Reliable Facility Location: from Supply Chain Network Design to Traffic Sensor Deployment

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Reliable Supply Chain Design

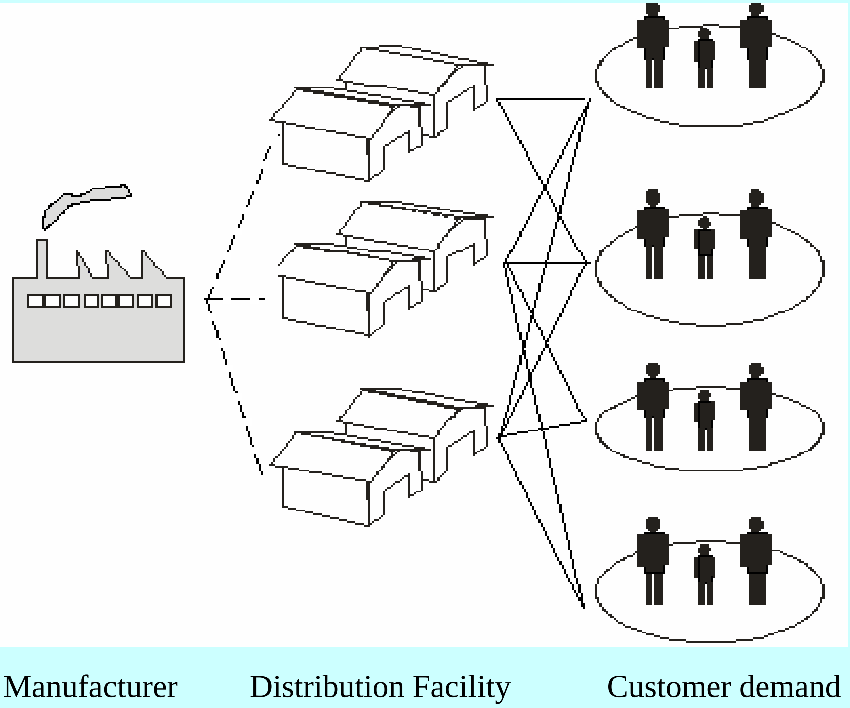
References

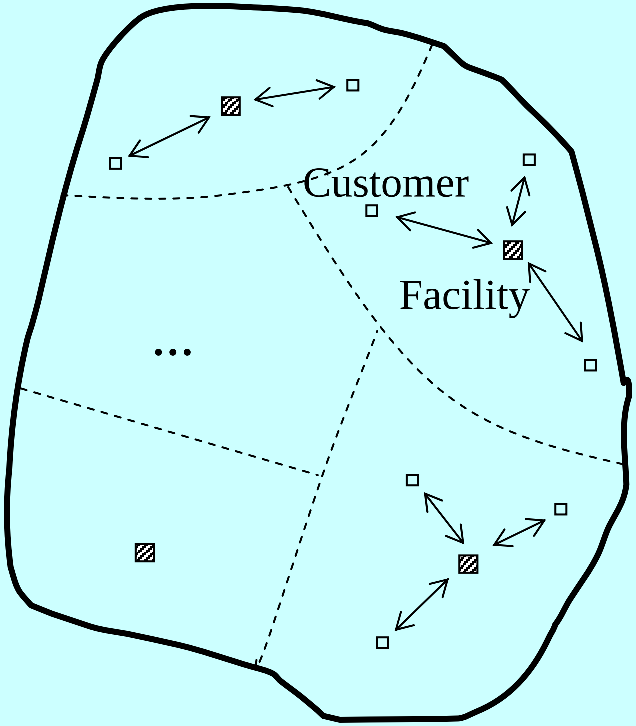
Li, X. and Ouyang, Y. (2009a) "A Continuum Approximation Approach to Reliable Facility Location Design under Correlated Probabilistic Disruptions." ***Transportation Research Part B***. In press.

Cui T., Ouyang, Y. and Shen, Z.J. (2009) "Reliable Facility Location under the Risk of Disruptions." ***Operations Research***. In press.

