Deriving all Passenger Flows in a Railway Network from Ticket Sales Data

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Task

Belgian Infrastructure Management Company: Infrabel:

"Optimize Passenger Train Service, Minimizing Passenger Travel Time"

Goals:

Increased: Passenger Satisfaction, Robustness, Capacity Usage, Transfer Efficiency

Fixed:

Infrastructure, Train Lines, Halting Pattern, Delay Probabilities

Variable:

Timing: Supplement Times at every Ride, Dwell, Transfer Action

Specifics:

One Busy Day, Morning Peak Hour

Task Notes

- Demand by Infrastructure Company, not main operator: NMBS
- Robustness against Delays necessitates Stochastic Approach.
- Minimization Passenger Time implies
  - knowledge of local passenger flows
  - specific, automatic trade-off between robustness and speedy service.
- Single criterium where all terms have same units: time.

Goal Function:

Stochastic Total Expected Passenger Travel Time: $GF(E) = \sum_{e \in E} f_e d_e$

Constraints:

Periodicity, Symmetry, Regularity, Minimum Action (Ride, Dwell, Transfer) Times, Minimum Headway Times, Macro Approach.
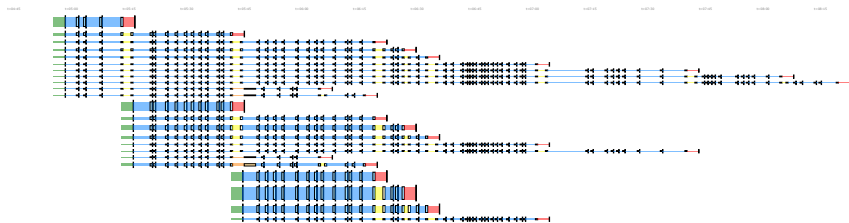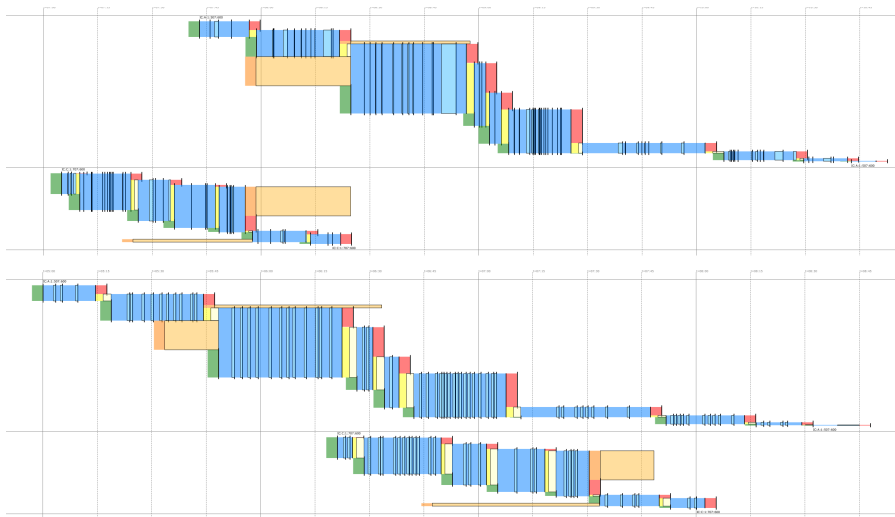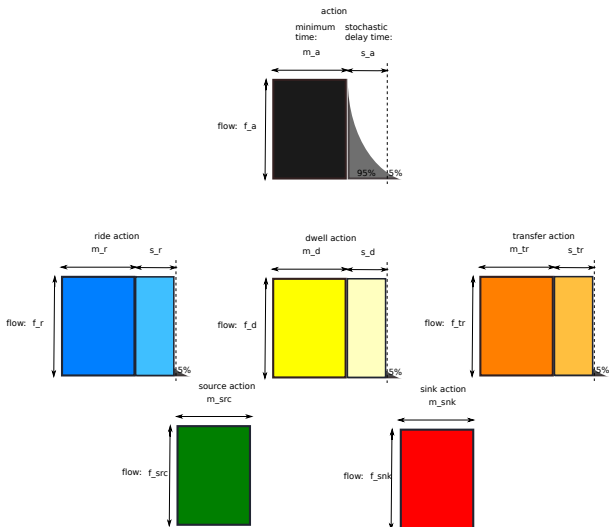
Per OD-Pair Grouping

