Improving passenger robustness by taking passenger numbers and recurring delays explicitly into account on the tactical level

Sofie Burggraeve
Thijs Dewilde
Peter Sels
Pieter Vansteenwegen

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Objective

Improving passenger robustness

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Short travel times

Reliability

Minimizing total weighted real travel time of all passengers in case of frequently occurring small delays

Framework

We focus on the tactical level:
timetable – routing plan – platform assignment

busy railway station areas

small daily delays

Approach

Optimization algorithm

strives to maximize
the sum of the minimal buffer times
between all trains in a fixed time window

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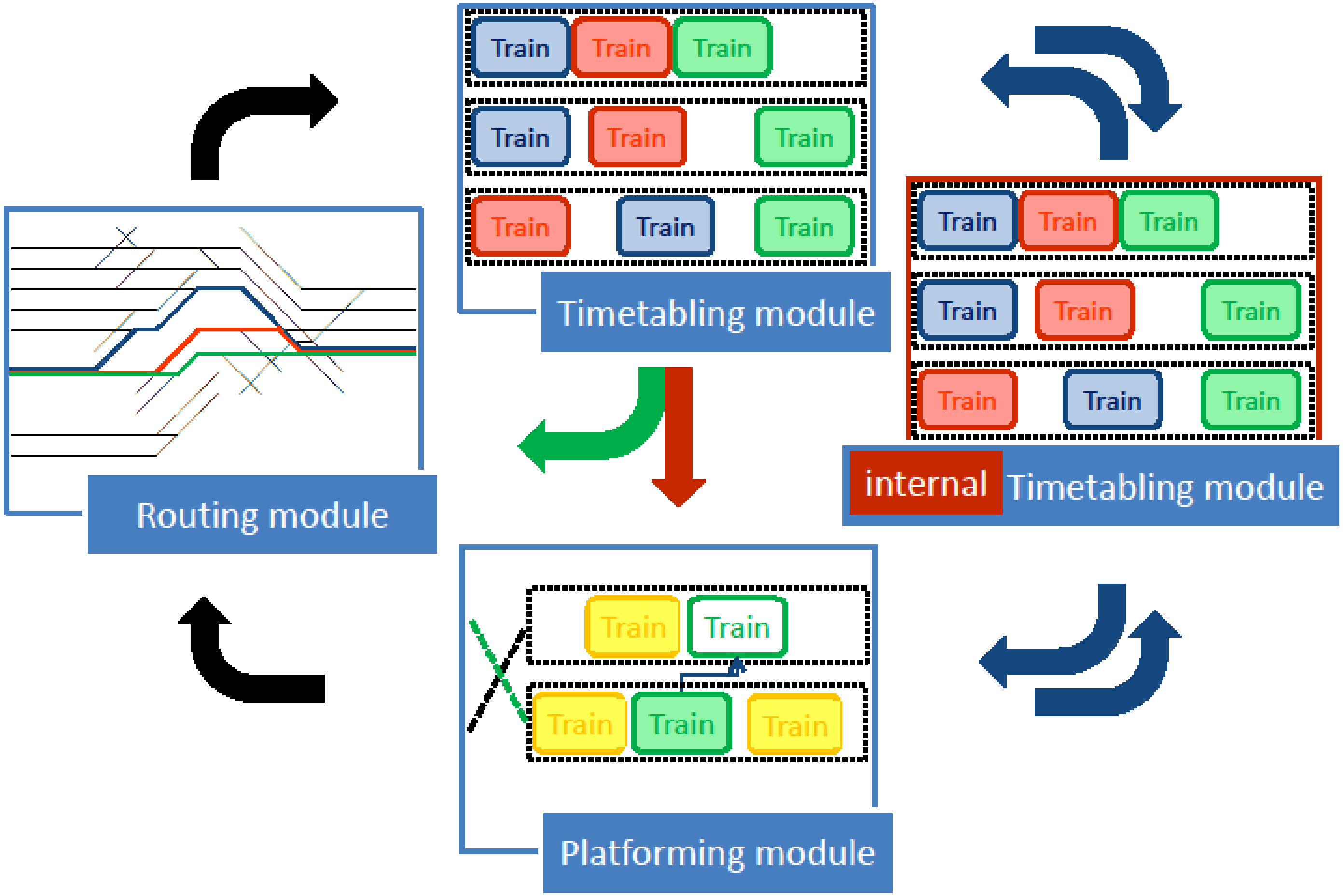
indirectly improves passenger robustness
of an existing timetable

