Case Studies of Infrastructure Resilience in the VI

David Alderson, PhD
Daniel Eisenberg, PhD
LCDR Jeff Good, USN
Cpt Dominik Wille, GER
Operations Research Department
Center for Infrastructure Defense
Naval Postgraduate School

2019 Hazard Mitigation and Resilience Workshop – St. Thomas, USVI
12-13 September 2019

Naval Postgraduate School (NPS)

America's national security research university

History Highlights

1909 Founded at U.S. Naval Academy

1951 Moved to Monterey, CA

Operations Research Curriculum

- Facilities of a graduate research university
- Faculty who work for the U.S. Navy, with clearances
- Students with fresh operational experience

FY2017:

- 65 M.S. and 15 Ph.D. programs
- 612 faculty
- 1432 resident students includes (166 international / 47 countries)
- 909 distributed learning students

What is Operations Research?

- Operations Research (OR) is the science of helping people and organizations make better decisions using
  - mathematical models, statistical analyses, simulations
  - analytical reasoning and common sense

  to the understanding and improvement of real-world operations.

Source: IDC/KDnuggets Advanced Analytics Survey, 2016

informs

MORS Military Operations Research Society

NAVAL POSTGRADUATE SCHOOL

Center for Infrastructure Defense

www.nps.edu/cid

Welcome | Our Work | About Us | Student Theses | Resources

David Alderson
Professor, OR
Director, NPS Center for Infrastructure Defense

Ph.D., Stanford University, 2003

Daniel Eisenberg
Research Assistant Professor, OR
Deputy Director, NPS CID

Ph.D., Arizona State University, 2018

Infrastructures are systems of components that work together to achieve a desired function. The consequence of infrastructure disruption is the loss of that function.

<u>Motivation</u>: Concern about accidents, failures, natural hazards, attacks on critical infrastructures

How to Think About Critical Infrastructure

- A list of *<u>assets</u>*
- An interconnected (network) *<u>system</u>* that works to achieve a particular function

Motivation: Concern about accidents, failures, natural hazards, attacks on critical infrastructures

How to Think About Critical Infrastructure

✖ • A list of *assets*

✔ • An interconnected (network) *system* that works to achieve a particular function

Motivation: Concern about accidents, failures, natural hazards, attacks on critical infrastructures

How to Think About Critical Infrastructure

✖ • A list of *assets*

✔ • An interconnected (network) *system* that works to achieve a particular function

We want to make our operations (e.g., lifeline systems) resilient to disruptive events.

We need our infrastructure systems to continue to function even when “bad things” happen.

Operations Research Analysis of Critical Infrastructure

Key Recognition: Need an *Operational View* of Infrastructure

- **Systems Modeling**: We model system function
  - Assets → Systems → Function → Capability → Mission

Operations Research Analysis of Critical Infrastructure

Key Recognition: Need an *Operational View* of Infrastructure

- **Systems Modeling**: We model system function
  - Assets → Systems → Function → Capability → Mission

Modeling

We build models to assess the capability of a system to deliver service under different scenarios:

- Loss of assets / components – due to failure, etc
- Given the ability of the system operator to adapt (e.g., rebalance flows, change operations)
- In order to achieve ”mission success”

Operations Research Analysis of Critical Infrastructure

Key Recognition: Need an *Operational View* of Infrastructure

- **Systems Modeling**: We model system function
  - Assets → Systems → Function → Capability → Mission

Modeling **Stakeholder Values**

We build models to assess the capability of a system to deliver service under different scenarios:

- Loss of assets / components – due to failure, etc
- Given the ability of the system operator to adapt (e.g., rebalance flows, change operations)
- In order to achieve "mission success"

Defining "mission success" is for stakeholders, not modelers

Operations Research Analysis of Critical Infrastructure

Key Recognition: Need an *Operational View* of Infrastructure

- **Systems Modeling**: We model system function
  - Assets → Systems → Function → Capability → Mission
  - We assess degradation from loss of sets of components
- **Red Teaming**: We identify worst-case disruptions
- **Blue Teaming**: We identify optimal investments to maximize system resilience

We connect models of individual infrastructures together to assess dependencies and “full spectrum” threats.

NPS Center for Infrastructure Defense: www.nps.edu/cid
USVI project page: faculty.nps.edu/dlalders/usvi

Today's Agenda

- Provide an overview of our ongoing modeling and analysis of lifeline critical infrastructure systems in the VI
- Discuss the role of this work for hazard mitigation and resilience
- (to include capacity building and include workforce development)

Our USVI work: part of a broader team effort

Our USVI work: current project timeline

27 Feb 2018	Project Start
26-30 Mar	**NPS site visit to STX, STT**
11-15 Jun	**NPS site visit to STX, STT**
14-15 Jun	UVI/VITEMA Hazard Mitigation Workshop
21 Sep	MS Thesis by LCDR Brendan Bunn
22-26 Oct	**NPS site visit to STX, STJ, STT**
01 Dec	NPS Technical Report: Preliminary Analysis
9-11 Dec	UVI site visit to Stanford, NPS
24-29 Mar 2019	**NPS site visit to STX, STT**
9-13 Sep	**NPS site visit to STX, STT**
12-13 Sep	UVI/VITEMA Hazard Mitigation Workshop
27 Sep	MS Thesis by LCDR Jeff Good (expected)
TBD Oct	NPS site visit (telecom/internet)
13 Dec	MS Thesis by CPT Dominik Wille (expected)
Spring 2020	Launch of UVI course on infrastructure resilience

Our USVI work: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

– Energy (emphasis on electric power)
– Water (emphasis on potable storage and distribution)
– Transportation & Supply Chains
– Telecommunications & Internet

Effort 2 - Support for development of a new Hazard Mitigation and Resilience Plan

– in partnership with UVI / VITEMA (POC: Kim Waddell, Greg Guannel)

Effort 3 - Capacity building & workforce development program

– in partnership with UVI (POC: David Morris, Greg Guannel)

Our USVI work: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

Our USVI work: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

- Alderson DL, Bunn BB, Eisenberg DA, Howard AH, Nussbaum DE, Templeton JC, **"Interdependent Infrastructure Resilience in the U.S. Virgin Islands: Preliminary Assessment,"** NPS Technical Report NPS-OR-18-005, Naval Postgraduate School, Monterey, CA, December 2018.

Report Contributions: an integrated view of "how stuff works"

1. Explaining the structure, function, and tensions associated with critical infrastructure that were chronic problems *prior* to the hurricanes.
2. Documenting hurricane response, recovery, and mitigation activities for these infrastructure systems *after* the hurricanes.
3. Discussing these changes in the context of potential barriers to resilience.

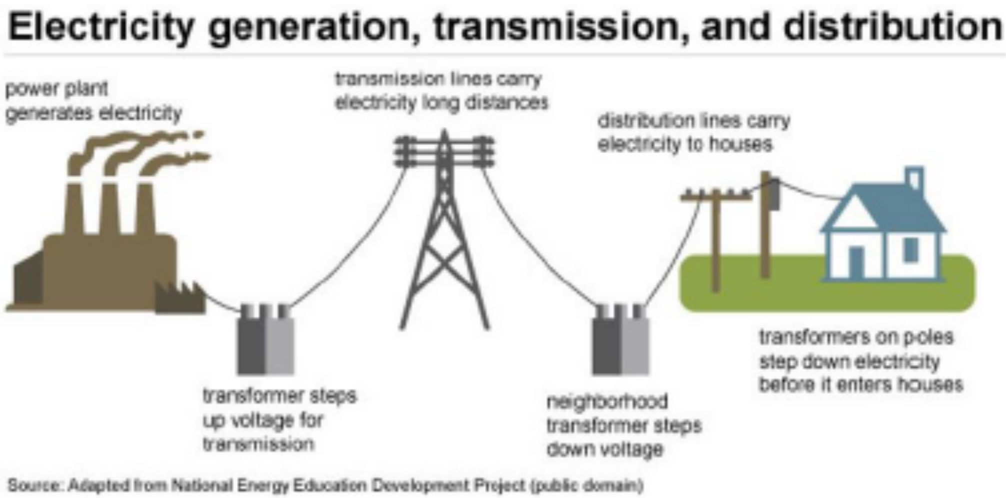
Our USVI work: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications

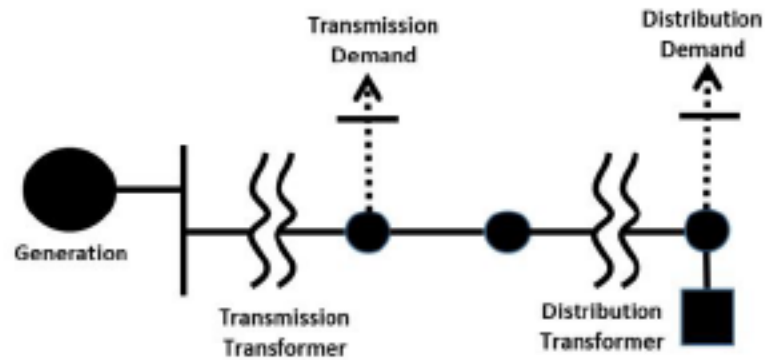
- Bunn BB, 2018, **"An Operational Model of Interdependent Water and Power Distribution Infrastructure Systems,"** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2018.

- Wille D, 2019, **"Simulation Optimization for Operational Resilience of Interdependent Water-Power Systems in the US Virgin Islands,"** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, December 2019 (expected).



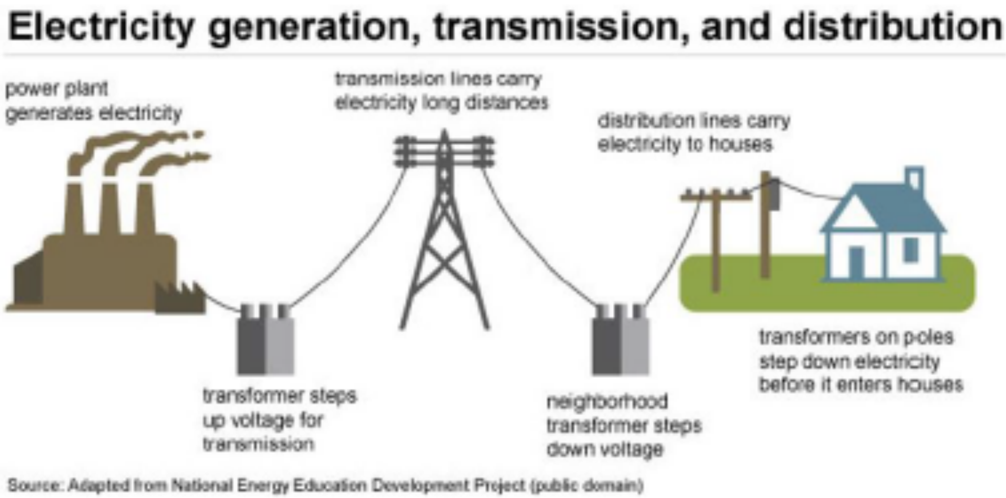
Electricity generation, transmission, and distribution
power plant generates electricity
transmission lines carry electricity long distances
distribution lines carry electricity to houses
transformers on poles step down electricity before it enters houses
transformer steps up voltage for transmission
neighborhood transformer steps down voltage
Source: Adapted from National Energy Education Development Project (public domain)

(a)

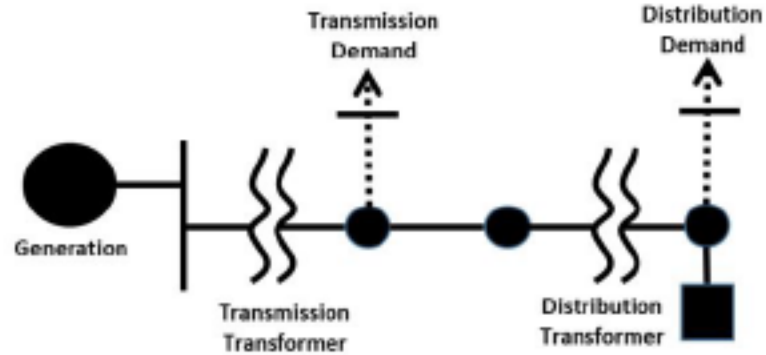


Transmission Demand
Distribution Demand
Generation
Transmission Transformer
Distribution Transformer

(b)



(a)



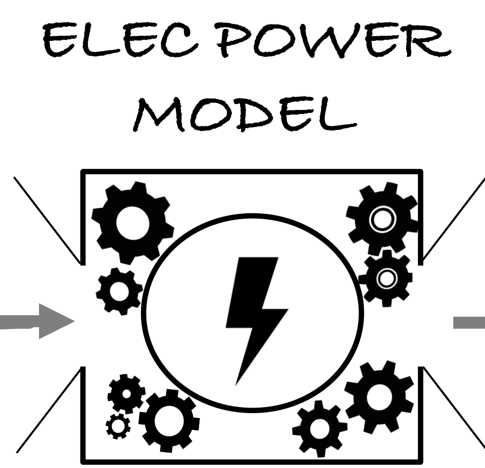
(b)

Physical Grid Data:

- Generators (supply sites)
- Lines
- Transformers
- Buses (demand sites)
- Thermal limits, voltage bounds, impedance, etc.

