

Design of Robust Topologies for Logistics Networks

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Introduction

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Introduction

Long-distance distribution networks:

1. Nodes:

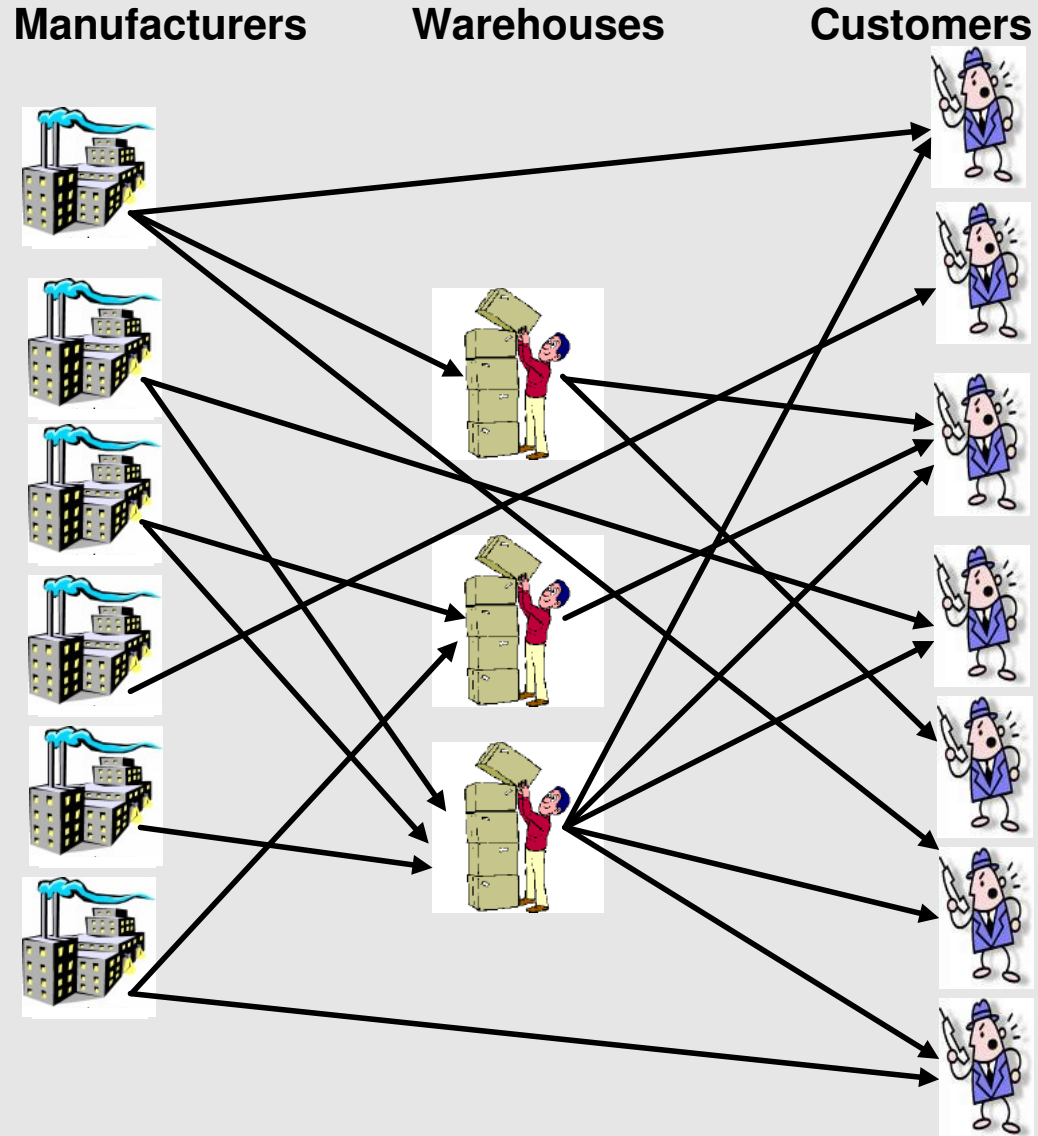
- Manufacturers (stochastic supply, zero inventory)
- Warehouses (temporary storage)
- Customers (stochastic demand, zero inventory)

2. Links

- Roads

A logistics provider takes over the management of the distribution problem.