Introduction

- Location problem for supply chain design
  - Given customer distribution, find optimal facility number and location
  - Balance between <u>facility costs</u> and day-to-day <u>transportation costs</u>



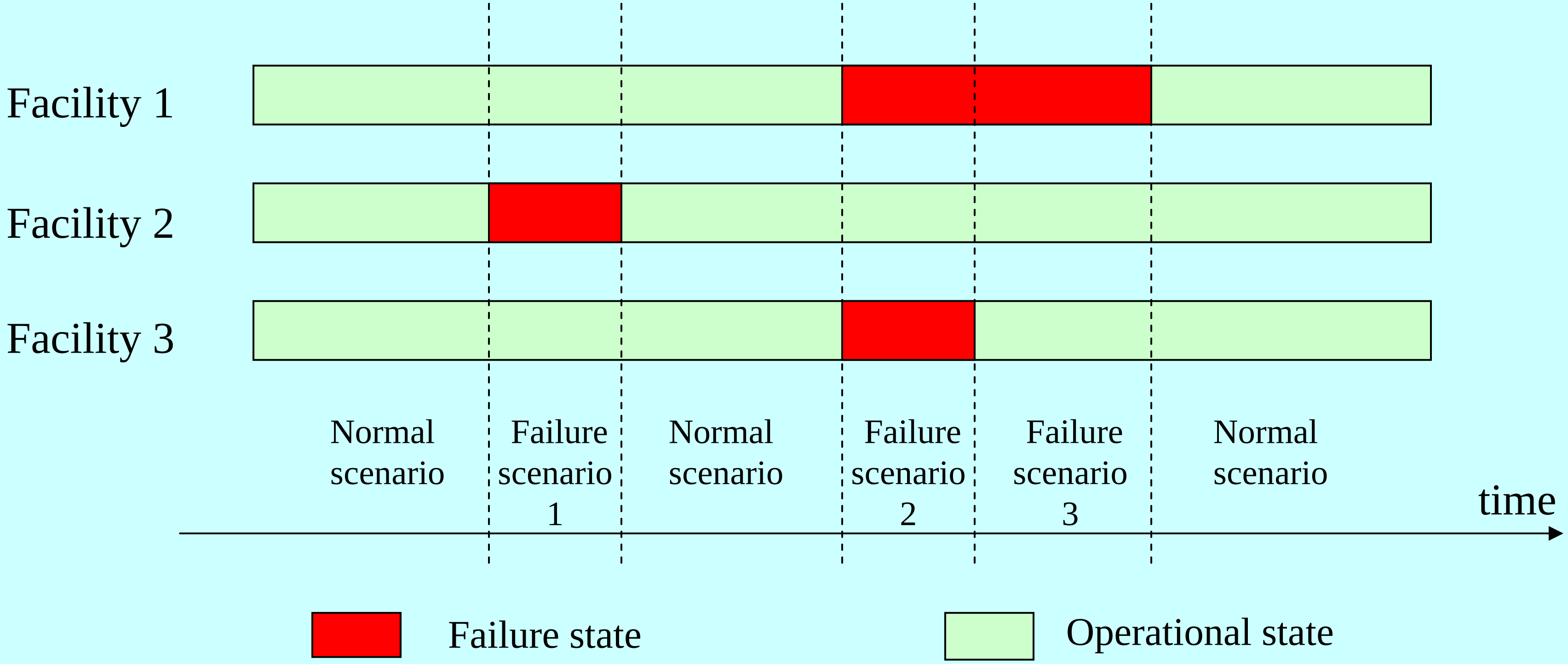


Facility Disruptions

- Classical location models assume that the facilities remain operational once built
- In reality, facilities may become unavailable from time to time
  - inclement environment
  - natural disasters
  - labor activities
  - terrorist attacks or military actions
  - pandemic outbreaks
- Examples
  - The 2005 Hurricane Katrina idled all facilities in the U.S. Gulf Coast region
  - The west-coast port lockout in 2002 strangled U.S. retailers' supply lines
  - The 2003 massive power outage in the Northeast disabled all major transportation modes in that region