Scenario Data:

- Generation capacity
- Customer demands
- Priority per demand
- Availability/damage to grid components

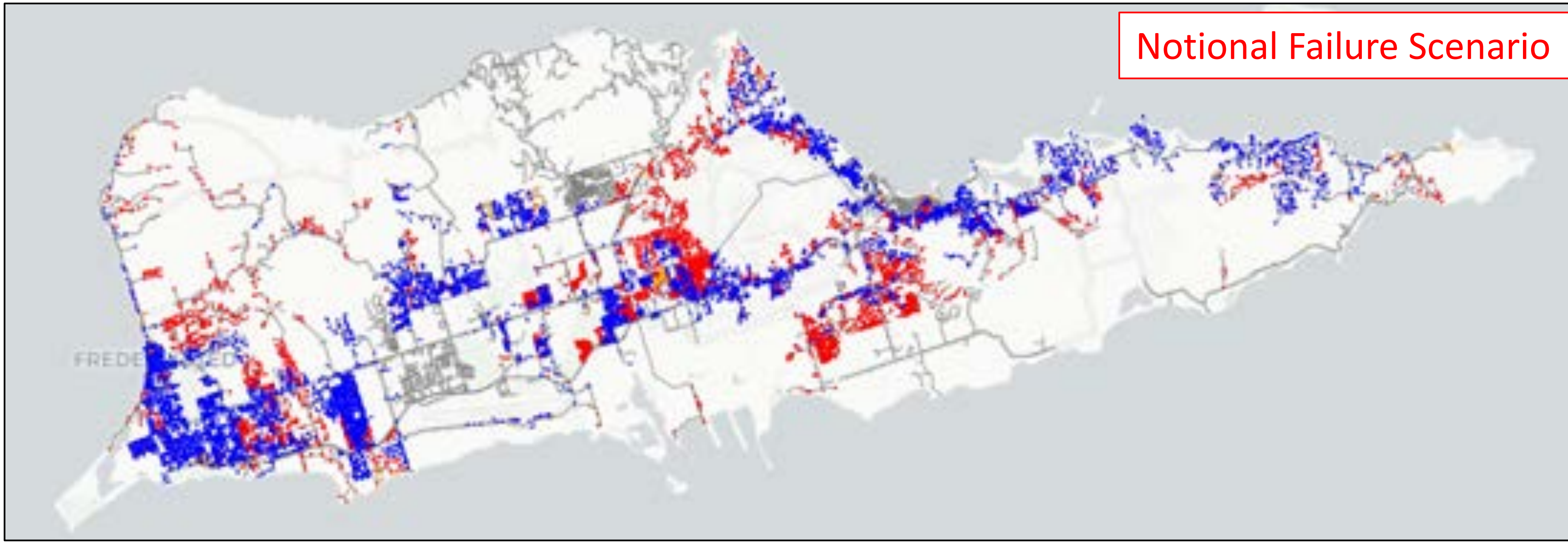


How “best” to operate the system:

- generation, switches

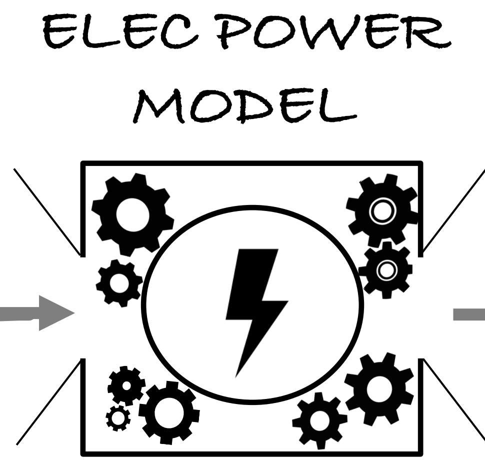
to minimize unmet demand

- delivered flows
- who can get power, who cannot



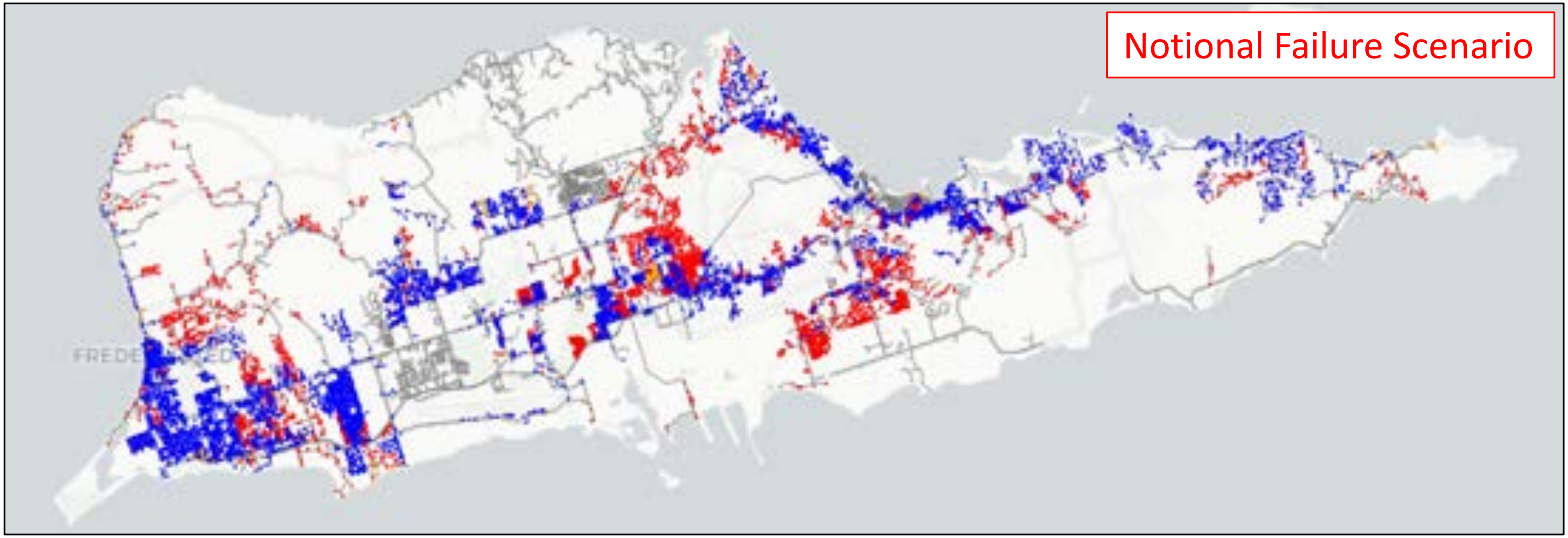
Physical Grid Data:
- Generators (supply sites)
- Lines
- Transformers
- Buses (demand sites)
- Thermal limits, voltage bounds, impedance, etc.

Scenario Data:
- Generation capacity
- Customer demands
- Priority per demand
- Availability/damage to grid components



How "best" to operate the system:
- generation, switches

to minimize unmet demand
- delivered flows
- who can get power, who cannot



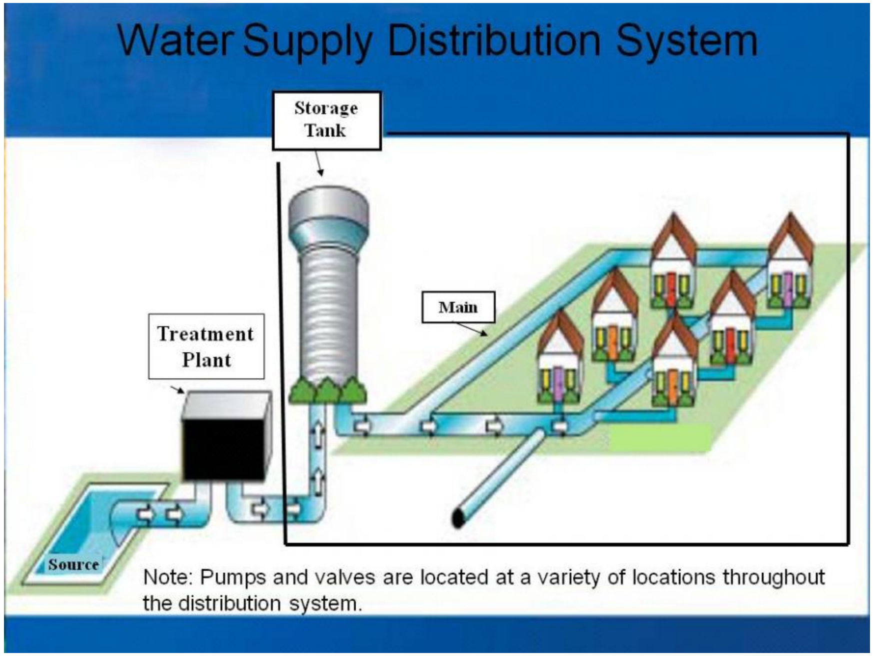
St. Croix Electric Power Distribution *Operator Model*

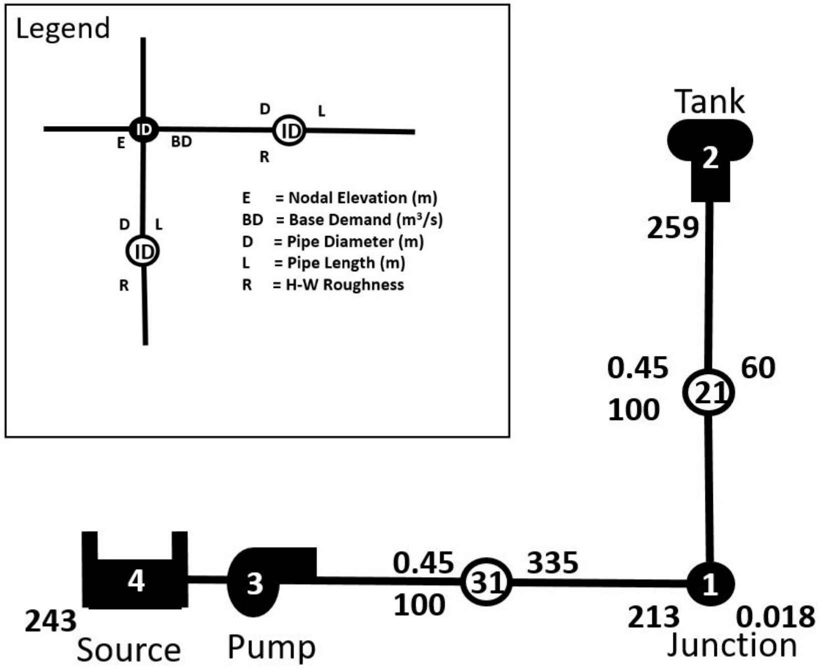
- ***System Size:*** Power Line Segments (40k), Customers (17k), Transformers (3.8k)
- ***Physics:*** 3-Phase AC Power Flow (unbalanced)
- ***Model Objective:*** Dispatch Power to Minimize Customer Load Shed
- ***Results:*** Power Flow (direction & quantity), Customers Served

Questions that Can be Answered (among others):

- Optimal Dispatch for Different Amounts of Generation and Customer Load
- Customer Impacts from Component Failures (load shed)

We present results in the form of interactive web-based maps.

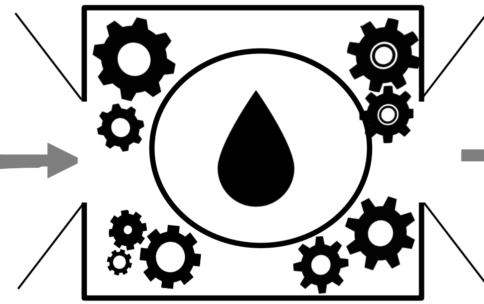

Water Supply Distribution System
Storage Tank
Main
Treatment Plant
Source
Note: Pumps and valves are located at a variety of locations throughout the distribution system.


Legend
ID
E
BD
D
L
R
E = Nodal Elevation (m)
BD = Base Demand (m³/s)
D = Pipe Diameter (m)
L = Pipe Length (m)
R = H-W Roughness
Tank
2
259
0.45
60
21
100
4
3
0.45
31
335
1
243
100
213
0.018
Source
Pump
Junction

Physical Network Data:
- Production (supply sites)
- Pipes, junctions, valves
- Pumps, curves
- Elevations, diameters, etc.

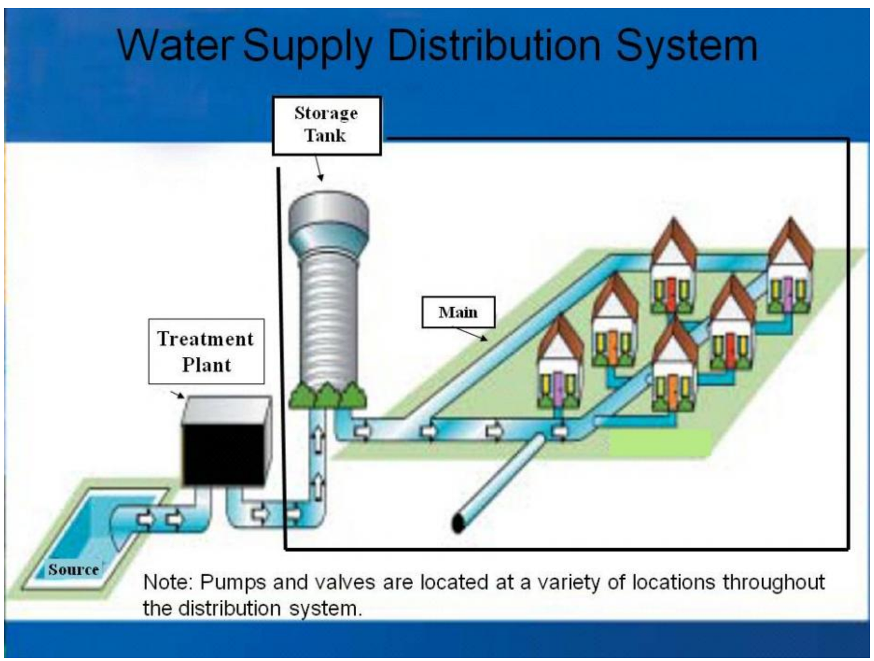
Scenario Data:
- Production capacity
- Initial tank levels
- Customer demands + priorities
- Availability/damage

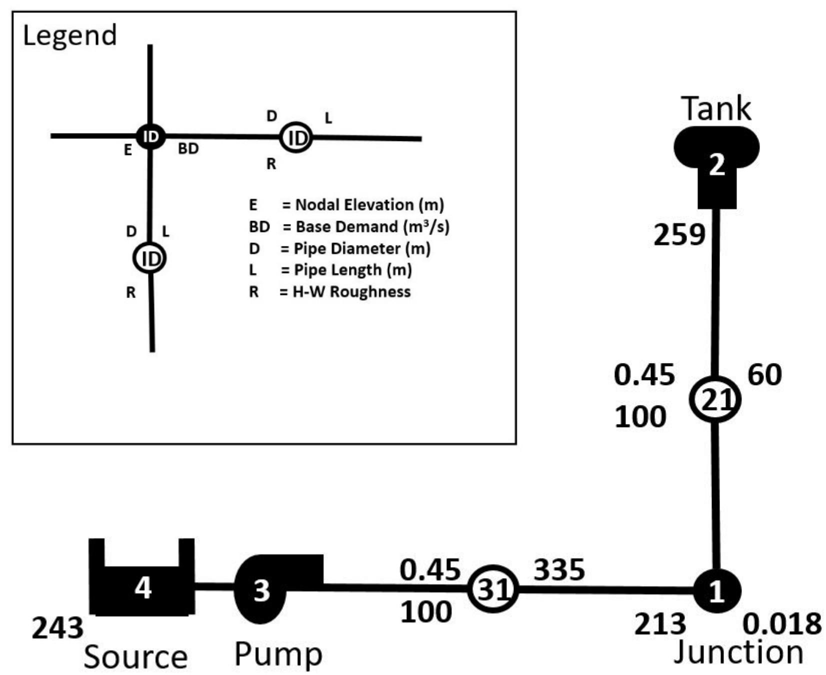
WATER MODEL



How "best" to operate the system:
- Pumps, valves, pressures

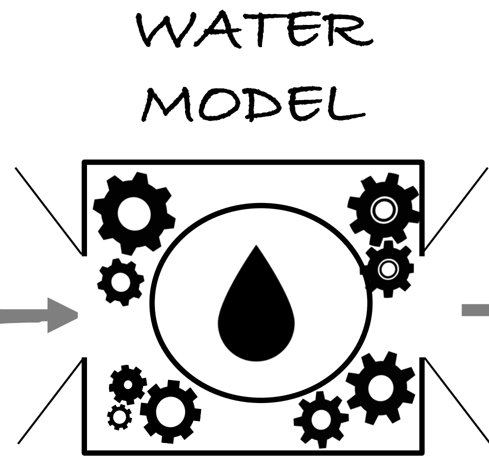
to minimize unmet demand
- delivered flows
- who can get water, who cannot





Physical Network Data:
- Generation (supply sites)
- Pipes, junctions, valves
- Pumps, curves
- Elevations, diameters, etc.

