G7 ITALIA 2024

MOST CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

POLITECNICO MILANO 1863

G7 Transport Academic Workshop

Behavioral Models and Microsimulation for Passenger and Freight Resiliency Analyses

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Politecnico di Milano, Bovisa Campus, Milan (Italy)

Outline

- Black Swan Events (BSE)
- Impacts of BSE
- Simulation Laboratory
- Application: Transit Disruptions in Singapore
- Conclusion

Black Swan Events (BSE)

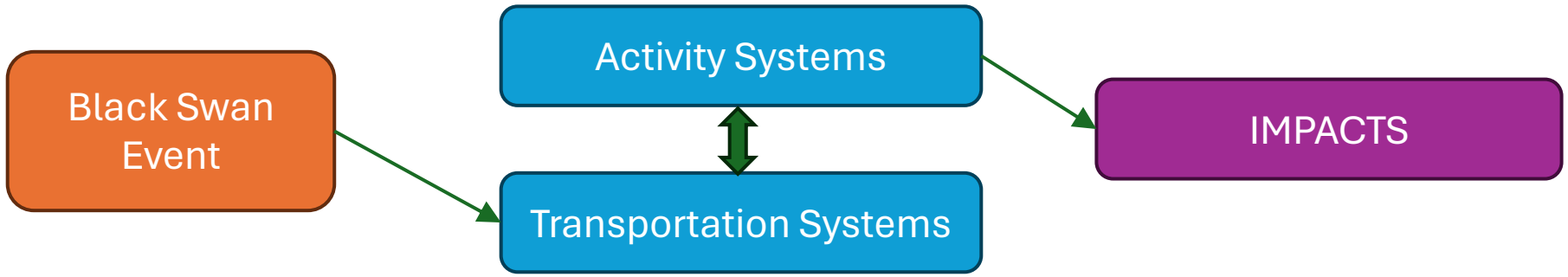
- Unpredictable events with severe consequences for many
  - Pandemic
  - Extreme weather
  - Infrastructure disruption
  - Strikes/labor disputes
  - Cyberattacks
  - Terrorism/war

How to prepare for a diverse array of disruptions?

BSE and Transportation

How do these events affect transport?

- Supply side → connectivity, capacity, recovery time
- Demand side → essential human needs
  - Physiological (e.g., food, water, shelter, clothing)
  - Safety & security (e.g. health services, personal security, income/employment)



Evaluation of preparedness measures should be based on the demand!

Preparedness Measures

Measures are both by *design* and *intervention*

Supply-side

- Redundancy
- Diversity
- Modularity of the transportation system
- Driving restrictions
- etc.

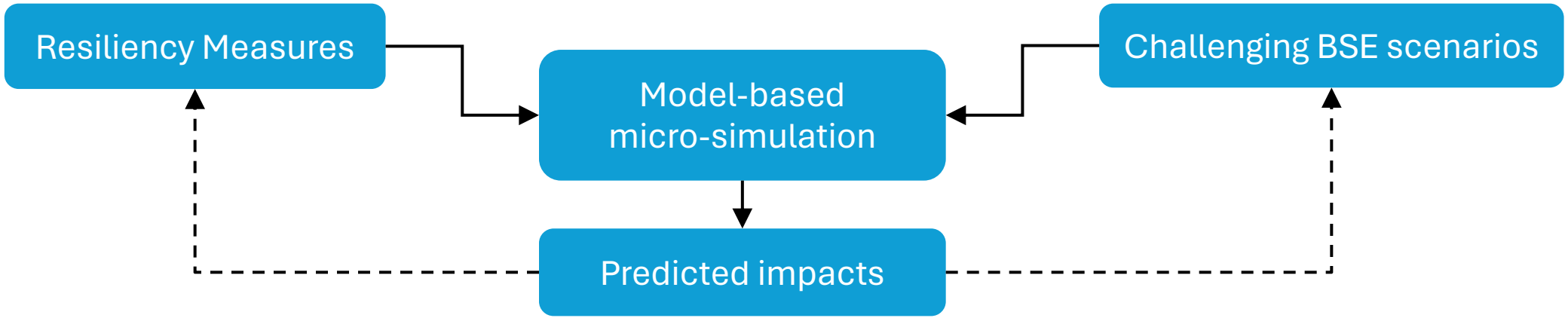
Demand-side

- Pre-positioning of emergency supplies
- Telecom activities (remote work, telemed)
- etc.

