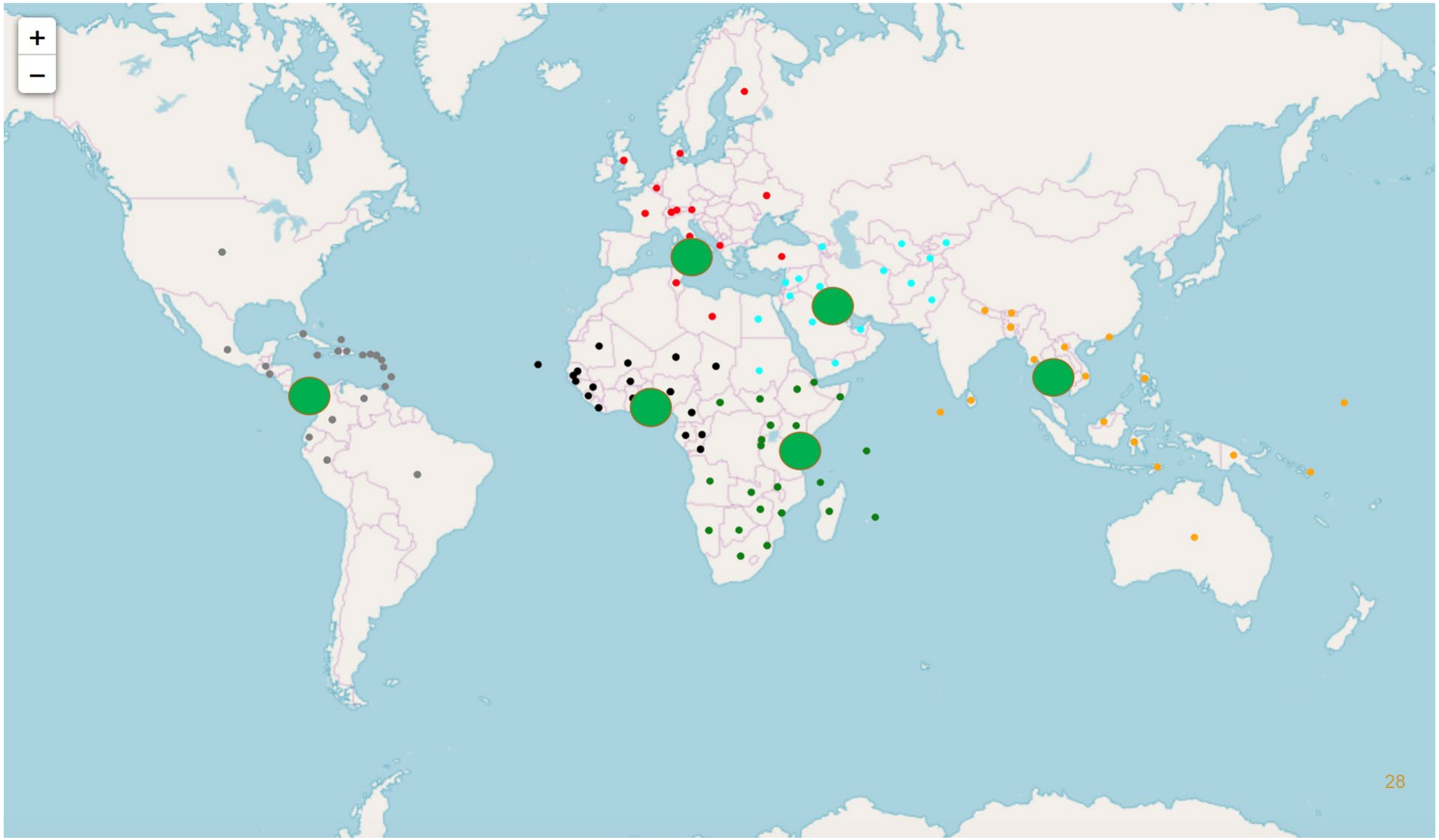


Maximum response time 26 hours

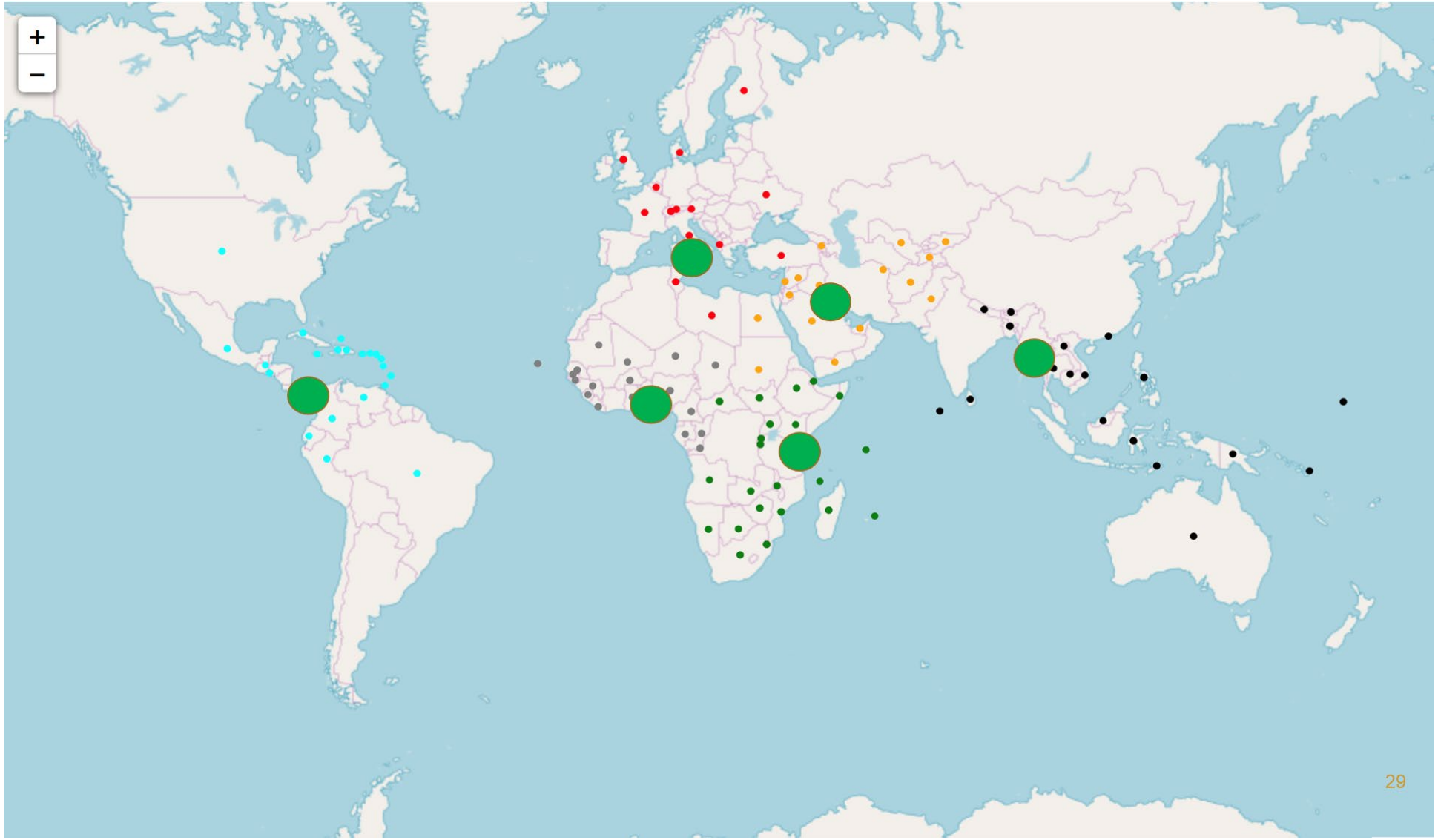


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Maximum response time 27 hours



Maximum response time 28 hours



Expansion situation

The Pareto points of this problem are:

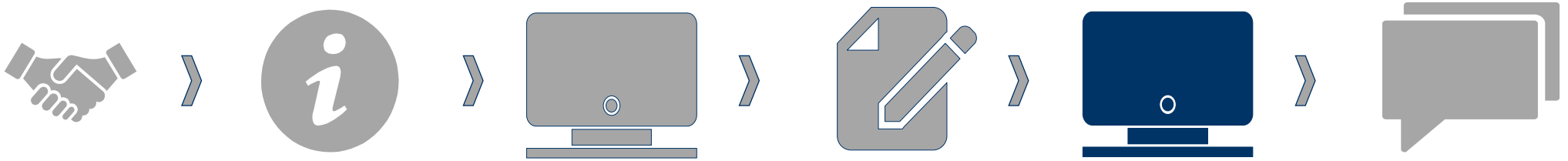
	Lower bound	Upper bound
Maximum response time	25h	26h
Transportation costs	\$46,525,268	\$67,332,325

For the 25h Pareto point, we obtain the following alternatives (all with a 25h max response time)

Cost	Location	EODB	CPI	LPI	PSnV	RQ	RoL	CoC
\$ 67,332,325	Adelaide, Australia	18	13	18	78	98	93	93
\$ 67,492,574	Port Moresby, Papua New Guinea	108	138	148	26	28	21	17
\$ 67,579,616	Auckland, New Zealand	**1**	**2**	**15**	**99**	**99**	**98**	**100**

For the 26h Pareto point, we obtain the following alternatives (all with a 26h max response time)

Cost	Location	EODB	CPI	LPI	PSnV	RQ	RoL	CoC
\$ 46,525,268	Mombasa, Kenya	61	144	68	13	44	38	15
\$ 54,857,215	Jeddah, Saudi Arabia	92	58	55	24	55	57	66
\$ 61,372,771	Durban, South Africa	82	73	**33**	**36**	63	52.4	57
\$ 62,812,927	Eilat, Israel	**49**	**34**	37	17	**87**	**82**	**80**
\$ 64,159,343	Yangon, Myanmar	171	132	137	13	19	17	32



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Introduction

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Intermediate results

Robust approach

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Uncertainty

- Previous results based on historical disasters
- Number of affected people in future disasters are unknown
- $\overline{a}_c$ average number per year within a region → nominal $a_c = \overline{a}_c$
- In robust model a_c is represented by uncertainty set

Uncertainty

Two important assumptions:

- The total number of affected people across the world remains similar:
  - $\sum_{c \in C} a_c \leq \sum_{c \in C} \overline{a}_c$

- Number of effected people is bounded from below and above:
  - $l_c \leq a_c \leq u_c$

This gives a budget uncertainty set:

$$\mathcal{U} = \left\{ a \in \mathbb{R}^{|\mathcal{C}|} : \sum_{c \in \mathcal{C}} a_c \leq p,\ l_c \leq a_c \leq u_c \quad \forall c \in \mathcal{C} \right\}$$

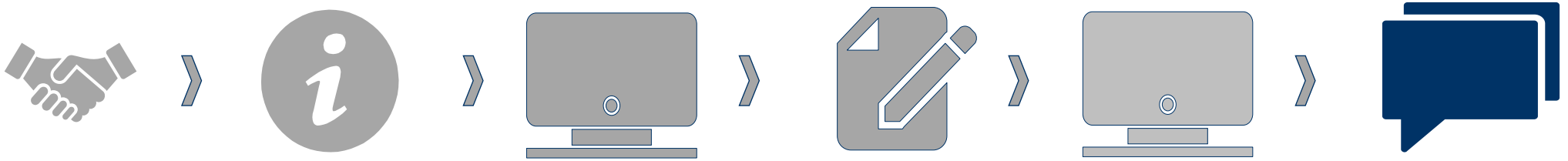
General Results

Name	Average	Worst Case
Nominal	25.3M	71.5M
[min,max]	29.9M	62.3M

Real Uncertainty

- Previous results were obtained using “artificial” uncertainty
- What is we use real uncertainty?

- Split data in training and test set
- One year of training data



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Introduction

Nominal approach

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Conclusion

- Nominal and Robust model developed for selecting potential hub locations
- Conclusions for nominal approach
  - Four hubs overlap with current locations
  - Expand network with hub in Mombasa

- Conclusions for robust approach:
  - Use robust optimization approach if expect different type of disasters than past



Thank you

https://www.tilburguniversity.edu/research/impact/creating-value-data/zero-hunger-lab

Make data **truly** valuable!