Scenario Data:
- Generation capacity
- Tank levels
- Customer demands + priorities
- Availability/damage



How "best" to operate the system:
- Pumps, valves, pressures

to minimize unmet demand
- delivered flows
- who can get water, who cannot

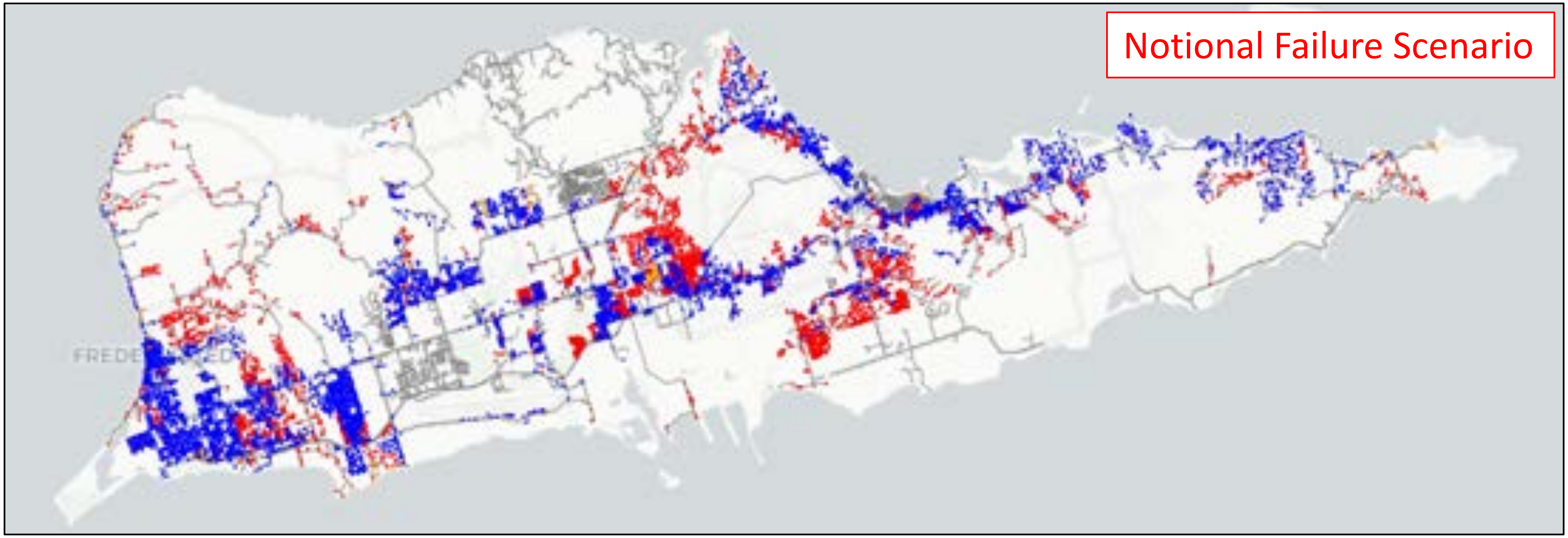
St. Croix Water Distribution *Operator Model*

- ***System Size:*** Pipes (847), Pumps (7), Junctions (670), Tanks (6), Reservoirs (1)
- ***Physics:*** Demand (EPANET) & Pressure Dependent (WNTR) Hydraulic Balancing
- ***Model Objective:*** Extended Period Simulation of Water Flow and Headloss
- ***Results:*** Pipeline Flow, Pump Operations, Tank Levels, Customers Served

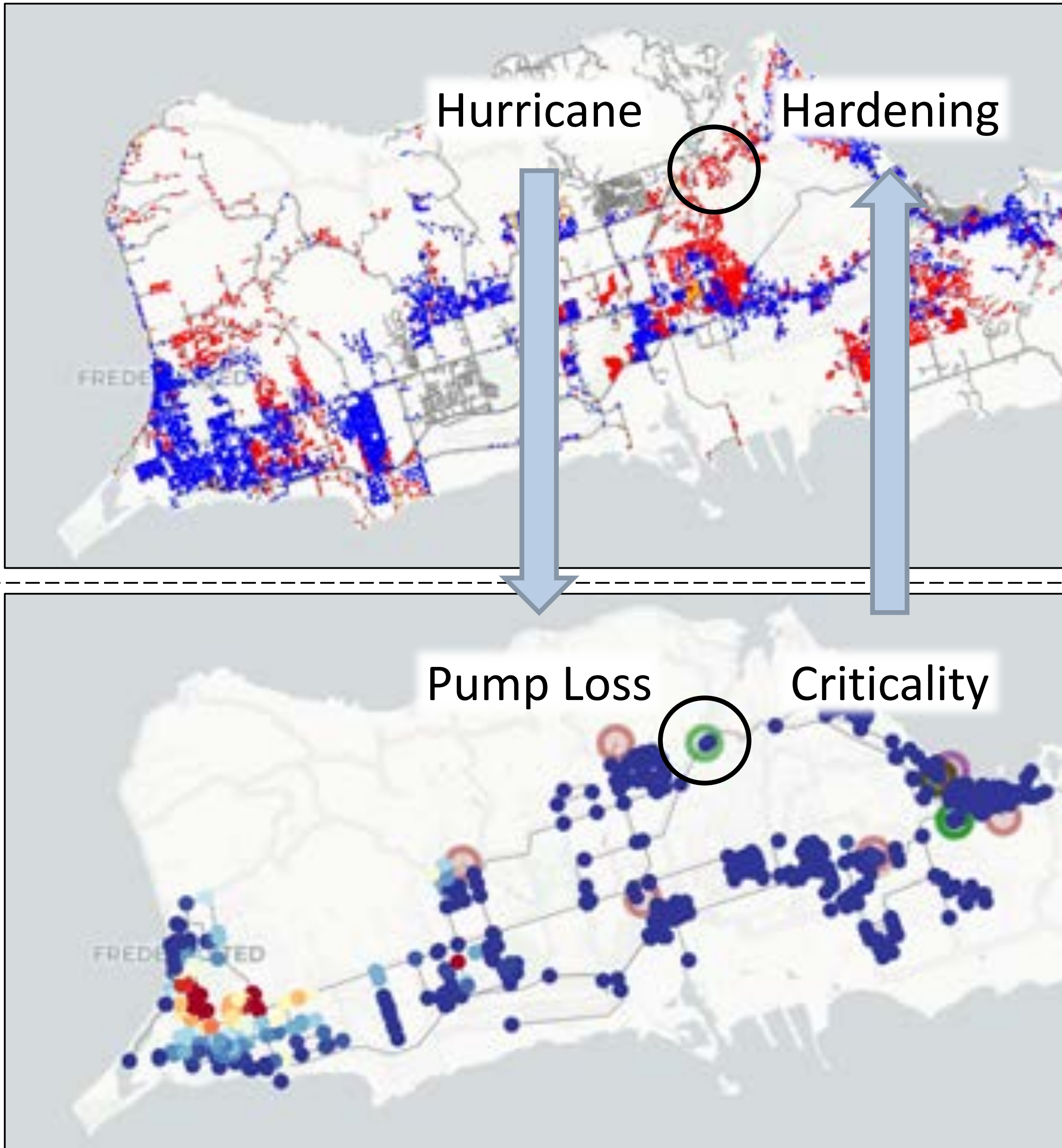
Questions that Can be Answered (among others):

- Optimal Pump Settings and Tank Levels to Serve Customers
- Customer Impacts of Component Failures (water service availability)

We present results in the form of interactive web-based maps.


Notional Failure Scenario
FREDE TED


FREDE TED
Notional Failure Scenario



Power Simulation-Optimization:

- **Simulation:** How do hurricanes impact customers & water pumping stations?
- **Optimization:** What power infrastructure hardening is best for both electricity and water systems?

Water Simulation-Optimization:

- **Simulation:** How long can the water system provide service without electricity?
- **Optimization:** Find critical pump & tank operations to maximize water service availability during blackouts.

Our USVI work: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

- Good JE, 2019, **“An Operational Model of the Critical Supply Chain for the U.S. Virgin Islands,”** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2019 (expected).

- Good JE, 2019, **“An Operational Model of the Critical Supply Chain for the U.S. Virgin Islands,”** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2019 (expected).

- Good JE, 2019, **“An Operational Model of the Critical Supply Chain for the U.S. Virgin Islands,”** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2019 (expected).

Goals:

- Assess how USVI food supply chains and transportation systems perform during normal and post-hurricane conditions
- Consider new courses of action that ***minimize*** household travel time, ***maximize*** supply chain access, and support ***faster*** recovery

- Good JE, 2019, **"An Operational Model of the Critical Supply Chain for the U.S. Virgin Islands,"** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2019 (expected).

Goals:

- Assess how USVI food supply chains and transportation systems perform during normal and post-hurricane conditions
- Consider new courses of action that ***minimize*** household travel time, ***maximize*** supply chain access, and support ***faster*** recovery

Understand transportation infrastructure to support:

- Movement of goods into ports and onto stores via surface roads
- Movement of people from their homes to stores via surface roads

- Good JE, 2019, **"An Operational Model of the Critical Supply Chain for the U.S. Virgin Islands,"** M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2019 (expected).

Goals:

- Assess how USVI food supply chains and transportation systems perform during normal and post-hurricane conditions
- Consider new courses of action that ***minimize*** household travel time, ***maximize*** supply chain access, and support ***faster*** recovery

Understand transportation infrastructure to support:

- Movement of goods into ports and onto stores via surface roads
- Movement of people from their homes to stores via surface roads

Quantify impacts of:

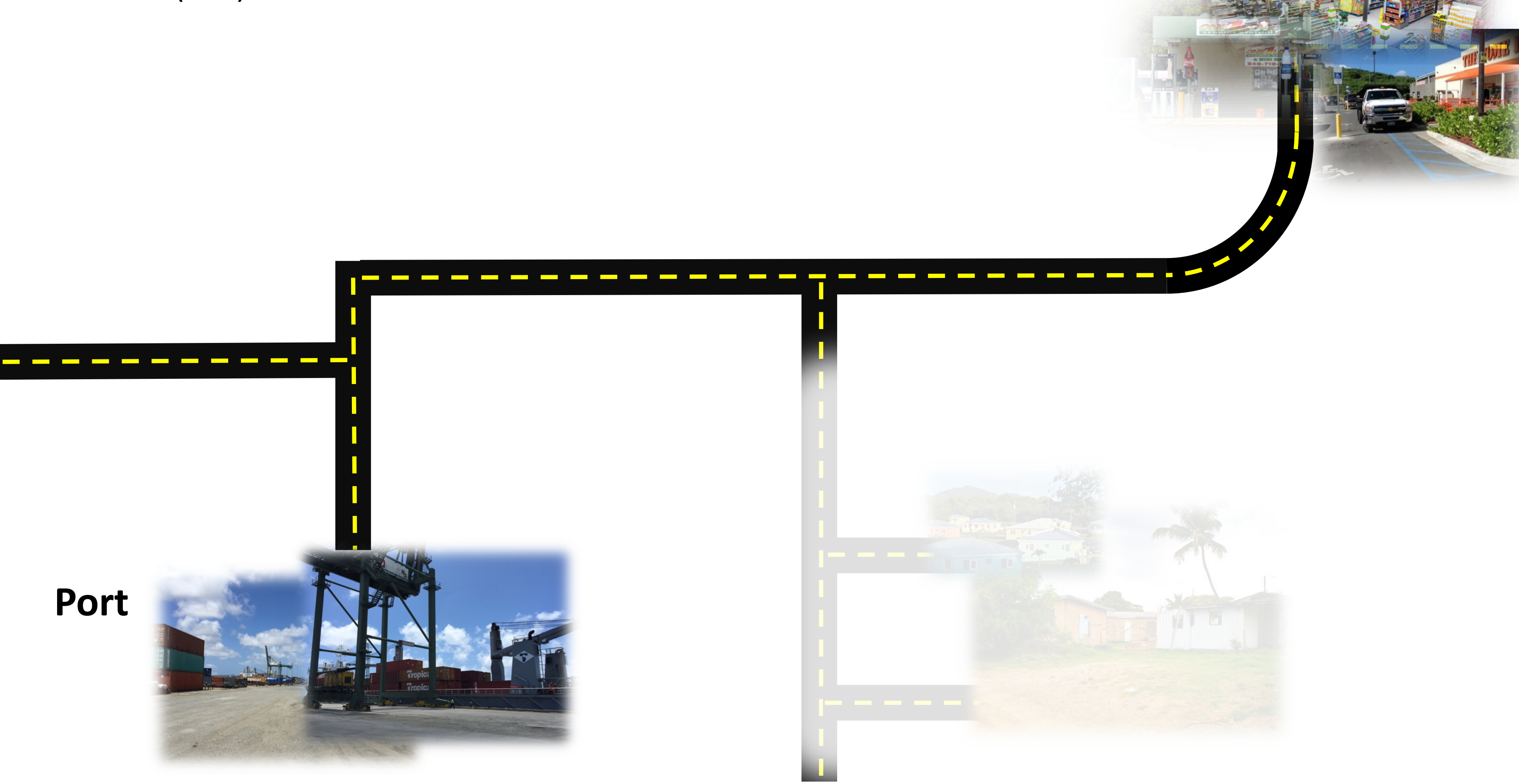
- Imposed curfews
- Surface road restrictions or blockages
- Alternative relief locations

