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

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Reliable Supply Chain Design

References


Introduction

- Location problem for supply chain design
  - Given customer distribution, find optimal facility number and location
  - Balance between facility costs and day-to-day transportation costs
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 \textit{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
  \( (1^{\text{st}}\text{-choice facility, } 2^{\text{nd}}\text{-choice facility, } \ldots) \)

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

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<th>Supply chain</th>
<th>Traffic sensor network</th>
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</thead>
<tbody>
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<td><strong>Facility</strong></td>
<td><img src="image1" alt="Supply chain facility" /></td>
<td><img src="image2" alt="Traffic sensor network" /></td>
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<td><strong>Service target</strong></td>
<td><img src="image3" alt="Service target" /></td>
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<td><strong>One-time cost</strong></td>
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Reliable Traffic Sensor Deployment

References


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

Traffic flow  

Candidate location  

Installed sensors
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
- How to maximize the expected surveillance benefit under probabilistic sensor failures (Rajagopal and Varaiya, 2007; Carbunar et al. 2005)?
  - Known sensor failure probability
When traffic units flow on a general large-scale transportation network, where shall we install sensors to best monitor traffic condition?

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- Known sensor failure probability
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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