Appendices

Appendix A

Definitions

Arrival track is the track from which the trains arrive at the junction.

Arrival track costs are costs computed over the trains found on the arrival tracks.

Bidirectional destination track is the destination track that is used in both directions.

Block is a part of the track where only one train can be found at the same time. Every track is divided into one or more blocks. The length and the position of the blocks is defined by the safety system being used. Some systems use fixed blocks which are physically separated by signals or other hardware units. Other systems use the notion of moving blocks which is basically the amount of track ahead of the train which is reserved for the train and claimed by it.

Delay management is the technique of oppressing the delays found at the railways usually by setting a (new) train order and possibly re-routing some trains. Compare to disruption management.

Destination track is the track which is shared with trains from other routes.

Destination track costs are costs computed over the trains found on the destination track.

Destination track movement is the movement of a train on the destination track from the block it currently occupies to the new block it will occupy some time unites later.

Destination track phase is the phase of the transition process involving the changes on the destination track.

Destination track probability is the probability of a certain movement of the train(s) on the destination track as a result of the time jump.

Disruption management Is the technique of solving a severely disrupted situation usually involving deleting train services or shortening their service, rerouting trains to different destinations. Other resolution methods can involve assigning extra stopping locations to some of the train services to make up for the deleted services. Compare to delay management.

Double track is a track section that has two tracks exclusively for a particular direction. This allows for two trains to run next to each other.

Externality costs are the costs that represent the stay time of the rejected train in the system if it were to be allowed to enter the system.

Fixed block safety system is a safety system which makes use of fixed blocks. Every block is enclosed by signals or other hardware units which ensure that only one train is located within the same block at the same time.

Headway is the minimal amount of time between two subsequent trains. This value should be respected and is enforced by the security system.

Headway-Poisson process or $\mathcal{HP}$-process is a Poisson arrival process that takes into account the minimal safety inter-arrival time between the trains that we call headway.

Junction crossing phase is the phase of the transition process involving the crossing of the junction by the train. That is, leaving the arrival track and entering the destination track.

Line section is a part of a line segment.

Line segment is a part of the railway network connecting two railway hubs. It can be devided into a number of line sections (or track sections).

Maximal speed is the maximal speed that the train can achieve taking into consideration the type of locomotive, the number of the carriages, the mass of the train and the maximal permitted speed on the track section.

Moving block safety system is a safety system which makes use of moving blocks. A moving block is basically the amount of track ahead of the train which is reserved for the train and is claimed by it. This space moves along with the train.

New arrivals phase is the phase of the transition process involving the newly arriving trains.

Path is a series of successive time stamps of a train service. Within a timetable, each path is assigned to a certain train service. Unless a train is delayed, the train will follow this path.

Planned speed is the speed of the train according to the timetable.

Primary delay is the delay caused by external factors not involving other trains. Compare to Secondary delay.

Punctuality the punctuality is defined as the percentage of trains with the delay less than some predefined threshold value. In Netherlands this threshold value is equal to three minutes.

Railway hub is a (large) railway station within a railway network where trains from different destinations come together.

Secondary delay is the delay caused by conflicts between trains. Compare to Primary delays.

Single track is a track section that has one track per direction. Trains can not overtake each other at the single track and run behind each other.

Speed indicator is a label assigned to every arrival track. This label provides information about the speed of the trains on that track.

SMD table is a list of local rules meant for train conflict resolution. The rules prescribe train orders for a list of possible cases. These rules are a result of the SMD model discussed in this thesis.

State is a description of the situation at some particular point in time. This description involves the positions, the speeds and the types of the trains located in a certain area.

TAD or TAD table is a list of local rules meant for train conflict resolution. The rules prescribe an order with which the trains should proceed for a list of possible cases. These rules are currently in use by ProRail.

Time jump is an amount of time being skipped as a result of a decision. This decision gives permission to a certain train to cross the junction. This junction is then blocked for other trains for a certain amount of time. As no decisions can be made in the meanwhile, the time can be advanced by this amount of time.

Track section see Line section.

Track speed Is the speed of the 'flow' on the destination track. By flow we mean the trains running on the destination track at some particular point in time.

Track speed phase is the transition phase involving changes in track speed.

Train movement is the path that a train takes from its starting location until the destination.

Train rejection costs see Externality costs.