Understanding Traffic Demand (Congestion): Delivery Model

Objective: ***Maximize*** supply chain access

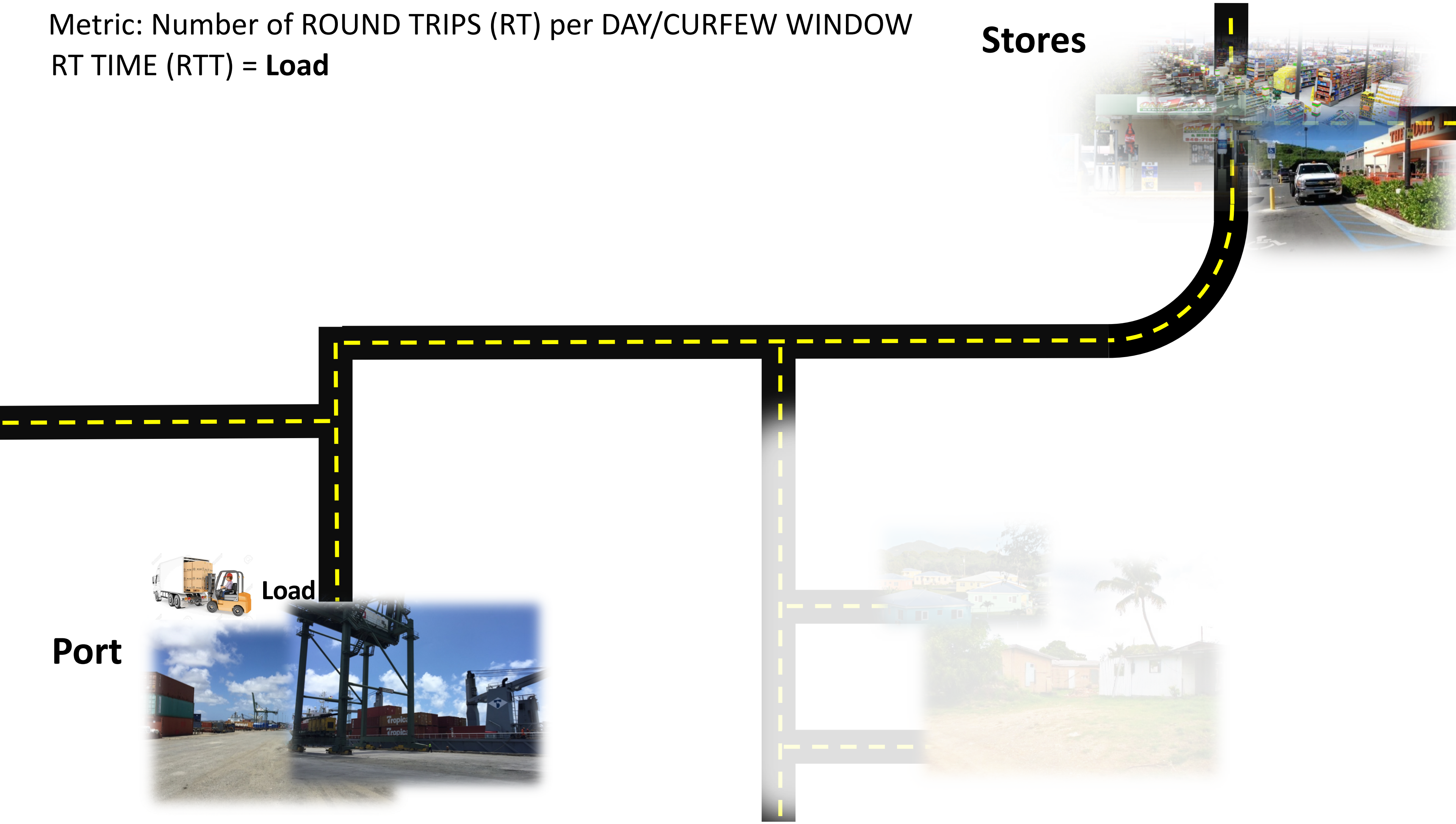
Metric: Number of ROUND TRIPS (RT) per DAY/CURFEW WINDOW

RT TIME (RTT)



Understanding Traffic Demand (Congestion): Delivery Model

Objective: ***Maximize*** supply chain access
Metric: Number of ROUND TRIPS (RT) per DAY/CURFEW WINDOW
RT TIME (RTT) = **Load**