Probabilistic Failure Scenarios

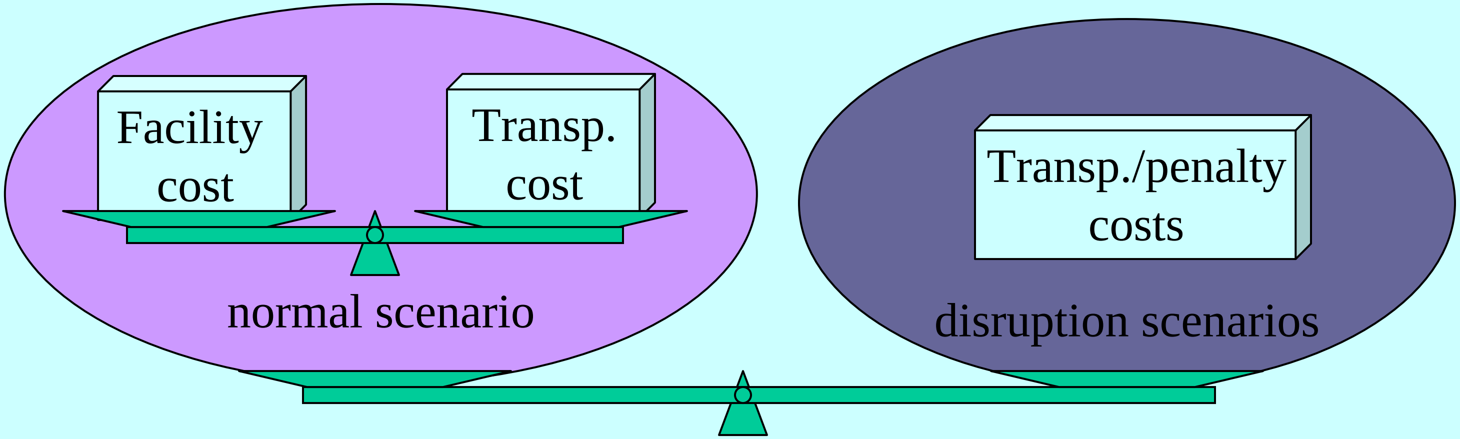
- Facility failure probability = long-term fraction of time for the facility to be in the failure state
- The number of failure scenarios *increases exponentially* with the number of facilities



Reliable Location

- When a facility fails, its customers
  - Seek more distant facilities (excessive transportation costs), or
  - Lose service (high penalty)

- Reliable planning against possible failure
  - Not only minimize facility and transportation costs in the normal scenario
  - But also hedge against costs under rare and unexpected disruptions



Assumptions

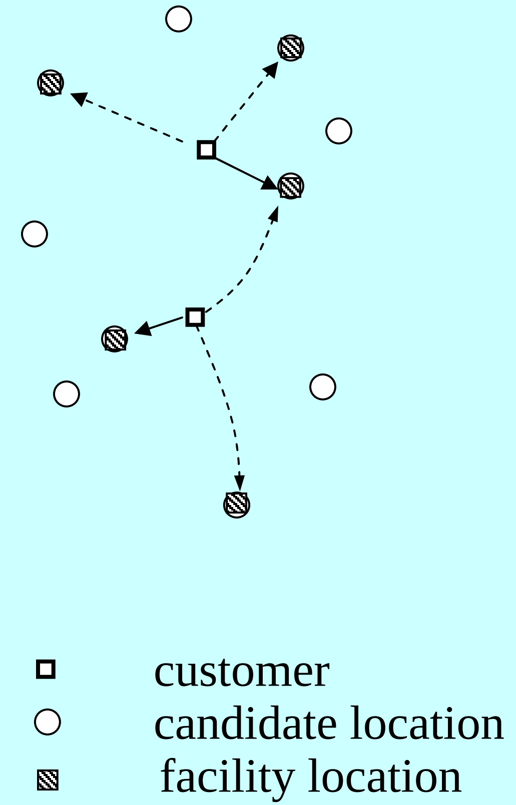
- Each facility is subject to probabilistic failure
- Failure probabilities are site-dependent and known *a priori*
- Facility failures are independent (or correlated)
- Customer demand known and deterministic
- Each customer is assigned to a number of facilities
- If all assigned facilities have failed, the customer incurs a penalty cost

The Discrete Model

Input
- Discrete customer demand
- Discrete candidate locations
- Facility costs
- Facility failure probabilities
- Maximum assignment level

determine:
- Facility number and locations
- Customer assignment plan
  (1st-choice facility, 2nd-choice facility, …)

Solved by Lagrangian relaxation and other techniques
- Solve moderate instances (up to 150 nodes, customers visit at most 4 facilities) to 1% gap within 3600 CPU seconds



