Disruptions in railway/public transport networks

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Chair for Transport Systems
Those slides

- Bad models
- Good reality
- Interactions
- Understanding more
- Understanding even more
Bad Models

F Corman, Assessment of advanced dispatching measures for recovering disrupted railway situations. Transportation Research Record
Routing /scheduling: Interesting instances

- When things are constant, and nobody influences anybody else: relatively easy
- In reality, there is some influence

- Routing in time and space models explicitly changes over time

- Interesting case: When capacity of links or intersections is limited
- Opportunity: When vehicles/people can be “controlled”
- Issues: when things “interact”
A space network in Toronto
An extended time space network
Some disruption management models

\[
\begin{align*}
\text{min} & \quad t_n - t_0 \\
\text{s.t.} & \quad t_j - t_i \geq w_{ij} \\
& \quad (t_j - t_i \geq w_{ij}) \lor (t_k - t_h \geq w_{hk}) \\
& \quad (i,j) \in F \\
& \quad ((i,j),(h,k)) \in A
\end{align*}
\]
Delay minimization via optimized traffic management

Distribution of delay propagation depending on traffic control algorithm

2700 block sections, 150 trains / h, ~300 km

Average Delay decreases

Variation in observed delays decreases

Traffic Control Algorithms:
- Optimized Orders
- First In First Out
- Rule-based
- Keep the Timetable Order

Delay Propagation in the systems, [s] average over all traffic
Disruption situation

Situation → Resolution → Disposition
A lot of resolution scenarios
## A lot of performance indicators

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Gener Traveltime Ht→Aco</th>
<th>Freq Services Ht→Aco</th>
<th>Freq Services Ht→Ut</th>
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**Situation → Resolution → Disposition**
A lot of performance indicators

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<th>Average Delay (s)</th>
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<th>Max Total Delay (s)</th>
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<th>Max Consecutive Delay (s)</th>
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<th>Canceled trains (absolute number)</th>
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TIMETABLE REF

Institut für Verkehrsplanung
Institute for Transport Planning

F. Corman  | 30.03.2019  | 18
### Comparing them

| Alternative | Average Delay (s) | Total Max Total | Average Consecutive Delay (s) | Max Consecutive Delay (s) | Punctuality % (min) | Cancelled trains (absolute number) | Capacity | Extra compared plan | Units:Gener | Traveltime Ht→Aco | Freq Services Ht→Ut | Gener TravelTime Ht→Ut | Freq Services Ut→Aco | Gener TravelTime Ut→Ht | Freq Services Aco→Ut | Gener TravelTime Aco→Ut | Freq Services Aco→Ht | Gener TravelTime Aco→Ht | Freq Services Aco→Ut |
|-------------|-------------------|-----------------|------------------------------|----------------------------|---------------------|-----------------------------------|----------|-------------------|----------------|-------------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| 12_0_0      | 43.8998           | 510             | 21.2463                      | 510                        | 94.78684            | 0.234                | 0                   | 3714  | 5                 | 4075  | 8                 | 2344              | 15                  | 2198              | 6.5               | 4455              | 4.5               | 3452             | 11.5             |
| 12+shuttle_0_0 | 43.256         | 510             | 21.0339                      | 510                        | 85.8333             | 1.242                | 0                   | 3714  | 5                 | 4075  | 8                 | 3179              | 15                  | 2518              | 6.5               | 7697              | 3.5               | 4010             | 12.5             |
| 8_4_0       | 98.8813          | 1739            | 67.4402                      | 1206                      | 88.88889            | 1.143                | 4                   | 3854  | 6.5               | 3844  | 6.5               | 3216              | 14.5                | 2104              | 4                 | 6215              | 4                | 4704             | 11               |
| 8+shuttle_4_0 | 96.73           | 1739            | 65.6454                      | 1206                      | 89.16667            | 1.114                | 8                   | 3839  | 3.5               | 3825  | 6.5               | 4333              | 15.5                | 2187              | 6                 | 9358              | 2.5               | 5164             | 12.5             |
| 8_0_4       | 37.2391          | 510             | 14.6082                      | 510                        | 97.22222            | 0.959                | 0                   | 3748  | 3.5               | 4326  | 5.5               | 3010              | 8.5                 | 3153              | 3                 | 5502              | 2                 | 3660             | 7                |
| 8_0_4+shuttle | 37.1944         | 510             | 14.4421                      | 510                        | 97.2973             | 0.948                | 0                   | 3708  | 3.5               | 4326  | 5.5               | 2653              | 12                  | 2440              | 6.5               | 6545              | 3.5               | 4028             | 9                |
| 8+shuttle_0_4+shuttle | 36.7468 | 510         | 14.2366                      | 510                        | 96.49123            | 0.948                | 0                   | 3732  | 3.5               | 4593  | 5.5               | 2929              | 12                  | 2518              | 6.5               | 7826              | 2.5               | 4248             | 8.5               |
| A_4_4       | 56.6107          | 1739            | 24.9972                      | 1206                      | 92.79279            | 0.948                | 0                   | 3744  | 3.5               | 5055  | 3.5               | 5055              | 8.5                 | 3390              | 2                 | 7175              | 0.5               | 4370             | 4.5               |
| 4_4_4+shuttle | 56.818          | 1739            | 25.2173                      | 1206                      | 92.98246            | 0.948                | 4                   | 3719  | 1.5               | 5055  | 3.5               | 3828              | 12.5                | 2187              | 6                 | 8194              | 1                 | 4706             | 5.5               |
| 4_0_8       | 28.668           | 510             | 6.70236                      | 510                        | 100                 | 0.959                | 0                   | 4000  | 0                 | 4000  | 2                 | 4000              | 0                   | 4000              | 0                 | 4000              | 0                 | 5000             | 1.5               |
| 4_0_8+shuttle | 29.3327         | 510             | 6.78802                      | 510                        | 100                 | 0.959                | 0                   | 3750  | 1                 | 5471  | 2                 | 2424              | 9                   | 2518              | 6.5               | 8776              | 1.5               | 5592             | 4.5               |
| TIMETABLE REF | 26.8934         | 510             | 5.81801                      | 510                        | 100                 | 0                   | 0                   | 3672  | 7                 | 3589  | 8                 | 2840              | 14                  | 2540              | 6.5               | 4294              | 4.5               | 3228             | 11.5             |
Disruption management is complex