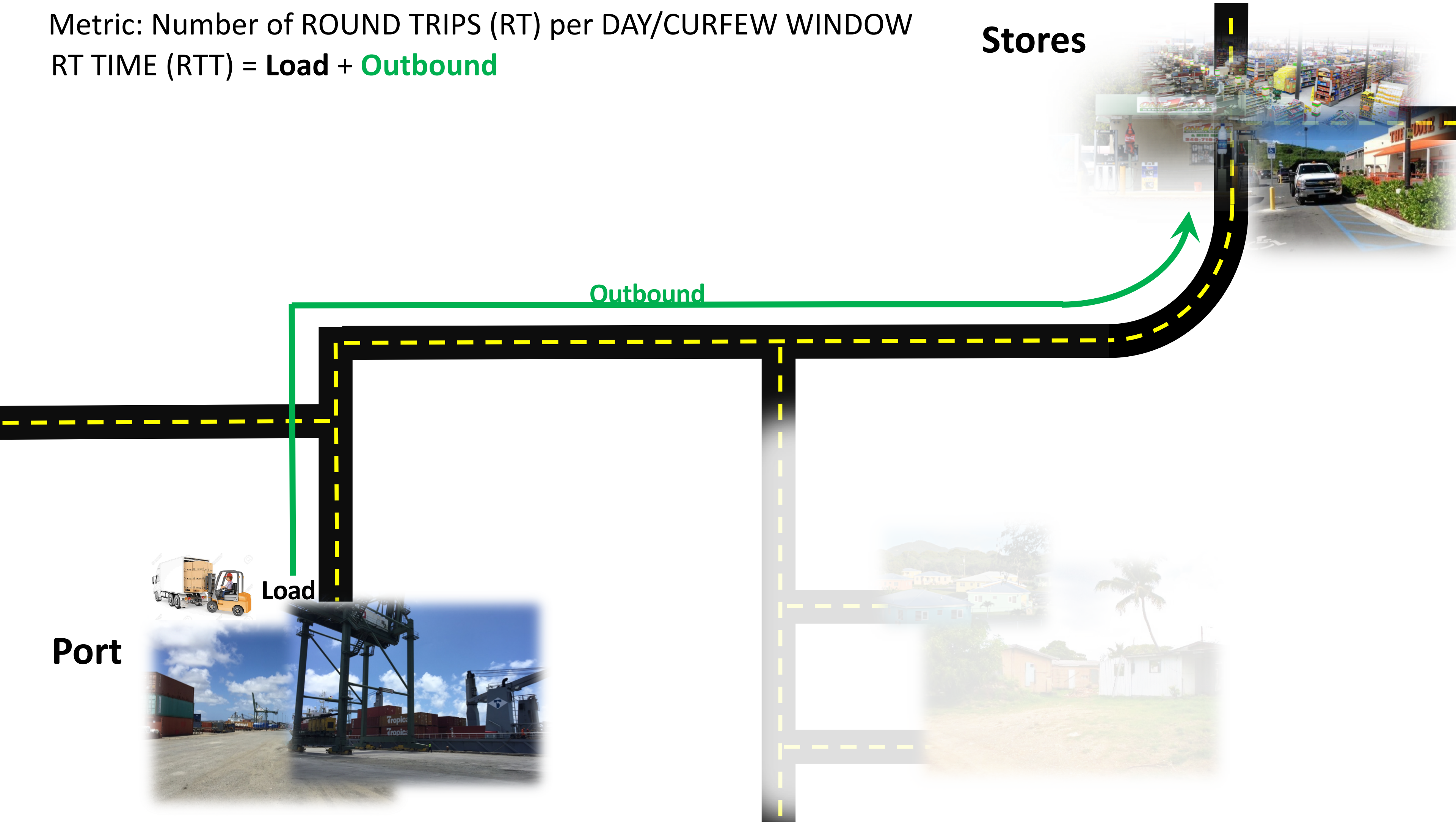


Understanding Traffic Demand (Congestion): Delivery Model

Objective: ***Maximize*** supply chain access

Metric: Number of ROUND TRIPS (RT) per DAY/CURFEW WINDOW

RT TIME (RTT) = **Load** + **Outbound**

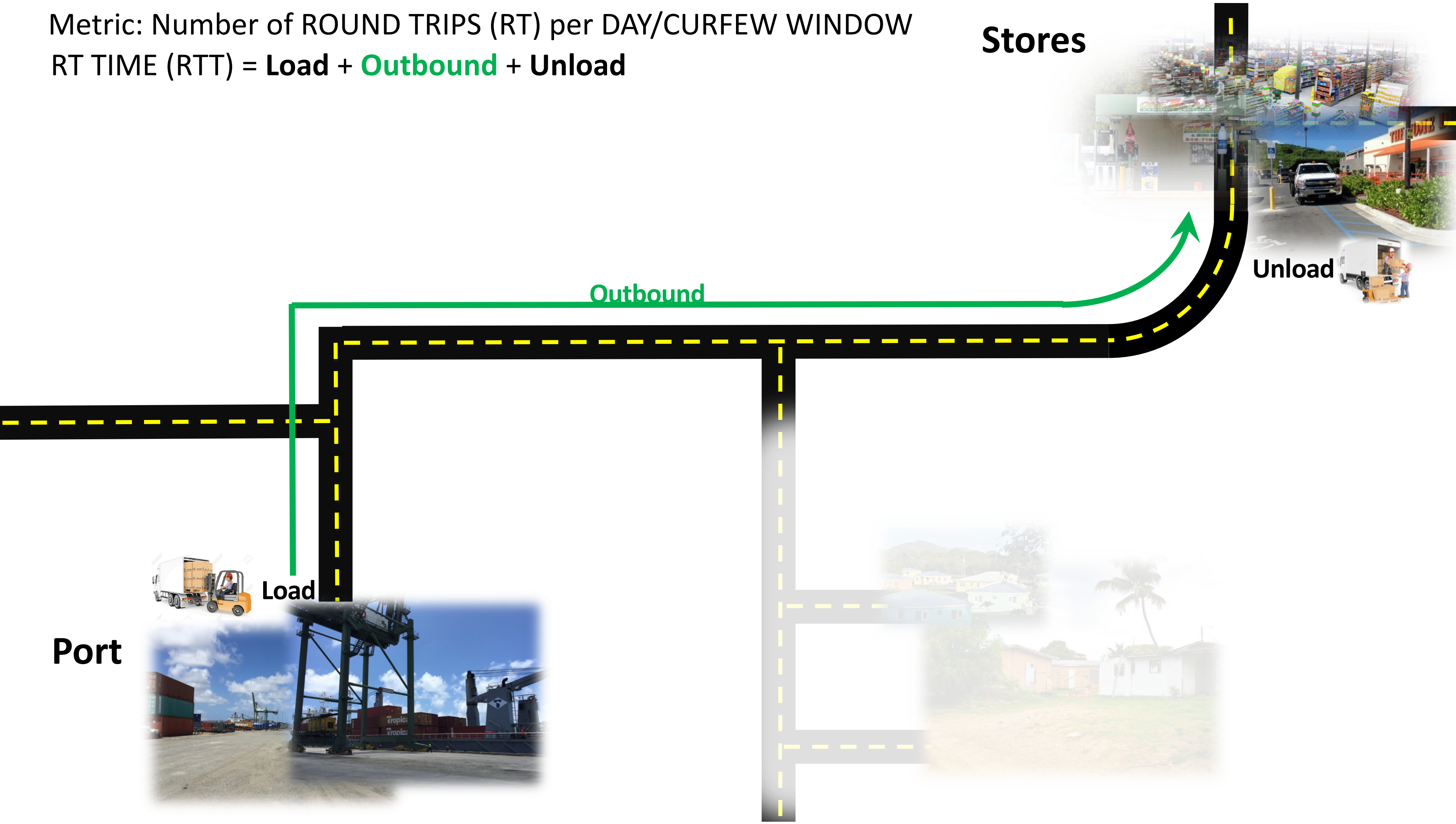


Understanding Traffic Demand (Congestion): Delivery Model

Objective: ***Maximize*** supply chain access

Metric: Number of ROUND TRIPS (RT) per DAY/CURFEW WINDOW

RT TIME (RTT) = **Load** + **Outbound** + **Unload**

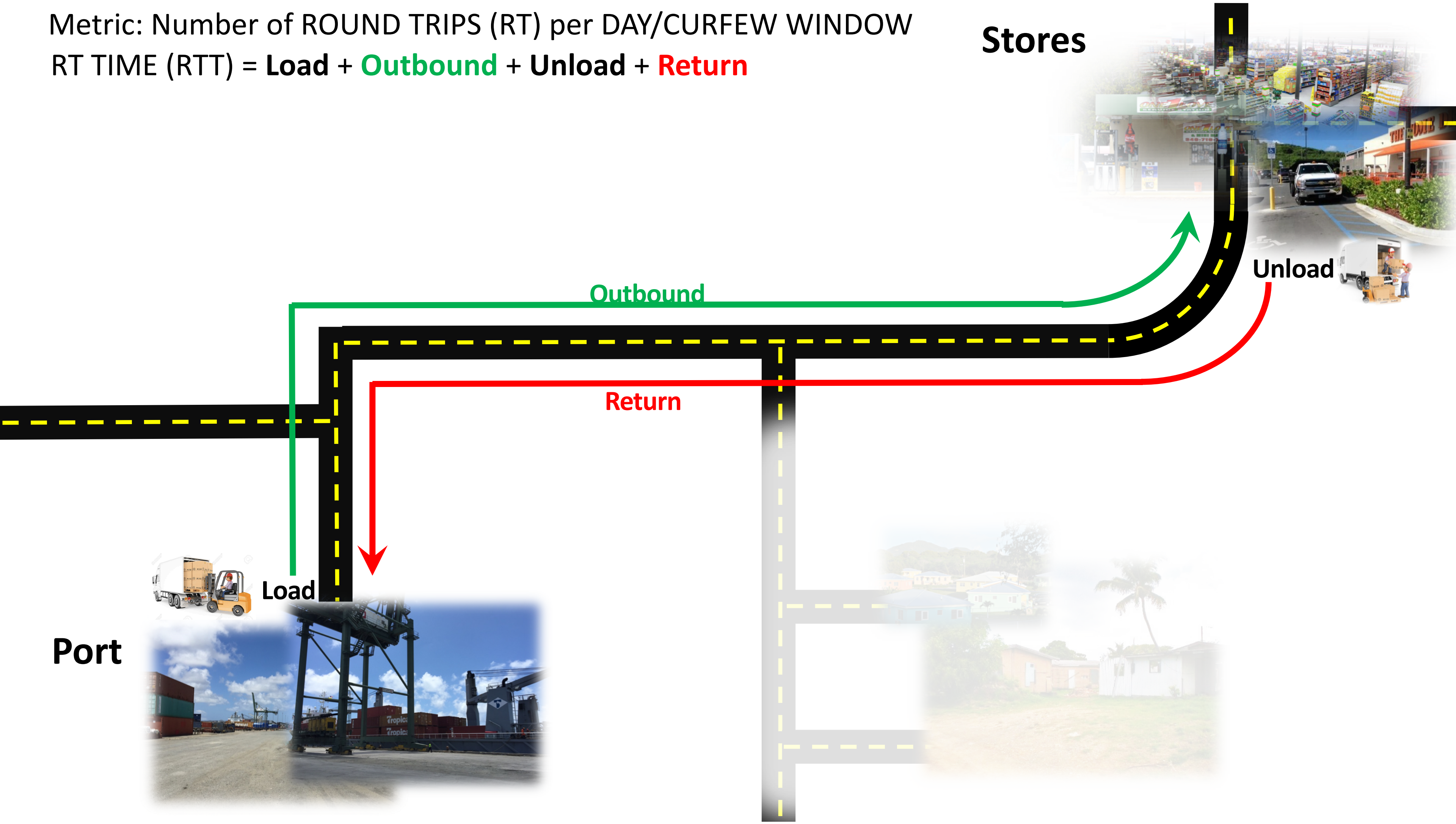


Understanding Traffic Demand (Congestion): Delivery Model

Objective: ***Maximize*** supply chain access

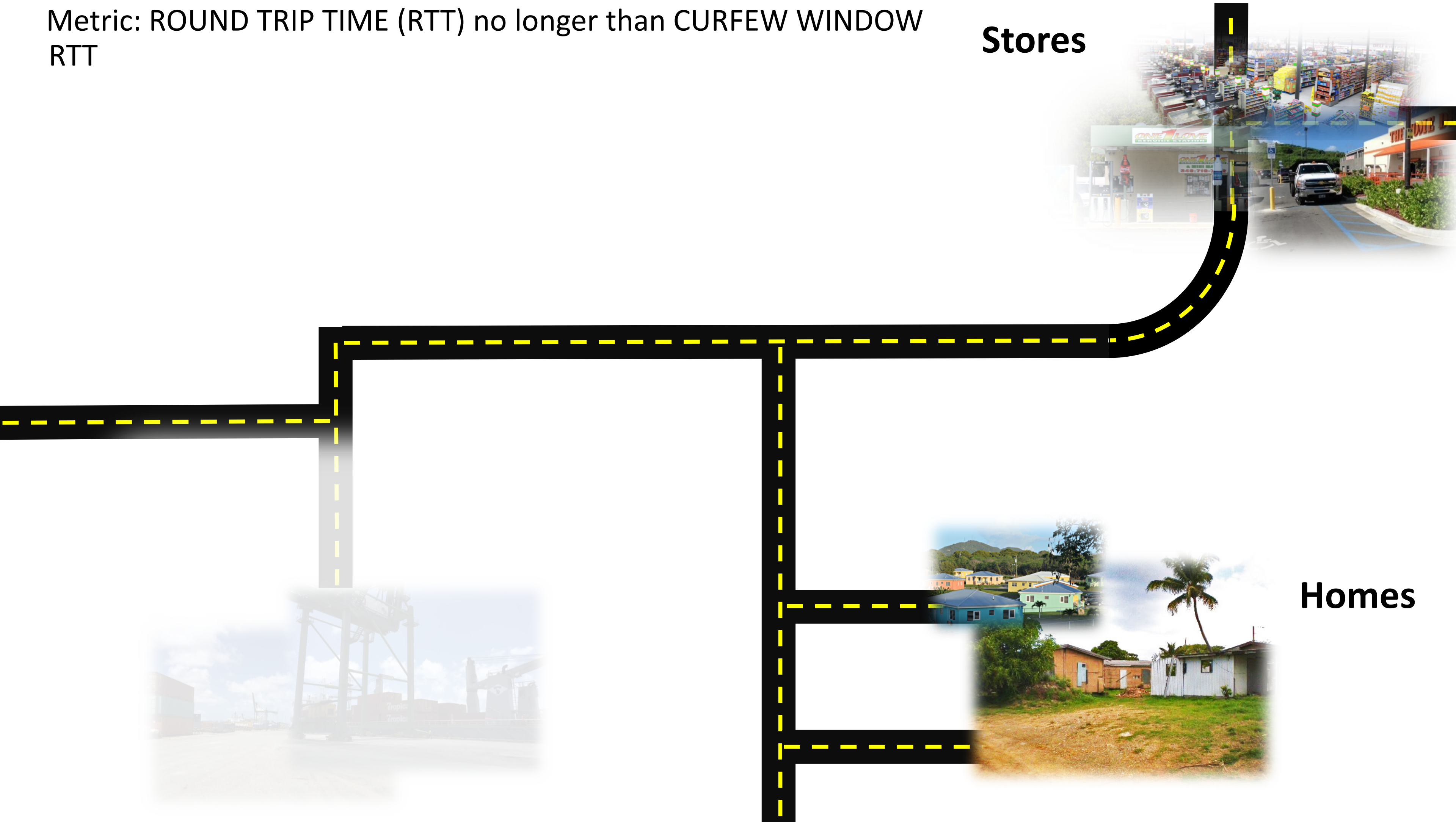
Metric: Number of ROUND TRIPS (RT) per DAY/CURFEW WINDOW

RT TIME (RTT) = **Load** + **Outbound** + **Unload** + **Return**



Understanding Traffic Demand (Congestion): Customer Model

Objective: ***Minimize*** household travel time
Metric: ROUND TRIP TIME (RTT) no longer than CURFEW WINDOW
RTT



Understanding Traffic Demand (Congestion): Customer Model

Objective: ***Minimize*** household travel time
Metric: ROUND TRIP TIME (RTT) no longer than CURFEW WINDOW
RTT = **Outbound**

Understanding Traffic Demand (Congestion): Customer Model

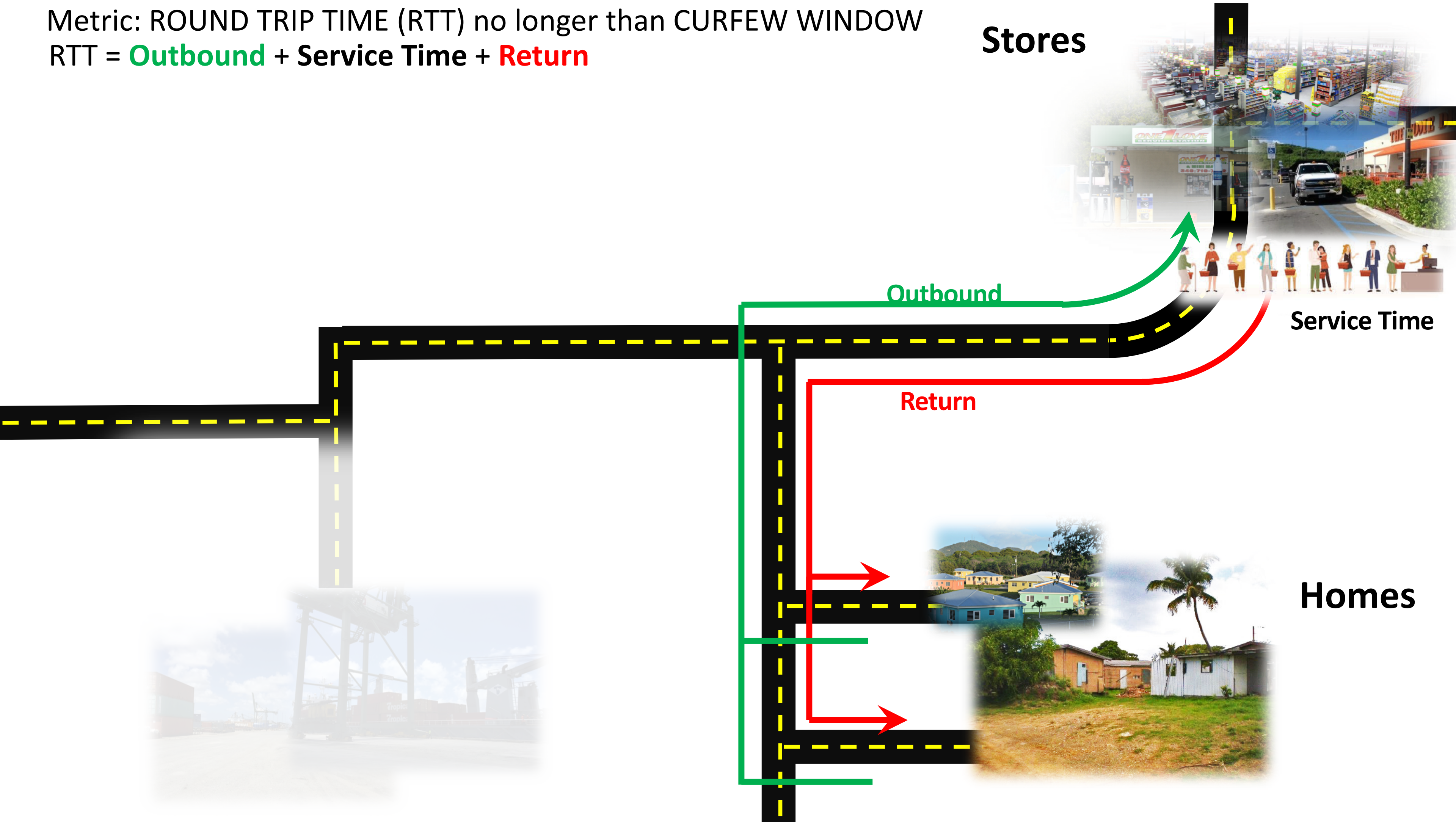
Objective: ***Minimize*** household travel time
Metric: ROUND TRIP TIME (RTT) no longer than CURFEW WINDOW
RTT = **Outbound** + **Service Time**

Understanding Traffic Demand (Congestion): Customer Model

Objective: ***Minimize*** household travel time

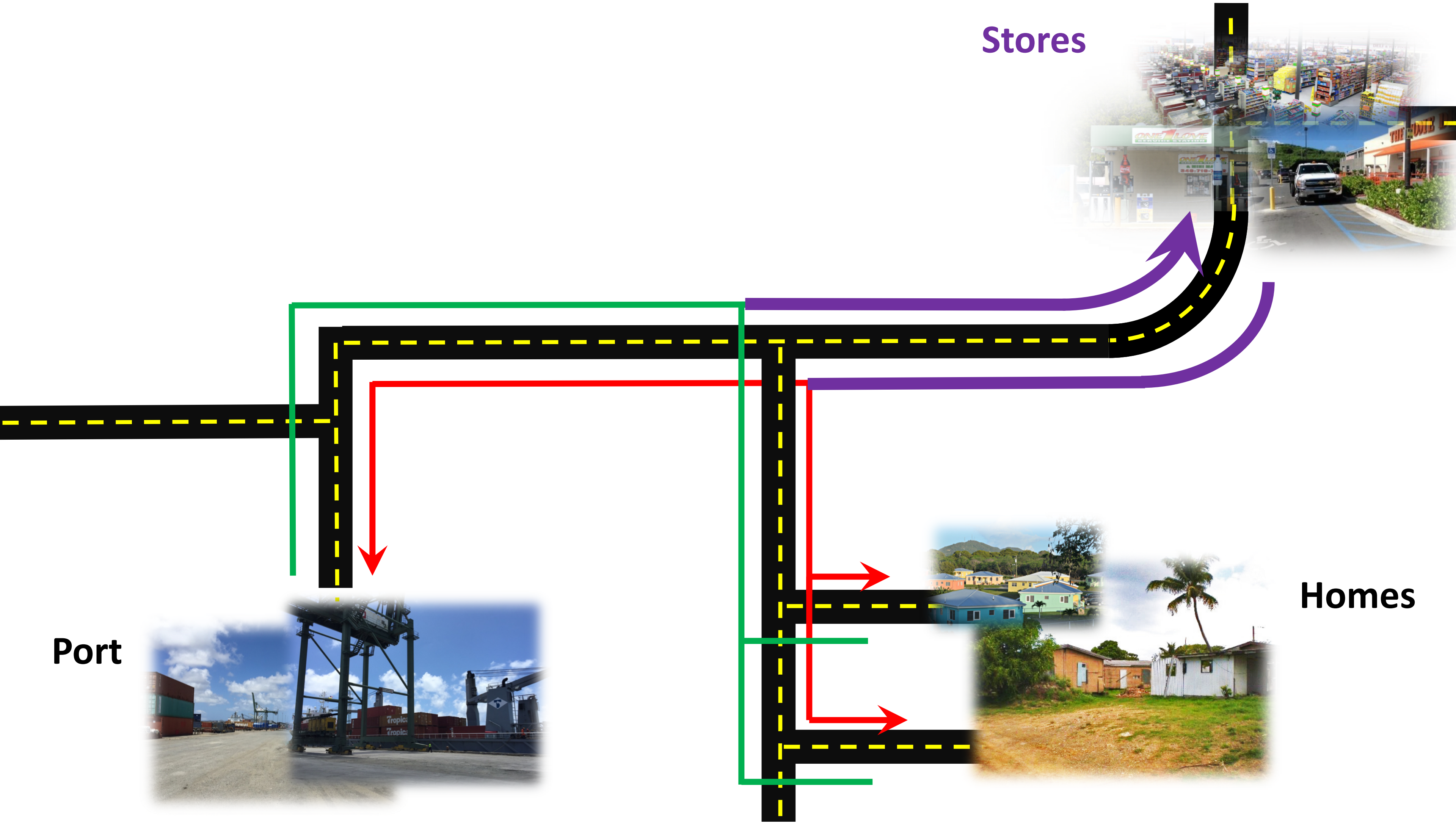
Metric: ROUND TRIP TIME (RTT) no longer than CURFEW WINDOW