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Consider distribution by a third-party logistics provider:

- Number + location of manufacturers, warehouses and customers given
- Supplies and Demands:
 - uncontrollable
 - known over restricted time horizon
- Costs associated with storage, transportation, backlog

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Problem:

- Which transportation links to use?
- How much to ship through them?

s.t.

- Costs are minimized
- Demands are met

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1. Given the supply $\underline{M}(t)$, the demand $\underline{C}(t)$, warehouses \underline{W} and their locations, find a network topology s.t.
 - Costs are close to minimal,
 - Number of links is close to minimal.
2. Investigate the robustness of this topology to changes in stochastic behavior of $\underline{M}(t)$ and $\underline{C}(t)$.

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1. Optimization

- Level 1, Model Predictive Control:
Optimal shipping schedule for certain topology
- Level 2, Heuristic:
Close to optimal topology

2. Robustness

- Evaluate performance of found topology for different supply and demand distributions

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Optimization, level 1 (MPC):

1. Assume a horizon of ω days, $\omega \ll T$
2. Define $\underline{u}(k)$ to be the amounts of products shipped through the links in the considered network at day (k)
3. Define costs per day $\alpha(\underline{u})(k)$
4. Minimize total costs for days $k, \dots, k + \omega - 1$

$$\min_{\underline{u}(k), \dots, \underline{u}(k+\omega-1)} \sum_{q=0}^{\omega-1} \alpha(\underline{u})(k+q) \quad (1)$$