Resiliency is a ‘system of systems’ problem

Impact Prediction

- We observe the behavior of *existing* transport *users*, however…
  - the **impacts** of a *specific* BSE on *specific users* and *specific* human *needs* are by definition **unobservable**
- Thus, prediction of impacts cannot be exclusively data-driven but requires **modeling** and **simulation experiments**



Simulation Laboratory: SimMobility

- **SimMobility**: an integrated simulation platform for analyzing future mobility scenarios
  - Agent-based (individual and business establishment)
  - Activity-based (derived demand)
  - Multi-modal
  - Multi-sectoral (passenger and freight)
  - Multiple spatial-temporal scales
  - Fully integrated and modular

SimMobility Structure

Long-Term

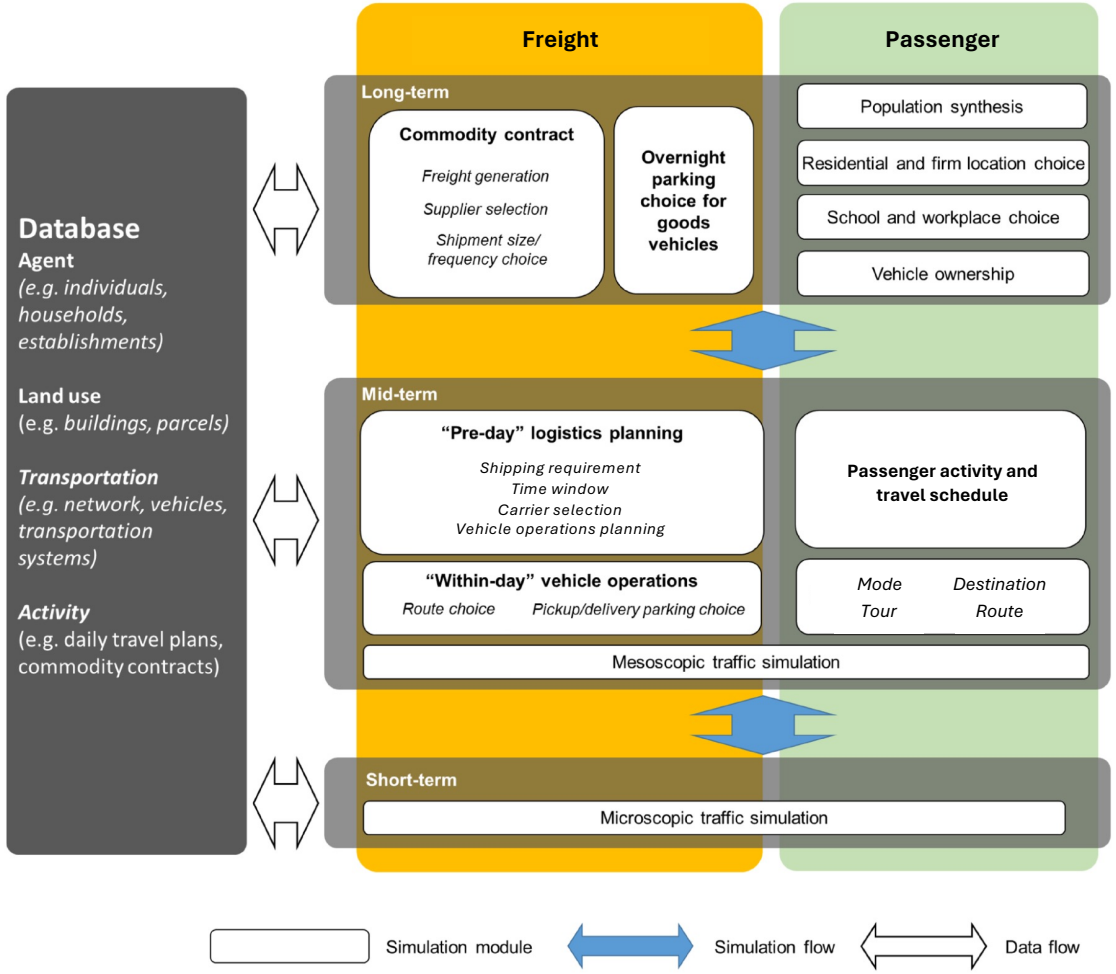
- Month-to-month and year-to-year behavioral dynamics

