Operation optimization at DSB S-tog
- The Copenhagen suburban railway operator

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Agenda

• Intro to S-tog
• Planning process
• Rolling stock planning
• Crew planning
Figures on S-tog

• Major supplier of rail traffic in the greater Copenhagen area

• More than 300,000 passengers daily

• Annual turnover is more than 2,600,000,000
Production planning

- Part of Production Division

- Staff a mixture of experienced planners with traffic experience, dispatchers and staff with academic background
  
  - 10 crew planners
  - 5 rolling stock planners
  - 9 rolling stock dispatchers
  - 7 academic analysts/developers
  - 1 partly funded ph. d. student
  - 3 IT-supporters
  - 4 managers
Resources at DSB S-tog

170 km double tracks
84 stations
104 “1/1” train units, 336 seats
31 “1/2” train units, 150 seats
Approx. 550 drivers

~1200 departures on a daily basis
84 “1/1” train units + 2 standby
26 “1/2” train units + 1 standby
Approx. 250 drivers incl. standbys

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Depots and maintenance

- Rolling Stock depots at line terminals and Central station
- Crew depot with break facilities at Central station
- Maintenance in Høje Tåstrup
- Expanded cleaning (train wash) in Hundige
Density of network
Quantifying product quality
Planning levels

Network planning
Line planning
Timetabling
Rolling stock planning
Crew planning

Rolling stock planning:
- Compositions
- Rotations
- Depot planning

Crew planning:
- Duty scheduling
- Rostering
- Assigning drivers

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Planning levels in time

Long term: 10-5 years

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Planning levels in time

Long term: 1 year
Planning levels in time

Strategic ➔ Tactic ➔ Operational ➔ Short term ➔ Real time

3-2 months
Planning levels in time

- Strategic
- Tactic
- Operational
- Short term
- Real time

14 - 1 day

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Planning levels in time

Strategic → Tactic → Operational → Short term → Real time

Day-of-operation

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Rolling stock planning
Strategic rolling stock planning

• Fleet management
  • Quantify future needs
  • Distribution of “1/2” and “1/1” units
  • Estimate future need for rolling stock given expected demand
  • Scenario testing with different objective functions

• Challenges
  • Passenger forecasting for future timetable
  • High degree of uncertainty
  • Defining costs

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Tactic rolling stock planning

- Currently a manual process based on experienced planners
  - Compositions change 4 times during a normal day
  - Use the 104 “1/1” units and 31 “1/2” units taking into account number of passengers and operating costs

- Challenges:
  - Cost of “1/1” per km = 1.65*(cost of “1/2” per km)
  - “Up” and “down” on depots - of varying size
  - Limits on shunt personnel at the depots
  - Depot balances at the end of the day
  - Regular maintenance - 60 days or 20,000 km
Rolling stock optimization - OMPLS II

- Based on expected savings of the order 3 - 5 %
- A system development process has been initiated - vendor: Jeppesen
- Expected delivery in 6 - 12 months

**Solution method:**
1. Solve the composition problem based on passenger estimates – Pass solution to the circulation problem
1. Solve the circulation problem
   - If infeasible return to 1)
   - If feasible pass solution to depot planning
   - If depot planning infeasible return to 2) with new constraints
3. Until feasible
Operational rolling stock planning

- Same tools as tactic planning
- Less time for planning

Challenges
- Most days have planned rail works
- Same as tactic
  - Limited depot capacity
  - Limit shunting personnel
  - Maintaining end of day balance
  - Enabling regular maintenance
- Applying changes – data
Operational rolling stock planning

- Same tools as tactic planning
- Less time for planning

- Challenges
  - Most days have planned rail works
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  - Enabling regular maintenance
  - Applying changes – data
Rolling stock dispatching

- Allocate train units of right type and number in time to each departure
  - Restriction on driven km
  - Planned repairs at the workshop
  - Planned cleanings at prepare centre
  - Unexpected defects on train units
- Planning of central station depot
- Updating of MSS w.r.t. driven rolling stock

