Fleet management in rail transport: Petroleum rakes in Indian Railways
For workshop on Urban Freight and Transport: A Global Perspective

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Affiliation

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- Mr S S Gupta, WR, POL, IR
- Mr Beji George, Mr Manish, Mr Raman, CRIS, Delhi
- Colleagues Suresh B and Shabd Vaish, IEOR, IIT Bombay, for simulation project
- Mr Ummapathy, Mr Ranveer Singh, IOCL
Outline

Understanding the problem

Proposed solution to deterministic problem

Proposed solution to stochastic problem

Current work

Future possibilities
Understanding the problem

- Placement of indents from Oil Industry (about 30 loading points and 100+ unloading points)
- What to do with a petroleum rake once it gets empty? (about 200 rakes and about 50 loadings/unloadings every day)
- Multiple products and rake compatibility
- Maintenance of rakes
- Terminal capacities
- Uncertain environment
- The current process is repetitive, time consuming and involves lot of man hours
- Passenger traffic gets higher priority than freight trains
Breaking up the problem in 2 parts

- 1st Part: Outstanding known indents in the system, deterministic
- 2nd Part: Prediction for future demand, anticipated
Proposed solution to deterministic problem

- Linear Programming model
- Input to model
  - Rake status, outstanding indents
  - Terminal points, decision matrix
- Output of model
  - Assignment of rakes to indents
  - Unassigned rakes and indents
- Objective:
  - Minimise empty running
  - Minimise difference between due date of indent and travel time
  - Prioritise indents
- Constraints:
  - A rake should be assigned to only 1 indent and vice versa
  - Terminal capacity constraints
  - Only assign compatible rakes
Size of the problem

Number of rakes  200
Number of indents  50
Number of loading points  50
Horizon for indents  7
Decision variables  $200 \times 50 = 10000$
Assignment constraint  50
Indent constraint  200
Compatibility constraint  $200 \times 50 = 10000$
Terminal capacity constraint  $50 \times 7 = 350$
Total number of constraints  $200 + 200 + 10000 + 350 = 10750$
Figure 1: Overall flow diagram for daily decisions
Model architecture explanation

Preprocessing using python scripts

Distance and Time Matrix
Loading, Unloading and Base Depots
Indents
Rake Status

Read data

Rake Loadable to any indent?

yes

Separate problem
This problem can be solved separately to decide what to do with these rakes?

no

Figure 2 : Model architecture 1/2
Model architecture explanation

Figure 3: Model architecture 2/2
What should be the arrival rate of rakes as to minimise the time spent in the terminal point.
Development of the model

- Meeting with Mr S. S. Gupta (Western Division, IR)
- Understanding the steps involved at the loading terminal.
- Anylogic simulation software.
- Gives the arrival rate of rake.
- The model can be replicated for each loading terminal.
Simulation model

Figure 4: Simulation model
Compatibility and extension

- Compatibility of the model:
  - Current system is compatible with the data already collected by Indian Railways
  - The input can be used by the model with very little preprocessing for the file formats required
  - The output is text based representation of assignments which can be then transformed to any format required

- Extension to the model:
  - The objective functions can be combined together and be given weights
  - For example: Objective functions o1, o2, weights w1, w2
  - Sample objective: \( w1 \times o1 + w2 \times o2 \)
Performance

Environment Software
- 2.4 GHz Intel Core i5 CPU
- 4 GB RAM

Optimization Algorithm
- IIT Bombay Optimus Server
- AMPL + CPLEX 12.5
- OS: Fedora 14 Intel X4300 M3, Quad core Xeon E5506, 64GB RAM
- Post graduate - 4GB
- Database - SQLite

Setup
1. Connecting to Database
2. Writing the files in the concerned format
3. approx. 3 seconds

Optimization running time
1. Running the model on solver
2. approx. 1 second
Proposed solution to stochastic problem

- Prediction model for unassigned rakes
- Use of monthly planning meet with oil industry
- Inputs to the model are indents already placed and anticipated demand
- Past history for a loading point
- Simple system statistic which would define the objective to be used on a given day
Currently working on

- Proof of concept for entire implementation
- Distribution of rakes to maintenance points
- Prediction model for anticipated indents
- Unimodularity of the mathematical model developed
- Undertaking of scientific paper writing for Informs Journal
Future possibilities

- Extending the model for other railway commodities (for example, coal)
- Facility location decision for train maintenance points
- Better forecasting models for arrival time of freight trains
- Number of rakes required
- Analytical inputs to pricing
Thank you!
Rake linking for suburban train services

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Context

• Approximately 1200 services on the Western Railway line in Mumbai
  – 3 minute frequency in peak hours
  – Each train carries 4500-5000 people
• Approximately 80 rakes (train units – mostly 12 car rakes) used
• Each rake used for 12-15 services
• 2 car sheds (housing about 30 rakes each) and about 8 stabling locations (for 3-5 rakes)
Timetable and rake linking

• Timetable of services created for meeting demand and keeping constraints in mind (headway, platforms, rake availability, etc.)
• Each service has to be assigned a rake
• Normal rake linking done together with timetabling
  – Platforms not adequate in some key locations
  – Rakes a constraint in offering services
• During (minor) disruptions and during planned maintenance, rake linking for target timetable is a challenging problem
Service graph

• Nodes
  – Start node for a service
  – End node for a service
  – Rake depot (start and end of a link for the rake)
• Arcs
  – Service arc
  – Linking arc (waiting)
  – Linking arc (empty run)
  – Start of service arc
  – End of service arc
Costs and capacities

• Costs
  – On each rake from depot (meet timetable with minimum number of rakes)
  – Empty running costs

• Capacities
  – Service arc [1,1]
  – Linkage arcs [0,1]
  – Depot supply arcs [0,K]
(Single commodity) min cost network flow model

• Straightforward flow model to minimize total costs
  – Cost of running each rake
  – Empty running costs
  – Combination of the above

• Outcomes are
  – Rake links and rake cycles
  – Rake stabling during reduced service times (Sundays and maintenance periods)
  – Sensitivity analysis to turn around times at terminals
Extensions

• Multiple rake types and compatibilities
  – Multi commodity integer flow problem, tough problem to solve

• Rake cycle constraints
  – Rostering of rakes

• Terminal constraints