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Scheduling railway maintenance projects considering passenger hindrance and event requests

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Research Contribution

- Develop a framework to determine the optimal maintenance schedule such that passenger hindrance is minimized.
- Alter the model of Boland et al. (2013) by converting the maximum flow problem with one origin and destination to a shortest path problem with multiple origins and destinations.
- Extend the arcs characteristics such that not only the availability is known, but also the travel time that corresponds to the availability.
- Reformulate the problem as a mixed-integer linear problem and solve it with exact methods (branch and bound).

Assumptions

- The overall passenger hindrance should be minimized, but that should not lead to an infeasible maintenance schedule considering other rail traffic.
- To guarantee feasibility for other rail traffic, corridor book restrictions are interpreted as hard constraints.
- Within the event requests, the maximum capacity of alternative services should be sufficient to able to handle the outflow of event visitors.
- Regarding the consideration of events in the scheduling of maintenance projects, only event requests are included as these form a bottleneck. Other restrictions concerning events are not included in this model.

Problem Formulation

$$\min \sum_{(o,d)\in\mathcal{N}\times\mathcal{N}} \sum_{t=1}^{T} \phi_{o,d,t}(v_{o,d,t}-\Omega_{o,d}) \tag{1a}$$

$$\sum_{t=0}^{T-\pi_j+1} y_{j,t} = 1 \qquad (\forall j \in \mathcal{J}) \tag{1b}$$

$$y_{j,t} = 0 \qquad (\forall j \in \mathcal{J}, t \in \mathcal{T}_f) \tag{1c}$$

$$x_{at} + \sum_{t'=t-\pi_j+1}^{t} y_{jt'} \leq 1 \qquad (\forall a \in \mathcal{A}, t \in \mathcal{T}, j \in \mathcal{J}_a) \tag{1d}$$

$$\sum_{t\in\mathcal{T}} x_{at} = |\mathcal{T}| - \sum_{j\in J_a} \pi_j \qquad (\forall a \in \mathcal{A}) \tag{1e}$$

$$w_{at} = x_{at}\omega_a^e + (1-x_{at})\omega_a^i \qquad (\forall a \in \mathcal{A}, t \in \mathcal{T}) \tag{1f}$$

$$\sum_{a\in c}(1-x_{a,t}) \leq 1 \qquad (\forall c \in \mathcal{C}, t \in \mathcal{T}, j \in \mathcal{J}) \tag{1g}$$

$$\sum_{j\in J} \sum_{t'=t-p_j-\tau}^{T} y_{j,t} \leq 1 \ (\forall t \in T) \tag{1h}$$

$$\sum_{a\in s} \sum_{(o,d)\in\mathcal{N}\times\mathcal{N}} \sum_{i=1|a\in R_{o,d,i}}^{k} h^i_{o,d,t}\beta_{o,d,t}\phi_{o,d,t} \leq \Lambda_{s,t} + \sum_{a\in s} x_{a,t}M(\forall s \in \mathcal{E}_t, t) \tag{1i}$$

$$\sum_{i=1}^{k} h^i_{od,t} = 1 \qquad (\forall (o,d) \in \mathcal{N}\times\mathcal{N}, t \in \mathcal{T}) \tag{1j}$$

$$v_t^{od} \geq \sum_{a\in R_{od_k}} w_{at} - M(1-h^k_{od,t}) \qquad (\forall i \in [k], (o,d) \in \mathcal{N}\times\mathcal{N}, t \in \mathcal{T}) \tag{1k}$$

$$v_t^{od} \leq \sum_{a\in R_{od_k}} w_{at} \qquad (\forall i \in [k], (o,d) \in \mathcal{N}\times\mathcal{N}, t \in \mathcal{T}) \tag{1l}$$

where the objective function strives to minimize the passenger delays.

Case Study

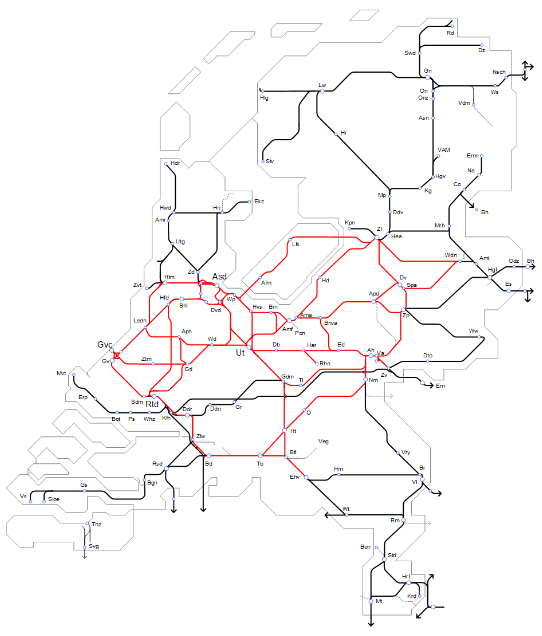

Figure 1: Network for the case study (source: ProRail)

- The case study area contains 109 stations and a total of 290 direct travel connections.
- The considered time period is April 1st to June 30th, 2023.
- A total of 19 unique event requests are submitted by the passenger operator for the considered period.