Figure: Follow all Passengers from Origin to Destination

Per Train Grouping

Action: Negative Exponential Delay Distribution

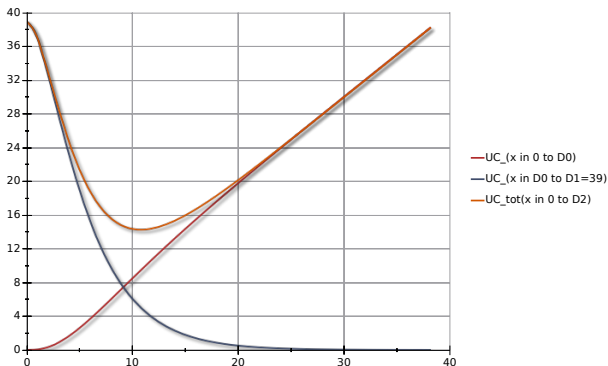# Goal Function: Stochastic Expected Passenger Travel Time

Figure: D_0 is introduced supplement, $D_1 > D_0$ is delta time of next chance action. Curve maps planned time to expected time.

Belgian Passenger Service Graph: Main Figures

Table: Many Transfers between Train Categories

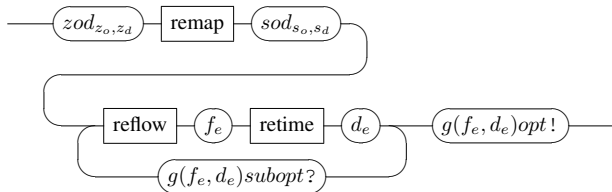| Train Type	Lines	Service Edges		Potential Transfer Edges to					Total
		Ride	Dwell	IC	IR	L	CR	P	
IC	50	2294	2244	2897	2205	1338	989	38	7467
IR	41	1390	1349	2159	1431	1181	682	36	5489
L	92	1723	1631	1319	1184	1542	238	47	4330
CR	20	528	508	989	701	237	850	54	2831
P	2	53	51	35	34	45	50	0	164
Total	205	5988	5783	7399	5555	4343	2809	175	20281

FAPESP: Two Phased

FAPESP

Figure: Two Phased implies Iterations

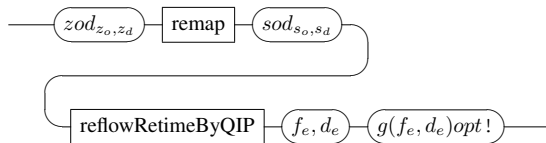# FAPESP: One Phased

FAPESPbyQIP

Figure: One Phased implies Optimal

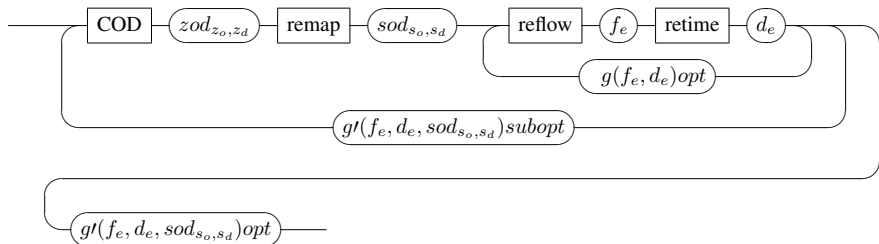# CODFAPESP: Two Nested Loops

CODFAPESP

Figure: CODFAPESP: Dependent around Independent Iterations

Origin-Destination (OD) Matrix

- Ticket OD-Matrix Currently Symmetric
- Ticket OD-Matrix Currently Formulated in Zones i.o. Stations
- Currently no Passenger Countings for Destination Station

