Actionable analytics for social good

Justin J. Boutilier







About me

My name is Justin Boutilier

I am an Assistant Professor of Management Analytics for Social Good at Telfer

&

a Research Chair in AI and Mental Health at Institut du Savoir Montfort

I am also affiliated with:

- Queensway Carleton Hospital
- UW-Madison Emergency Medicine
- MIT Sloan School of Management

About me

B.Sc. in Math, Stats, and Economics from Acadia University

PhD in Operations Research from the University of Toronto

Postdoc in Humanitarian Supply Chains from MIT



About me

Assistant Professor in Industrial and Systems Engineering at the University of Wisconsin Madison

Faculty Associate in Emergency Medicine

Lived in Madison for 5 years



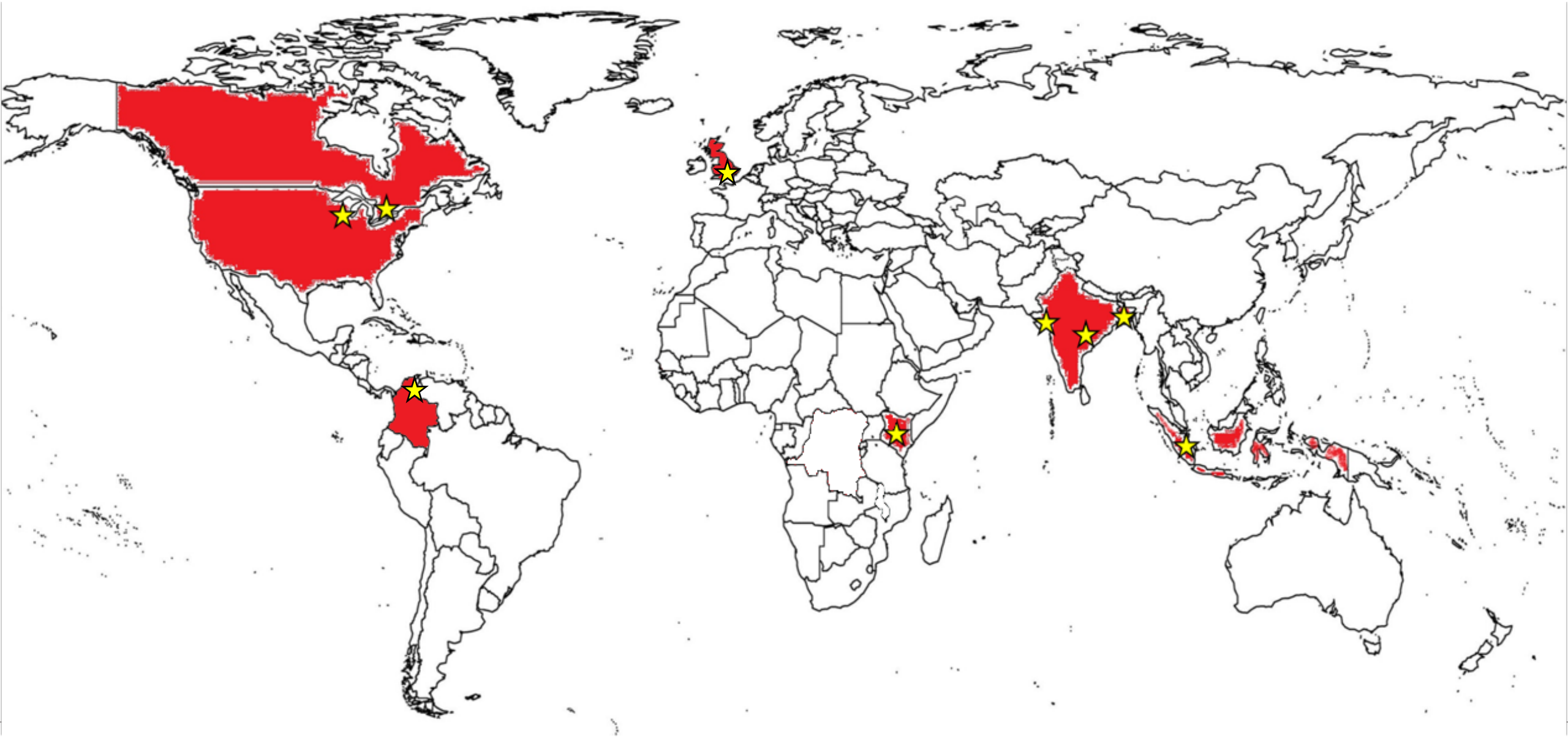
Research focus

Develop and apply actionable analytics to solve health and humanitarian problems

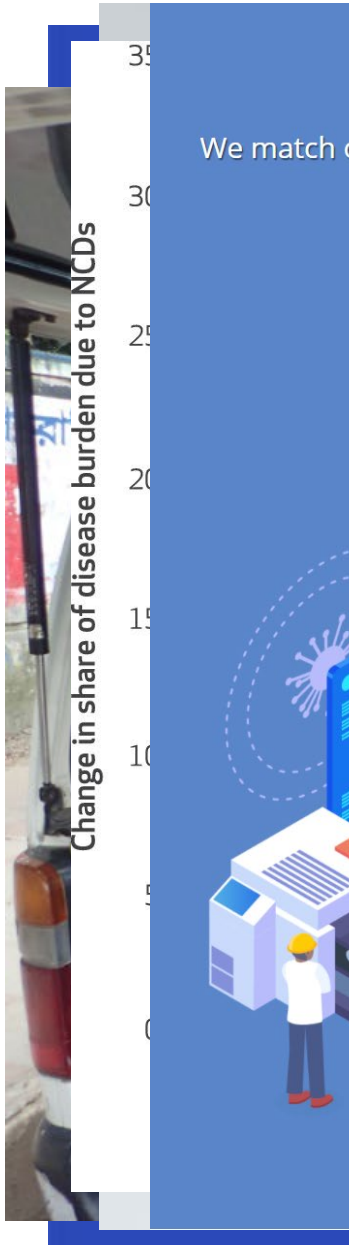
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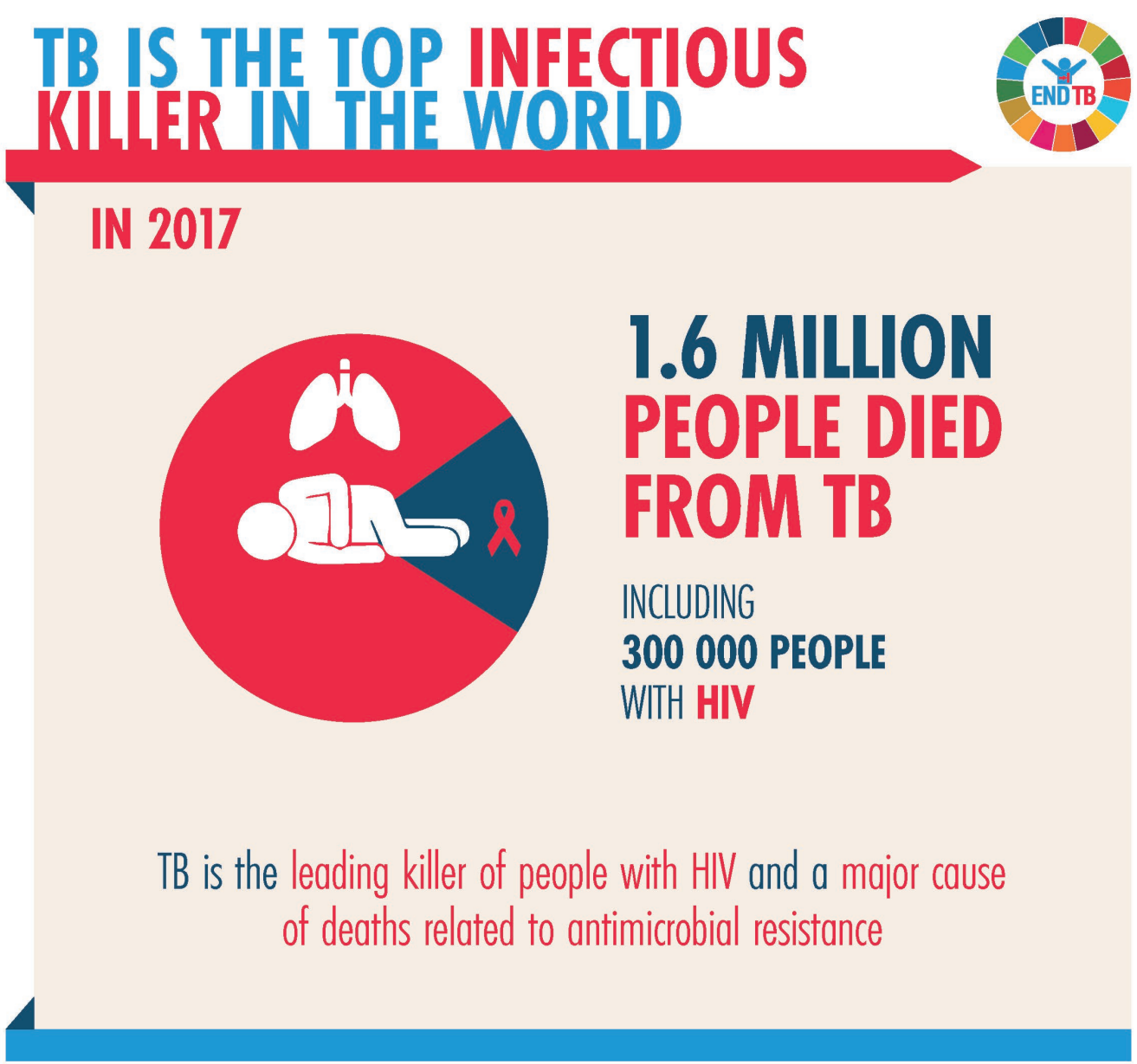
Develop and apply actionable analytics to solve health and humanitarian problems

Project locations



My research


We match
Change in share of disease burden due to NCDs


TB IS THE TOP INFECTIOUS KILLER IN THE WORLD
END TB
IN 2017
1.6 MILLION PEOPLE DIED FROM TB
INCLUDING
300 000 PEOPLE
WITH HIV
TB is the leading killer of people with HIV and a major cause of deaths related to antimicrobial resistance
World Health Organization

My research

My research approach is influenced by the ***Wisconsin Idea***

"Never be content until the beneficent influence of the university reaches every family in the state"

- Dr. Charles Van Hise (1904)

Today's plan

Tell some **stories** about my research projects and collaborations **with a focus on the important lessons learned**

Key lesson #1

“These projects would be easy if it weren’t for people”

- Rebecca Alcock

Dhaka, Bangladesh



Ambulance response optimization

Improve ambulance response times in developing urban centers



Ambulance response optimization

Improve ambulance response times in developing urban centers

Spent 1 month in Dhaka Bangladesh!