Simulation

directly evaluates passenger robustness

Optimization algorithm



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Optimization algorithm

Routing module

exact: based on a NPP

$$\min \sum_{(t,r)\in T\times R_t;(t',r')\in T\times R_{t'}} \frac{1}{B_{(t,r),(t',r')}} x_{(t,r)} x_{(t',r')}$$

$$\sum_{r\in \mathrm{R}_t} x_{(t,r)} = 1 \qquad \forall t \in T$$

$$x_{(t,r)} + \sum\nolimits_{r'\in R_{t'}^c} x_{(t',r')} \leq 1 \qquad \forall (t,r) \in T \times R_t, t' \in T \setminus \{t\}$$

$$x_{(t,r)} \in \{0,1\} \qquad \forall (t,r) \in T \times R_t$$

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Optimization algorithm

Routing module	exact: based on a NPP
Timetabling module	local search heuristic (tabu search): shift – combined shift - swap
Platforming module	local search heuristic (tabu search): platform change

Interaction between modules

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Some buffer times are more important than others

Passenger numbers

1000 passengers

5 passengers

Recurring delays

2 min

3 min

- 1 min

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Weighted buffer times

Passenger numbers (absolute)

number of passengers that are
on the second train or
will board on the second train
after the place of the shortest buffer time

$$\min \sum_{(t,r)\in T\times R_t;(t',r')\in T\times R_{t'}} \frac{N}{B_{(t,r),(t',r')}} x_{(t,r)} x_{(t',r')}$$

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Weighted buffer times

Recurring delays (relative)

the ratio of
the planned and expected buffer time

$$\min \sum_{(t,r)\in T\times R_t;(t',r')\in T\times R_{t'}} \frac{B_{(t,r),(t',r')}}{B^{expected}_{(t,r),(t',r')}} \frac{1}{B_{(t,r),(t',r')}} x_{(t,r)} x_{(t',r')}$$

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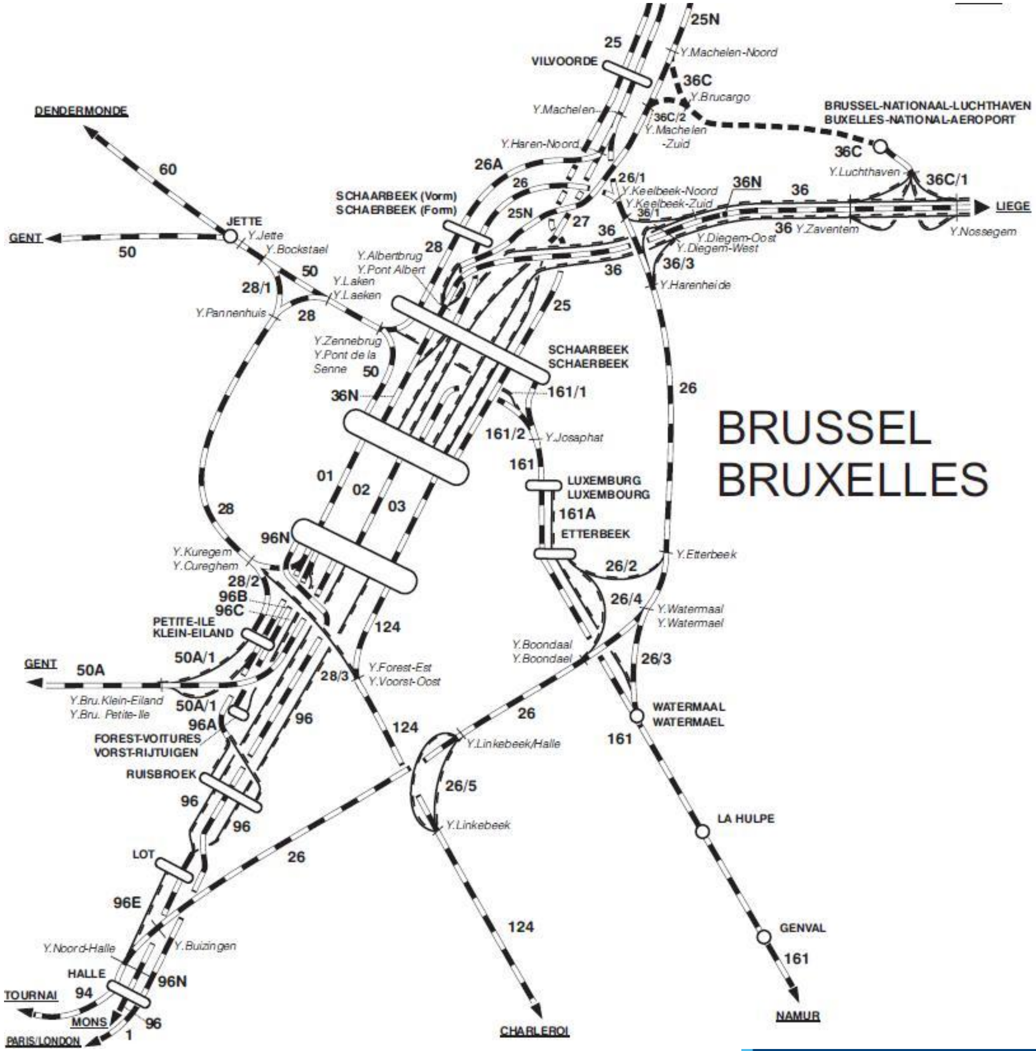
Case study


