Resource management for consolidation-based freight carriers

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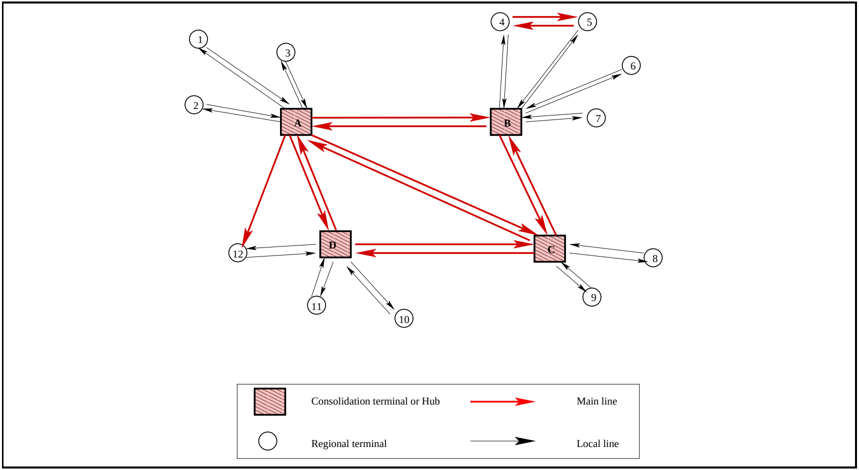
Outline

- Introduction and motivation
- Problem description
- Mathematical model
- Conclusion and perspective

Introduction

- Freight transportation constitutes a vital service in modern society: economical, social, environmental
- Freight move by rail, road, water, or air
- Intermodal freight transportation: multi-modal chain of transportation services
- Consolidated-based carriers move important parts
    - Railroads
    - LTL motor carriers
    - Ocean shipping lines

Network with consolidation terminals - Hubs



Introduction

- Railroads transportation represents a significant portion of freight transportation activities
- Based on RAC Railways Trends 2000
    - 40% of Canada's exports
    - 99% coal
    - 90% grain
    - 90% auto industry output
    - ...

  move by rail

Introduction

Railroads advantage

- Offer cost-effective long-haul transportation service
- Help to reduce road congestion, pollution and fuel consumption (5 times more fuel effective than inter-city truck)

Railroads goal

- The goal of railroads nowadays is to maximize profitability and to increase competitiveness relative to other modes of transportation
- This implies improve transportation system performance and provide the best done closer to the customer (on time, flexible and competitive service) while maximizing the company's profit

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General context

- General context of railroad freight transportation company:

  ⇒ Move demands between pairs of origin-destination locations

- This implies several operations & planning activities:
  - Providing empty cars
  - Consolidating cars into blocks
  - Planning trips for blocks
  - Assembling blocks to trains
  - Planning routes and schedules for trains
  - Planning and assigning power engines to trains
  - Planning and assigning crews

General Issues

- Each planning decision is very important to achieve transportation system performance
- Operations require several limited resources:
    - Infrastructure
    - Cars
    - Engines or locomotives
    - Crews
    - ...
- High cost of new acquisition

$\Longrightarrow$ One of the main issues: make " Optimal" use of available resources

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Research focus

We focus on two problems:

- Efficient management of power engines
- Improve empty cars supply

Managing locomotives: Problem setting

- Problem
    - Pre-planned train schedule to be served within a time horizon
    - Limited number of locomotives with various characteristics
    - Problem: Provide sufficient power to pull each train from origin to destination
- Data
    - Train: route, arrival/departure time, tonnage, length, possible power change points, etc
    - Locomotives fixed and variable characteristics: availability, fuel capacity, dynamic brakes, horse power, maintenance requirements, repair schedule, etc
    - Train requirement: horse power required per *route portion, special equipment requirement, etc*

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- Decision:
    - Assign a set of locomotives to each train at minimum cost
      $\Longrightarrow$ Active assignment, coupling/uncoupling decision
    - Move locomotives to shortage terminals at minimum cost
      $\Longrightarrow$ Deadhead assignment, coupling/uncoupling decision
- Issues
    - How much from each locomotive type
    - Which one from those available
    - When and where to do coupling/uncoupling
    - How to handle maintenance requirements
    - Have to maintain balance through rerouting

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Managing locomotives: General methodology

Manage locomotives within two steps:

- Tactical planning: Middle to short-time plan

  $\Longrightarrow$ Meta-route (number of each type at what time and which terminal)

  $\Longrightarrow$ Maintain balance by rerouting

  $\Longrightarrow$ Cyclique assignment

- Operational planning: Day-to-day operational decision

  $\Longrightarrow$ Schedule for each individual locomotive

  $\Longrightarrow$ Short cyclique route (appropriate in disruption situation)

$\Longrightarrow$ What details to consider at each step (Maintenance, fuel, ...)