RTT = **Outbound** + **Service Time** + **Return**



Understanding Traffic Demand (Congestion): Combined Model

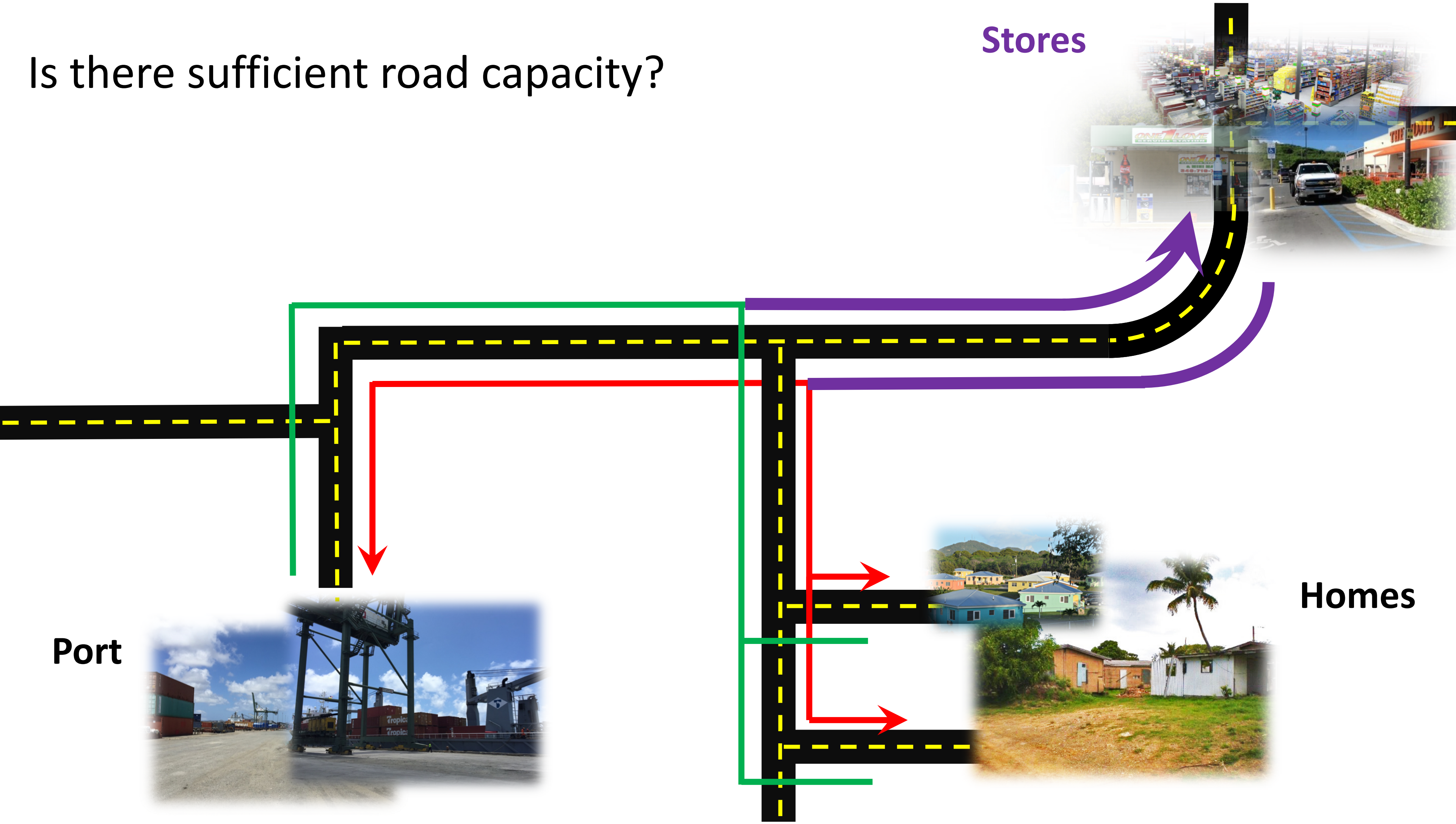
Shared: Roads and Stores



Understanding Traffic Demand (Congestion): Combined Model

Shared: Roads and Stores

Is there sufficient road capacity?



Understanding Traffic Demand (Congestion): Combined Model

Shared: Roads and Stores

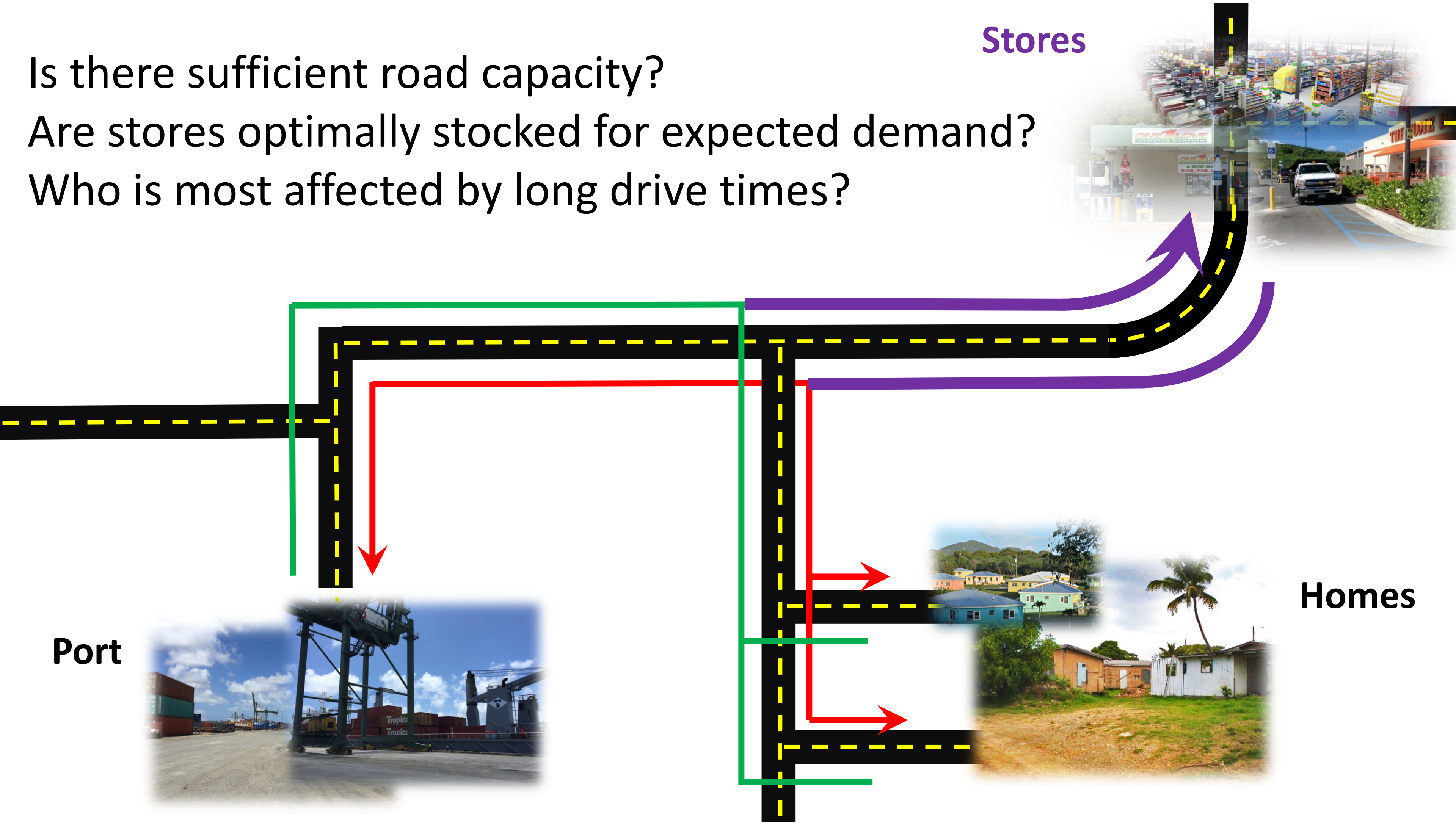
Is there sufficient road capacity?

Are stores optimally stocked for expected demand?

Understanding Traffic Demand (Congestion): Combined Model

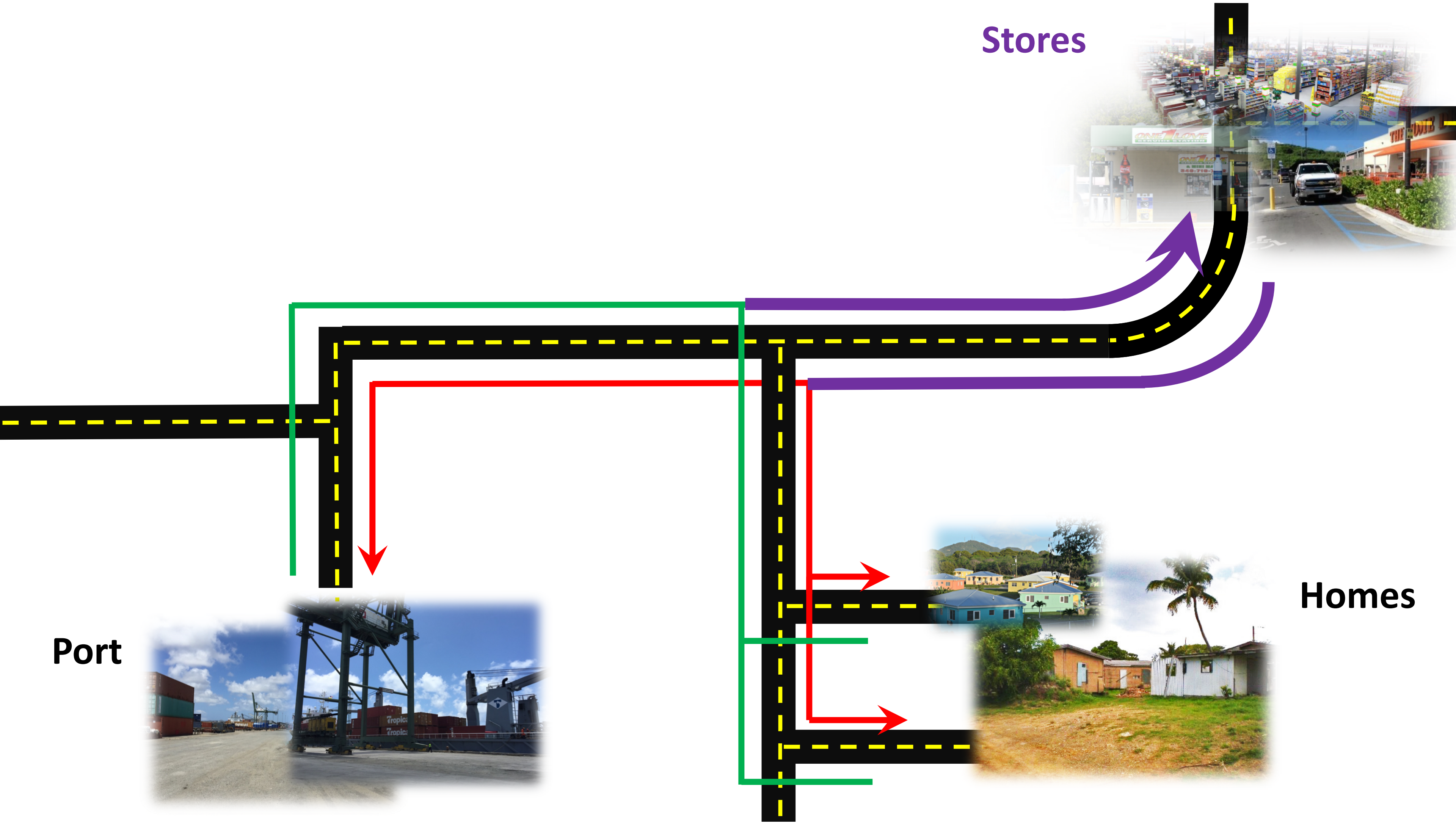
Shared: Roads and Stores

Is there sufficient road capacity?
Are stores optimally stocked for expected demand?
Who is most affected by long drive times?



On-going Work: Sponsor Interest

What ifs?

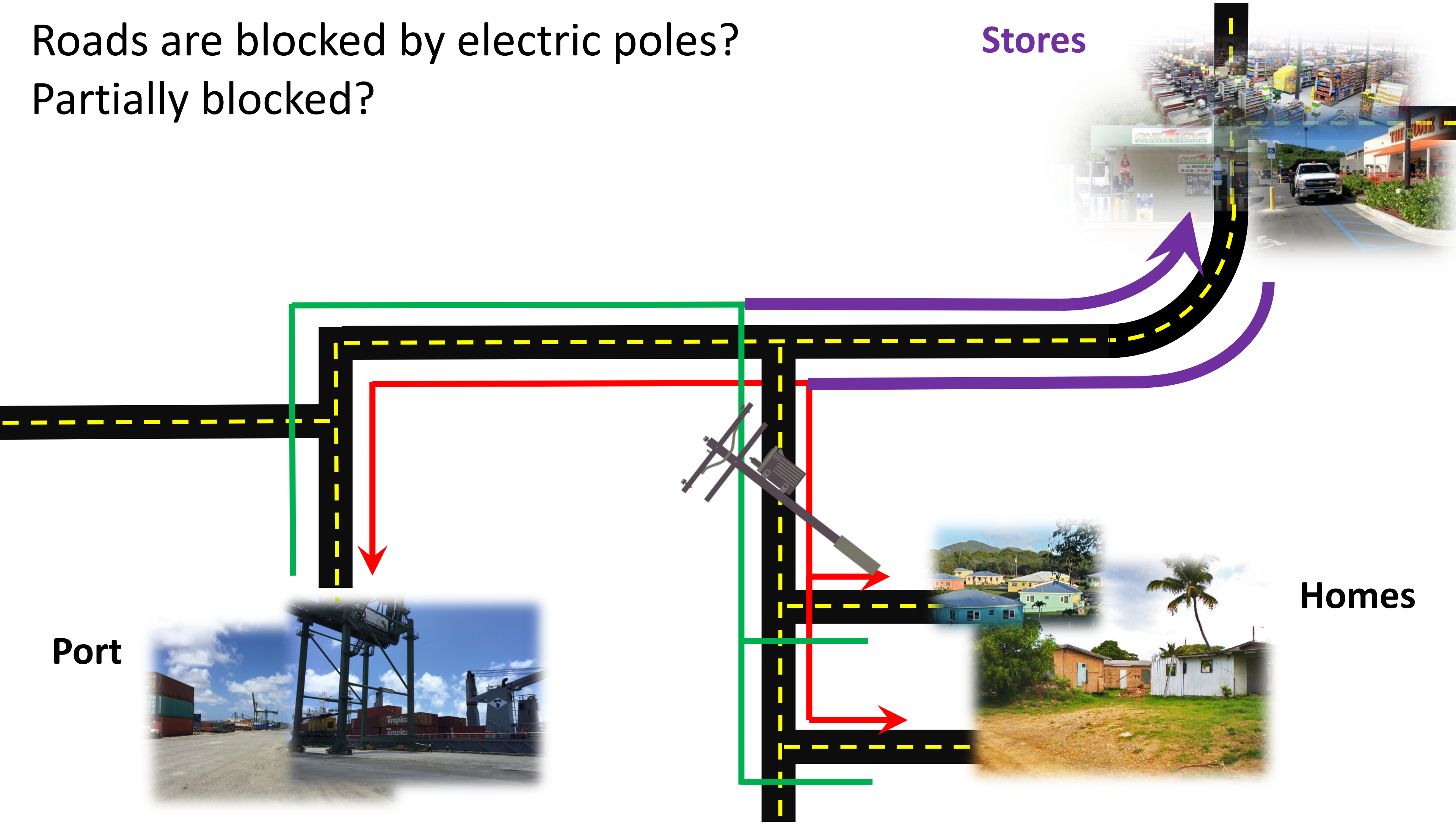


On-going Work: Sponsor Interest

What ifs?

