DM204 – Spring 2011

Scheduling, Timetabling and Routing

Lecture 10

Public Transports

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Outline

Course Overview

- ✔ Scheduling
  - ✔ Classification
  - ✔ Complexity issues
  - ✔ Single Machine
  - ✔ Parallel Machine
  - ✔ Flow Shop and Job Shop
  - ✔ Resource Constrained Project Scheduling Model
- Timetabling
  - ✔ Sport Timetabling
  - ✔ Reservations and Education
  - ✔ University Timetabling
  - ✔ Crew Scheduling
  - Public Transports
- Vechicle Routing
  - Capacited Models
  - Time Windows models
  - Rich Models

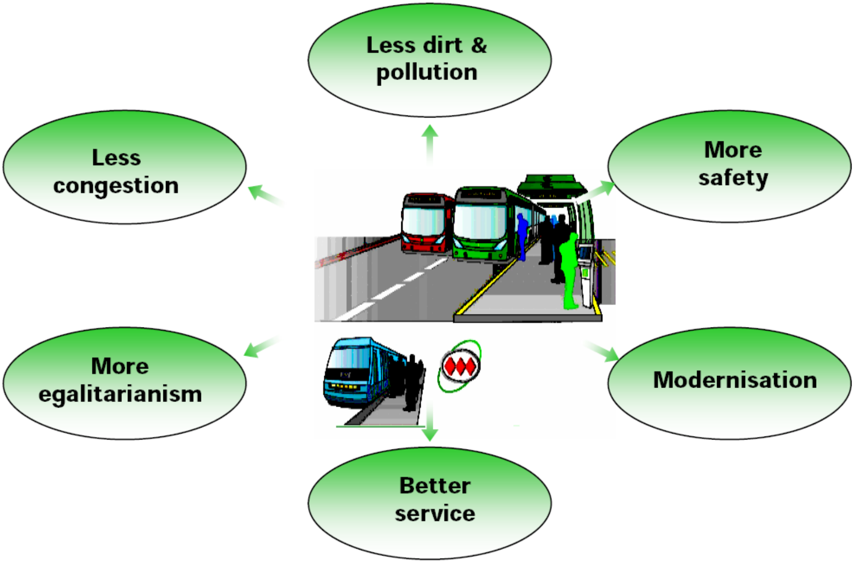
Outline

Planning problems in public transport

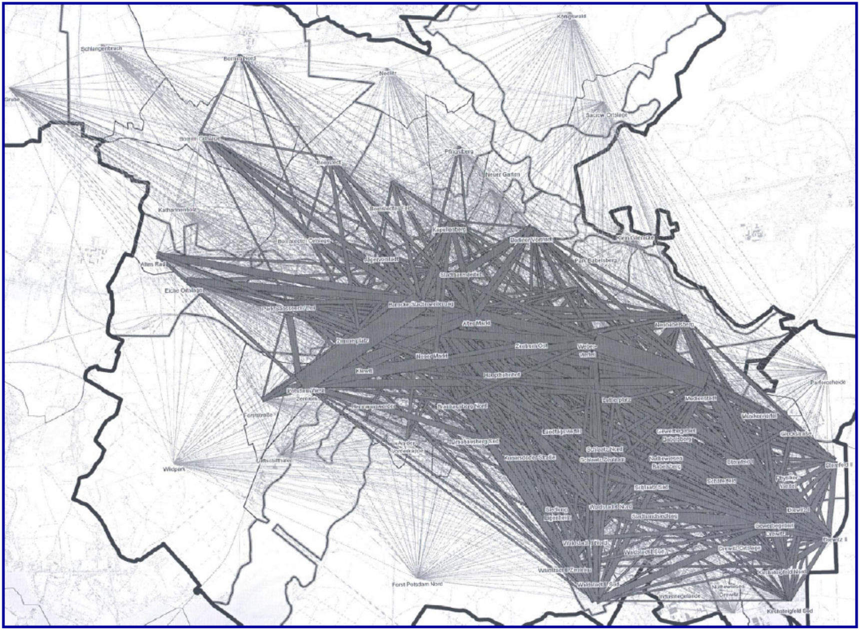
Phase:	Planning	Scheduling	Dispatching
Horizon:	Long Term	Timetable Period	Day of Operation
Objective:	Service Level	Cost Reduction	Get it Done
Steps:	Network Design Line Planning Timetabling Fare Planning	Vehicle Scheduling Duty Scheduling Duty Rostering	Crew Assignment Delay Management Failure Management Depot Management

