Maintenance integration in Railway networks

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Managing a scarce resource

- Railway safety system
- Expensive infrastructure
Managing a scarce resource

- There is growing competition within/across class across usage
- Capacity allocation via timetable is a lengthy and suboptimal process
Managing a scarce resource

- Competition across usages: I need maintenance operation, even though they subtract capacity from commercial operations

- Maintain a lot, with high costs but little disruptions?
- Maintain little, with limited costs but necessity to take into account large disruptions?
Integrated Planning


Background – integrated planning approach

Planning **together:**

- Train scheduling, along routes, arrival/departures times at stations
- Infrastructure maintenance: the rail infrastructure requires periodic maintenance works to be performed by means of limited resources.
- Minor possessions, not allowing any rail traffic during maintenance activities
Types of constraints considered

- Route ↔ time
- Flow balance
- Capacity (trains)
- Time-space
- Travel time
- Maintenance tasks
- Deadlines
- Capacity (maintenance)
- Routing of trains
Single possessions

- Integrated is better than \( n \) sequential solutions
Tradeoff integrated vs sequential planning

- Sequential planning model is easier to solve, suboptimal
- Integrated planning potentially better, computationally difficult
- Lagrangian relaxation scheme to solve the integrated problem
Ideas of the results, real life case

- Chinese High speed network
- Heterogeneous traffic
- Hard to plan maintenance
Real life case, results

- Integrated always at least as good as sequential
- Computation time proves acceptable

\[\text{Deviation time (unit: minute)}\]

(a) Case with 2 trains
(b) Case with 4 trains
(c) Case with 6 trains
(d) Case with 8 trains

\[\text{Planning horizon } T \text{ (unit: minute)}\]

\[\text{+ integrated solution} \quad \circ \text{sequential solution}\]
Multiple possessions

- Inherently Multi objective; delays of trains and activities pairing to decrease possessions
- To minimize possession setup/ release time
- To minimize disturbances to rest of the traffic
- Minimize timetable deviation
- Maximize amount of paired works
Example

Timetable deviation

Paired works

Pareto Front
**Example**

- **Train 1**
  - 1
  - 2
  - 3
  - 6

- **Train 2**
  - 4
  - 5

- **Train 3**
  - 13
  - 14

- **Train 4**
  - 15
  - 16
  - 17

- **Maintenance area**
  - 8
  - 9
  - 11
  - 12

**Paired works**

**Pareto Front**
Results

- Increased effectiveness - more than 25% improvement by integrated planning
- Increase efficiency - good quality can be obtained quickly, less than 60 seconds
- The experiments demonstrate that the integrated scheduling method is at least as good as the sequential one, and the proposed algorithm is able to exploit the large solution space effectively.
- Identify Pareto-optimal solutions within multi objective problems
- Possibility to plan for uncertain duration, uncertain maintenance requirements
Future
Increasing mobility needs

- Increasing mobility needs; Mobility as a service; urban & interurban level
- Higher reliability, performance, availability
More sensitivity to disruptions

What happens to supply chain performance during an unforeseen event?

Global Surface Temperatures
Four independent records show nearly identical long-term warming trends.

Rastatt Tunnel disruption, August-October 2017-DB AG

Amount of events classified as disruption, Dutch Network [Corman]
More demanding people; less budget available for operations

![Graph showing five-year CAGR 154%](source)

Same-day delivery will grow in the triple-digits
Future works

- Understand better the link data-information-value
- Stronger mathematical formulations, able to handle complex infrastructure and vehicle processes
- Improve the optimization planning for practical instances with more trains and more complex railway infrastructures.
- Deeper integration of stochastic condition monitoring and optimization
- Integration of the proposed methodology within the railway process, train planning and management tools
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