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An alternative IP formulation for zone-based tariff design (aihe-esittely)

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Public transportation networks

- Tariff design is important when developing efficient and cost-effective public transportation networks.
- Smart zone-based tariff design eases the comprehensibility of the network for the customer and exploits their willingness to pay to maximize the profit for the transportation provider.
- The zone-based tariff design problem (ZTDP), defined by B. Otto *et al*. [1], offers diverse possibilities for further research.

Modelling the problem mathematically

- Integer programs (IP's) are mathematical optimization problems where some or all variables must be integers.
- In article [1], the generic form of ZTDP has the following objective function:

$$R(\pi) = \sum_{c \in C} \underbrace{f_c}_{\text{trip frequency}} \times \overbrace{\pi_c}^{\text{trip cost}}$$

  which is subject to some zoning and pricing constraints.
- Importantly, the more computationally complex part of the IP is the zoning constraints.
- The zoning in the article is made using the IP, where the constraints ensure a feasible zoning, e.g. that each zone remains connected and follows the specified structure (connected, ring).

Goals and scope

- Is it possible to make the process of solving the IP more computationally efficient?
- How will making the zone choosing process simpler affect the computational complexity?

An example

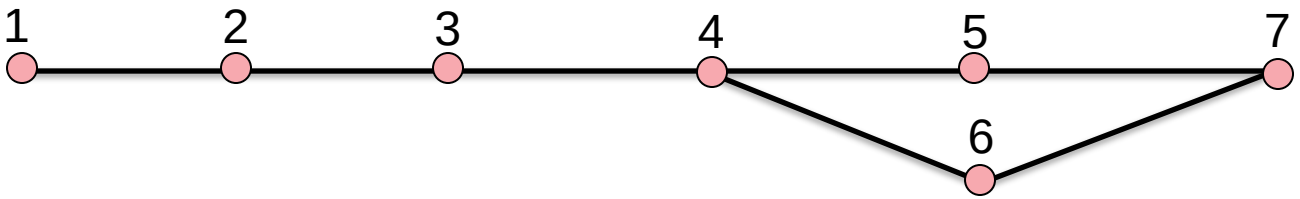

Figure 1: An example public transportation network

- Set of nodes: V = {1,2,3,4,5,6,7}.
- With the set of nodes/stops, a set of possible zones is formed, which is provided as a parameter for the IP
- Example set of zones: Z = {{1,2,3}, {1,7}, {4,5,6}, {4,5,6,7}, {3,4}}
- Each stop must be in exactly one zone. This is ensured with constraints:

$$x_{ij} = \begin{cases} 1, & \text{if stop } v_i \text{ is assigned to zone } Z_j \\ 0, & \text{otherwise} \end{cases}$$

$$\sum_{j \in \{1,2,\ldots,|Z|\}} x_{ij} = 1, \forall v_i \quad i \in \{0,1,\ldots,|V|\}$$

- Here the obvious solution would be choosing zones Z1 and Z4, since no other zone combination could give a feasible solution.

Methods / Tools

- The alternative IP will be tested with LinTim-software [2], by simulating a transport network with a data-set.

- The complexity of the algorithm will be analyzed with the same software to compare to the results in article [1].

Schedule

- Topic presentation on 12.2.2025
- The IP-model and testing will begin in February 2025
- Writing process from March to April 2025
- Results and the thesis ready in May 2025

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Thank you!

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Sources

1) Benjamin Otto and Nils Boysen: Zone-Based Tariff Design in Public Transportation Networks (2017)
2) P. Schiewe, A. Schöbel, S. Jäger, S. Albert, C. Biedinger, T. Dahlheimer, V. Grafe, O. Herrala, K. Hoffmann, S. Roth, A. Schiewe, M. Stinzendörfer, and R. Urban. LinTim - Integrated Optimization in Public Transportation. Homepage. https://www.lintim.net