BRUSSEL
BRUXELLES
VILVOORDE
DENDERMONDE
BRUSSEL-NATIONAAL-LUCHTHAVEN
BUXELLES-NATIONAL-AEROPORT
GENT
JETTE
SCHAARBEEK (Vorm)
SCHAERBEEK (Form)
SCHAARBEEK
SCHAERBEEK
LIEGE
LUXEMBURG
LUXEMBOURG
ETTERBEEK
PETITE-ILE
KLEIN-EILAND
FOREST-VOITURES
VORST-RIJTUIGEN
RUISBROEK
LOT
HALLE
TOURNAI
MONS
PARIS/LONDON
CHARLEROI
WATERMAAL
WATERMAEL
LA HULPE
GENVAL
NAMUR
Y.Machelen-Noord
Y.Brucargo
Y.Machelen
Y.Machelen-Zuid
Y.Haren-Noord
Y.Luchthaven
Y.Keelbeek-Noord
Y.Keelbeek-Zuid
Y.Zaventem
Y.Nossegem
Y.Diegem-Oost
Y.Diegem-West
Y.Harenheide
Y.Jette
Y.Bockstael
Y.Albertbrug
Y.Pont Albert
Y.Laken
Y.Laeken
Y.Pannenhuis
Y.Zennebrug
Y.Pont de la Senne
Y.Josaphat
Y.Etterbeek
Y.Kuregem
Y.Cureghem
Y.Watermaal
Y.Watermael
Y.Boondaal
Y.Boondael
Y.Forest-Est
Y.Voorst-Oost
Y.Bru.Klein-Eiland
Y.Bru. Petite-Ile
Y.Linkebeek/Halle
Y.Linkebeek
Y.Noord-Halle
Y.Buizingen
25N
25
36C
36C/2
36C/1
26A
26
26/1
36N
36
36/1
36/3
27
28
28/1
28/2
28/3
50
60
50A
50A/1
161/1
161/2
161
161A
01
02
03
96N
96B
96C
96A
96
96E
124
26/2
26/4
26/3
26/5
94
1

Results

Timetable	Ref	No weights	P	D	$P \cdot D$
Passenger robustness	$4.15 \cdot 10^6$	$3.84 \cdot 10^6$	$3.77 \cdot 10^6$	$3.72 \cdot 10^6$	$3.68 \cdot 10^6$
% improvement		*7.47%*	*9.16%*	*10.36%*	*11.33%*
Total knock-on delay per hour for all trains (minutes)	211.53	145.31	142.17	136.38	138.40
% improvement		*31.30%*	*32.79%*	*35.53%*	*34.57%*
Percentage extra delayed trains	47.71%	37.36%	38.53%	36.98%	37.66%

Conclusion

We further improve passenger robustness up to 11%
by taking passenger numbers and recurring delays
explicitly into account on the tactical level

Future research

More delay scenarios (dwell delays)
Taking transferring passengers into account
Constructing a timetable and routing plan from scratch