This determines $\underline{u}^*(k)$

5. Total costs Ω for time period T for certain topology:

$$\Omega = \sum_{k=1}^T \alpha(\underline{u}^*)(k) \quad (2)$$

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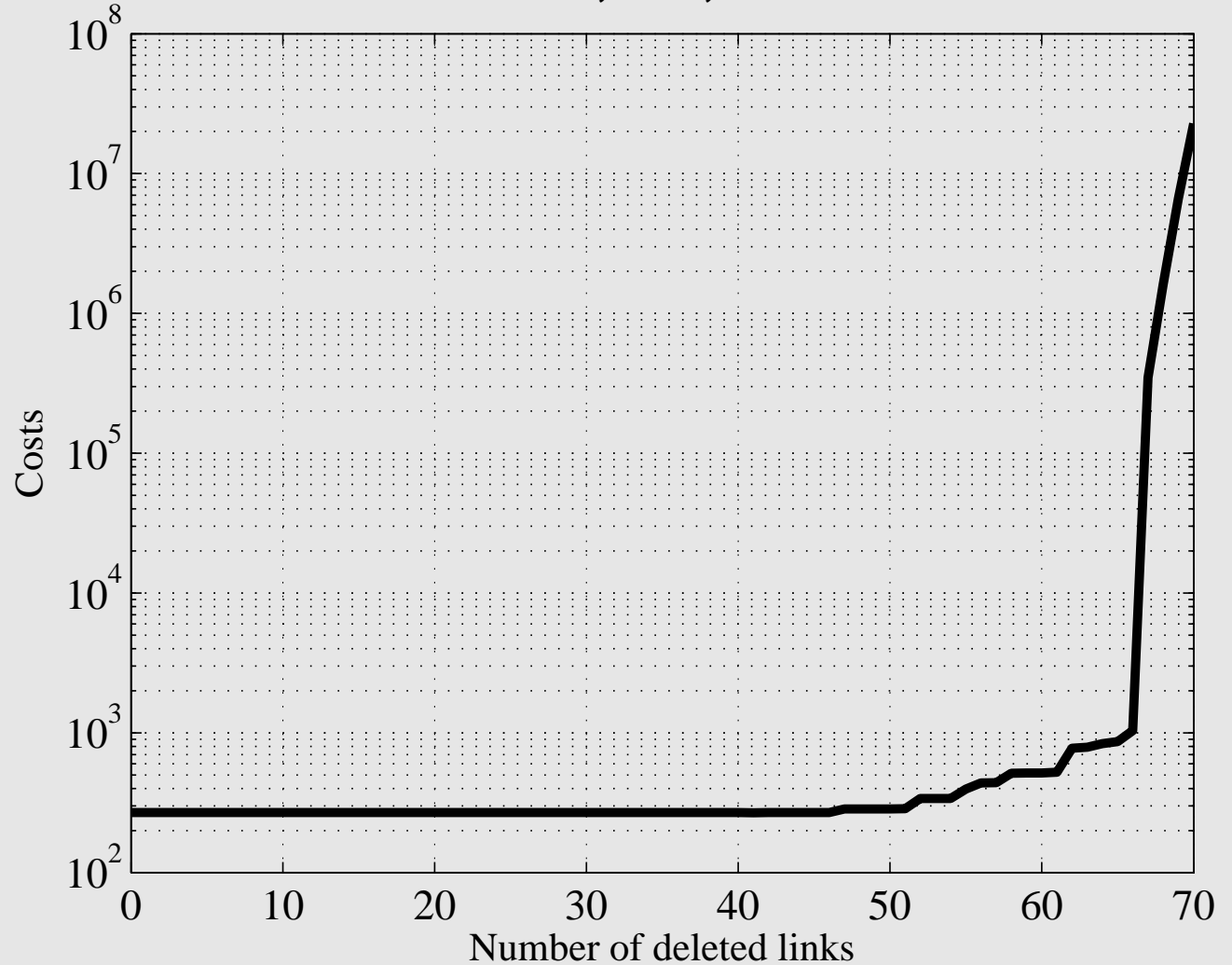
Optimization, level 2 (Heuristic):

1. Start with the fully connected network
2. Until the network is minimally connected:
 - (a) Run the MPC scheme for time period T and compute total costs Ω
 - (b) Delete one of the least used links
3. Plot total costs Ω against number of deleted links