Routing Algorithms

- Dijkstra: hours
- Modfied Dijkstra (includes Priority Queue): 20 min
- Johnson: to do

Biggest Stations: Current, Robust Schedule Flows and Average Edge Durations

Station Name	In= Out	Ride		Dwell		Transfer	
		F	$\overline{D}$	F	$\overline{D}$	F	$\overline{D}$
	p/day	p/day	min	p/day	min	p/day	min
BRUSSEL-NOORD	20202	304820	1.6	158844	0.8	18001	6.9
BRUSSEL-ZUID	24403	321084	1.6	174662	0.8	13715	5.4
GENT-SINT-PIETERS	18201	73259	2.7	10252	2.2	8211	8.2
OTTIGNIES	2929	52873	1.8	17343	0.9	7766	8.1
MECHELEN	8294	95020	2.0	52031	0.4	6949	6.4
DENDERLEEUW	2900	68479	2.5	23959	1.8	7381	6.7
BRUSSEL-CENTRAAL	36983	203596	1.3	59419	1.0	5419	6.3
LEUVEN	10879	80074	2.5	31865	1.2	4313	7.4
LIEGE	6554	31750	2.6	12478	0.6	3521	7.4
NAMUR	9083	43395	2.9	15861	0.6	2950	10.4
ANTWERPEN-BERCHEM	6351	52855	0.8	17751	0.8	2327	6.7
BRUGGE	8590	84921	2.0	38947	0.2	1722	10.2
CHARLEROI	5149	17968	2.3	2601	1.4	1683	10.4
ANTWERPEN-CENTRAAL	8186	24523	1.8	2430	1.0	1647	6.1
KORTRIJK	4500	25185	1.6	7020	0.2	1078	17.0
MONS	4646	18828	3.6	4050	1.4	718	14.0

Biggest Stations: Untimed, Tight Schedule Flows and Average Edge Durations

Station Name	In=	Ride		Dwell		Transfer	
	Out	F	$\overline{D}$	F	$\overline{D}$	F	$\overline{D}$
	p/day	p/day	min	p/day	min	p/day	min
BRUSSEL-NOORD	20202	287067	1.6	153069	0.8	11253	15.0
BRUSSEL-ZUID	24403	312473	1.6	169762	0.8	12660	15.0
GENT-SINT-PIETERS	18201	71557	2.7	10480	2.1	7133	15.0
OTTIGNIES	2929	52399	1.8	19399	0.9	5450	15.0
MECHELEN	8294	96507	2.0	54846	0.4	5364	15.0
DENDERLEEUW	2900	64645	2.5	21538	1.4	7885	15.0
BRUSSEL-CENTRAAL	36983	198001	1.3	61262	1.0	779	15.0
LEUVEN	10879	78962	2.5	32845	1.4	2659	15.0
LIEGE	6554	30965	2.6	12370	0.6	2951	15.0
NAMUR	9083	43755	2.9	15663	0.5	3323	15.0
ANTWERPEN-BERCHEM	6351	50715	0.8	16269	0.8	2739	15.0
BRUGGE	8590	82429	2.0	36973	0.2	1511	15.0
CHARLEROI	5149	17541	2.3	1619	1.1	2445	15.0
ANTWERPEN-CENTRAAL	8186	22454	1.8	2573	1.0	470	15.0
KORTRIJK	4500	25976	1.6	7180	0.2	1313	15.0
MONS	4646	18481	3.6	3838	1.5	757	15.0

Conclusions & Future Work

- Conclusions
  - extended PESP (retime) to FAPESP (reflow + retime)
  - implemented remapping, reflowing
  - generated all current local passenger flows
  - recommended data collection procedures
  - first retiming results

- Further Work
  - further verification with new data
  - faster routing algorithms (Johnson)
  - more refined routing algorithms, balancing multiple path choices
  - complete retime phase
  - iterate
  - possibly combine reflow and retime in one phase

Research

Figure: Research not Accountable for its Actions?...

Questions

Figure: Fire Your Questions

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