TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Transportation and Traffic Sciences „Friedrich List“ Chair of Traffic Flow Science

Combining Cyclic Timetable Optimization and Traffic Assignment

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Motivation

- TAKT: software system for automatic timetavle generation
- powerful automatic timetable calculation suitable for complex real-world problems
- timetable optimization possible
- no satisfying estimation of variables' weighting for large networks

Goal

- traffic assignment fitted to timetable optimization

Outline

- Fundamentals
  - Timetabling
  - Traffic Demand Modeling
- Traffic Assignment Methods
  - Graph of Itineraries
  - Quantifiying Itineraries
  - Finding Reasonable Itineraries
- Conclusion

Periodic Event Scheduling Problem (PESP)

- periodic event network $\mathcal{N} = (\mathcal{K}, \mathcal{A}, t_T)$ mit
  - period $t_T \in \mathbb{N}^+$
  - node $i \in \mathcal{K}$ with potential T_i
  - arc $a \in \mathcal{A}$: $i \to j$ with span $x_a = T_j - T_i - z_a t_T$ $(i, j \in \mathcal{K}, z_a \in \mathbb{Z})$
    - x_a with lower bound $t_{min,a}$ and upper bound $t_{max,a}$
- periodic timetable $\vec{T}$: $\forall i \in \mathcal{K}$: $T_i \in \mathcal{N}, 0 \leqslant T_i < t_T$
- periodic timetable $\vec{T}$ is feasible for an event network $\mathcal{N}$ if and only if
  - $\forall a \in \mathcal{A}$: $i \to j$: $\exists z_a \in \mathbb{Z}$: $t_{min,a} \leqslant T_j - T_i - z_a t_T \leqslant t_{max,a}$
- PESP: decision problem, whether there exists a feasible timetable for $\mathcal{N}$

Periodic Event Scheduling Problem (PESP)

- timetable optimization by minimization of slacks y_a weighted with ω_a

$$
\begin{aligned}
\sum_{a \in \mathcal{A}} \omega_a y_a &\rightarrow min \\
T_j - T_i - z_a t_T &\geqslant t_{min,a} \\
T_j - T_i - z_a t_T &\leqslant t_{max,a} \\
y_a - T_j + T_i + z_a t_T + t_{min,a} &= 0 \qquad\qquad \forall a\colon i \rightarrow j \in \mathcal{A} \\
z_a &\in \mathbb{Z}
\end{aligned}
$$

Fundamentals

the classic transport model:

- trip generation
- distribution (choice of destination)
- modal split (choice of mode)
- assignment (route choice)

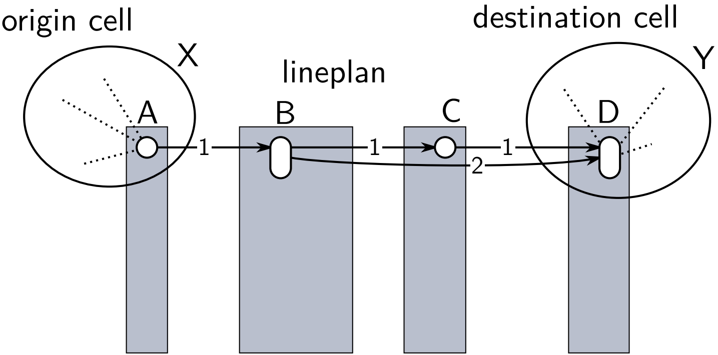
Traffic Assignment Sequence

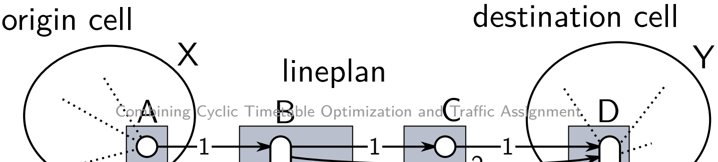
for every origin-destination pair:

- determination of all reasonable itineraries
- quantification of itineraries
- distribution of the trips to itineraries