Led to similar projects in Indonesia



Ambulance response optimization

Major chapter in my PhD dissertation

Published in *Operations Research* – best healthcare paper award runner-up



http://pubsonline.informs.org/journal/opre

OPERATIONS RESEARCH
Vol. 68, No. 5, September–October 2020, pp. 1315–1334
ISSN 0030-364X (print), ISSN 1526-5463 (online)

Contextual Areas

Ambulance Emergency Response Optimization in Developing Countries

Justin J. Boutilier,[a] Timothy C. Y. Chan[b]

Challenges in LMICs

Optimizing the transport of emergency patients in LMICs comes with unique challenges:

1. **Travel times:** Route disruptions occur regularly and it is not the norm to yield for emergency vehicles

2. **Spatial demand:** Many LMICs do not collect historical emergency call data



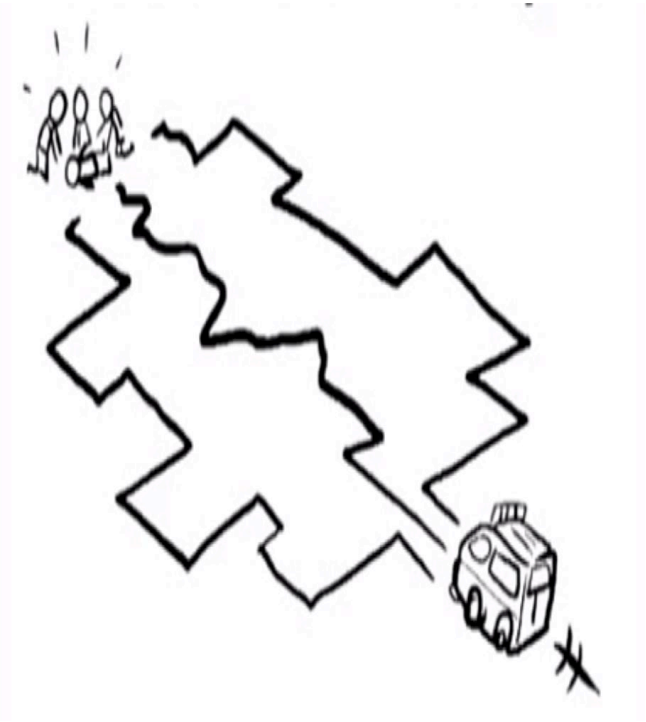
Context

We develop a robust framework that optimizes in two stages:

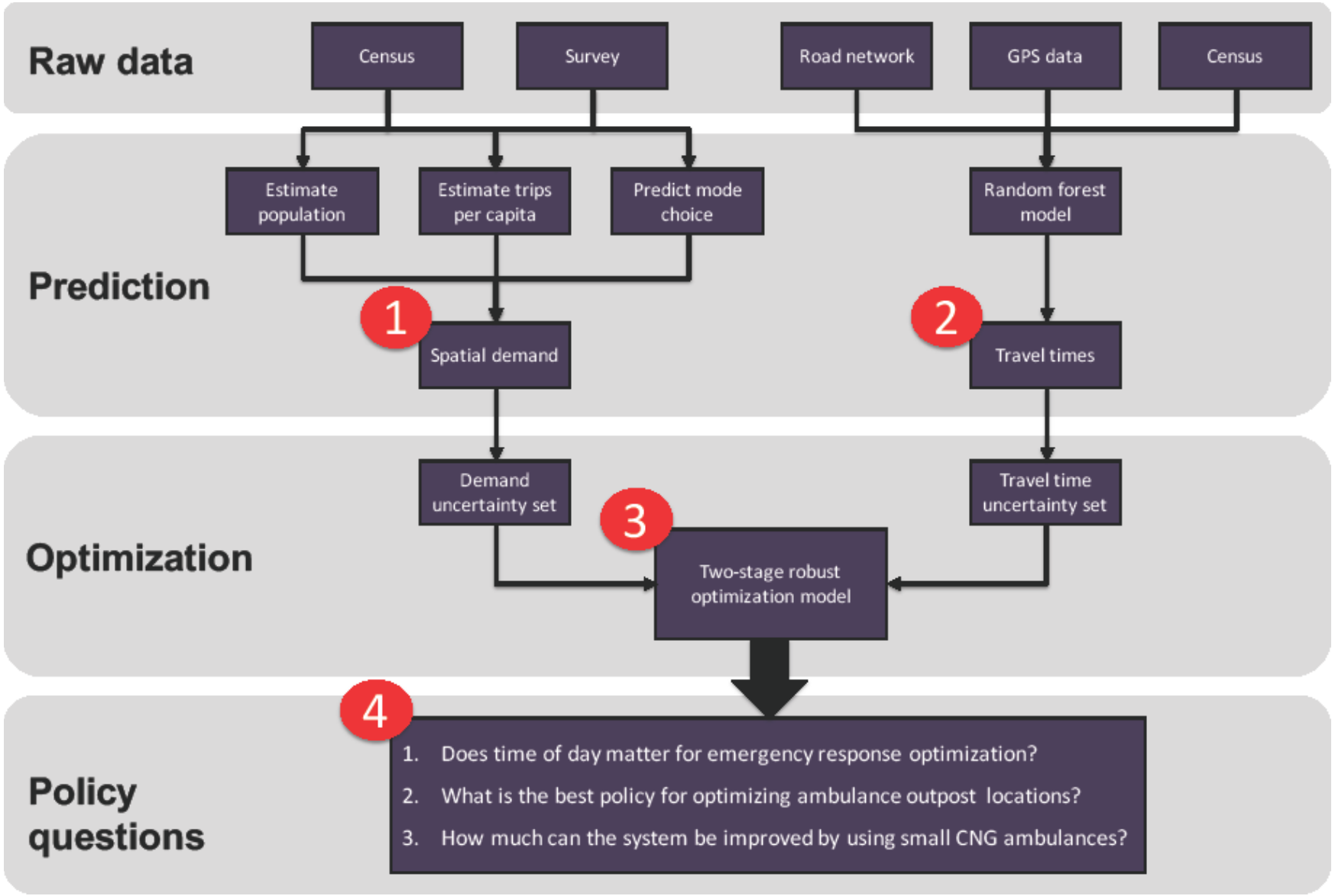
1. the location of emergency response vehicle outposts,
2. the routing of emergency response vehicles,

incorporating uncertain travel times and uncertain spatial demand.





Overview


Raw data
Census
Survey
Road network
GPS data
Census
Prediction
Estimate population
Estimate trips per capita
Predict mode choice
Random forest model
1
Spatial demand
2
Travel times
Optimization
Demand uncertainty set
Travel time uncertainty set
3
Two-stage robust optimization model
4
Policy questions
1. Does time of day matter for emergency response optimization?
2. What is the best policy for optimizing ambulance outpost locations?
3. How much can the system be improved by using small CNG ambulances?

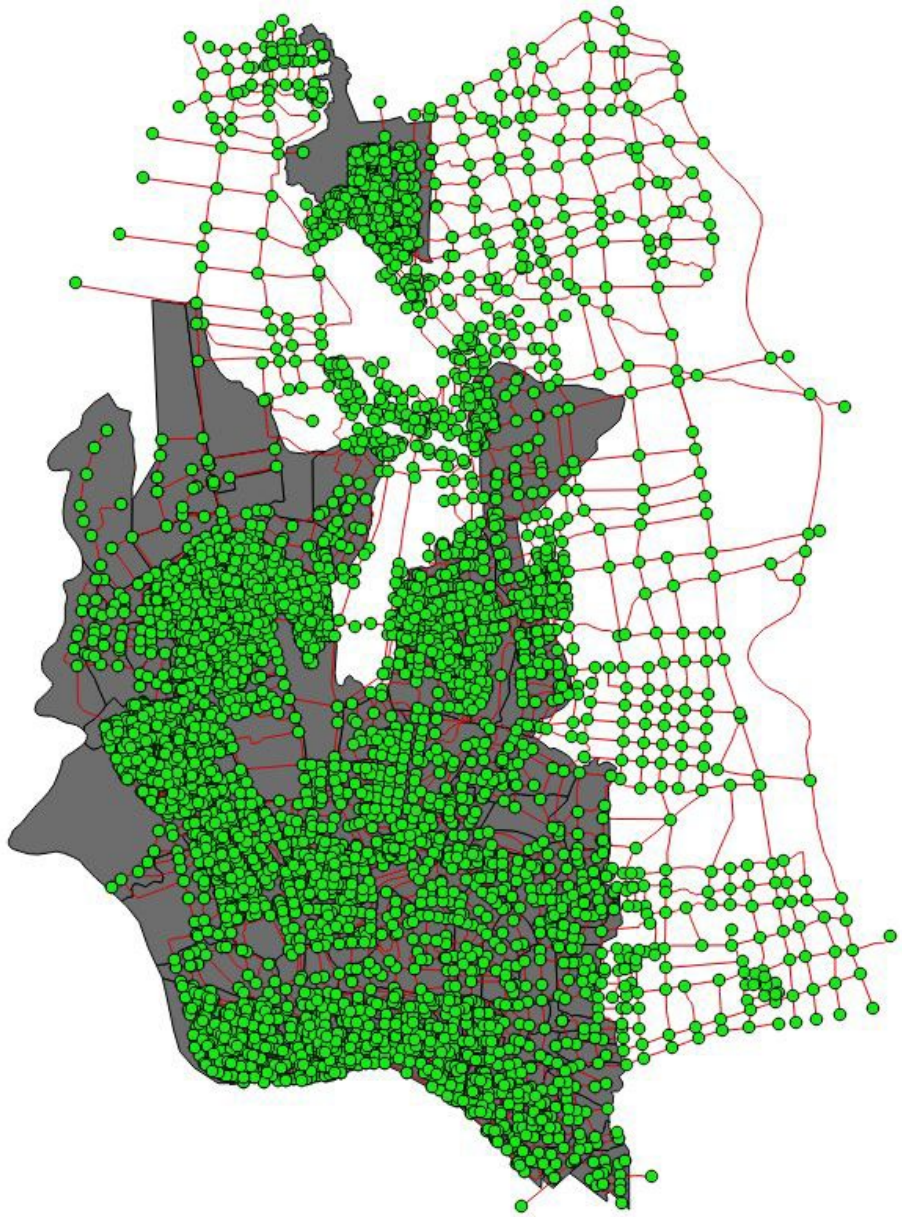
Dhaka's road network

Complete road network

Contains:

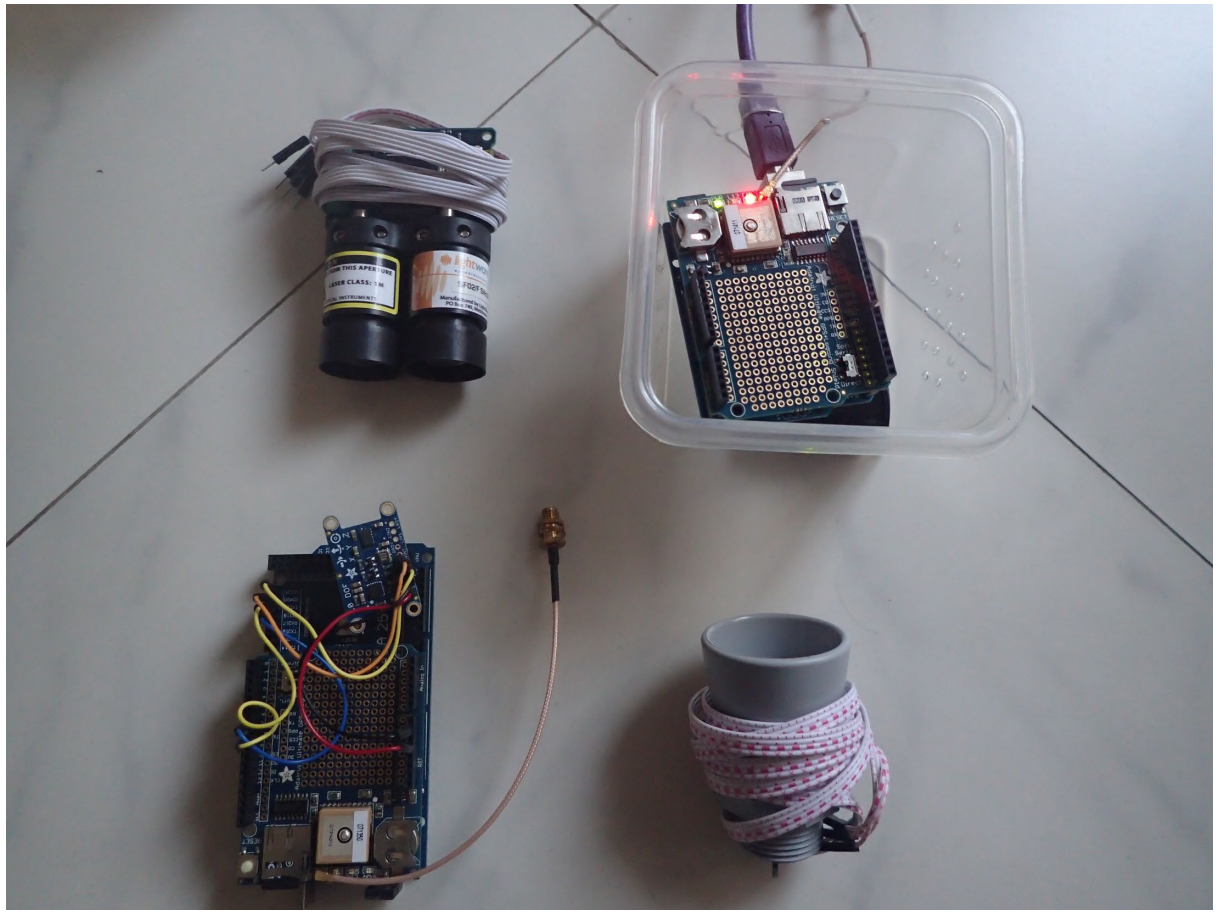
- 5,358 nodes
- 16,538 edges

Overlaid on Dhaka's 92 wards



Data collection

Collected travel time and traffic data for 30 days using custom GPS devices installed in volunteer cars

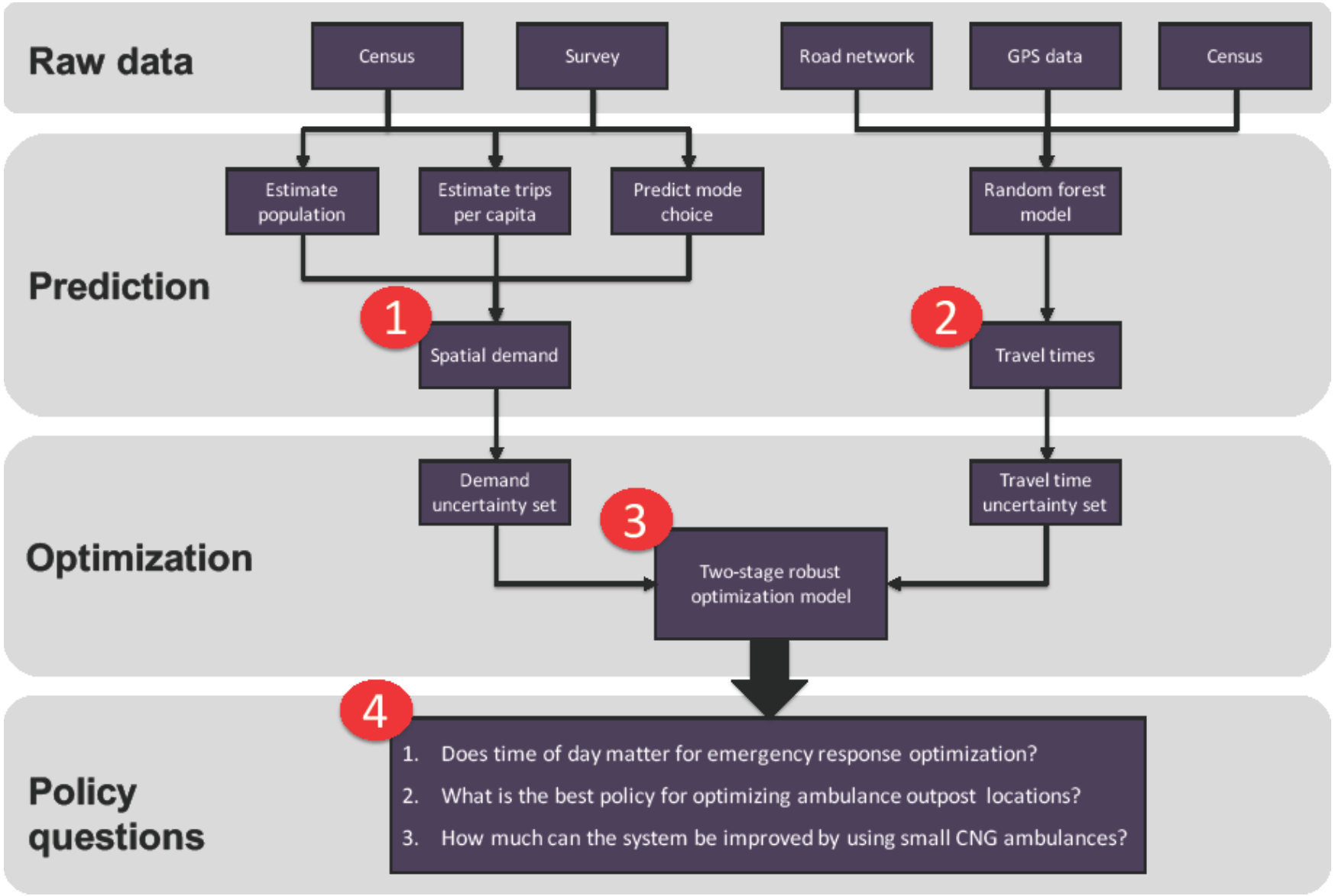


Data collection

2808 surveys administered by physicians to patients arriving at emergency departments in 16 major hospitals



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Key lesson #2

“Jugaad: be creative with what you have”

– Kayla Huemer

433 million people obtain care in a facility without reliable electricity access

Lower availability of medical equipment and therefore lack of basic health services

- Administrative services
- Cold storage
- Diagnostic equipment
- Laboratory services
- Sterilization equipment
- Preventative and therapeutic care services



Safety of providers and patients at risk

Difficulty with worker recruitment, retention → discontinuity in care and chronic understaffing

“Delaying electrification means denying access to life saving services”

Gujarat, India
- Increased probability of childhood vaccination (DPT, polio, BCG, and measles) and antenatal care

(Chen et al 2019)

India (national level)
- Delivery and vaccination services to 50% more patients
- Improved availability and retention of staff

(Mani et al 2021)

Uganda
- 73.5% decrease in perinatal deaths
- 53% decrease in maternal deaths

(We Care Solar 2018)

What options do last-mile facilities have?

What even are these?!



Mamos and sagas



Midwives



Health post

The local health system

What options do last-mile facilities have?

Without the right renewable energy design tools, clinics must:

- Wait for grid connection
- Turn to carbon-based decentralized alternatives
- Follow a non-tailored design approach

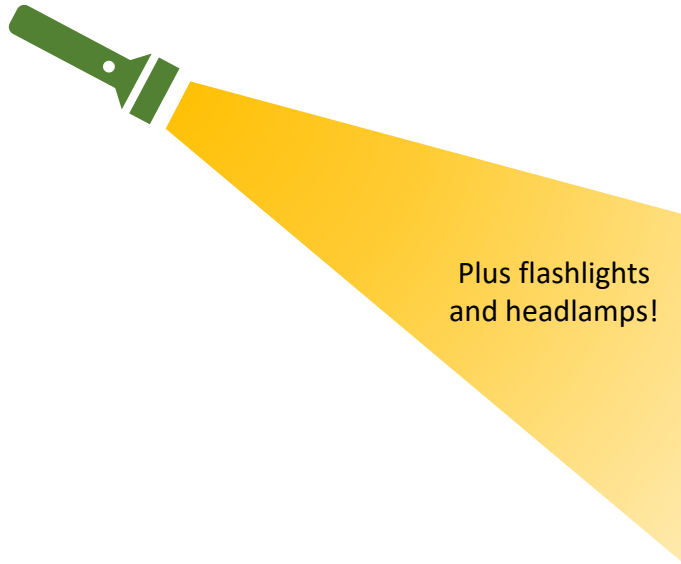
“…optimizing system design tailored to healthcare facilities continues to be a challenge…”

– World Health Organization, 2023

What options do last-mile facilities have?