Mid-Term

- Day-level dynamics of transportation demand and supply for passenger and goods

Short-Term

- Fractions of a second traffic dynamics



Multi-Modal and Multi-Agent

- Demand
  - Individuals (including drivers)
  - Households
  - Establishments/Firm
- Supply
  - Transit operators
  - Fleet operators/managers (incl. on-demand services, taxis, freight carriers)
  - Network operators (incl. information providers)
  - Real-estate developers
  - Infrastructure (incl. traffic signals, loop detectors)

Multiple Temporal Scales

Short-Term

- Early warning systems
- Emergency response plans
- Traffic control

Medium-Term

- Policy measures
- Work-from-Home policies
- Pricing & incentives
- Humanitarian logistics
- Drainage and pumping
- Protecting Infrastructure

Long-Term

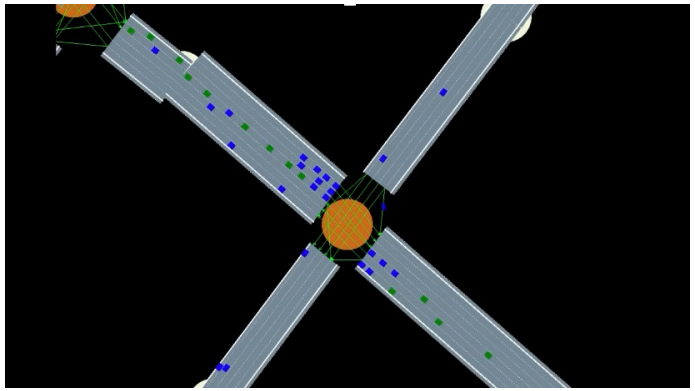
- Infrastructure retrofitting (elevated structures)
- Sustainable development
- Soft infrastructure (wetlands, forests)
- Land-use policy

