Topological analysis of public transport networks' recoverability

NAS group seminar

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Short intro of myself

  

Margarita-Salas call for postdoctoral research abroad by Universidad de Cádiz (funded by NextGenerationEU).

2 years @ TU Delft + 1 year @ Universidad de Cantabria.

Joined the Smart Public Transport Lab (T&P department @ CiTG) on Feb 2022, supervised by Oded Cats.

Recoverability of PTN

Motivation
Reducing the impact of disruptions is key for providing attractive PT services.

Many works assessing vulnerability and robustness of PTN.

Little is known on the topological aspects of the recovery process once disruptions occur.

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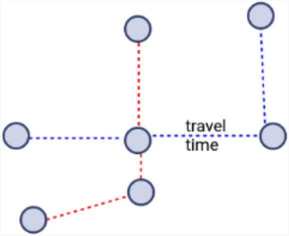
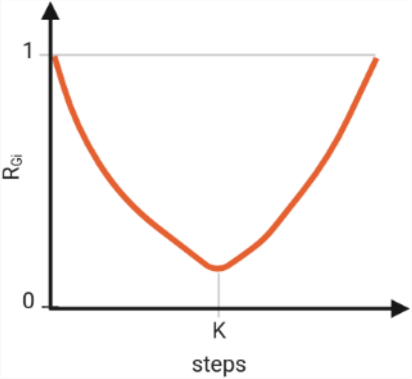
Inspiration
We study the notion of *recoverability*, inspired by the work of Sun et al. (2021) for optical networks.

Problem formulation



- $G_0(N, L_0)$ be the **L**-space representation of a PTN

Problem formulation



- $G_0(N, L_0)$ be the **L**-space representation of a PTN
- M_{G_0} original performance of the network
- We model failure/recovery of *edges* in K steps
- Retained performance ratio: $R_{G_i} = \frac{M_{G_i}}{M_{G_0}}$

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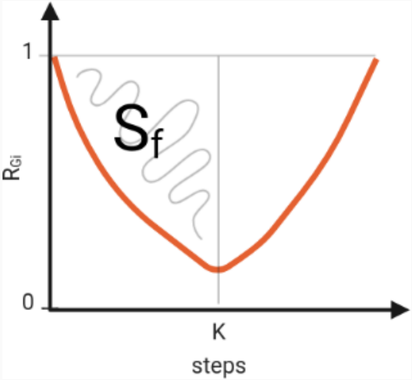

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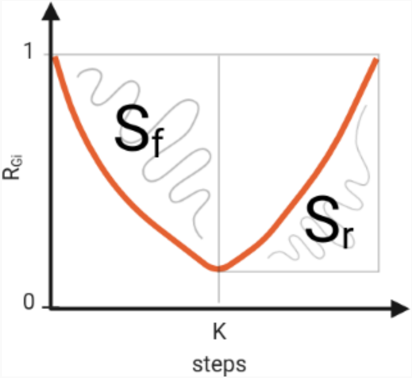

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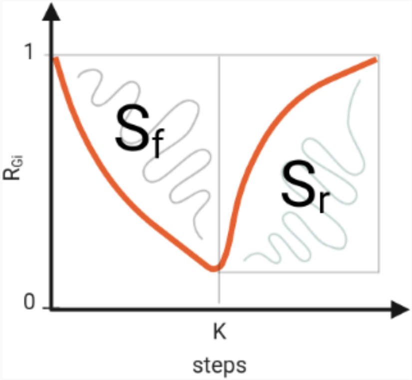

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- Rebound ratio: $\eta = \frac{S_r}{S_f}$

Performance metrics and failure/recovery strategies

Performance metrics

Connectivity

$$C_G = \frac{\sum_{i \neq j \in G} 1_{\text{exists a path (i,j)}}}{N \times (N-1)}$$

Efficiency

$$E_G = \frac{\sum_{i \neq j \in G} 1/\text{travel\_time}(i,j)}{N \times (N-1)}$$