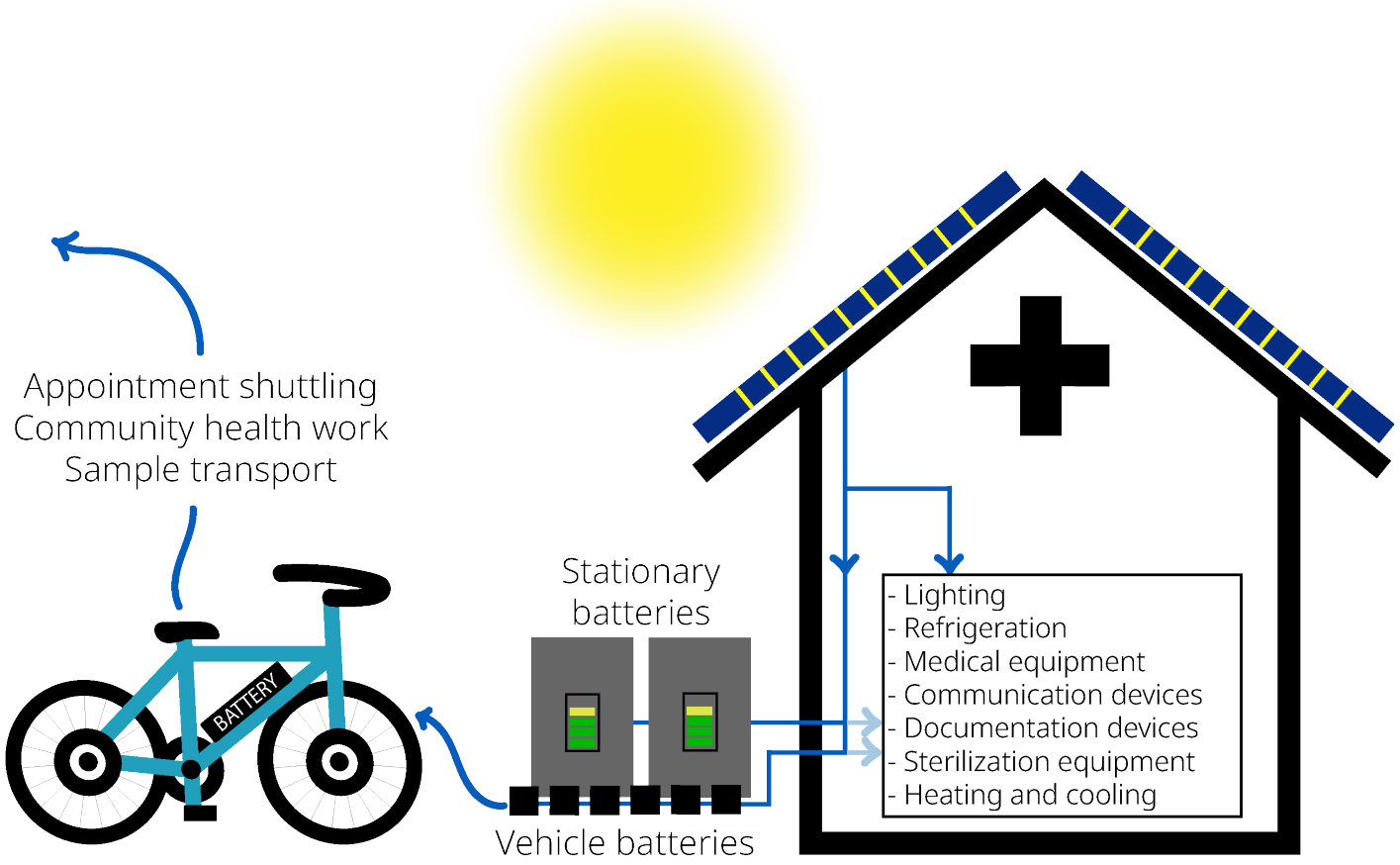






Our approach: a design toolkit for off-grid solar + storage + micromobility systems

timely clean resilient



Our approach: a design toolkit for off-grid solar + storage + micromobility systems

But why micromobility…?

1. Established and valued mode of patient and sample transport
2. Supports the mission of achieving universal health coverage!

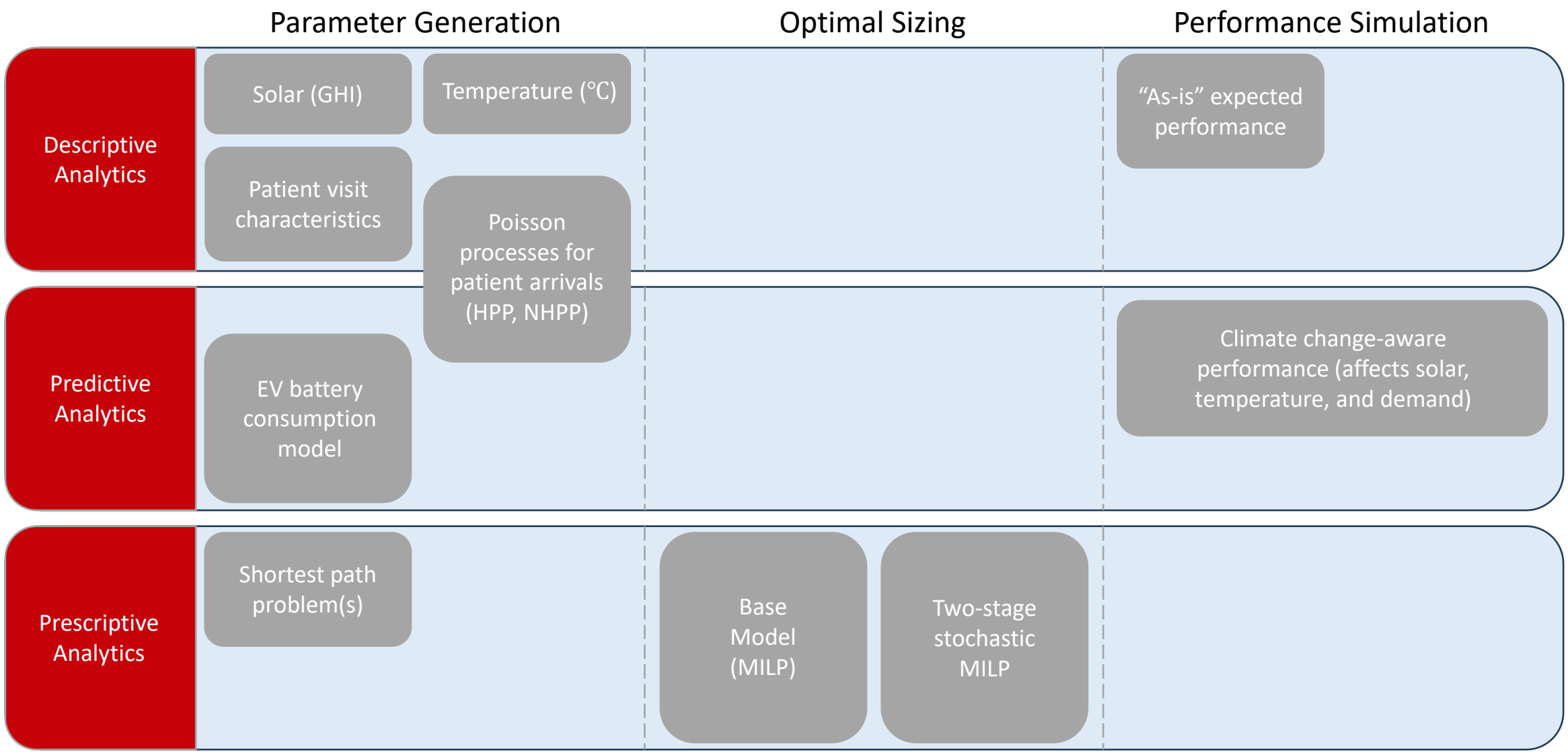
Health facility electrification does not alone translate to greater healthcare utilization (Javadi et al. 2020)

The number one cited barrier was transportation!

Partner community (Colombia)



the MtM Toolkit



the MtM Toolkit

Parameter Generation

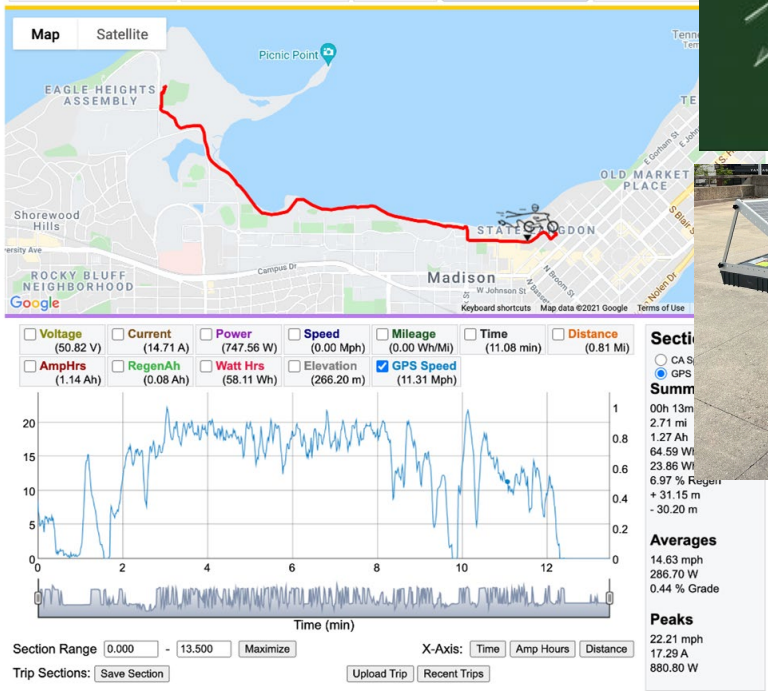
Descriptive Analytics	Solar (GHI)	Temperature (°C)
	Patient visit characteristics	Poisson processes for patient arrivals (HPP, NHPP)
Predictive Analytics	EV battery consumption model	
Prescriptive Analytics	Shortest path problem(s)	