↑ Master Schedule —Dynamic Management→ Conflict resolution ↑

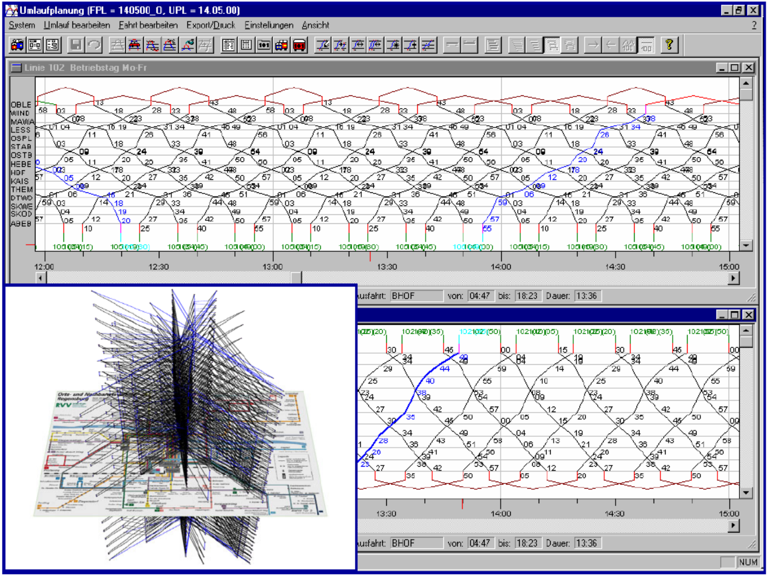
[Borndörfer, Grötschel, Pfetsch, 2005, ZIB-Report 05-22]



[Borndörfer, Liebchen, Pfetsch, course 2006, TU Berlin]


Bornim Nord
Sacrow Ortslage
Pfingstberg
Neuer Garten
Kapellenberg
Jägervorstadt
Alter Markt
Zentrum Ost
Hauptbahnhof
Wildpark
Forst Potsdam Nord
Kirchsteigfeld Süd

Time-space diagram



[Borndörfer, Liebchen, Pfetsch, course 2006, TU Berlin]

Terminology

- Rolling stock, block, freight or passenger trains
- Railway network, track
- Stations, junctions
- Headway
- Dwell time and transfer/correspondence times
- Line, Line planning problem
- Train timetabling problem; integrated, symmetric, periodic timetable; robustness
- Train routing/platforming problem
- Train sequencing/pathing/scheduling
- Train dispatching/rescheduling problem
- Shunting/parking problem
- Marshalling/classification problem

Here we see:

- Train timetabling
  - single track
  - perodic railways timetabling model (PESP)
- Train dispatching
- Crew scheduling (already seen)

Train Timetabling

Input:

- Corridors made up of two independent one-way tracks
- L links between $L + 1$ stations.
- T set of trains and T_j, $T_j \subseteq T$, subset of trains that pass through link j

Output: We want to find a periodic (eg, one day) timetable for the trains on one track (the other can be mirrored) that specifies:

- y_{ij} = time train i enters link j
- z_{ij} = time train i exists link j

such that specific constraints are satisfied and costs minimized.

Constraints:

- Minimal time to traverse one link
- Minimum stopping times at stations to allow boarding
- Minimum headways between consecutive trains on each link for safety reasons
- Trains can overtake only at train stations
- There are some "*predetermined*" upper and lower bounds on arrival and departure times for certain trains at certain stations

Costs due to:

- deviations from some "*preferred*" arrival and departure times for certain trains at certain stations
- deviations of the travel time of train i on link j
- deviations of the dwelling time of train i at station j

Solution Approach

- All constraints and costs can be modeled in a MIP with the variables: y_{ij}, z_{ij} and $x_{ihj} = \{0, 1\}$ indicating if train i precedes train h
- Two dummy trains T' and T'' with fixed times are included to compact and make periodic
- Large model solved heuristically by decomposition.
- Key Idea: insert one train at a time and solve a simplified MIP.
- In the simplified MIP the order in each link of trains already scheduled is maintained fixed while times are recomputed. The only order not fixed is the one of the new train inserted k (x_{ihj} simplifies to x_{ij} which is 1 if k is inserted in j after train i)

Overall Algorithm

Step 1 (Initialization)
Introduce in T_0 two "dummy trains" as first and last trains

Step 2 (Select an Unscheduled Train) Select the next train k through the train selection priority rule

Step 3 (Set up and preprocess the MIP) Include train k in set T_0
Set up MIP(K) for the selected train k
Preprocess MIP(K) to reduce number of 0–1 variables and constraints

Step 4 (Solve the MIP) Solve MIP(k). If algorithm does not yield feasible solution STOP.
Otherwise, add train k to the list of already scheduled trains and fix for each link the sequences of all trains in T_0.

Step 5 (Reschedule all trains scheduled earlier) Consider the current partial schedule that includes train k.
For each train $i \in \{T_0 - k\}$ delete it and reschedule it

Step 6 (Stopping criterion) If T_0 consists of all train, then STOP otherwise go to Step 2.

PESP model

Periodic event scheduling problem:

in terms of potentials

$$\begin{aligned} \min \quad & w_{ij}^T(\pi_j - \pi_i + T \cdot p_{ij} - l_{ij}) \\ & l_{ij} \leq \pi_j - \pi_i + T \cdot p_{ij} \leq u_{ij} \quad \forall ij \in A \\ & 0 \leq \pi_i \leq T(1-\epsilon) \quad \forall i \in V \\ & p \in Z^{|A|} \end{aligned}$$

in terms tensions $x_a = \pi_j - \pi_i + T \cdot p_a$

$$\begin{aligned} \min \quad & w^T x \\ & \sum_{a \in C^+} x_a - \sum_{a \in C^-} x_a = Tq_C \quad \forall C \in \mathcal{C} \\ & l_a \leq x_a \leq u_a \quad \forall a \in A \\ & q_c \in Z, \quad \forall C \in \mathcal{C} \end{aligned}$$