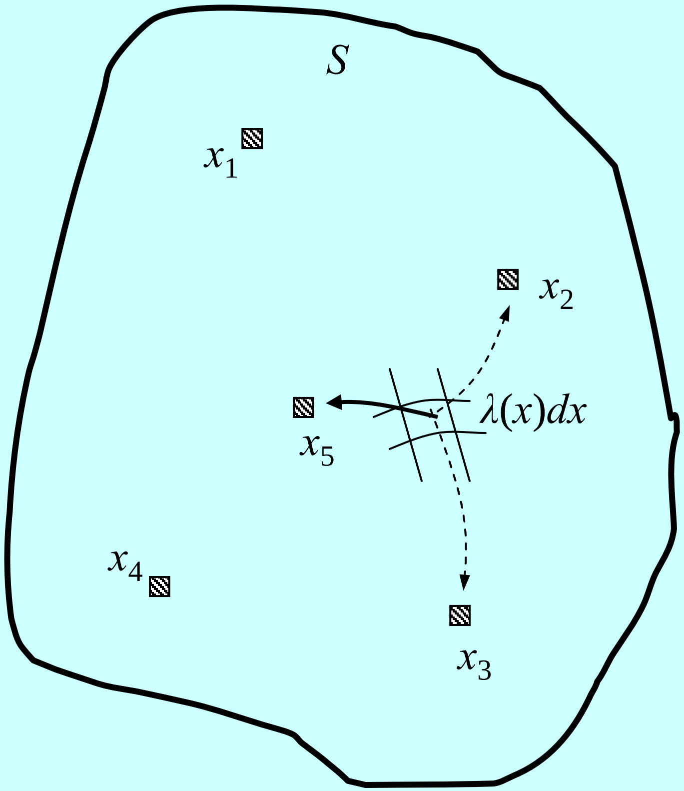
The Continuous Model

Continuous area S, at location x

- Customer demand density $\lambda(x)$
- Facility cost $f(x)$
- Failure probability $q(x)$
- Penalty cost $\varphi(x)$
- Maximum assignment level R

determine:

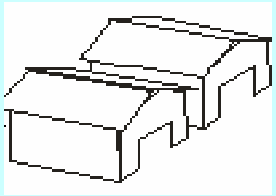
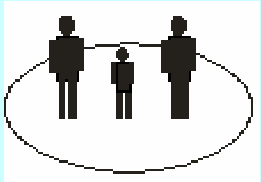
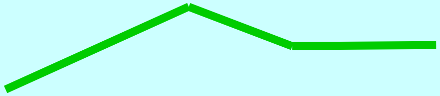
- Facility number
- Facility locations
- Customer assignment plan



Solved by the continuum approximation approach

- Quick approximate solution
- Near-optimum (~3% gap)

Supply Chain v.s. Traffic Sensor Network

	Supply chain	Traffic sensor network
Facility		
Service target		 
One-time cost	Facility construction	
Day-to-day cost	Transportation/delivery	Surveillance effectiveness/error

Reliable Traffic Sensor Deployment

References

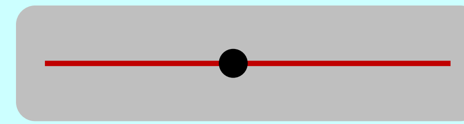
Li, X. and Ouyang, Y. (2009b) “Reliable sensor location model for network traffic surveillance.” ***Transportation Research Part B***. Revision under review.

Li, X. and Ouyang, Y. (2010) “A general framework for reliable deployment of traffic surveillance sensors.” ***Working Paper***.

Benefits from Deploying Traffic Sensors

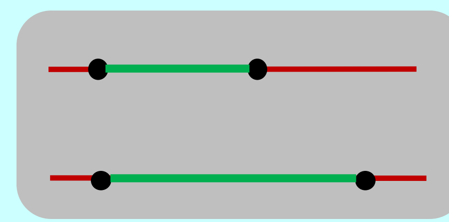
Flow Coverage (Single-Sensor Coverage)

