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Sensitivity analysis of critical infrastructure network fortification (topic introduction)

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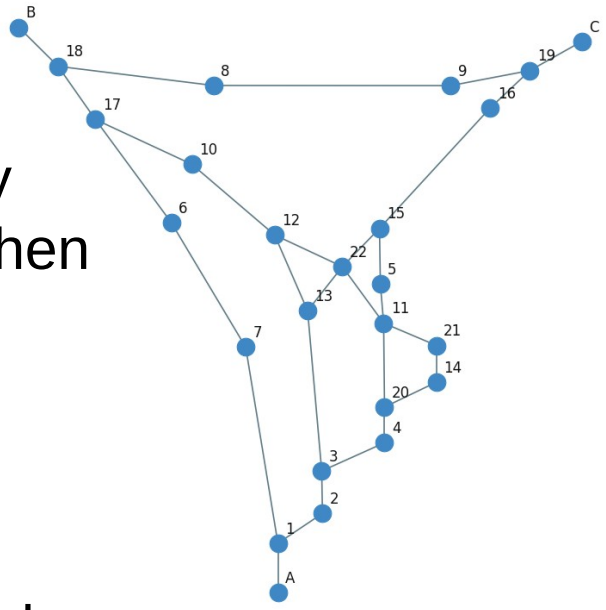
Background

- Critical infrastructure networks (e.g. railway networks) must remain operational even when components fail.
- Railway networks can be represented as graphs.
  - Switches are modeled as nodes.
  - Tracks connecting switches are modeled as edges.
- de la Barra et al. (2026) present a Multi-criteria Portfolio Decision Analysis approach to identify cost-efficient fortification actions for railway networks.



Example graph presentation of a train network.

Background

- The impact of component failure can be quantified by failure probabilities and restoration times.
  - Failure probabilities can be lowered by implementing fortification actions.
- Estimated parameters about failure probabilities and restoration times involve uncertainties.
- It is important to explore how these parameters impact recommended portfolios of fortification actions.

Background

- Reliability is the probability that the network remains operational over a given time horizon under specified operational conditions.
- Resilience measures the network's capacity to absorb component failures and recover from them.
- The Pareto frontier is the set of portfolios that are Pareto optimal, meaning no other feasible portfolio can improve reliability or resilience without compromising the other.

Objective

- Study the robustness of optimal portfolios to changes in the parameters.
  i. If a decision is made based on current parameters and then parameters change, how much does performance change?
  ii. If parameters change and a decision is then made, does the recommended solution stay the same?
- Which portfolios near the Pareto frontier are such that their performance is least sensitive to the choice of parameter values.

Methods

- Optimization methods from de la Barra et al. (2026)
- Monte Carlo simulations implemented in Python.

References

- de la Barra, J., Salo, A., Olander, L., Barker, K., & Kangaspunta, J. (2026). Fortifying critical infrastructure networks with multicriteria portfolio decision analysis: An application to railway stations in Finland. Reliability Engineering & System Safety, 268, 112006. https://doi.org/10.1016/j.ress.2025.112006

- Olander, L., Salo, A., Barra, J. D. L., & Sauni, M. (2025). Developing measures for node importance in critical transportation networks—an illustration to the analysis of switches at Finnish railway stations. 35th European Safety and Reliability Conference (ESREL 2025) and the 33rd Society for Risk Analysis Europe Conference (SRA-E 2025), 338–345. https://doi.org/10.3850/978-981-94-3281-3_ESREL-SRA-E2025-P9106-cd

Schedule

- Presentation of the topic 04/2026
- Literature review 05/2026
- Sensitivity analysis 06/2026
- Writing the thesis 05-07/2026
- Thesis ready 07/2026
- Presentation of the thesis 07/2026