Traffic Assignment Method

Graph of Itineraries





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Traffic Assignment Method

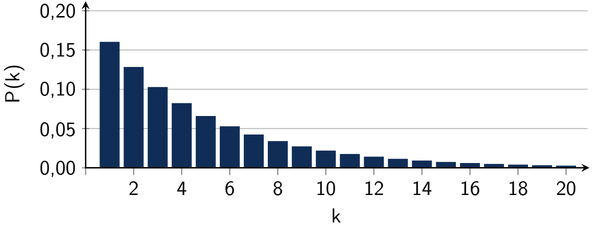
Quantification of Itineraries

- most important criterion: traveling time
- existing timetables are no useful basis
- assumption of general, constant transfer times bears large deviation
- exact traveling times are unknown until conduction of timetable optimization
- traffic assignment and timetabling are interdepent; successive process leads to error
- error can be reduced by retrieving information from the event network
- bounding travel times without premature decision of timetable structure

Traffic Assignment Method

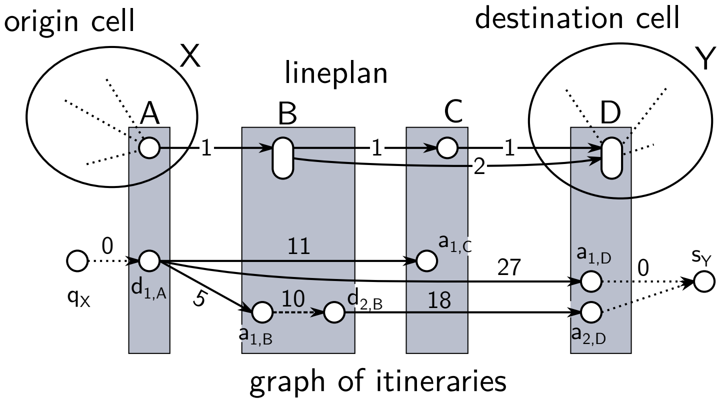
Estimation of Traveling Times

- bounded values allow estimation of traveling times
- derived from delay distributions
- geometric distribution of probabilities of all permitted values: $\mathrm{P}(k) = p(1-p)^k$
- e. g., $p = 0.2$:



Traffic Assignment Method

Weighted Graph of Itineraries



- set arc weights to estimatad times

Traffic Assignment Method

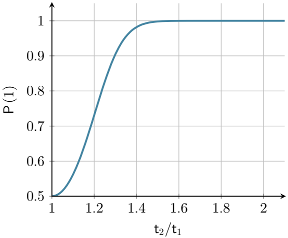
Search of Itineraries

- estimation of shortest paths between all nodes (Floyd-Warshall algorithm)
- definition of maximum tolerable detour
- starting from all origins:
  construction of a tree of reasonable itineraries
  - exclusion of loops and side trips
  - exclusion of transfers which are in no way reasonable

Traffic Assignment Method

Distribution of the Trips to Itineraries

- proportion of trips to reasonable itineraries by means of quantification
- number of trips for every stop and transfer
  ≙ weights for timetable optimization



Conclusion

- traffic assignment method tailored for periodic timetable optimization
  - connection of transport planning and periodic timetabling
  - consideration of characteristics of regional and intercity rail passenger transport
- further outlook:
  - implementation of presented method
  - detailed analysis of parameters' effects
  - application of the findings in other fields like conflict resolving and traffic distribution

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Thank you for your attention.

References

Jens Opitz: *Automatische Erzeugung und Optimierung von Taktfahrplänen in Schienenverkehrsnetzen*. PhD thesis, Technische Universität Dresden. Wiesbaden: Gabler Research, 2009. ISBN: 978-3-8349-2128-4.

Juan de Dios Ortúzar und Luis G. Willumsen: *Modelling Transport*. 4. Aufl. Chichester: John Wiley & Sons, 2011. ISBN: 9781119993520.

Traffic Assignment Method

Information Retrieval from Event Network

- constraint propagation within the event network
  - initialization of one potential to $T_0 = \{0\}$
  - initialization of all other potentials to $T_i = [0, t_T - 1]_{t_T}$
  - every constraint $a\colon i \rightarrow j$ has a set of feasible spans $\Delta_{ij}^{(t_T)} = [t_{min,a}, t_{max,a}]_{t_T}$
  - every constraint holds $T_j = T_j \cap \left(T_i + \Delta_{ij}^{(t_T)}\right)$ and $T_i = T_i \cap \left(T_j - \Delta_{ij}^{(t_T)}\right)$
  - further propagation of constraints to all nodes within the network
  - new (smaller) set of spans $\Delta_{ij}^{(t_T)} = T_j - T_i$ for each arc