The Simultaneous Vehicle Scheduling and Passenger Service Problem

Oli B.G. Madsen
Professor, Dr.Techn., Ph.D.
Technical University of Denmark
Joint work with

• Allan Larsen, DTU Transport

• Hanne Løhmann Petersen, DTU Transport

• Stefan Ropke, DTU Transport

This work forms a part of Hanne L. Petersens Ph.D.-thesis
The sequential planning approach
The Vehicle Scheduling Problem (VSP)

- Given a timetable
- Assign vehicles to trips
- All trips must be operated
- Lowest possible cost

- The problem is solved by the operator
- The service requirements are given by the service provider (authorities)

- Usually timetabling and vehicle scheduling are solved sequentially
The multi depot vehicle scheduling problem

Surveys:

• Desrosiers, Dumas, Solomon and Soumis 1995

• Desaulniers and Hickman 2007

• Pepin, Desaulniers, Hertz and Huisman 2009

Papers:

• Löbel 1999

• Hadjar, Marcotte and Soumis 2006
The Simultaneous Vehicle Scheduling and Passenger Service Problem (SVSPSP)

- The timetable is still given but it is allowed to make small changes in the timetable

Main idea:
During the vehicle scheduling, bus timetables can be modified (timeshifted)

- The objective is twofold:
  - Solve the vehicle scheduling problem
  - Reduce the passenger waiting time
- SVSPSP allows the timetable to be modified
- Frequencies/levels of service are kept unaltered
- Driving and dwell times are not changed
The sequential planning approach
The Simultaneous Vehicle Scheduling and Passenger Service Problem – related papers

- Serafini and Ukovich 1989 (PESP, Periodic Event Scheduling Problem)

- Liebchen and Möhring 2007 (PESP and extensions)
  - Periodic schedules and no deadheading

  - Passenger waiting times are ignored

- Wong, Yuen, Fung and Leung 2008
  - No. of vehicles is kept constant

- Guihaire and Hao 2008
  - The single depot case
  - No. of vehicles, quality of transfer and frequency regularity
The Simultaneous Vehicle Scheduling and Passenger Service Problem – related papers

• Serafini and Ukovich 1989 (PESP, Periodic Event Scheduling Problem)

• Liebchen and Möhring 2007 (PESP and extensions)
  – No deadheading and periodic schedules

• Van den Heuvel, van den Akker and van Koten Niekerk 2008
  – Passenger waiting times are ignored

• Wong, Yuen, Fung and Leung 2008
  – No. of vehicles is kept constant

• Guihaire and Hao 2008
  – The single depot case
  – No. of vehicles, quality of transfer and frequency regularity
  – Most similar to our problem
The local train network of Copenhagen
The S-bus network; trains are shown as thin lines
SVSPSP II

• Input
  – Initial bus time table
  – Fixed train timetable !!
  – Number of transferring passengers
  – Costs (waiting time, deadheading, vehicles)

• Output
  – Updated bus timetable
  – Passenger waiting time (value of time)
  – Cost

• The waiting time is considered relative to trains and busses
• Memorability of the timetable is not considered
Real-life aspects in the project

We have the following data:

• Bus and train networks
• Train timetables
• Original bus timetables
• Activity estimates for stations and time of the day

Data we don’t have:

• (Dis)Embarking passenger counts
  – Based on: Line, time of the day, station
• Transfer distribution
  – Estimated from driving direction and knowledge of the network
Model

Each trip in the original timetable is converted to a metatrip

- Specifies different possible departure times for the trip
- Each subtrip belonging to a metatrip represents a copy of the original trip
- Each metatrip must be covered
- Not all single trips (subtrips) are covered (only one trip within each metatrip)
Incompatible trips

- Mutually incompatible trips
- For example trip 6 and 7 (too close)
- - and may be trip 2 and 11 (too far apart)

- If departures at regular intervals are required trip 2 may be incompatible with for example 8, 9, 10 and 11
Mathematical models

• Model 1: Simpler model where only shifts between trains to busses and busses to trains are allowed

• Model 2: More complex model also allowing shifts between busses
Mathematical models

- Model 1: Simpler model where only shifts between trains to busses and busses to trains are allowed

- Model 2: More complex model also allowing shifts between busses

- Even model 1 can only be solved to optimality for very small instances by standard optimization software
  - We are developing a heuristic method based on large neighbourhood search
Large Neighbourhood Search (LNS)

- Initial solution: Greedy heuristics (does not consider time shifting)

- Destroy: Remove $r$ trips (for example 5-30 trips)
  - Random trips (prob. 0.15)
  - Similar trips: Shared end points, close in time (relatedness, Shaw 1998) (prob. 0.85)
    - Select an initial seed trip at random
    - Calculate the relatedness measure
    - Select trip to be removed favouring trips with high relatedness value

- Repair: Reinsert removed trips using a randomised greedy heuristic and based on a calculated insertion cost
  - Insert cheapest trip
  - The chosen trip should be compatible with all active trips

- Acceptance: Like in Simulated Annealing
Test instance: S-busses and local trains in CPH
Test instances

• 3 lines. 538 trips.
  – All bus lines are circular lines with 5–6 intersections with the train network, but only few interconnections between the buses. Many passengers.

• 5 lines, 792 trips.
  – All bus lines are circular lines with 4–6 intersections with the train network, and only few interconnections between the buses. Some lines are passenger intensive.

• 8 line, 1400 trips.
  – Combination of circular and radial bus lines. The radial lines only have 2–3 connections to trains, but more connections to other buses. Most lines are passenger intensive.
Results

- **cost**: Cost reduction compared to the initial solution (waiting costs, deadheading costs, vehicle costs)

- **empty**: The reduction of empty mileage costs

- **time**: The reduction of total passenger waiting time

- **shifts**: The percentage of the original trips that have been time shifted

- **mem.**: The percentage of trips for which the gap to the preceding trip on the same line is a multiple of 5

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Sensitivity analysis

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Sensitivity analysis on the distribution of passenger transfers did not change the results significantly.
Conclusion

- The Simultaneous Vehicle Scheduling and Passenger Service Problem presents a new way of integrating timetabling and vehicle scheduling
  - The results based on large neighbourhood search heuristic are promising
    - 16% reduction in passenger waiting time using the same number of busses
    - An increase in deadheading was necessary
  - Better data are required for a real-life implementation
Further research

• Getting better data (TU data and later on a General Travel Card)

• Developing exact solution methods

• Investigation of the result of better solutions:
  – change in passenger behaviour
  – increased number of passengers
Thank you for your attention

Oli B.G. Madsen
Department of Transport, Build. 115
Technical University of Denmark
DK 2800 Kgs. Lyngby
Denmark
ogm@transport.dtu.dk