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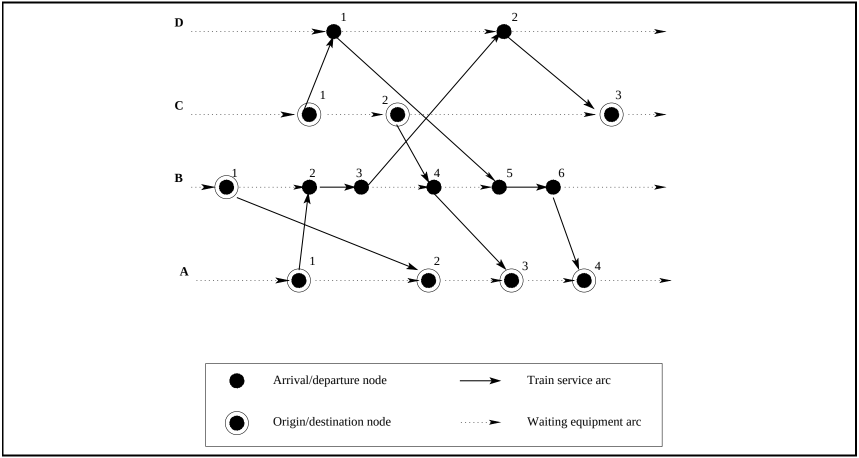
Managing locomotives: Tactical planning

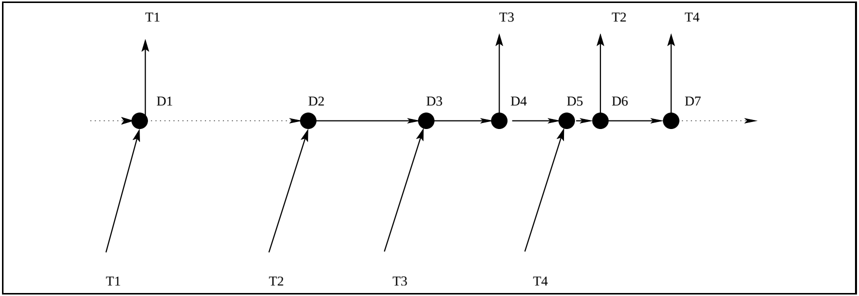
- Tactical planning leads to locomotive routing/scheduling problem: very large combinatorial optimization formulation
- Service space-time network: Physical network expanded in space and time
  - Nodes: Station-time
  - Arcs: Train legs and positioning arcs
- Variables:
  - $x_{ij}^{k} \in N$: Number of type k loco actively assigned to (i, j)
  - $y_{ij}^{k} \in N$: Number of type k loco deadheaded/repositioned to (i, j)
  - $z_{ij} \in \{0, 1\}$: 1 if (i, j) is used, 0 otherwise