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Results

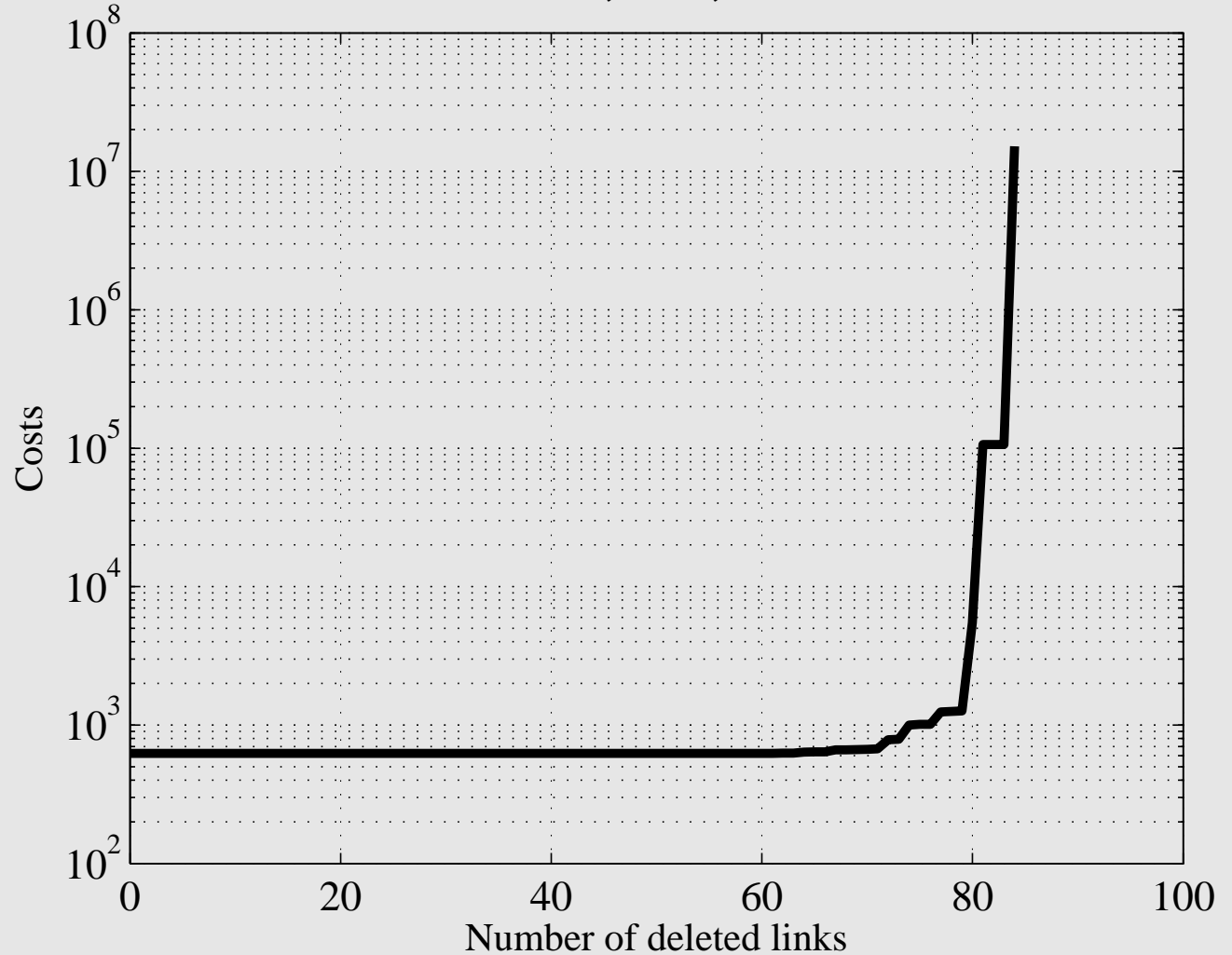
$m=6, w=3, c=7$



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Results

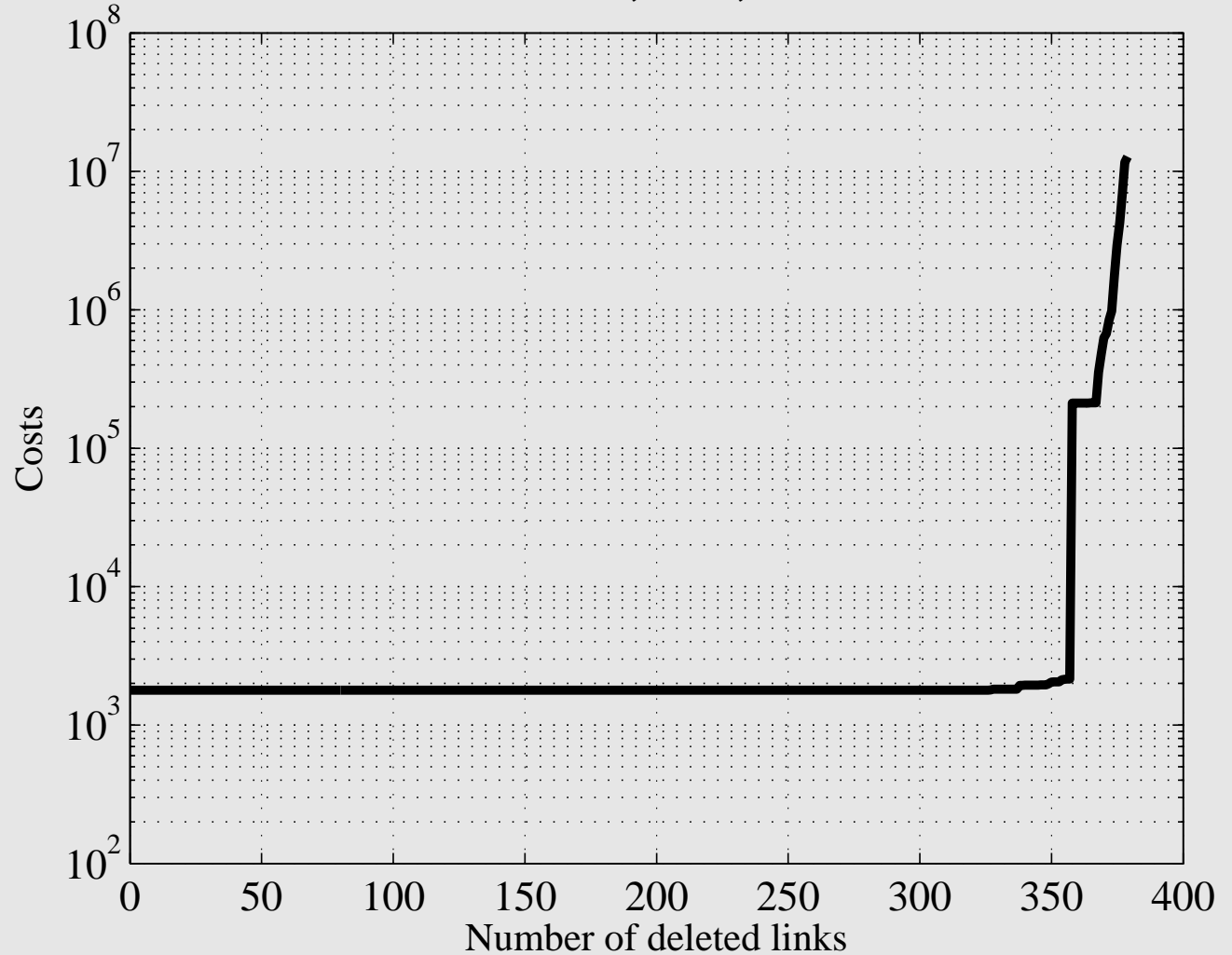
$m=3, w=2, c=20$



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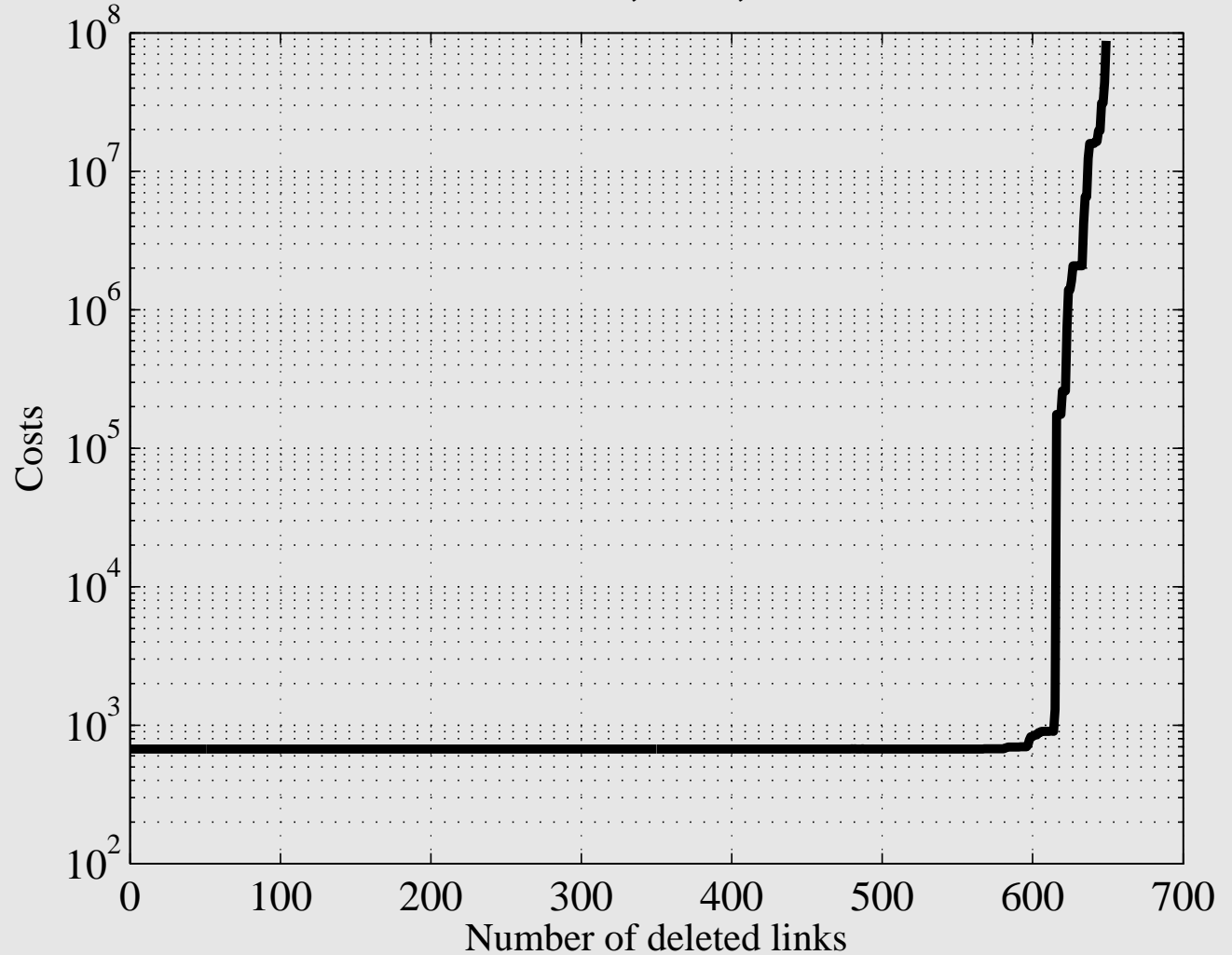
$m=15, w=3, c=20$



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$m=20, w=4, c=25$



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Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

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Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

1. **Same** type of distr., **same** means, **same** variances.

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Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

1. **Same** type of distr., **same** means, **same** variances.
2. **Different** type of distr., **same** means, **same** variances.

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Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

1. **Same** type of distr., **same** means, **same** variances.
2. **Different** type of distr., **same** means, **same** variances.
3. **Sinusoidal** time series, **same** means, **same** variances.

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Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

1. **Same** type of distr., **same** means, **same** variances.
2. **Different** type of distr., **same** means, **same** variances.
3. **Sinusoidal** time series, **same** means, **same** variances.
4. **Same** type of distr., **same** means, **different** variances.