THE PEOPLE'S FARM



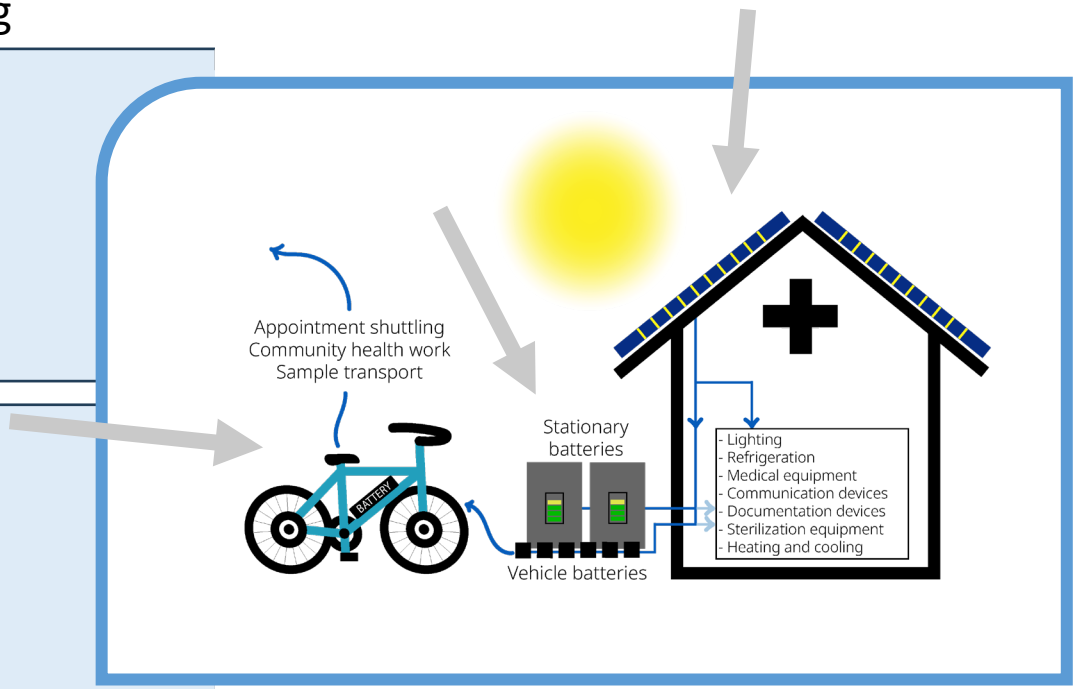
We make the most of limited data!

$f($  $) =$

Day	Time	Cost	Urgency	Reason	Off-site	Location	Roundtrip cost
1	10am	0.9 kWh	0	Respiratory illness	0	0	0
1	12pm	0.5 kWh	0	Dental issue	1	Home 8	0.21 kWh
1	3pm	1.1 kWh	1	Pregnancy complication	0	0	0
…	…	…	…	…	…	…	…
365	11pm	0.2 kWh	1	Accident	1	School	0.05 kWh

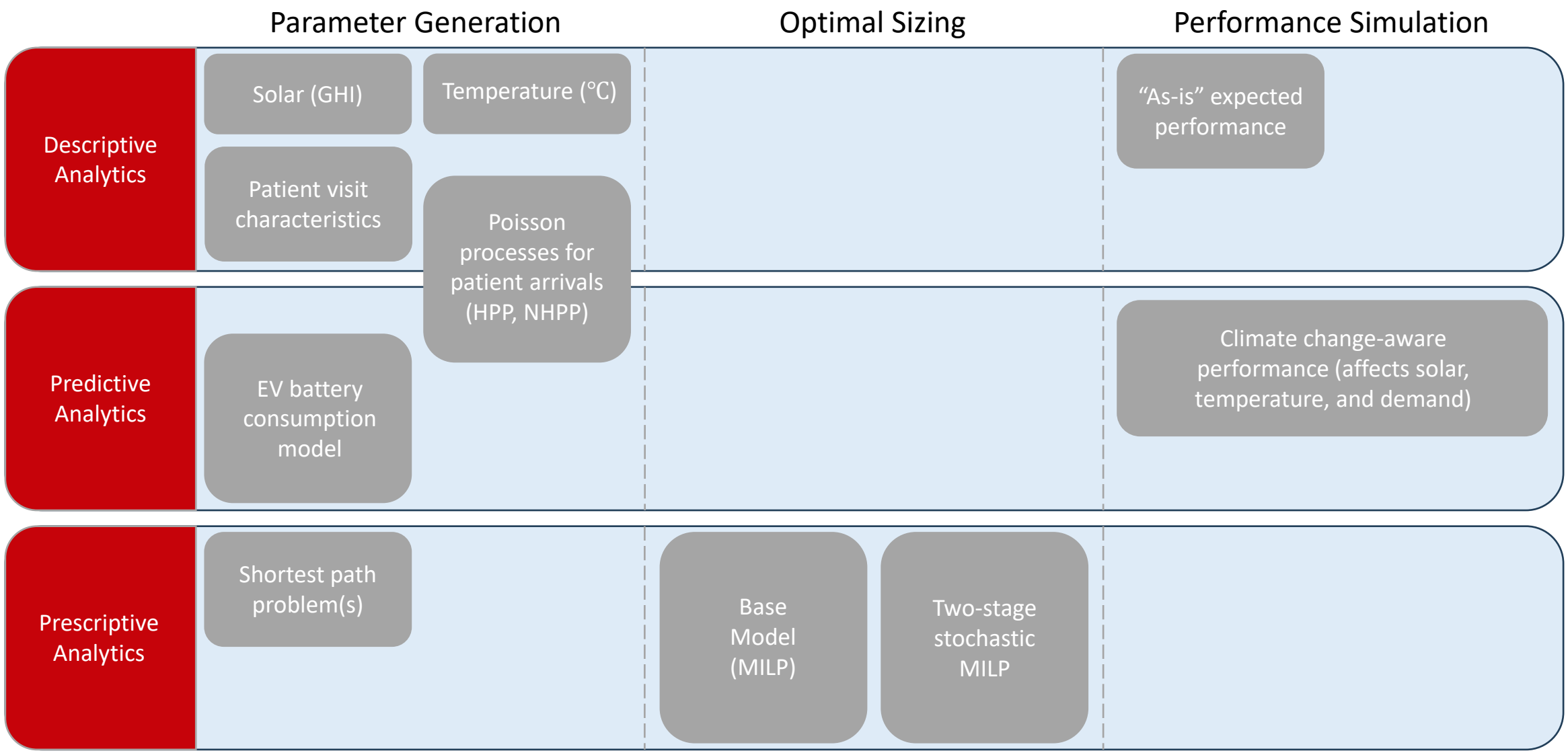
the MtM Toolkit

	Parameter Generation		Optimal Sizing	
Descriptive Analytics	Solar (GHI)	Temperature (°C)		
	Patient visit characteristics	Poisson processes for patient arrivals (HPP, NHPP)		
Predictive Analytics	EV battery consumption model			
Prescriptive Analytics	Shortest path problem(s)		Base Model (MILP)	Two-stage stochastic MILP



System architecture

the MtM Toolkit



Key lesson #3

“Persistent whole-body problem-solving”

– Lennon Rodgers

From global to local

Apply learnings and experience to solve local problems, such as:

- Improve patient flow in the emergency department
- Improve care pathway allocation for mental health outpatients

Collaborations include:

- Queensway Carleton Hospital
- Montfort Hospital
- The Royal Mental Health Center
- Ottawa Food Bank

Summary

Strong collaborations, community engagement, and team science are critical for project success and continuity

Real-world projects are messy and creative innovation is needed to make the best of what you have

Don’t be afraid to think outside the box and use your non-research skills

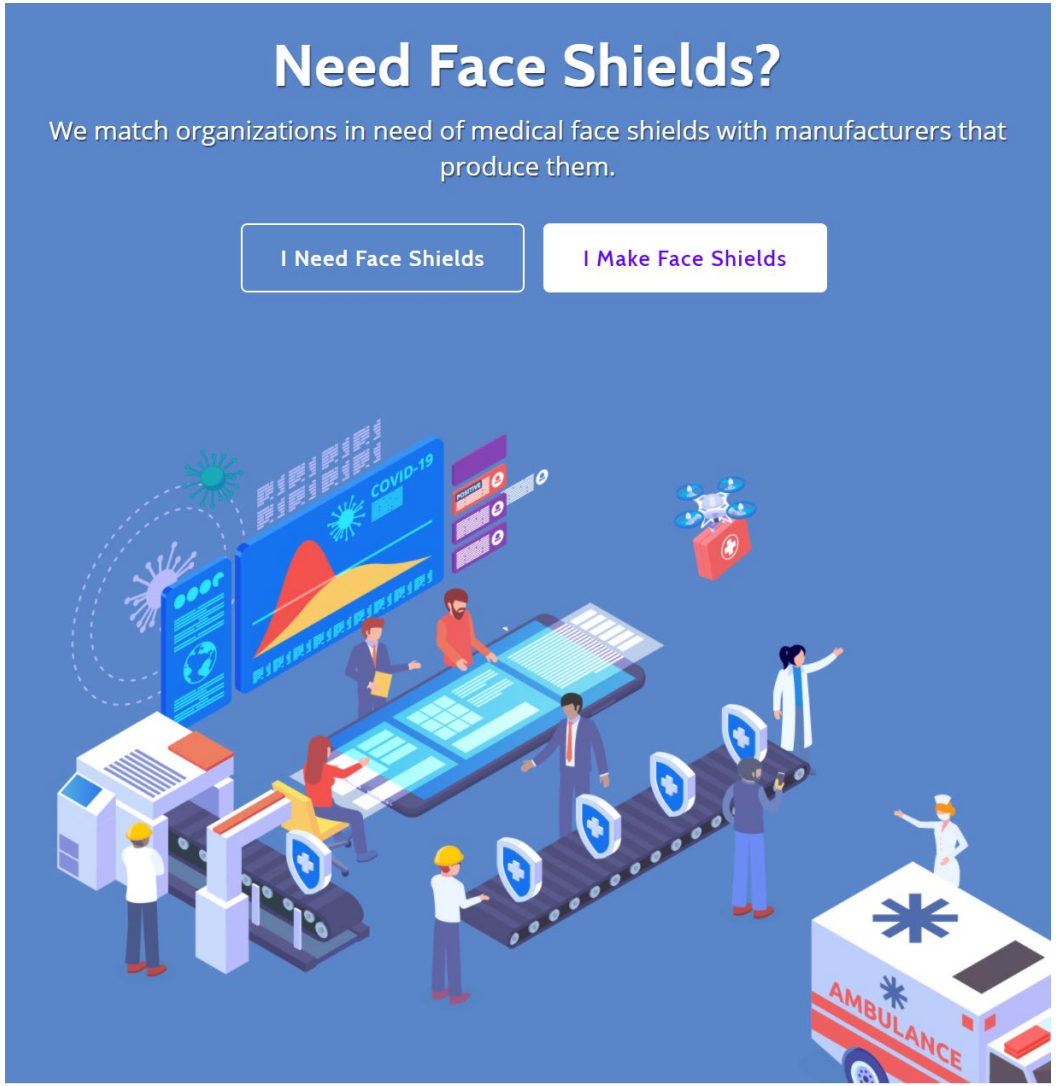
Thank you for listening!