- Models can help, ...
- If you know which solutions would be acceptable (automatic scenario generation?)
- If you know which constraints exist (better model, more integration)
  If you know how dispatcher would take decisions (?)
- If you know how passengers would react
- Statistics cannot help
- More integration/optimization make smaller problems disappear, bigger problems arise
Some positive thoughts

T Partl, Master Thesis ETH
Rastatt

- Disruption for about two months, 15.08 to 02.10 2018. No traffic.
Rastatt

- European corridor Rotterdam Genoa
Cancellations; delays

- Cancel train
- Buses, passengers
- Freight? (not counted)

Figure 7: Numbers of extra and cancelled trains arriving at Zurich HB and Olten
Primary delays

- Trains coming from Germany

Figure 19: Yearly pattern of average delays of all trains from Germany arriving at Basel SBB

Figure 21: Delays of all trains from Germany arriving at Liestal and Zurich HB, which non-stop came from Basel SBB
Secondary delays

- (delays at other stations have been checked and are not relevantly changed)

Figure 15: Yearly pattern of median delays in Liestal, Laufen and Rheinfelden including its moving average

Figure 17: Yearly pattern of median delays in Zurich HB and Olten including its moving average
Disruptions are good (?)

- Clear effect of isolation of network, → less delays
- Possibility to understand the degree of interconnection of networks
- Lessons learnt for internal dynamics/ external dynamics
- Never again!
Interaction modelling
Passengers Routing in public transport networks

- Divide hierarchically into layers post process, simulate, adjust
- Equal importance given to problem: iterate coordinate, converge
Schedule-based Transit assignment

Knowing passengers demand per time
Routing of passengers is based on shortest travel time
Vehicles (trains) have infinite passengers capacity

(relatively strong assumptions!)

Schedule-based assignment → min cost flow problem
scheduling trains in an infrastructure with limited capacity, taking into account the number of passengers per train

What I believe the other person would do

What will I do?

routing of passengers by taking into account the train schedule, their origin and destination, the minimization of their discomfort

What I believe the other person would do

What will I do?
Possible solutions – who does what, why?

- Optimize everything (integrated model) ~System optimum

- Minimize delay weighted by passengers; Passengers react to schedule, trains react to passengers choice ~Nash

- Keep the timetable order; or optimize schedule Passengers adjust route choices ~Inv. Stackelberg

- Passengers publish their choices / cost functions; optimize schedule to minimize travel time ~Stackelberg
Upper bound to optimum

Delaying trains instead of passengers:
12% shorter travel time vs timetable
11% optimality gap
Larger/better models

N. Leng, Agent-based simulation approach for disruption management in rail schedule, CASPT
Operations are not terribly good

- Example delay in Zurich
- Very dense network
A larger perspective onto activities - MATSim
Example disruption, Zurich

Oerlikon
~300 trains/ day
~85000 pax/day

Main station
~2900 trains/ day,
450000 pax/ day
I know things in advance
“Vision of God”

I never update my plan;
Pessimistic
Lessons learnt

- Large simulation models are complex
- The realistic behavior of people is complex to attain
- Interplay between operations, passengers decisions and (limited) information is crucial, but hard to model
- New developments possible soon
More understanding

A, Marra, Multimodal passive tracking of passengers to analyse public transport use, STRC
Study mobility in-vivo

- Typically user interaction-intensive
- Typically battery intensive
- Own developed
- Tested on ~50 students
Cleaning of data
This is different!

Fig. 7 Continuous tracking of a single user for one month. Activities in the same place have the same color, that goes from red to yellow according to the time spent in the activity. A white space indicates absence of signal.
Lessons learnt

- Disruptions are gray
- Large samples might help; data must be complemented with annotations
- Choice models can be estimated
- Mobility providers might know about us than we know
Disruptions in railway/public transport networks

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