- Aggregated traffic volume or vehicle count
- Speed
- Congestion at a point



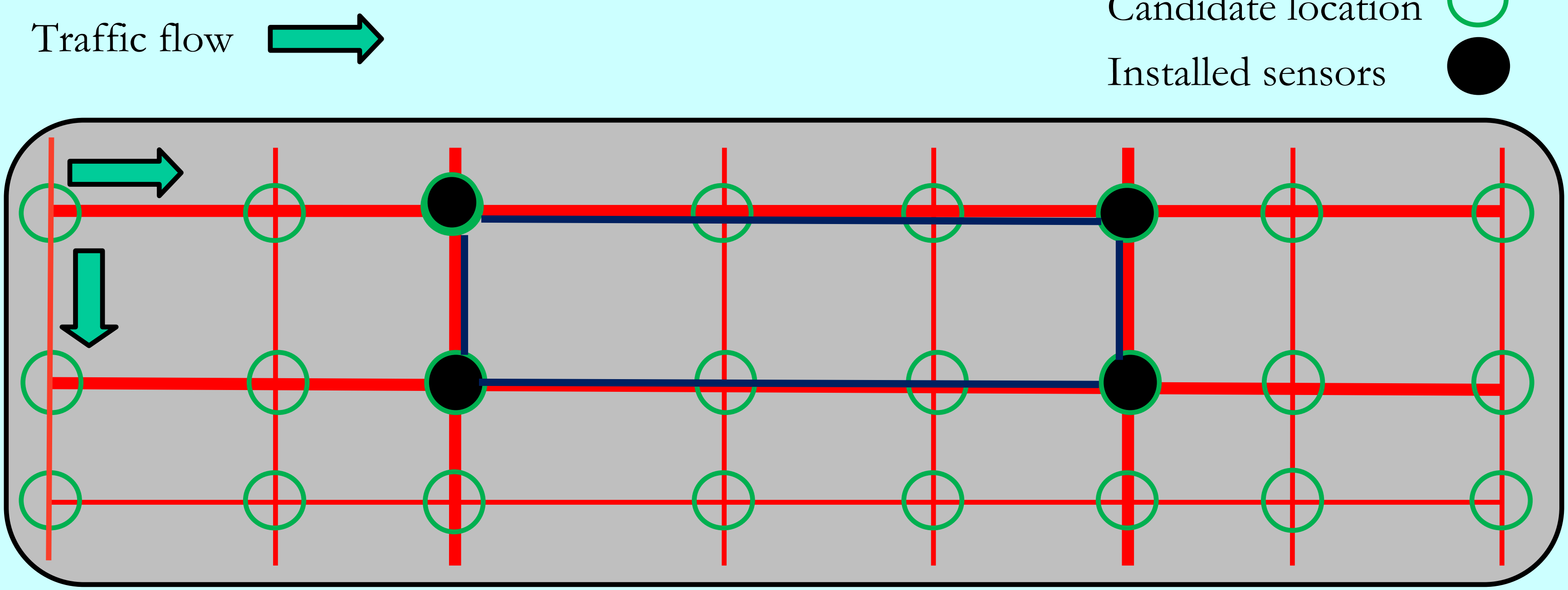
Path Coverage (Two-Sensor Coverage)

- Disaggregated vehicle information
- Travel time estimation
- Congestion over a segment



Reliable Sensor Location

- When traffic units flow on a general large-scale transportation network, where shall we install sensors to best monitor traffic condition?
  - Limited budget (i.e., # of sensor installations)
  - Flow coverage v.s. path coverage



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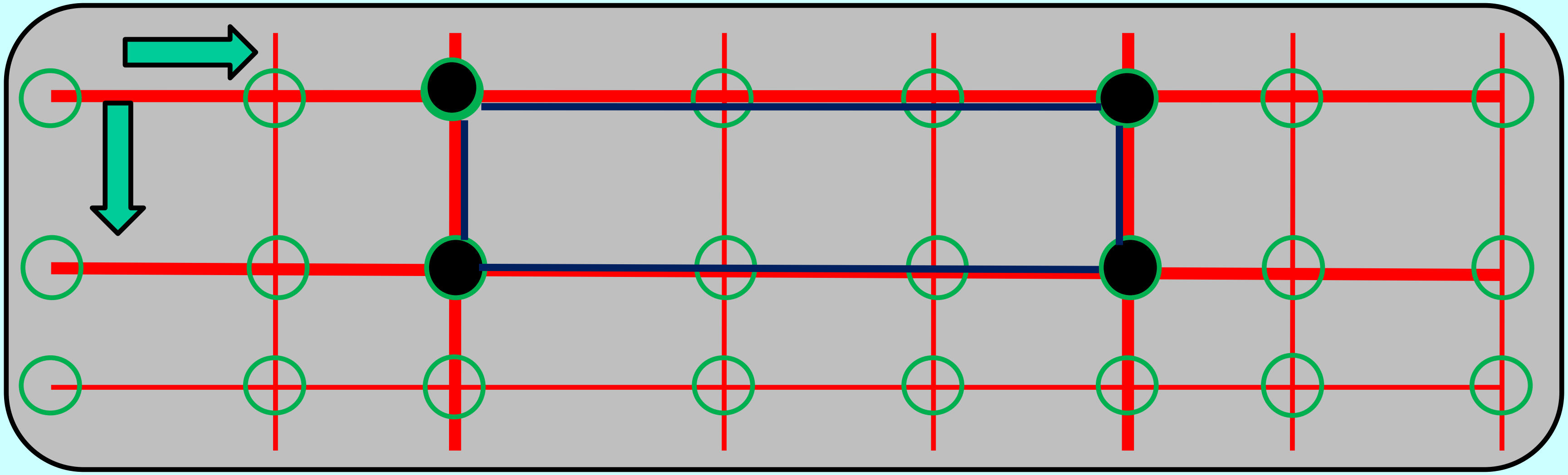
  - Known sensor failure probability