boutilier@telfer.uottawa.ca

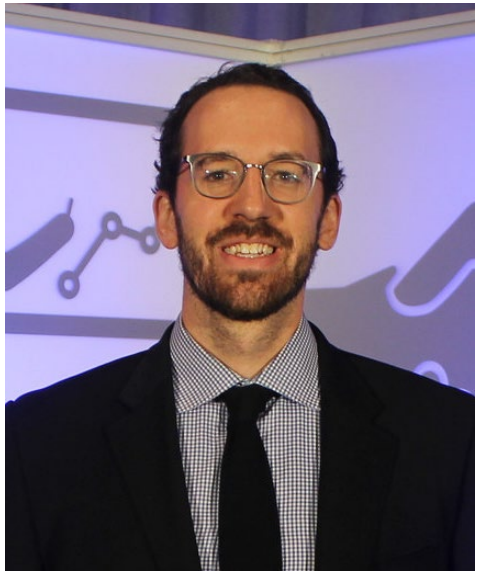
a4hd.github.io

Backup slides

My first real implementation: ***Shield-Net***



The Team



Prof. Justin J. Boutilier
Industrial & Systems Engineering
UW-Madison

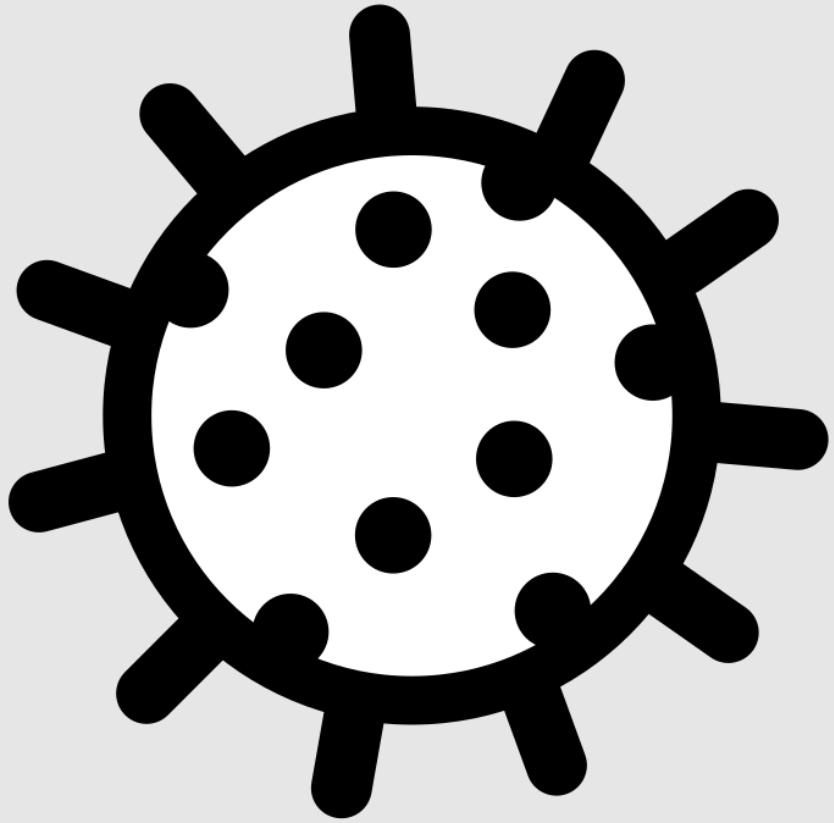


Prof. Auyon Siddiq
Anderson School of Management
UCLA



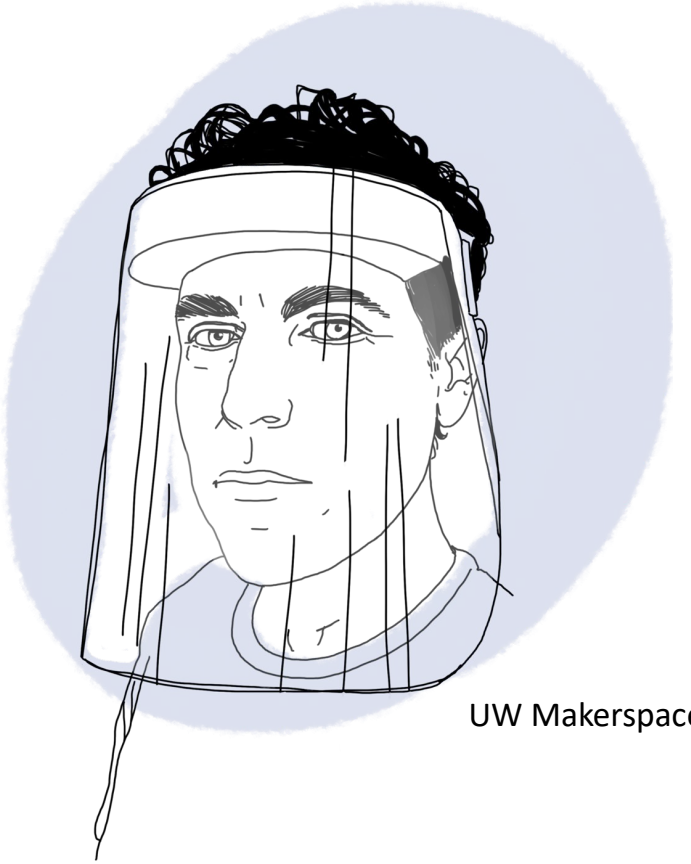
Rebecca Alcock (PhD candidate)
Industrial & Systems Engineering
UW-Madison

I. The Problem



The COVID-19 pandemic led to unprecedented and widespread supply chain disruption.

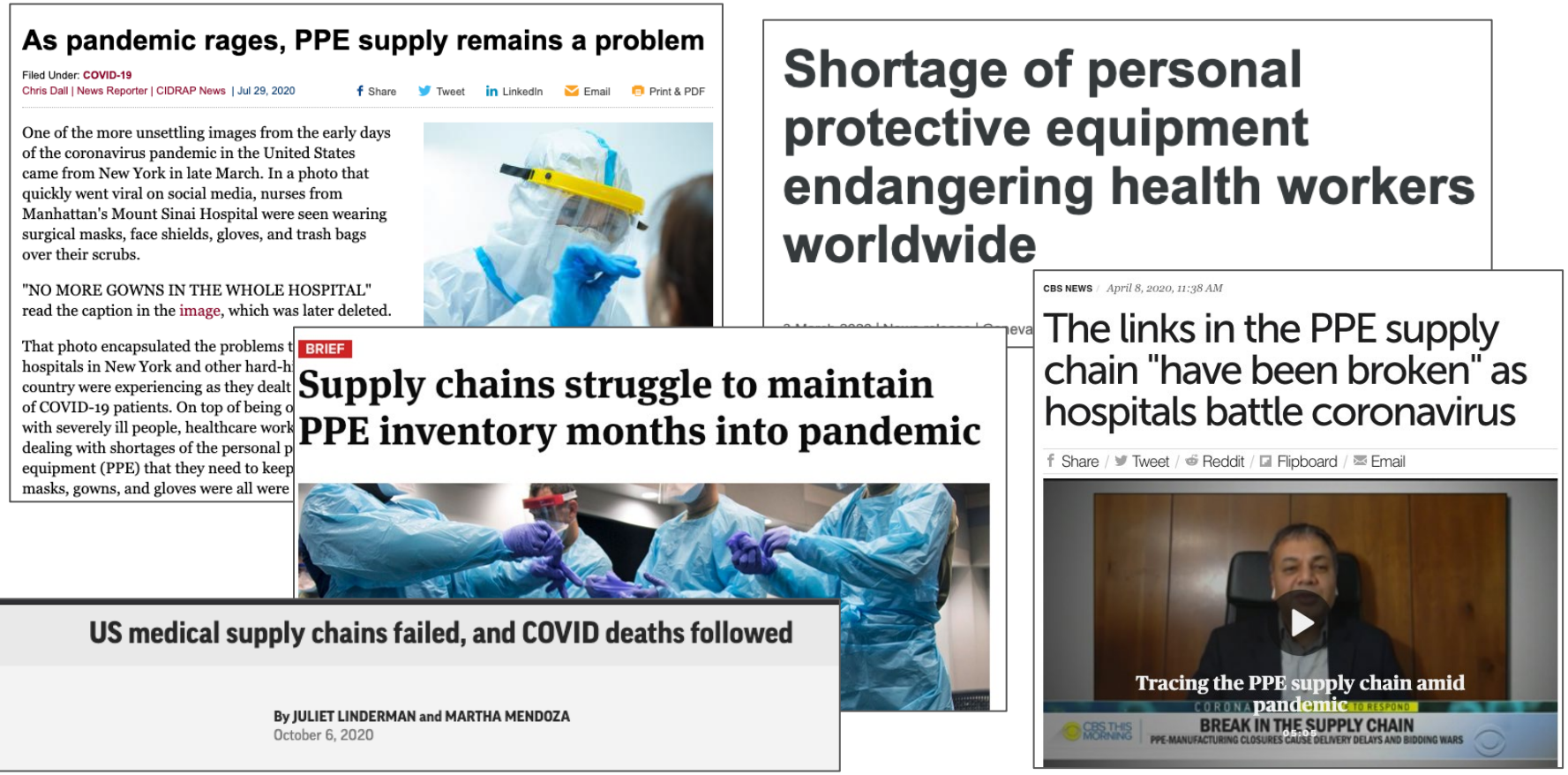
- Disruptions procuring personal protective equipment or PPE
- 90% of supplies in the US strategic national stockpile had been used by April 2020
- New strategies for rationing and reusing PPE