SHORT-TERM
Microscopic - fractions of a second

MID-TERM
Day-level dynamics

LONG-TERM
Month-to-month and year-to-year dynamics

Multiple Spatial Scales

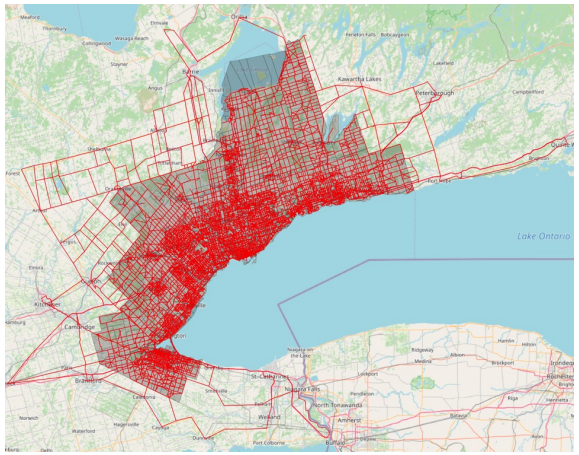


Lane Level

Network Level

A Small Network

A toy city of 13 km x 11.5 km, 254 links



A Large Network

Greater Toronto and Hamilton Area, 56.6 K links

SimMobility Applications

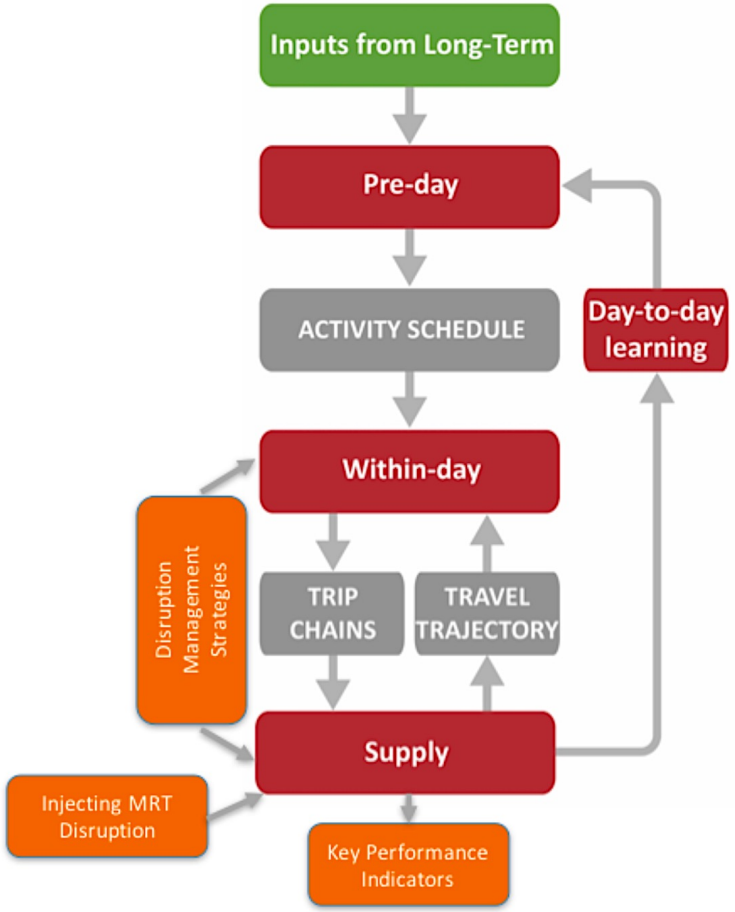
- Automated Mobility-on-Demand
- Sustainability incentives
- Transit disruptions
- Transit pricing
- Overnight freight vehicle parking
- Freight consolidation centers
- Night/Off-peak deliveries
- Route restrictions
- Freight-on-Demand
- Congestion pricing
- Urban air mobility
- Mobility as a Service
- Post-pandemic changes in travel and activities

Application: Transit Disruptions in Singapore

SimMobility Mid-Term

Simulates daily travel at household and individual levels

- Activity-based demand with dynamic multi-modal assignment
- Three components:
  - Pre-day
  - Within-day
  - Supply



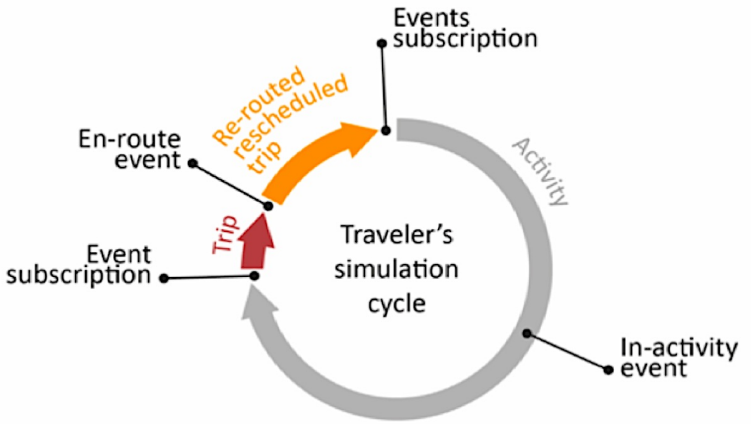
Adnan, M., Pereira, F. C., Azevedo, C. L., Basak, K., Koh, K., Loganathan, H., Peng, Z. H., & Ben-Akiva, M. (2016, November 30). Evaluating Disruption Management Strategies in rail transit using SIMMOBILITY mid-term Simulator: A study of singapore MRT North-East Line. Transportation Research Board 96th Annual Meeting. https://trid.trb.org/View/1439637

Application: Transit Disruptions in Singapore (2)

Publish/subscribe mechanism

Demand agent:

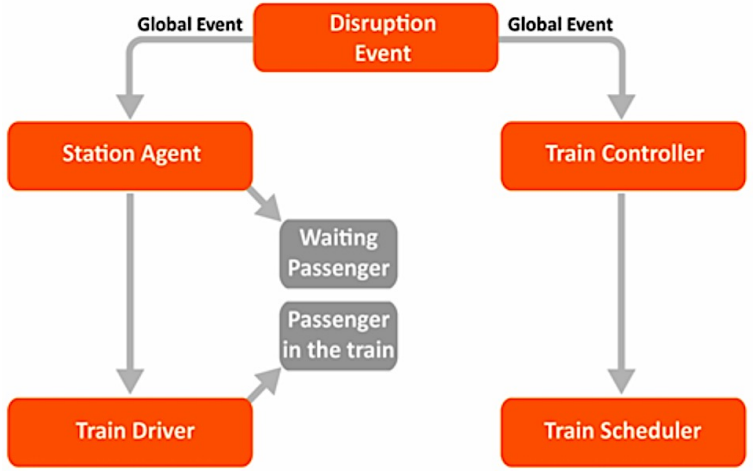
- Subscribe to events before starting trip (e.g., excessive delay, disruption, household interactions)
- After revising choice, changes in trip or activity are executed



MT Simulator-Event simulation cycle

Supply agent:

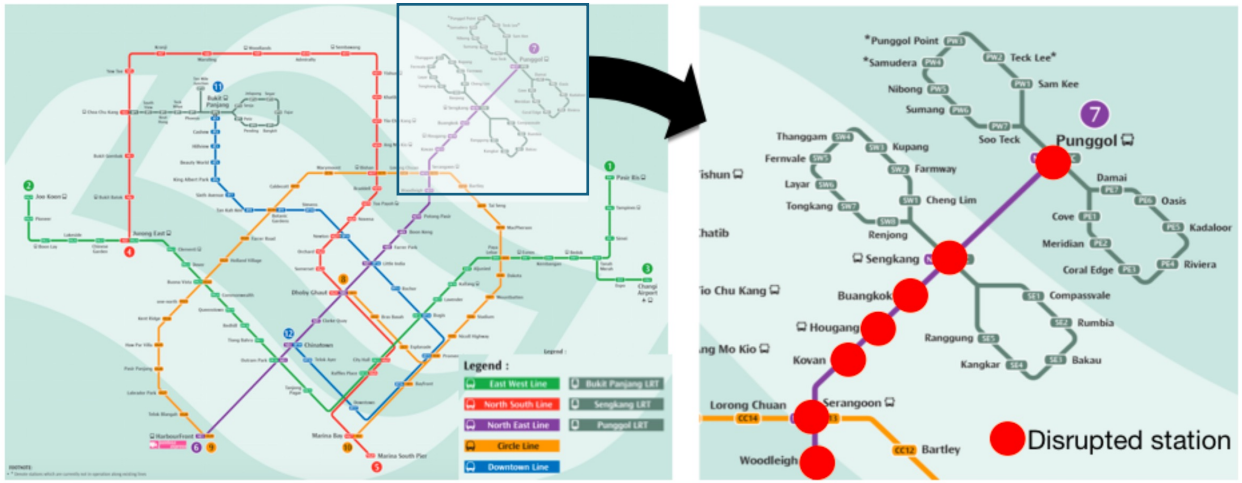
- Station agent: manages stations, transits information to passengers and train drivers
- Train controller: in charge of movement of the vehicles and transmits to train scheduler



Application: Transit Disruptions in Singapore (3)

Experiment design

- June 19, 2013 from 18:15-20:35: train stalled and caused disruption
- Simulate the impact of this historical event on peak hours (8 – 10 AM)
- Scenarios:
  - No disruption
  - Disruption with no extra service
  - Disruption with shuttle service: bus bridging between every two MRT connected stations among the disrupted stations