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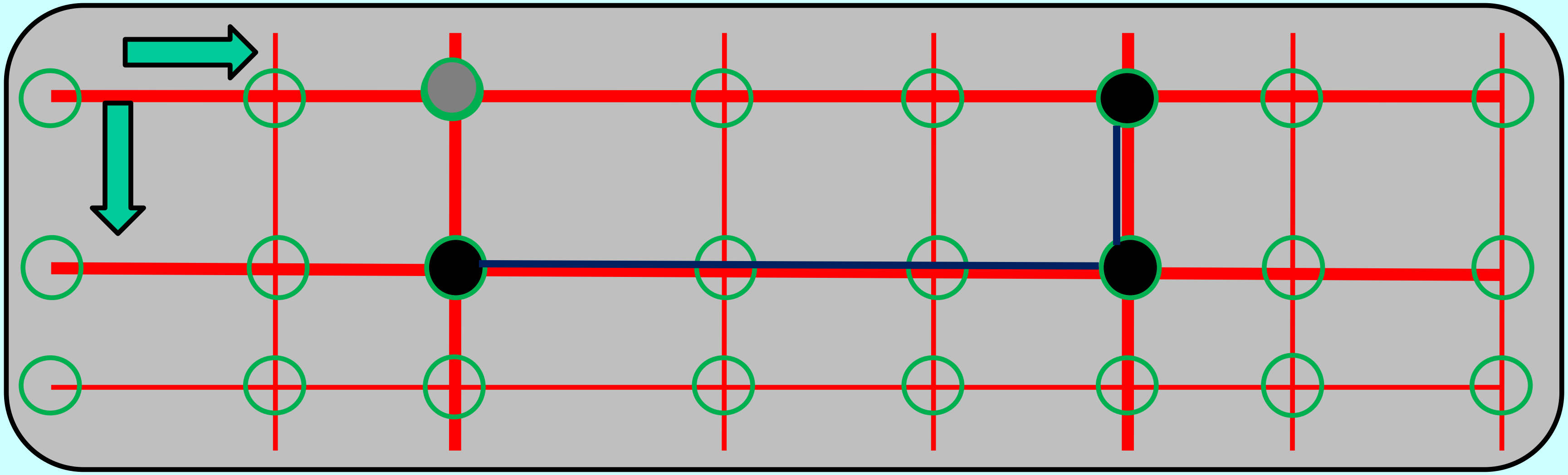