Roads are blocked by electric poles?

Partially blocked?



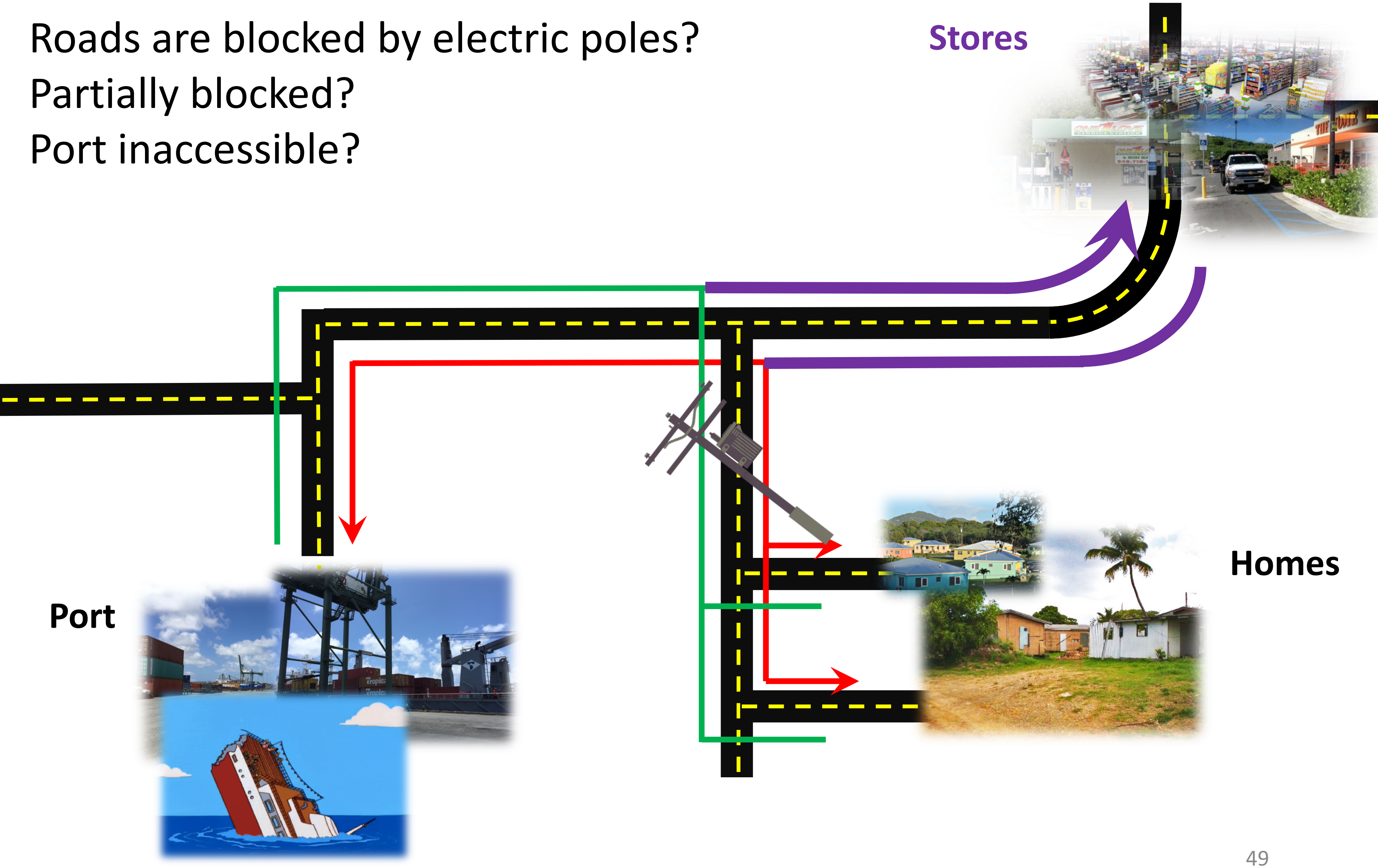
On-going Work: Sponsor Interest

What ifs?

Roads are blocked by electric poles?

Partially blocked?

Port inaccessible?



On-going Work: Sponsor Interest

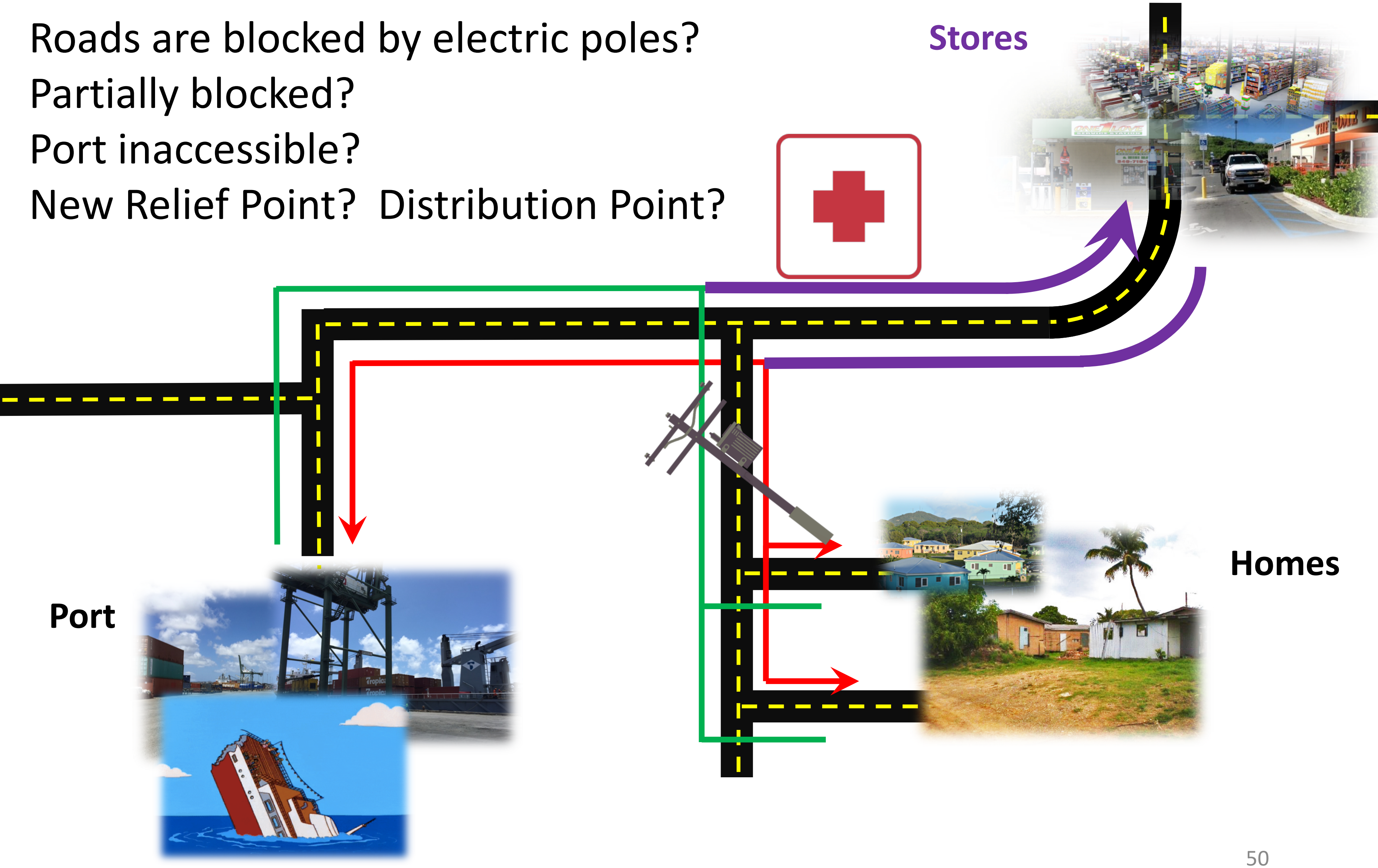
What ifs?

Roads are blocked by electric poles?

Partially blocked?

Port inaccessible?

New Relief Point? Distribution Point?



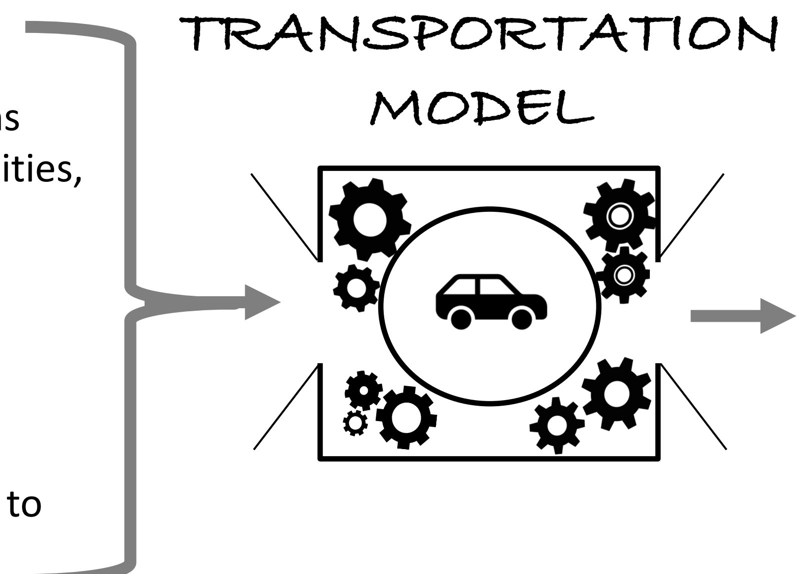
St. Croix Road Transportation *Operator Model*

- **Traffic origins:** 233 Estates + 1 Port
- **Traffic destinations:** 38 (grocery, gas, hardware)
- **Road network:** 2,353 road segments (3 types)
- **Equilibrium model:** given available roads and congestion, how *should* traffic flow between origins and destinations to minimize overall travel time

---

Road Network Data:
- Estates + Populations
- Roads: Types, Capacities, Distances
- Store locations
- Relief locations

Scenario Data:
- Traffic demands
- Availability/damage to road segments



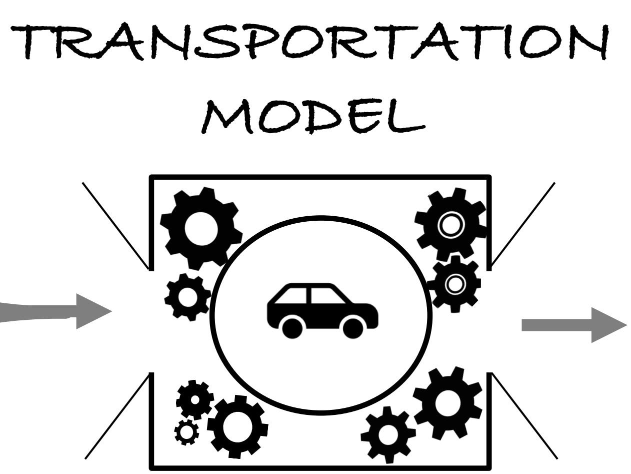
The “best” routes for traffic:
- routes

to minimize travel times
- traffic flows
- round trip times
- time lost in congestion

Results: Insufficient Capacity with “Selfish” Routing

Road Network Data:
- Estates + Populations
- Roads: Types, Capacities, Distances
- Store locations
- Relief locations

Scenario Data:
- Traffic demands
- Availability/damage to road segments



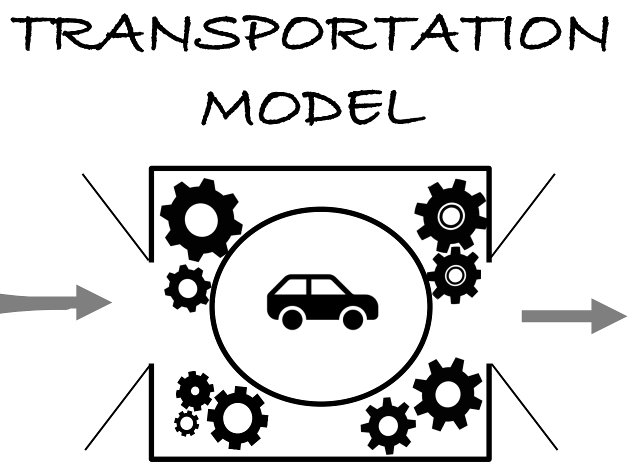
The “best” routes for traffic:
- routes

to minimize travel times
- traffic flows
- round trip times
- time lost in congestion

Results: Routing of Longest Travel Times for All Store Types

Road Network Data:
- Estates + Populations
- Roads: Types, Capacities, Distances
- Store locations
- Relief locations

Scenario Data:
- Traffic demands
- Availability/damage to road segments



The "best" routes for traffic:
- routes

to minimize travel times
- traffic flows
- round trip times
- time lost in congestion

Our work in the USVI: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

Our work in the USVI: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

Telecommunication systems are different from other public infrastructures:

- prevalence of private companies who tend to hide system details
- virtual nature of internet connectivity and related "cloud-based" services

Result: need to combine measurement, modeling, and analysis

Our Focus: connectivity models of Internet & digital services in VI Territory

- Physical – above/below ground, undersea, fiber/wireless, etc.
- Logical – intra/inter island, organizational, etc.