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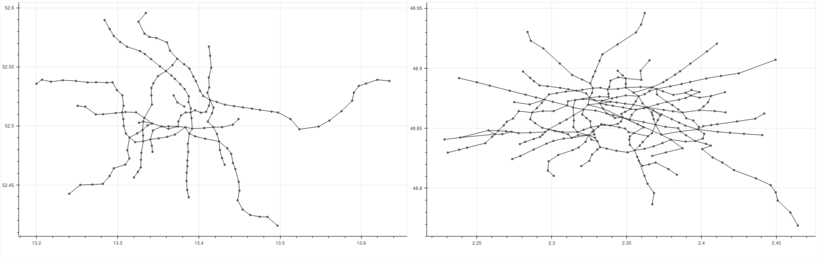
Failure/recovery strategies

- *Random*: links are iteratively removed/added to the graph randomly and uniformly.
- *Greedy (C_G)*: selects the link to remove/add that would render the largest decrease/increase in C_G.
- *Greedy (E_G)*: same but with the E_G performance metric.

Preliminary results

Studied scenarios



(a) Berlin (172 nodes, 183 links) **(b)** Paris (302 nodes, 359 links)

Figure: Metro networks used in the experiments

Experiments
We simulated a random failure process of $K = 30$ steps on each city and report the average results for 10 independent executions.

Preliminary results

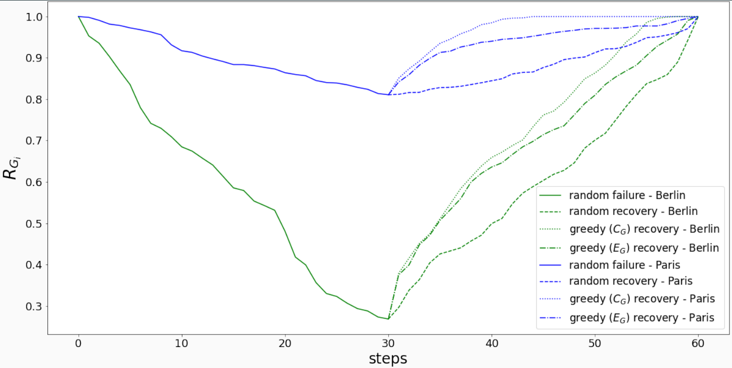


Figure: C_G metric

city	*metric*	*recovery strategy*		
		random	*greedy C_G*	*greedy E_G*
Berlin	C_G	0.833 (12.748;10.619)	1.141 (12.748;14.545)	1.060 (12.748;13.500)
	E_G	0.904 (9.897;8.943)	1.098 (9.897;10.869)	1.102(9.897;10.910)
Paris	C_G	0.725 (3.121;2.263)	1.591 (3.121;4.968)	1.321 (3.121;4.122)
	E_G	0.938 (3.474;3.260)	1.240 (3.474;4.307)	1.293 (3.474;4.491)

Table: Average rebound ratio (η), performance loss (S_f), and gain (S_r) with random failure and varying recovery strategies. Notation: η (S_f;S_r).

Preliminary results

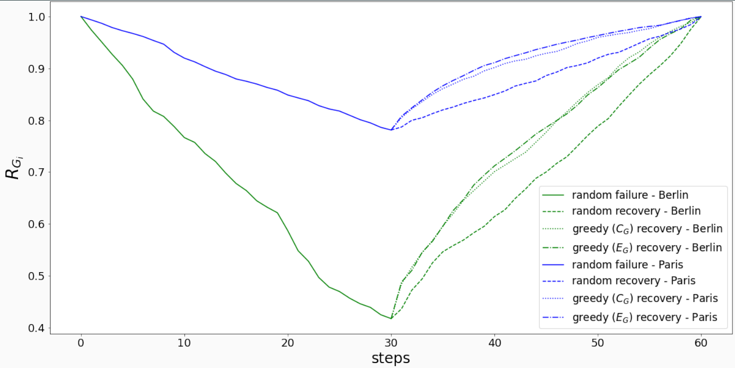


Figure: E_G metric

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Outlook

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We are starting research on a topological approach to measure recoverability in PTNs inspired by previous works in the field of optical networks.

Preliminary results showed that greedy recovery heuristics are able to rebound quickly from the loss of performance during the failure process.

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On-going and future work

- devise other failure and recoverability strategies
- incorporate new performance metrics
- test on a large number of PTNs worldwide
- incorporate equity in the recovery strategy

Thanks for your time :)

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