Network Design For SBB Cargo

Project report

Nikola Obrenović, Virginie Lurkin, Michel Bierlaire
Transport and Mobility Laboratory TRANSP-OR
École Polytechnique Fédérale de Lausanne EPFL

Vincent J. Baeriswyl, Markus Streckeisen, Jasmin Bigdon
SBB Cargo AG, Olten, Switzerland

October 25, 2018
Marshaling and shunting yards

- Bundling different commodities with close origins and close destinations

Diagram:
- Marshaling yard
- Shunting yard
- Station
Problem setting

- Existing SBB Cargo network
  - 2 inner marshaling yards
  - 3 border marshaling yards
  - Approx. 70 shunting yards
    – 50 can be changed

- Solution should provide:
  - Optimal number and locations of marshaling and shunting yards
  - Set of used trains
  - Assignment of commodities to trains
Problem definition

• Combination and extension of the Hub Location (HLP) and Multicommodity Network Design (MNDP) Problems

• Objective function:

\[
\min C_{ct} + C_{ls} + C_{cs}
\]

- Commodity transport costs
- Locomotive and staff costs
- Commodity shunting costs
Problem definition (cont.)

- Constraints from MNDP:
  - Flow conservation constraints for trains
  - Arc capacity constraints
- Constraints from HLP:
  - Hub capacity constraints
  - Maximal number of hubs
- Node type constraints:

\[ r_i + s_i + m_i = 1, \quad \forall i \in N \]
Problem definition (cont.)

- Trains modelling
  - Commodity assignment constraints
  - Flow conservation constraints for commodities
  - Train capacity constraints

\[
\begin{align*}
  f_{pq}^k &\leq s_p^k + m_p^k + o_{kp}, & \forall p, q \in N, \forall k \in K \\
  f_{pq}^k &\leq s_q^k + m_q^k + d_{kq}, & \forall p, q \in N, \forall k \in K \\
  \sum_{k \in K} f_{pq}^k v_p^k l_p^k &\leq L_t n_{pq}, & \forall p, q \in N
\end{align*}
\]
Data collection

- Close collaboration with Vincent J. Baeriswyl
- Received initial data set from SBB Cargo:
  - infrastructure, cost, and demand data (OD pairs)
- Additional data supplied when the requirement is identified
Heuristic algorithm

- Size of the SBB Cargo network: approx. 2100 stations, 2500 direct links, over 65000 commodities
  - Yearly demand, scaled to daily average
- Heuristic algorithm composed of 4 stages:
  - Yard location and sizing
  - Initial train generation
  - Commodity assignment (routing)
  - Train number reduction
Heuristic algorithm – Yard location and sizing

- Yard location:
  - Adaptive large neighborhood search (ALNS)
  - Variable neighborhood search (VNS)
Heuristic algorithm – Initial trains generation
Heuristic algorithm – Commodity assignment

- Commodity routing:
  - Prioritized assignment algorithm

Select commodity by priority
Path alternatives test
  - Via marshaling and shunting yards, shunting yards only, or direct train.
Path selection
  - Cheapest estimated, available path
Add necessary trains
  - If none of the paths is feasible
Heuristic algorithm – Reduction of train number

- Remove all unused trains
- VNS loop:
  - Marshaling yard
  - Shunting yard
  - Station
Heuristic algorithm – development details

• Developed algorithm is very flexible:
  • Easily extendable with additional neighborhood operators, i.e. network transformations
  • Easy definition of specific initial network states, e.g. all marshaling yards closed, several additional marshaling yards open, etc.

• Algorithm modes:
  • Daily average demand
  • Peak demand
Algorithm results

- Two usage strategies:
  - S1: allowing increase in the number of marshaling yards
  - S2: limiting the number of marshaling yards to the current one
- Initial network state
  - The current network state
  - Changed number and locations of the marshaling and shunting yard
Algorithm results

- Best resulting networks obtained from the current network state

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>VNS</td>
<td>2h</td>
<td>10.01%</td>
</tr>
<tr>
<td>S2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>49</td>
<td>ALNS</td>
<td>17h</td>
<td>16%</td>
</tr>
</tbody>
</table>

- S1 should in theory yield a better result, but the investigation in this direction was shorter due to a business decision
Algorithm results – Marshaling yards
Algorithm results – Shunting yards
Results analysis

- Locomotive and personnel (distance-dependent) costs are dominant over weight-dependent commodity transportation costs
- Costs of yard opening and maintenance are not taken into account
  - Potentially would further reduce the number of yards and their size
  - Could be included in another case study
- New yards can be near the existing ones
  - The objective function has been extended to penalize this situation
Results analysis - Routing
Conclusions

• Developed algorithm explores various network changes, their combinations and their influence to the transportation costs
  • Flexible, easily extendable algorithm
• The algorithm identified network changes resulting in transportation cost reduction
• The objective function should be extended with the real costs of maintenance of the marshaling and shunting yards
• Algorithm parallelization – performance improvement
Possible future collaborations

- Development of the exact solution method (on the whole set or subset of input data)
  - Also to benchmark the heuristic results
- Algorithm for daily cargo management
  - Train routing
  - Track allocation
  - Staff allocation
  - Demand prediction
Thank you!

Questions?

nikola.obrenovic@epfl.ch