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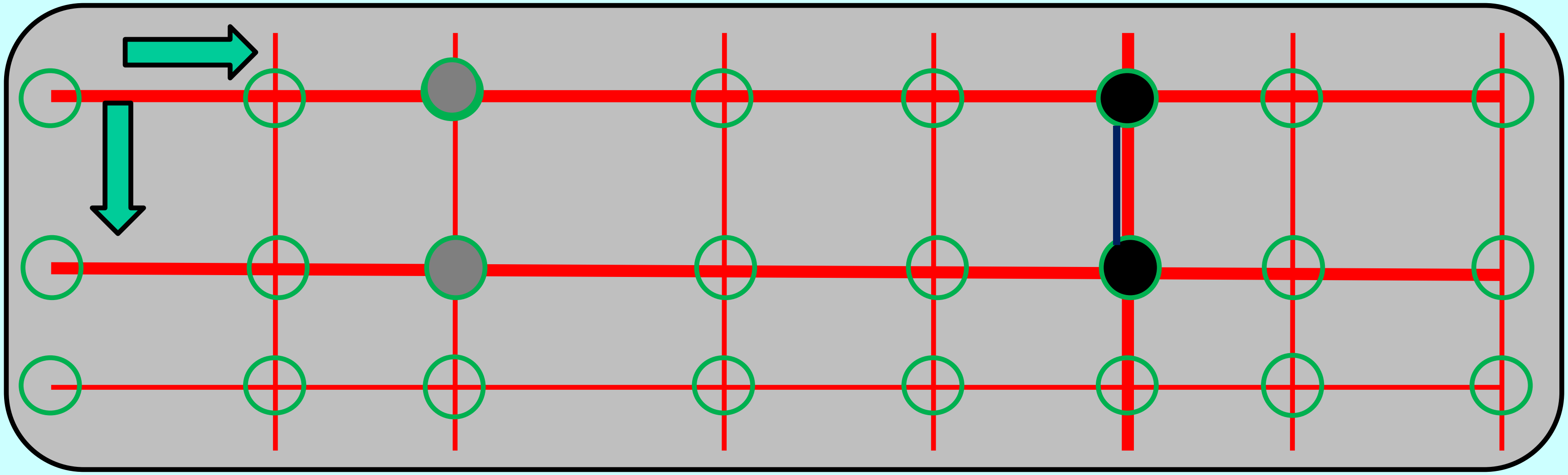

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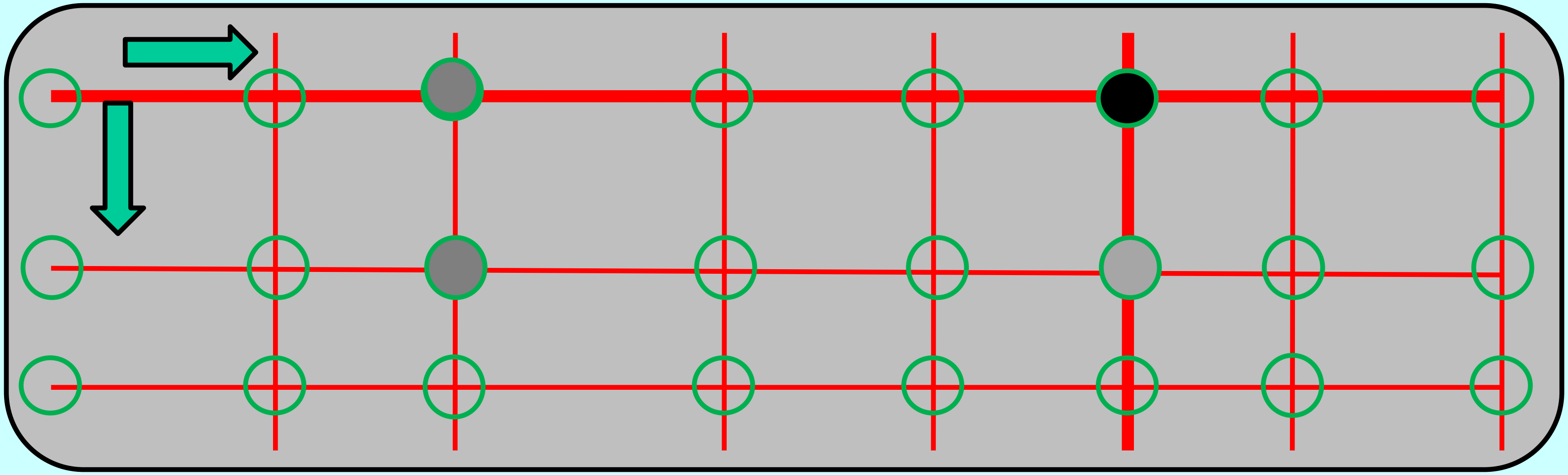

Possible Future Research

- Incorporate "user" behavior?
- Modeling failure mechanism?
  - Capacitated model
  - Partial capacity loss
  - Dynamic design
    - Frequency and duration of the disruptions
    - Cascading failure mechanism
  - Robust facility location?
- Other applications?
  - Urban infrastructure deployment