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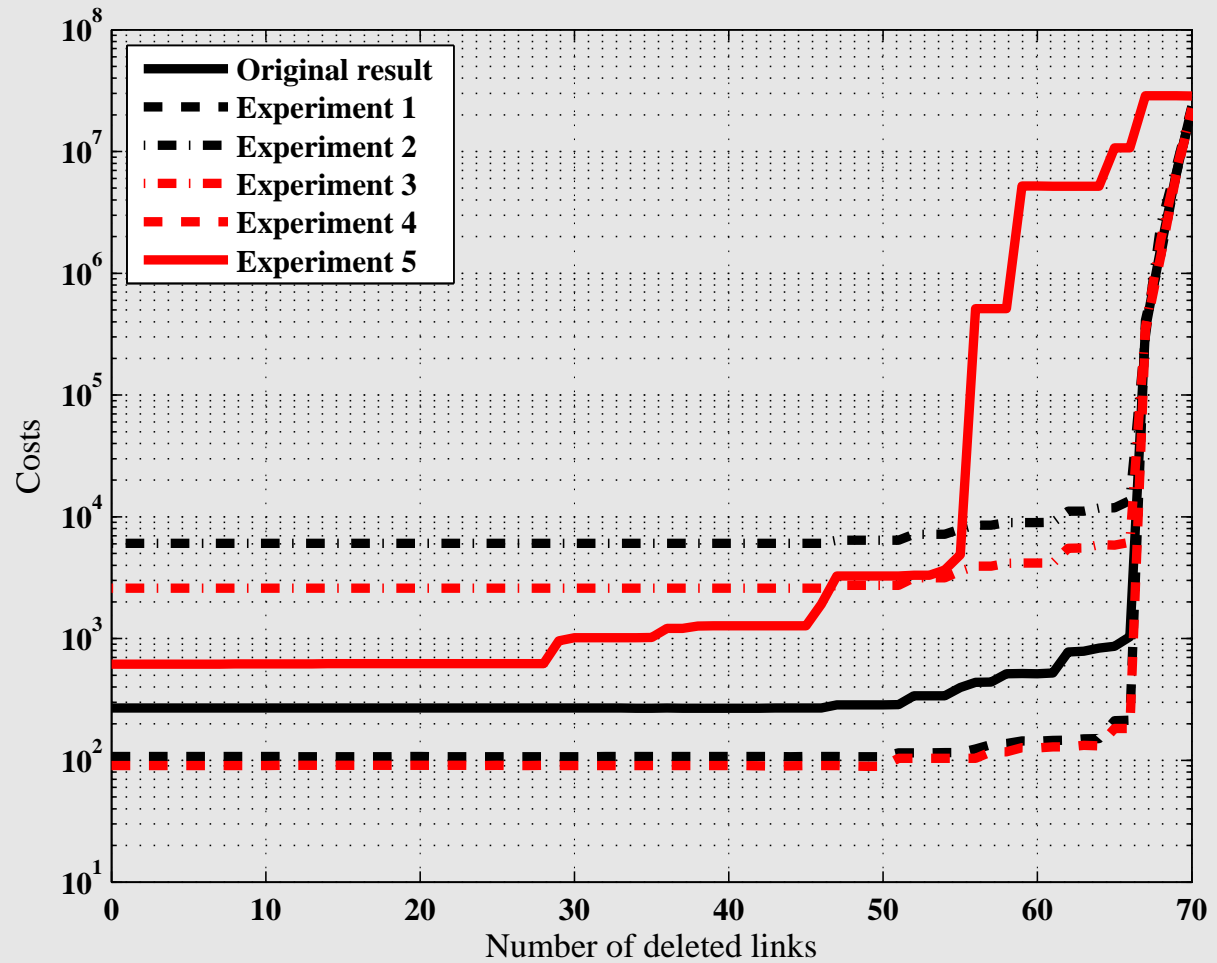
Robustness

Delete links in the same order for new $\underline{M}(t)$ and $\underline{C}(t)$ out of

1. **Same** type of distr., **same** means, **same** variances.
2. **Different** type of distr., **same** means, **same** variances.
3. **Sinusoidal** time series, **same** means, **same** variances.
4. **Same** type of distr., **same** means, **different** variances.
5. **Same** type of distr., **different** means, **same** variances.

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- The optimization procedure finds a cost-effective topology with only 5% of all possible links. This topology is only sensitive to changes in the 1st moments of supply and demand distributions.

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- The optimization procedure finds a cost-effective topology with only 5% of all possible links. This topology is only sensitive to changes in the 1st moments of supply and demand distributions.
- The 1st moments suffice to generate a set of stochastic supply and demand distributions from which such a close to optimal topology can be constructed.