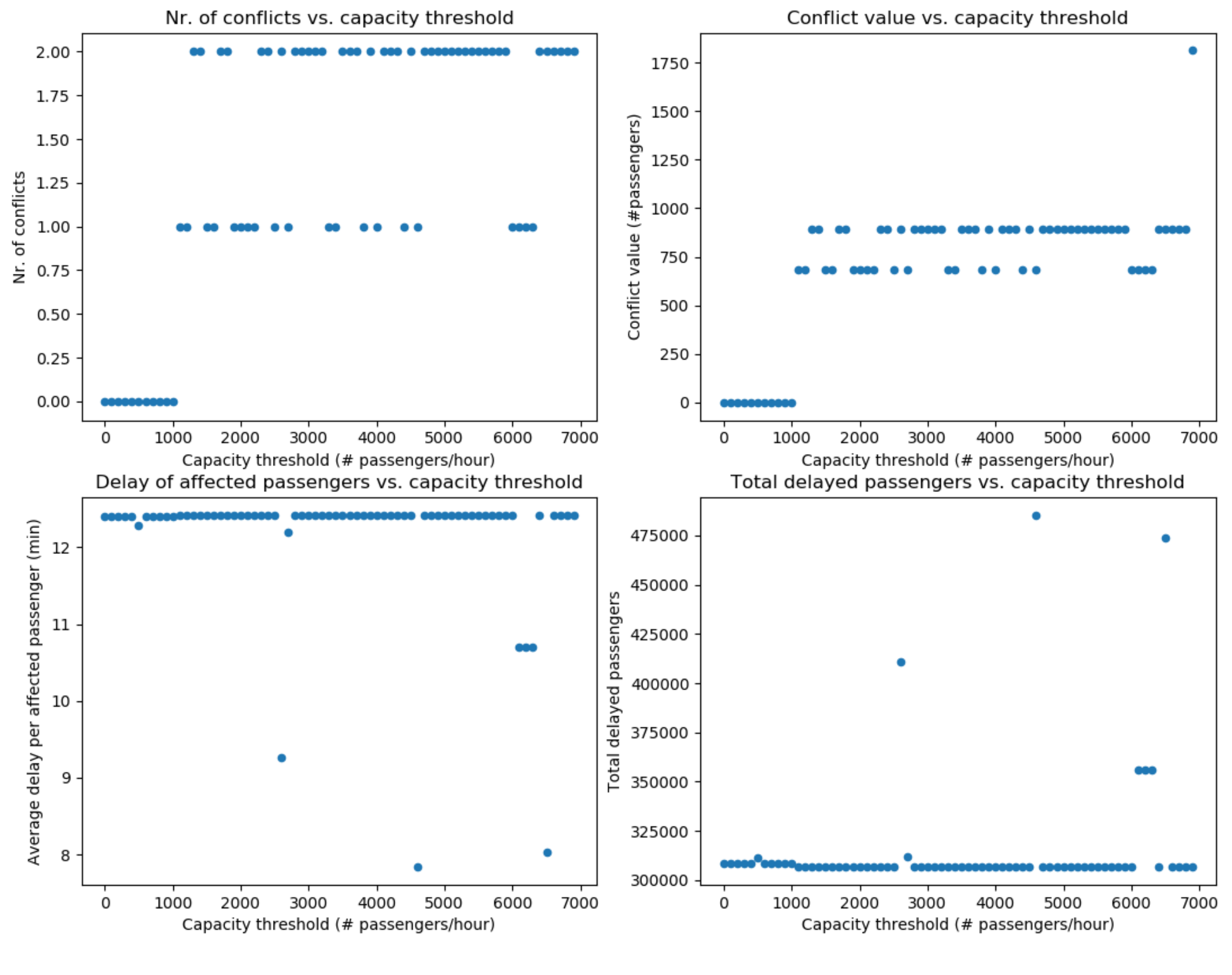

Figure 2: Values for the KPIs of the model applied on the case study with increasing threshold values

Key Findings

- Relaxing the event request constraint creates more scheduling options without necessarily increasing the passenger hindrance, and it might even reduce the passenger hindrance resulting in a better service.
- More flexibility in the scheduling may be obtained without increasing the passenger hindrance, where decision makers are able to choose for solutions that reduce the total number of delayed passengers or the average delay time.

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