Stability evaluation of a railway timetable at the station level

Xavier Delorme\textsuperscript{1}, Xavier Gandibleux\textsuperscript{2} and Joaquín Rodriguez\textsuperscript{3}

\textsuperscript{1} École Nationale Supérieure des Mines de Saint-Etienne, Centre Génie Industriel et Informatique

\textsuperscript{2} Université de Nantes, Laboratoire d’Informatique de Nantes Atlantique

\textsuperscript{3} Institut National de Recherche sur les Transports et leur Sécurité, Unité de Recherche Évaluation des Systèmes de Transports Automatisés et de leur Sécurité
Presentation overview

- Railroad infrastructure operation planning
- RECIFE project
- Stability evaluation model
- Example of stability evaluation
- Conclusion
Rail transport context

Rail transport
- Interest revival as road alternative
- Competition with other transport modes
  ⇒ Traffic increase and evolution

Tools are needed for
- evaluating networks limits
- studying modifications of the network
- determining a commercial strategy

How to plan railroad infrastructure operation?
Main questions considered

- Rail transport problems
- Planning problems
- Scheduling problems
- Development projects analysis
- Railroad capacity
- Routing optimization

- Real-time problems

Feasibility
Saturation
Preferences
Timetable stability

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Existing softwares

Homogeneous zones (lines)
- Analytical methods [UIC, 1978]

Heterogeneous zones (junction, station, network)
- Simulation
- Constructive methods
  - DONS [van den Berg and Odijk, 1994]
  - CAPRES [Hachemane, 1997]
  - DÉMIURGE [Labouisse and Djellab, 2001]

⇒ mainly on network level
Railroad infrastructure capacity

Given:

- Safety rules
- Rolling stock technical characteristics
- Service quality

- How many trains can be routed through the junction within a time interval?
- What is the best solution to route these trains?
RECIFE project

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The RECIFE project

Objective of RECIFE

- Models to evaluate railroad infrastructure capacity of junction or station
- Solvers based on combinatorial optimization algorithms
- Application on Pierrefitte-Gonesse node and Lille-Flandres station

⇒ Decision support software

Partners involved

- French institute on transport (INRETS)
- French railway society (SNCF)
- Ecole des mines de Saint-Etienne
- Nantes university
- Valenciennes university
Global scheme of the RECIFE software

Infrastructure
Service quality
Rolling stock
Safety rules

Simulation or operation data

Ressources use for each route

Modelization

Optimization problem

Exact or heuristic solver

Timetable(s)

Visualizations
Statistics
Stability evaluation

List of possible trains

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Model for capacity evaluation

Assumptions

- All possible routes are given
- All possible arrival-date are given

Combinatorial optimization model [Delorme, 2003]

- multiobjective extension of STATIONS model [Zwaneveld et al, 1996]

- based on binary decision variables

\[ x_{t,r,\delta} = \begin{cases} 
1 & \text{if the train } t \text{ is assigned to the route } r \text{ on clear-line with a delay } \delta \text{ on its arrival-date} \\
0 & \text{otherwise} 
\end{cases} \]
Visualization of timetables

Gantt chart
Visualization of timetables

- Gantt chart
- Space-time diagram

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Visualization of timetables

- Gantt chart
- Space-time diagram
- Tracks map
- Simulation
Stability evaluation model

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Previous works on stability

Classic methods are based on:
- either Petri nets
- or Max-plus algebra

Type of stability evaluation
- Recovering time for a cyclic timetable
  ⇒ impossible if non-cyclic
- Time margin of the trains
  ⇒ nearly null for saturated timetable

New model based on delay propagation
Delay propagation

2 types of delay
- primary delay caused by a disruption
- secondary delay due to interactions between trains

Impact of a primary delay
- secondary delays generated directly or indirectly

How to prevent conflicts
- delay of arrival-date of other trains
- Same routes and scheduling (no on-line Re-optimizing)
  \[\Rightarrow\] only short primary delay
Graph of potential direct conflicts

Use of potential direct conflict

Represented with a graph $G(V, E, w)$

Trains selected in the timetable

Train A

Train B
Graph of potential direct conflicts

Use of potential direct conflict

Represented with a graph $G(V, E, w)$

There is a potential conflict if the train A is delayed
Graph of potential direct conflicts

Use of potential direct conflict

Represented with a graph $G(V, E, w)$

Train A

Time available before the conflict occurs

Train B
Computation of stability evaluation

Computation of the secondary delays generated

- Time margin between Train A and B = shortest path in $G(V, E, w)$

- Secondary delay generated by a primary delay of Train A on Train B =

\[
\max(0, \text{Primary delay}(A) - \text{Shortest path}(A, B))
\]

Stability evaluation of a timetable

- Sum of all the secondary delays generated by each train
- Inspired by the know-how
- Importance of the primary delay

$\Rightarrow$ several values considered
Example of stability evaluation

- Railroad infrastructure operation planning
- RECIFE project
- Stability evaluation model
- Example of stability evaluation
- Conclusion
Description of the example

Didactic instance on Pierrefitte-Gonesse node

- 6 possible trains considered
- 450s between the first and last arrival dates

Optimization problem

- Conflicts determined with SYSIFE simulator [Fontaine and Gauyacq, 2001]
- Heuristic solver GRASP [Delorme et al, 2004]

⇒ \( \begin{align*}
5 \text{ trains routed (optimal solution)} \\
15 \text{ different timetables generated}
\end{align*} \)
One graph generated for each timetable

Graph of potential direct conflicts:

1. Node 1 with connections to:
   - Node 3: 135 s
   - Node 2: 216 s
   - Node 5: 71 s

2. Node 2 with connections to:
   - Node 1: 90 s
   - Node 5: 115 s

3. Node 3 with connections to:
   - Node 1: 135 s

4. Node 4 with connections to:
   - Node 3: 385 s

5. Node 5 with connections to:
   - Node 1: 237 s

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Shortest path computation
Shortest path computation

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Shortest path computation

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Resulting stability evaluation

Secondary delays computation

- for a primary delay of 180 s

Total delay generated by train 1: 45 s
Total delay generated by train 2: 155 s
Total delay generated by train 3: 109 s
Total delay generated by train 4 and 5: 0 s

Stability evaluation = 309 s
Resulting stability evaluation

Secondary delays computation

- for a primary delay of 180 s: 309 s
- for a primary delay of 300 s

Total delay generated by train 1: 333 s
Total delay generated by train 2: 395 s
Total delay generated by train 3: 229 s
Total delay generated by train 4 and 5: 0 s

Stability evaluation = 957 s
Comparison of the timetables

2 stability evaluation for each timetable

![Graph showing stability evaluation for various timetables](image)
Conclusion

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Conclusion

A new model for stability evaluation
- railroad timetable of junction or station
- delay propagation method
- using shortest path computation

⇒ integrated in a decision support system for railroad capacity evaluation

Future research works
- integration of multi-criteria analysis
- stability optimization