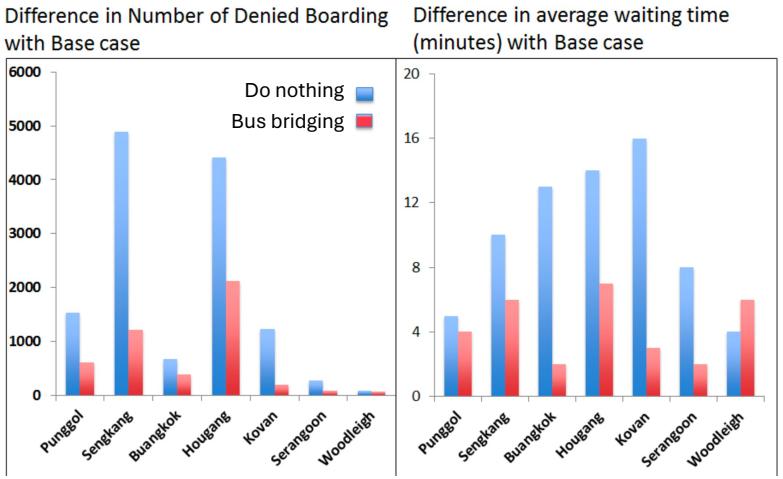


Singapore Mass-Rapid Transit Stations and Disrupted Stations

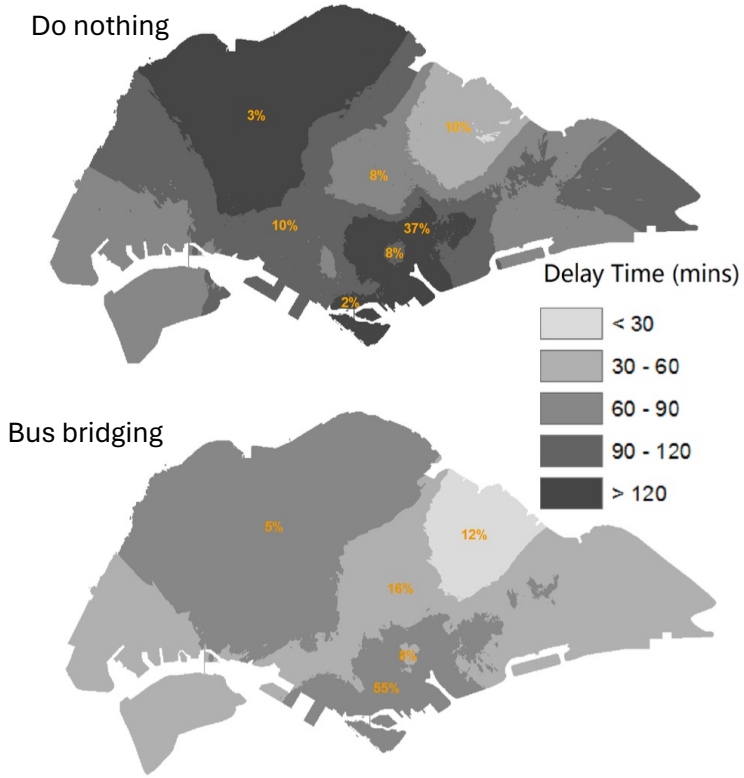
Application: Transit Disruptions in Singapore (4)

Results

- Bus bridging substantially reduces disruption delays
- Area most affected by the disruption is the central business district



Disruption delays



Spatial distribution of disruption delays across SG, by trip destination

*Map percentages: % of trips (that start or cross the MRT disrupted line) that end in that area, as an indicator of their relative importance.

Conclusion

- Resiliency is a system of systems problem
- Resiliency measures should be policy pathways
- Resiliency planning must involve search over carefully defined space of challenging scenarios
- Evaluation of investment priorities must depend on the demand for essential services
- Impact prediction requires a multi-agent, multi-modal and multi-sectoral model-based simulation laboratory

Thank you!

For additional information, see https://www.its.mit.edu/

Transportation Complexity

- Multi-modal integration
  - Private and public
  - Passenger and freight
  - Road, rail, water and air networks
- Varied temporal scales
  - Short-term (second)
  - Mid-term (day)
  - Long-term (month to year)
- Diverse geographical scales
  - Urban
  - Regional
  - National

How to plan for multi-layer complexity?

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