Models for Train Scheduling

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Innovative Scheduling Overview

- Optimization and simulation solutions for transportation, logistics, and scheduling applications.

- Data mining and business intelligence solutions.

- Software application development in a rapid development mode.

- One-stop shop for modeling, optimization/simulation engines, data mining/analytics, and packaging into web-based map-based interfaces.
The train schedule is one of the most critical components in the passenger or freight transportations.

The quality of a train schedule greatly impacts the service quality and operating cost.

The interplay between different assets and shared networks makes the train scheduling a complex optimization problem.

An effective solution approach must consider all assets in the integrated manner.

The train scheduling problem for high-speed trains is very similar to that arising in freight transportation.
Train Scheduling

- Train scheduling problem is to decide the route and the schedule of freight or passenger trains such that:
  - All railcars/passengers can be transported at minimum cost and time from their origins to their destinations.
  - Terminal and track capacity (also called Line Capacity) are honored.
  - Utilizations of assets is highest possible.

- A train schedule provides:
  - Trains and their routes.
  - Train arrival and departure times at each stop in the route.
  - Itinerary for each shipment/passenger.
  - Asset schedule.
Important Constraints

❖ A shipment should be transferred between trains at minimum number of stations in its itinerary.

❖ A shipment takes certain time to feasibly make a connection from an inbound train to an outbound train.

❖ Number of trains which can depart from a terminal in a given time window is limited.

❖ Locomotives and crews must stay at a terminal for a given minimum duration before they are assigned to the next train.

❖ Number of trains traveling on a track segment in a given time window is limited.
Important Cost Considerations

❖ The cost of a train schedule consists of variable operational costs and fixed assets costs.

❖ Important variable operational costs are:
  – Fuel cost
  – Crew operating costs like hotels, taxi, etc.
  – Car miles and hire costs
  – Locomotive maintenance

❖ Important fixed assets costs are:
  – Locomotive purchase/leasing cost
  – Crew hiring cost
  – Car hiring cost
Train Schedule Optimization

- The train scheduling is a complex optimization problem with millions of decision variables and constraints.

- We have developed a decomposition based approach to solve this problem arising in freight transportation.

- Our approach simulates the flow of all resources on space-time networks and assess the impact for any change in a schedule.

- We have applied our algorithms for all major Class I railroads in Northern America and have demonstrated substantial savings in the cost.

- These algorithms are also applicable for passenger railroads.
Decomposition-Based Algorithmic Approach

Routing Decisions
- Determine Optimal Train Routes (MIP)
  - Enumerate all potential train routes.
  - Formulate the problem to decide train routes and BTAs as an MIP and solve using an MIP solver.
  - Enumerate alternate BTAs and pass them to next phases.

Train Time Decisions
- Decide each train’s stop times along its route
  - Optimize one train time by considering all possible options.
  - Change train timings if savings are more than threshold.
  - Repeat for all trains one by one until a local optimal solution is obtained.

Operating Day Decisions
- Decide operating days of trains
  - Optimize one train’s or a pair of trains operating days by performing add/drop/exchanges of blocks.
  - Repeat for all trains one by one until a local optimal solution is obtained.

Block-Train Assign. Decisions
- Decide block-to-train assignments by day of week
  - Optimize one block’s assignment to trains by considering all options.
  - Repeat for all blocks one by one until a local optimal solution is obtained.
Main Contribution: Integration of All Resources

- Our methodology for train scheduling takes into account all the network and operating constraints and optimizes the cost of all assets in an integrated manner.

![Diagram showing integration of resources]

- Constrained by Operating Rules
- Constrained by Network Capacity
  - Optimizer
  - Locomotives
  - Crews
  - Railcars
  - Yards
  - Tracks
Space-Time Networks for Three Resources

Efficient Locomotive Flow Network

Efficient Crew Flow Network

Efficient Railcar Flow Network
We have packaged our model in analysis tool (Innovative Train Scheduling Optimizer) to view/update data and analyze train schedules.
ITSO was used to generate a clean-slate plan with no restriction on the extent of changes in the current plan.

ITSO performed an excellent trade-off between different cost components while optimizing the overall costs.

Most of the model recommendations were implemented by removing trains that provided the greatest benefit.

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>% of Total Cost</th>
<th>% Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Costs</td>
<td>4%</td>
<td>6.47%</td>
</tr>
<tr>
<td>Crew Costs</td>
<td>9%</td>
<td>10.60%</td>
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<tr>
<td>Locomotive Costs</td>
<td>38%</td>
<td>2.69%</td>
</tr>
<tr>
<td>Car Costs</td>
<td>48%</td>
<td>-0.19%</td>
</tr>
<tr>
<td>Overall Cost</td>
<td>100%</td>
<td>2%</td>
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Study II: Incremental Train Scheduling Results

- The ITSO was used to change timings of trains, if the savings in cost is more than $800 per train per day.

- ITSO recommended changing times of around 10% trains.

- The recommendations from ITSO were intuitive and convincing in terms of cost and implementation.

- The model demonstrated individually how changing the departure time of a train impacts locomotive and crew connections.

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Study III: Curfew-Constrained Scheduling

❖ Several corridors in a railroad network are under curfew at any point of time.

❖ A railroad adjusts the train schedule in a curfew corridor in terms of:
   – Train departure time at origin or at intermediate stops
   – Train operating days
   – Crew change points in the route

❖ We used ITSO to re-optimize the train schedule while honoring curfew constraints.

❖ Results of the study:
   – The cost impact of the curfew plan was over $10 million per year in railroad train plan.
   – ITSO created curfew-constrained train plan with a net saving of $13 million per year.
We believe that our models for train time scheduling can be extended to high speed trains.

The scheduling of passenger trains is similar to freight trains in terms of:
- Flow of shipments/passengers
- Network capacity constraints
- Locomotive and crew assignments

However, at the same time, passenger train scheduling is different in terms of:
- High weightage to the service quality
- Cycling of coach cars and locomotives
- Different crew and conductor rules
- Etc.
Modeling Modifications for High Speed Trains

❖ At the fundamental level, the high speed train scheduling can also be formulated on similar underlying cars, locomotives, and crews space time networks.

❖ The network structure can be modified to meet specific nature of high speed train operations.

❖ The efficiency to solve the flow problems on three space-time networks can be maintained.

❖ The similar greedy approach as in freight trains can be applied.