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Conclusions

- The optimization procedure finds a cost-effective topology with only 5% of all possible links. This topology is only sensitive to changes in the 1st moments of supply and demand distributions.
- The 1st moments suffice to generate a set of stochastic supply and demand distributions from which such a close to optimal topology can be constructed.
- The optimization procedure finds a cost-effective topology with only 15% of all possible links. This topology is insensitive to changes in supply and demand distributions.

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- Sensitivity analysis of the network performance dependent on changes in the 1st moments of supply and demand distributions.
- Analysis of the network structure dependent on the trade-off between different associated costs.

Link to paper:

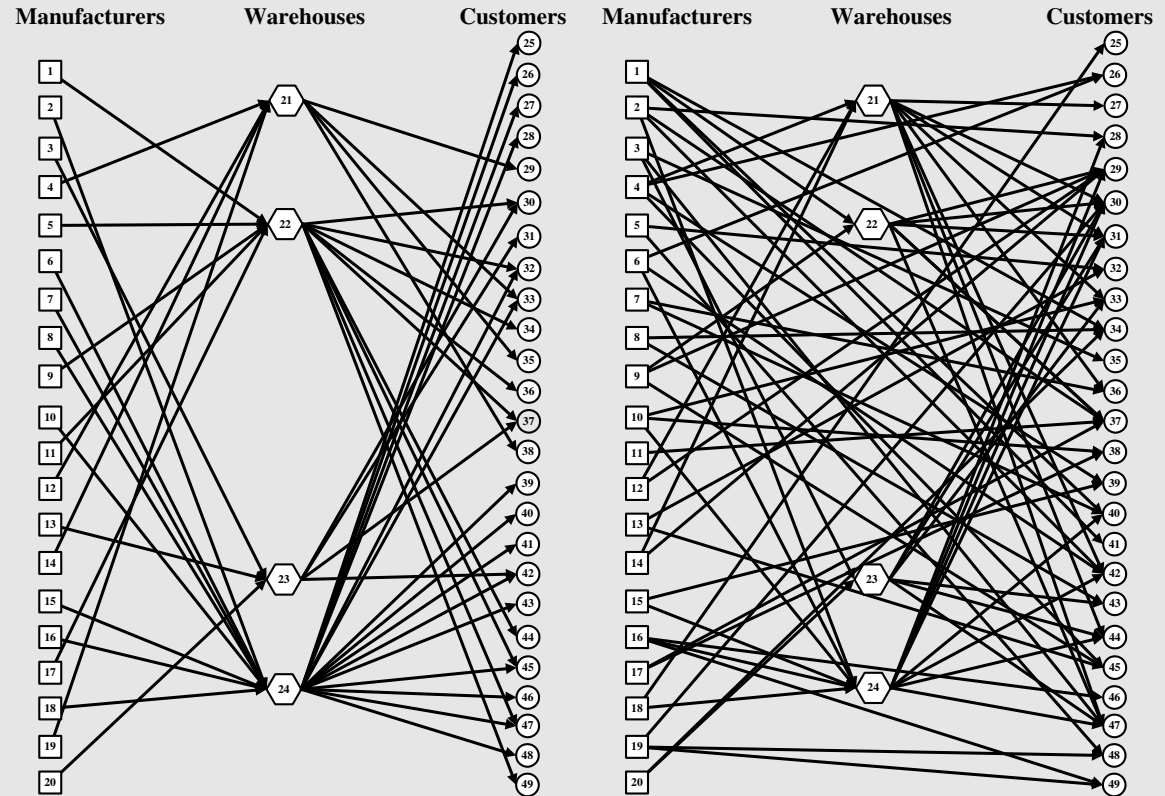
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⇒ SE Reports

⇒ SE Report 2006-06

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relatively low backlog costs

relatively high backlog costs

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