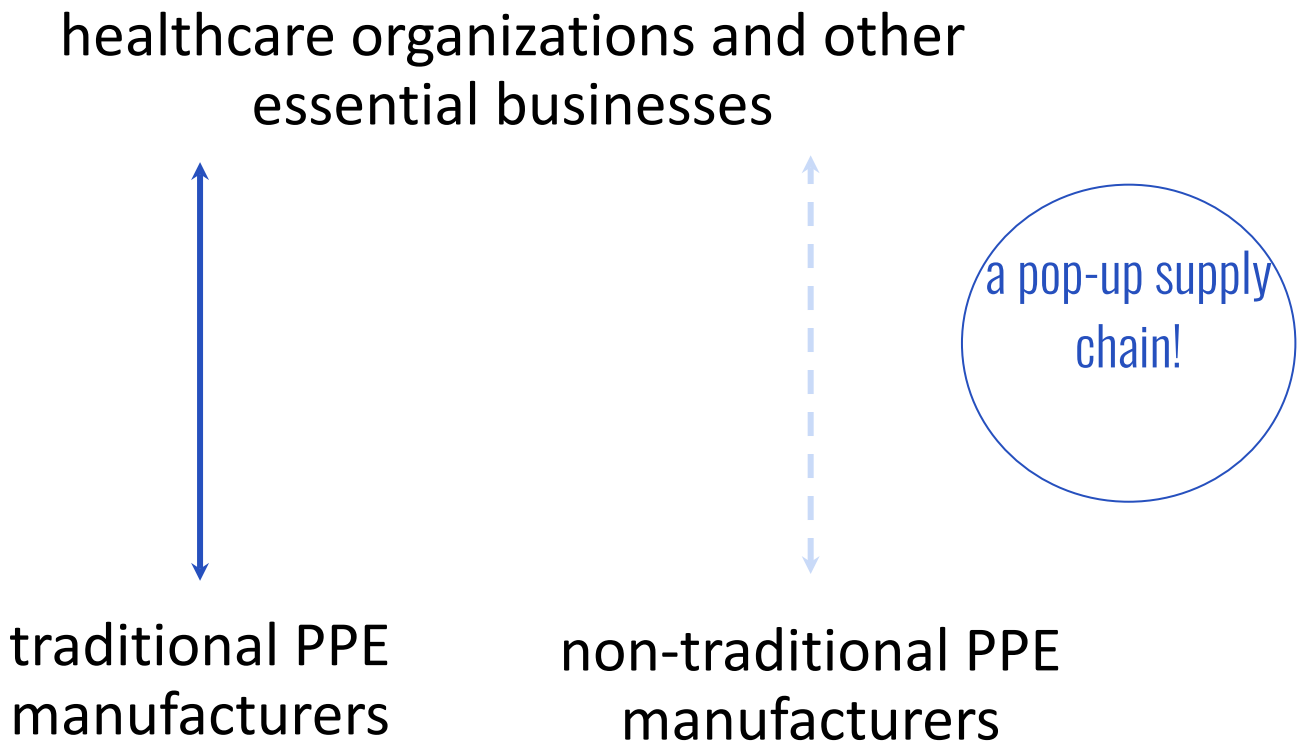
UW Makerspace

Shortages put first responders and healthcare workers at an increased risk of infection.

#WheresMyPPE
#GetMePPE



Meanwhile, closures of *non-essential* businesses led to a surplus of manufacturing capacity.



The pop-up PPE supply chain diverged from the conventional PPE supply chain in two key ways.

1. **Market concentration**

2. **Distribution channels**

Procurement remained a major challenge…

II. The Solution



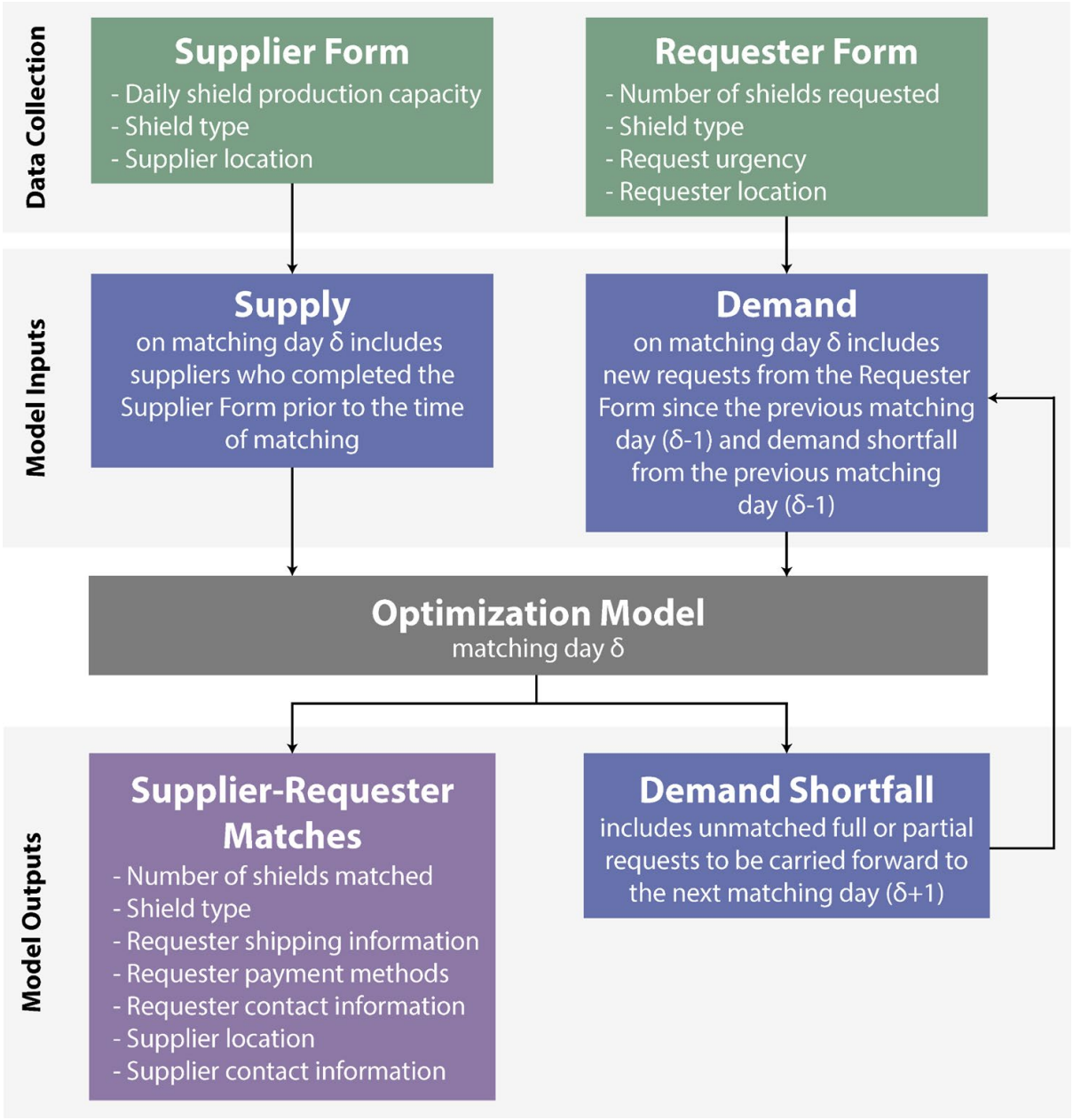
Need Face Shields?

Check out the database of face shield manufacturers linked below!
Manufacturers will be organized by state.

I Need Face Shields | I Make Face Shields

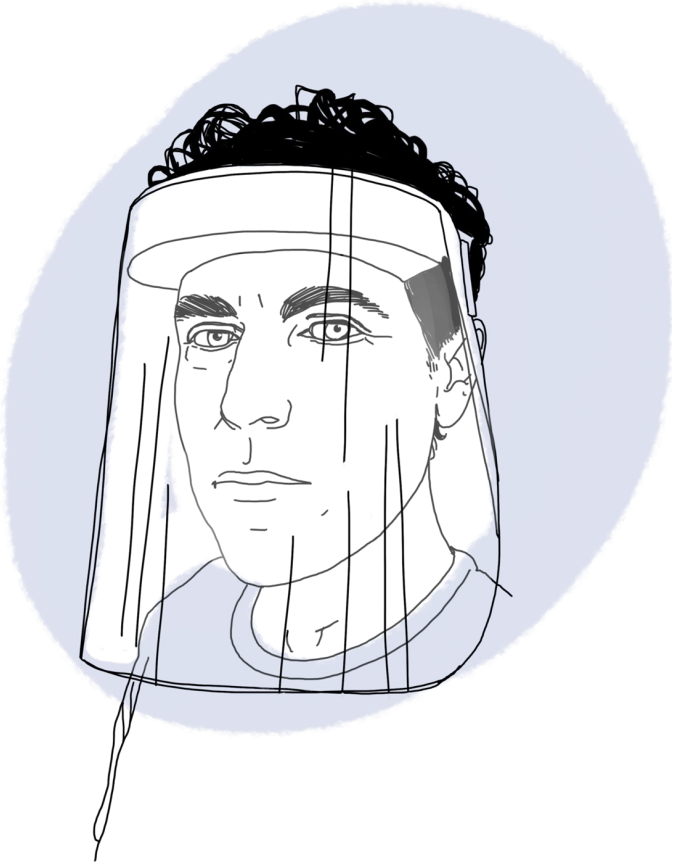


https://shield-net.org/



The optimization model prioritized urgent requests and minimized shipping distance:

minimize	urgency-weighted demand shortfall
	+ alpha * (cost * number of matched shields)
subject to	supplier capacity is not exceeded
	request size is not exceeded
	supplier-requester compatibility is guaranteed
	demand shortfall is captured