Network representation



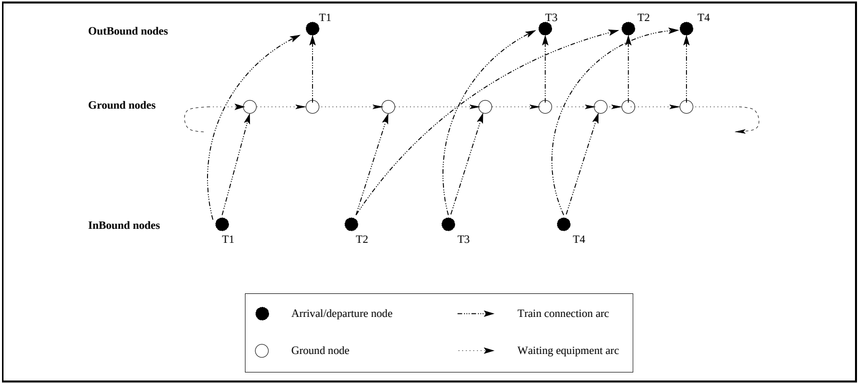
Service space-time network

Network representation



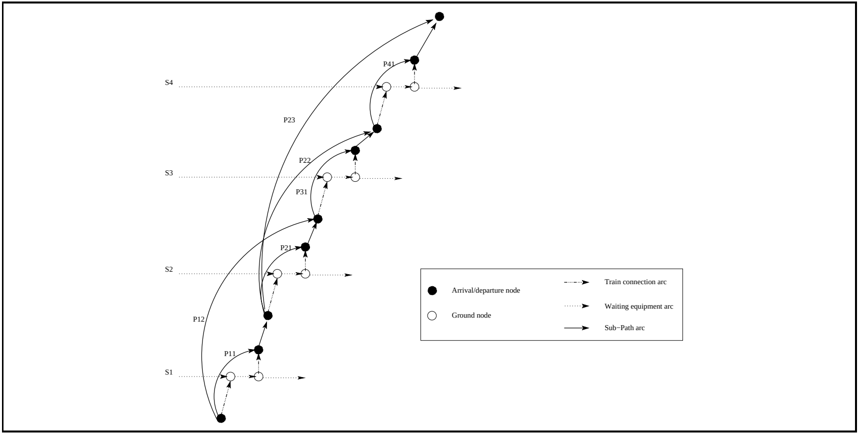
Space-time station representation

Network representation



Train in/out evolution at station

Network representation



Sub-Path service space-time network

Formulation

$$\min \sum_{(i,j)\in TrTr} \sum_{k\in\mathcal{K}} c_{ij}^k x_{ij}^k + \sum_{(i,j)\in\mathcal{A}} \sum_{k\in\mathcal{K}} d_{ij}^k y_{ij}^k + \sum_{(i,j)\in TrGr} \sum_{k\in\mathcal{K}} F_{ij} z_{ij} \qquad (1)$$

Flow balance:

$$\sum_{j\in i^-} (x_{ji}^k + y_{ji}^k) - \sum_{j\in i^+} (x_{ij}^k + y_{ij}^k) = 0 \qquad \forall i \in Tr, \forall k \in \mathcal{K} \qquad (2)$$

$$\sum_{j\in i^-} y_{ji}^k - \sum_{j\in i^+} y_{ij}^k = 0 \qquad \forall i \in Gr, \forall k \in \mathcal{K} \qquad (3)$$

Forcing busting:

$$\sum_{k\in K} (x_{ij}^k + y_{ij}^k) \leq Mz_{ij} \qquad \forall (i,j) \in \mathcal{A} \qquad (4)$$

Availability:

$$\sum_{j\in i+} (x_{ij}^k + y_{ij}^k) = \mathcal{B}_i^k \qquad \forall k \in \mathcal{K}, \forall i \in InG^0 \qquad (5)$$

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Formulation (continue)

Design balance:

$$\sum_{i^+} z_{ij} = 1 \qquad \forall i \in Orig \tag{6}$$

$$\sum_{i^-} z_{ji} = 1 \qquad \forall i \in Dest \tag{7}$$

$$\sum_{j\in i^-} z_{ji} - \sum_{j\in i^+} z_{ij} = 0 \qquad \forall i \in N\backslash(Orig \cup Dest) \tag{8}$$

Requirement:

$$\sum_{k\in\mathcal{K}} h^k x_{ij}^k \geq \underline{H}_{ij} z_{ij} \qquad \forall (i,j) \in TrTr \cup TrGr \cup GrTr \tag{9}$$

$$\sum_{k\in\mathcal{K}} h^k x_{ij}^k \leq \overline{H}_{ij} z_{ij} \qquad \forall (i,j) \in TrTr \cup TrGr \cup GrTr \tag{10}$$

Integrality:

$$x_{ij}^k \in N \qquad \forall (i,j) \in TrTr, \forall k \in \mathcal{K} \tag{11}$$

$$y_{ij}^k \in N \qquad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \tag{12}$$

$$z_{ij} \in \{0,1\} \qquad \forall (i,j) \in \mathcal{A} \tag{13}$$

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Conclusion and perspectives

- We proposed an IP formulation for the tactical planning level where some basic maintenance requirements are considered through network representation
- Forthcoming
    - Validate formulation through experimentation on real-life data using Cplex
    - Develop sophisticated solution methods based on Lagrangian decomposition
    - Use the meta-plan within the operational planning level
- Improve empty cars supply

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Thank you for your attention.

Questions?