Modeling and Analysis of USVI Territorial Internet Infrastructure

Goals:

- Model-based assessment of Internet & digital services in VI Territory during normal and post-hurricane conditions
- Inform efficacy/prioritization of new telecom investment

Modeling and Analysis of USVI Territorial Internet Infrastructure

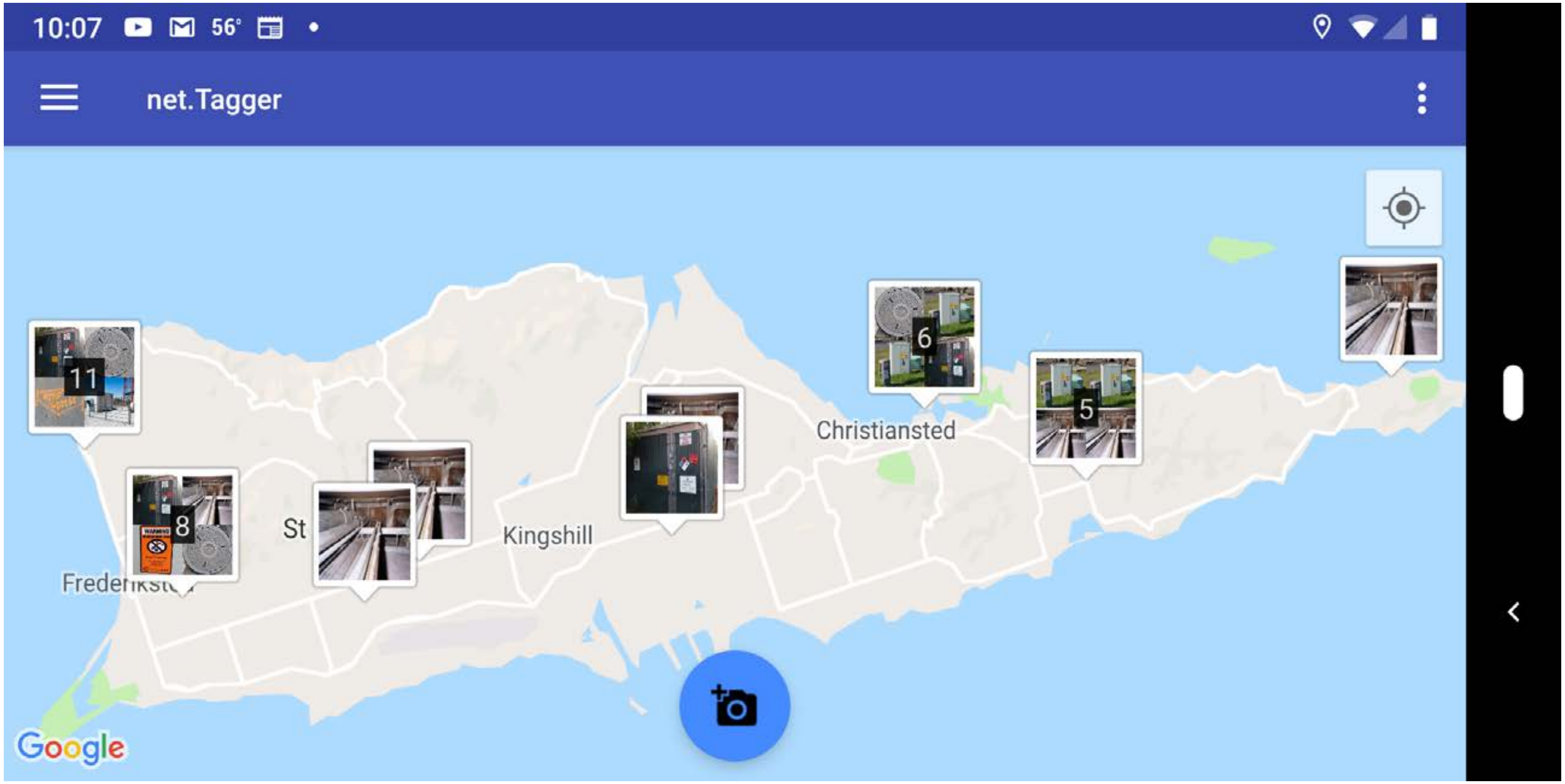
Goals:

- Model-based assessment of Internet & digital services in VI Territory during normal and post-hurricane conditions
- Inform efficacy/prioritization of new telecom investment

Methodology:

- Gather available data from viNGN and other stakeholders
- Supplement physical topology data with crowd-sourced data
  - net.tagger app (https://www.cmand.org/tagger/)

Supplementing physical topology: `net.tagger`



- Crowd-source physical communications infrastructure data
- App publicly available for Android/iPhone – anyone can contribute

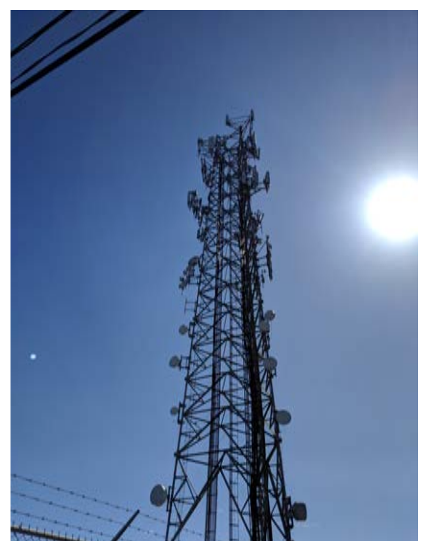
net.tagger sample tags

buried/hidden infrastructure




Infrastructure condition


wireless



power dependency

Modeling and Analysis of USVI Territorial Internet Infrastructure

Goals:

- Model-based assessment of Internet & digital services in VI Territory during normal and post-hurricane conditions
- Inform efficacy/prioritization of new telecom investment

Methodology:

- Gather available data from viNGN and other stakeholders
- Supplement physical topology data with crowd-sourced data
  - net.tagger app (https://www.cmand.org/tagger/)

Modeling and Analysis of USVI Territorial Internet Infrastructure

Goals:

- Model-based assessment of Internet & digital services in VI Territory during normal and post-hurricane conditions
- Inform efficacy/prioritization of new telecom investment

Methodology:

- Gather available data from viNGN and other stakeholders
- Supplement physical topology data with crowd-sourced data
  - net.tagger app (https://www.cmand.org/tagger/)
- Supplement logical topology data with Internet measurements
  - Yarrp measurement scans hosted at UVI St. Croix and worldwide (https://www.cmand.org/yarrp/)
  - CAIDA Ark historical and new measurements (http://www.caida.org/projects/ark/)
    New Ark node top be installed at UVI St. Croix (Oct 2019)

Ongoing Work: infrastructure interdependence

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications & Internet

Electric Power Model

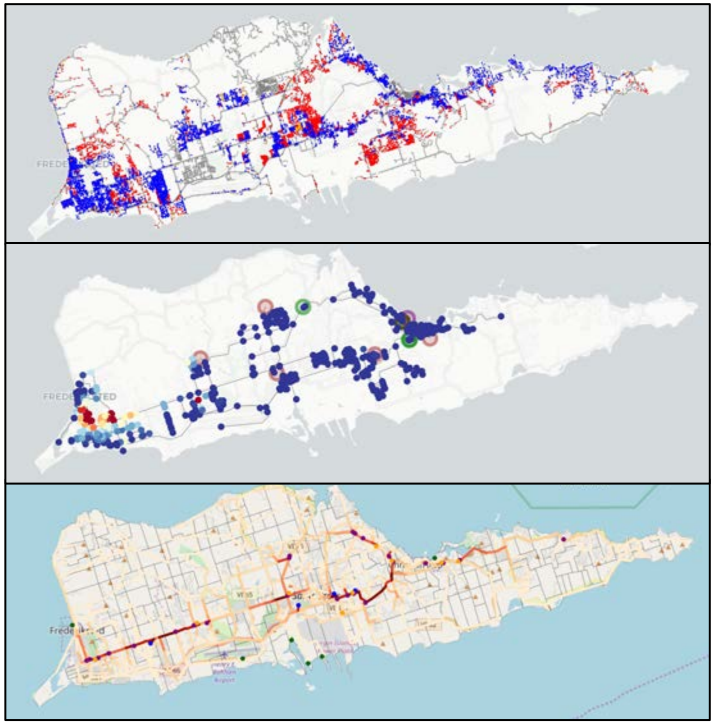
- Determine optimal load shed to keep critical loads running

Water Distribution Model

- Identify where water services will be lost when pumps & tanks fail

Transportation Model

- Measure optimal supply and roadway congestion post-disaster



Our work in the USVI: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications

Effort 2 - Support for development of a new Hazard Mitigation and Resilience Plan

- in partnership with UVI / VITEMA (POC: Kim Waddell, Greg Guannel)

Effort 3 - Capacity building & workforce development program

- in partnership with UVI (POC: David Morris, Greg Guannel)

How does this work help with risk and resilience?

How does this work help with risk and resilience?

CISA = Cybersecurity and Infrastructure Security Agency, https://www.dhs.gov/cisa

How does this work help with risk and resilience?

A Simplified View of Traditional Risk Analysis

Identify
- scenarios
- events
- threats

Assess
- likelihoods
- impacts

Evaluate
- risks
- average losses
- scores

Decide
- Avoid
- Mitigate
- Transfer
- Retain

CISA = Cybersecurity and Infrastructure Security Agency, https://www.dhs.gov/cisa

How does this work help with risk and resilience?

CISA Strategic Risk Management Process

A Simplified View of Traditional Risk Analysis

Identify
- scenarios
- events
- threats

Assess
- likelihoods
- impacts

Evaluate
- risks
- average losses
- scores

Decide
- Avoid
- Mitigate
- Transfer
- Retain

- You cannot predefine all threats!
- You will be surprised!

CISA = Cybersecurity and Infrastructure Security Agency, https://www.dhs.gov/cisa

Idea #1: **Start by focusing on delivery of services**, not mitigation of hazards/threats

Idea #1: **Start by focusing on delivery of services**, not mitigation of hazards/threats

What we need to do
(operation)

- Electricity
- Fuels
- Transportation
- Communications
- Water & Wastewater
- Emergency response

Idea #1: **Start by focusing on delivery of services**, not mitigation of hazards/threats

What we need to do (operation)	**What can go wrong** (interdiction)

What we need to do (operation)

- Electricity
- Fuels
- Transportation
- Communications
- Water & Wastewater
- Emergency response

What can go wrong (interdiction)

- Extreme Weather
  - Coastal Flooding
  - Rainfall Flooding
  - Wind
  - Drought
- Human accident
- Technological failure
- Deliberate attack

Idea #1: **Start by focusing on delivery of services**, not mitigation of hazards/threats

What we need to do (operation)	**What can go wrong** (interdiction)

What we need to do (operation)

- Electricity
- Fuels
- Transportation
- Communications
- Water & Wastewater
- Emergency response

What can go wrong (interdiction)

- Extreme Weather
  - Coastal Flooding
  - Rainfall Flooding
  - Wind
  - Drought
- Human accident
- Technological failure
- Deliberate attack

Idea #2: **Avoid getting stuck on predefined threat scenarios.**

- Surprise Happens. Things we have not imagined.
- Tunnel vision (on the last disaster). Need to be proactive, not reactive.

How does this work help with risk and resilience?

CISA = Cybersecurity and Infrastructure Security Agency, https://www.dhs.gov/cisa

How does this work help with risk and resilience?

How does this work help with risk and resilience?

- You cannot predefine all scenarios!
- You will be surprised!

How does this work help with risk and resilience?

- You cannot predefine all scenarios!
- You will be surprised!

What about resilience?

Resilience is not about *what you have*, its about *what you do!*

This is a common misperception.

Think of safety as a similar concept…

Resilience is not about *what you have*, its about *what you do!*

This is a common misperception.

Think of safety as a similar concept…

Think of resilience as a verb, not a noun!

Resilience is not about *what you have*,
its about *what you do!*

This is a common misperception.

Think of safety as a similar concept…

Think of resilience as a verb, not a noun!
resiliency

Resilience is not about *what you have*, its about *what you do!*

This is a common misperception.

Think of safety as a similar concept…

Think of resilience as a verb, not a noun!

~~resiliency~~

Resilience is not about *what you have*, its about *what you do!*

This is a common misperception.

Think of safety as a similar concept…

Think of resilience as a verb, not a noun!

~~resiliency~~

Our focus: Continued function of lifeline systems.

Resilience ≈ "being poised to adapt"

Emphasize active processes

Sensing • Anticipating • Adapting • Learning

Reference: Park J, Seager T, Rao P, Convertino M, Linkov I. Integrating risk and resilience approaches to catastrophe management in engineering systems. Risk Analysis. 2013, 23(3):356-367.

Our work in the USVI: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications

Effort 2 - Support for development of a new Hazard Mitigation and Resilience Plan

- in partnership with UVI / VITEMA (POC: Kim Waddell, Greg Guannel)

Effort 3 - Capacity building & workforce development program

- in partnership with UVI (POC: David Morris, Greg Guannel)


UVI
UNIVERSITY OF THE VIRGIN ISLANDS
1962

Effort 3 - Capacity building & workforce development program

Coursework + Internship + Mentorship

I am INQUISITIVE.

I am INVOLVED.

I am INNOVATIVE.

I am READY.

I am INQUISITIVE.

I am INVOLVED.

I am INNOVATIVE.

I am READY.

Effort 3 - Capacity building & workforce development program

Coursework + Internship + Mentorship

Students learn about a diversity of topics:

- technological systems (a.k.a. built infrastructure)
- human systems (a.k.a. social infrastructure)
- environmental systems (a.k.a. natural infrastructure)

Effort 3 - Capacity building & workforce development program

Coursework + Internship + Mentorship

Students learn about a diversity of topics:
- technological systems (a.k.a. built infrastructure)
- human systems (a.k.a. social infrastructure)
- environmental systems (a.k.a. natural infrastructure)

Students intern at local organizations:
- Infrastructure operators
- Local government
- Non-government organizations

I am INQUISITIVE.

I am INVOLVED.

I am INNOVATIVE.

I am READY.

I am INQUISITIVE.

I am INVOLVED.

I am INNOVATIVE.

I am READY.

<u>Effort 3</u> - Capacity building & workforce development program

Coursework + Internship + Mentorship

Students learn about a diversity of topics:
- technological systems (a.k.a. built infrastructure)
- human systems (a.k.a. social infrastructure)
- environmental systems (a.k.a. natural infrastructure)

Students intern at local organizations:
- Infrastructure operators
- Local government
- Non-government organizations

Students reflect on their experience
- Shared experience informs multiple perspectives
- New perspectives => new insights

Students are prepared to enter the workforces as agents of innovation and change.

Our work in the USVI: several related research efforts

Effort 1 - Modeling and analysis of interdependent critical infrastructure systems

- Energy (emphasis on electric power)
- Water (emphasis on potable storage and distribution)
- Transportation & Supply Chains
- Telecommunications

Effort 2 - Support for development of a new Hazard Mitigation and Resilience Plan

- in partnership with UVI / VITEMA (POC: Kim Waddell, Greg Guannel)

Effort 3 - Capacity building & workforce development program

- in partnership with UVI (POC: David Morris, Greg Guannel)

Contact Information

- Dr. David Alderson

  Director, Center for Infrastructure Defense

  Naval Postgraduate School

  831-656-1814, dlalders@nps.edu

  http://faculty.nps.edu/dlalders

- Dr. Daniel Eisenberg

  Deputy Director, Center for Infrastructure Defense

  Naval Postgraduate School

  831-656-2358, daniel.eisenberg@nps.edu

  http://faculty.nps.edu/deisenberg

- NPS Center for Infrastructure Defense

  http://www.nps.edu/cid