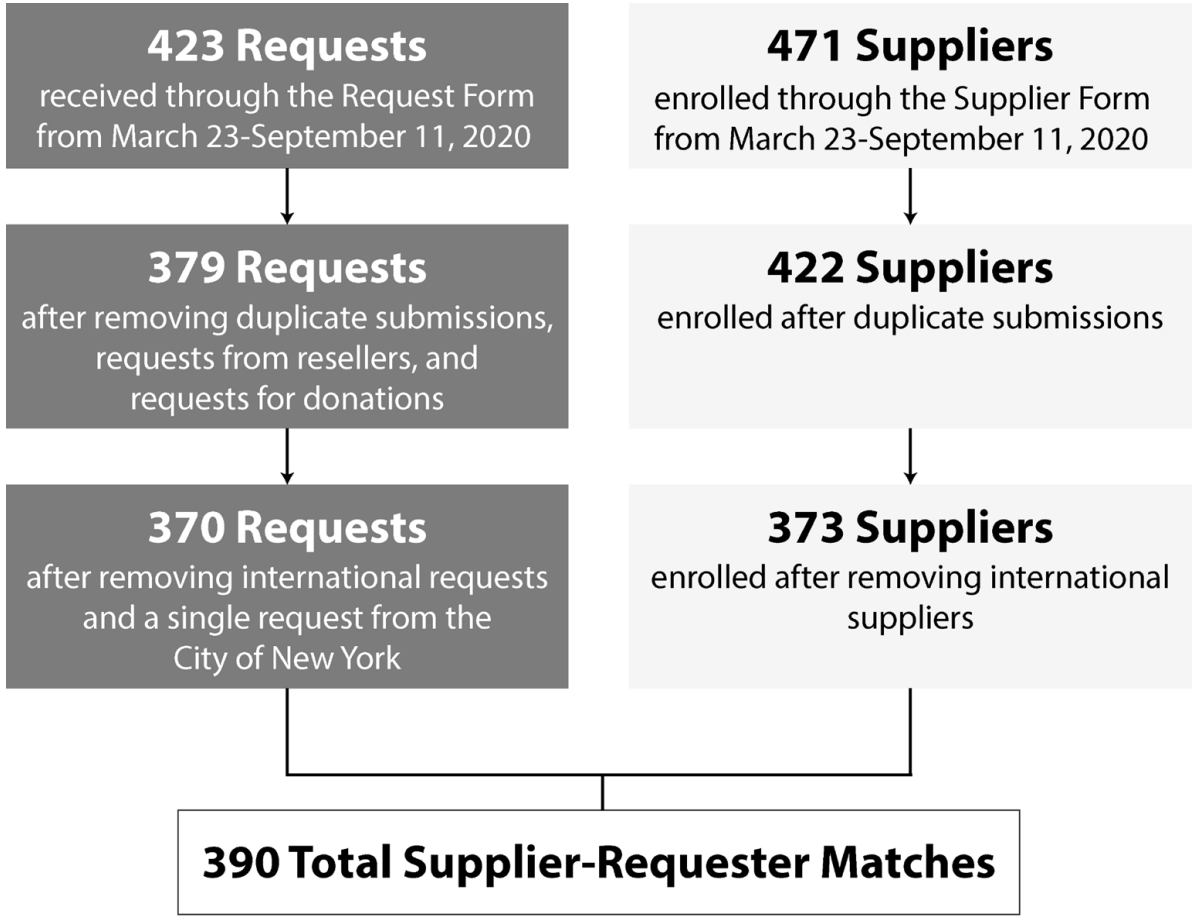
III. Results

During its operation, Shield-Net produced 390 matches between suppliers and requesters.

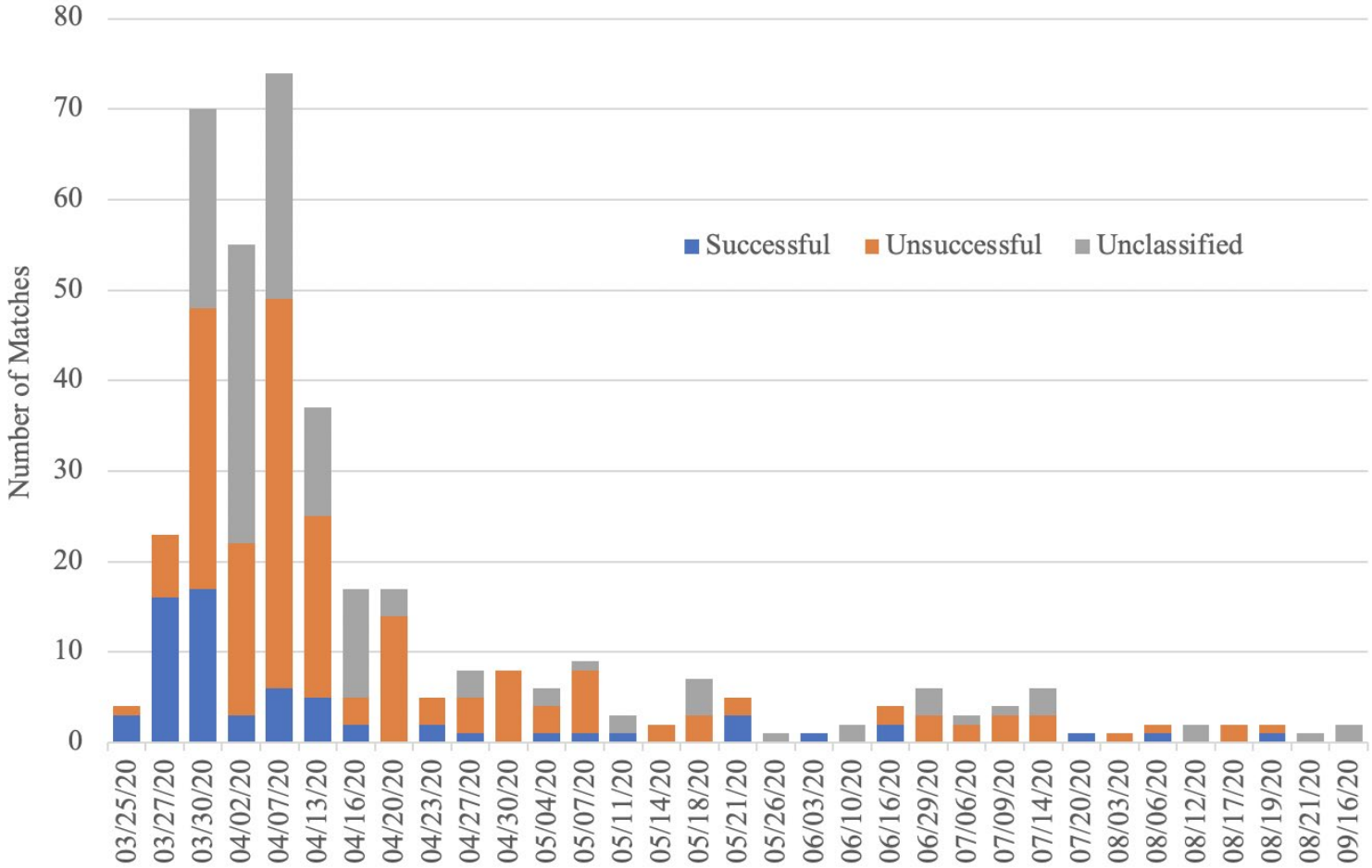
From March to September 2020:

- 370 valid requests for ~400,000 face shields from 43 states and Puerto Rico

- 373 suppliers from 40 states

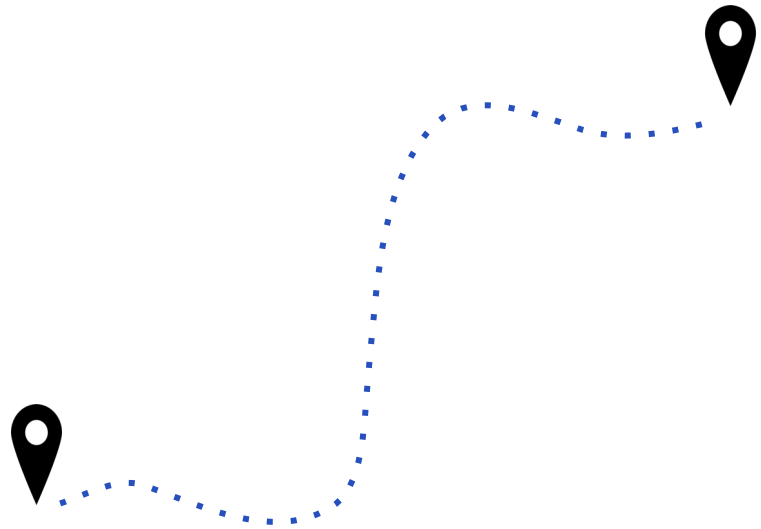


50,000+ face shields were delivered to 68 unique organizations.



More than half of the unsuccessful matches fulfilled their orders elsewhere.

successful match rates	
0.6-10%	online dating
9-15%	vacation rental booking
35%	job searching
27% (18%)	Shield-Net



Proximity matters

Shield-Net allowed suppliers to continue operating during the early economic shutdown.



Our transition to PPE production also allowed us to stay busy during COVID-19 shutdowns, keeping our regular staff of 40 employees working while also allowing us to hire 8 additional employees to help with the PPE business.

– Shield-Net manufacturer

IV. Broader Impacts



Photos courtesy of Rotary Club of Guatemala Vista Hermosa





Shield-Net's success led to collaborations with Engineers Without Borders and the United Nations Development Programme.



Engagement on community-centered PPE production in 13 countries

Shield-Net: Matching Supply with Demand for Face Shields During the COVID-19 Pandemic

Rebecca Alcock, Justin J. Boutilier, Auyon Siddiq

Published Online: 17 Jan 2022 | https://doi.org/10.1287/inte.2021.1112



Doing Good with Good OR - Student Paper Competition

INFORMS is again sponsoring a competition to encourage student research and practice that has societal impact. The "Doing Good with Good OR Student Competition" will feature the most exciting work performed by