- Challenges
  - No decision support
  - The present rolling stock dispatching system (MSS) does not update automatically
  - Many of the planning tasks has a high “in-hand” complexity
Rolling stock dispatching
Definition of train related terms

- **Train task**
- Train sequence
- Train unit
- Train composition
- Train
- Train Line
Definition of train related terms

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Rolling stock recovery - problem description

• Given a disrupted rolling stock schedule
  • Route train units to path feasible w.r.t.
    • End depot
    • Maintenance requirements
  • Cover train tasks according to demand
  • Composition changes must be legal

• Recovery period is predefined
• Train units directly affected by the disruption included
Open and closed end train

1. Arriving train
   Tracks to depot

2. Just after arrival
   Tracks to depot

3. Decoupling
   Tracks to depot

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A decomposed approach

Types assigned to tasks

Positioning model → Sequence model → Routing model

Preferences: Types to Sequences

Tasks all ready covered
The train unit position problem

\[ X_{tp}^m = 1, \quad \text{if task } t \text{ is covered in position } p \text{ by type } m \]

- Minimizing difference to desired end capacities
- Balances of train units on depots are controlled after each arrival
- Feasible composition changes are controlled by controlling open and closed position

\[ C_{tp} \cdot X_{tp}^m \leq X_{v(t)p}^m \]

Forcing the successor task, \( v(t) \), to be 1 if task \( t \) is one and unit is in closed position
Train unit routing problem

\( Q_t^k = 1, \text{ if train unit } k \text{ is allocated to train task } t \)

- Maximize the number of train tasks covered
- Maximize number of train units returning to original path
- Allocate train units to train tasks according to solution from Position model
- For each train unit a feasible path must be made
  - Start depot is given
  - Maintenance requirements must be fulfilled

\[ \sum_{t' \in T \cap \text{Pred}(t)} Q_{t'}^k \geq Q_t^k, \quad \forall t \in T, k \in K \]
Train unit routing problem

\[ Q^k_t = 1, \quad \text{if train unit } k \text{ is allocated to train task } t \]

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\[ \sum_{t' \in T \cap \text{TimeParallel}(t)} Q^k_{t'} = 1, \quad \forall t \in T, k \in K \]
The train sequence problem

- Allocate physical train units to train sequences taking into account
  1. Each train sequence must be assigned at most one train unit
  2. The path for each train unit must be feasible

- Priorities are for the train types w.r.t. each train sequence are derived from Position model

- Maximize the sum of priorities allocated
Crew planning
Tactic crew scheduling

- Crew scheduling has three components:
  - Building of duties from driving tasks, stand-bys, breaks, ...
    - Task: “1/2” round or full round.
    - Breaks: a) Break > 30 min; b) Break1 + Break2 > 45 min.
    - A substantial number of rules on duty time and variation.
  - Building of rosters from duties.
    - Varying, but even, number of weeks.
    - Rules for days off with respect to amount and week-ends.
    - Rules for average duty length etc.
  - Assigning persons to rosters - strict seniority.
PDS - Personnel dispatching system
TURNI - optimization tool for crew scheduling
Challenges in Crew Planning

• The general system in working quite well, but ...
  • Roster generation still manual.
  • Operational planning in relation to track-work etc.
  • Data integration (a general problem).
  • Decision support for real-time dispatch.
  • Integration with other planning tasks.
Train Driver Dispatching at S-tog

• Main responsibility is to cover uncovered task with train drivers.
  • Timetable affected by delays => train driver is late for next task
  • Train driver absent
  • Train driver is signing in late

• Combining different actions into solutions
  • Available stand-by
  • Swap of tasks to create available driver
  • Calling in stand-bys
Summing up

- Decision support systems based on mathematics and IT are valuable throughout an organization as S-tog
- Contact with system users from idea to system delivery is a must
- For moving forward the support from key persons in management is necessary