Transition or Transition process is the change from one state into another. As this change is a complex process, the transition process is divided into three phases, namely, Destination track phase or Track speed phase, Junction crossing phase and the new arrivals phase.

Appendix B

TAD rules of the Utrecht-Gouda line segment

Woerden to Gouda					
Decision point:Vtn					
			Delay		
Train	To	Time	From	To	Train order
4000	Gd	-.03/-.33	6	10	2000 - 2800 - FR - 4000
9800	Gd	-.21	3	9	1700 - 21700 - 9800
9800	Gd	-.51	3	9	500 - 20500 -9800

Table B.1: TAD 1: train dispatcher Woerden

Utrecht to Woerden					
Decision point: Lak					
			Delay		
Train	To	Time	From	To	Train order
2000	Gvc	-.29/-.59	6	10	2800 - 2000 - 9800
			11	∞	2800 - 9800 - 2000
Decision point: Uto					
2800	Rtd	-.03/-.33	8	∞	9800 - 2800

Table B.2: TAD 4: train dispatcher Ut Noord

Woerden to Hmla /Utrecht					
Decision point from Gouda: Odw Decision point from Apn: Bdg					
			Delay		
Train	To	Time	From	To	Train order
500	Ut	-.05	0	7	initial order Wd - Ut
1700	Ut	-.35	0	7	initial order Wd - Ut
2000	Ut	-.21	6	9	FR - 2000 8800 - (21700 or 1700)
2000	Ut	-.51	6	9	FR - 2000 8800 - (20500 or 500)
4000	Hlma	-.28/-.58	0	4	initial order
8800	Ut	-.26	4	11	21700 -1700 - 8800
8800	Ut	-.56	4	11	20500 - 500 - 8800
9800	Ut	-.09/-.39	0	5	initial order

Table B.3: TAD 2: train dispatcher Woerden

Decision points Nwk and Ztmo					
			Delay		
Train	To	Time	From	To	Train order
500	Wd	-.55	4	7	9800 - 500
1700	Wd	-.25	4	7	9800 - 1700
2000	Wd	-.11/-.41	6	9	4000 - 2000
9700	Gdg	-.29/-.59	0	7	initial order
9800	Gdg	-.21/-.51	0	9	initial order
9800	Gdg	-.21/-.51	6	9	9700 - 9800
2800	Wd	-.08/-.38	5	9	2000 - 2800
20500	Wd	-.52	7	9	500 - 20500
21700	Wd	-.54	7	9	1700 - 21700
12500	Wd	-.52	7	9	500 - 20500
12700	Wd	-.54	7	9	1700 - 21700

Table B.4: TAD 3: train dispatcher Gouda

Appendix C

SMD tables of the Utrecht-Gouda line segment

Nr	Track 1	Track 2	Track 3	Track 4	Details	Rule
1	-	-	-	-		Always 0
2	-	-	-	8800		Always 4: 8800
3	-	-	-	9800		Always 4: 9800
4	-	-	Freight	-		Always 3: Freight
5	-	-	Freight	8800	If Freight train is standing still	Always 4: 8800
6	-	-	Freight	8800	If Freight train is moving	Always 3: Freight
7	-	-	Freight	9800	If Freight train is standing still	Always 4: 9800
8	-	-	Freight	9800	If Freight train is moving	Always 3: Freight
9	-	(2000,500,1700)	-	-		Always 2: (2000,500,1700)
10	-	(2000,500,1700)	-	8800		If TS=70 then 4: 8800 else 2: (2000,500,1700)
11	-	(2000,500,1700)	-	9800		If TS=70 then 4: 9800 else 2: (2000,500,1700)
12	-	(2000,500,1700)	Freight	-	If Freight train is standing still	Always 2: (2000,500,1700)
13	-	(2000,500,1700)	Freight	-	If Freight train is moving	Always 3: Freight
14	-	(2000,500,1700)	Freight	8800	If Freight train is standing still	If TS=70 then 4: 8800 else 2: (2000,500,1700)
15	-	(2000,500,1700)	Freight	8800	If Freight train is moving	If TS=70 then 4: 8800 else 3: Freight
16	-	(2000,500,1700)	Freight	9800	If Freight train is standing still	If TS=70 then 4: 9800 else 2: (2000,500,1700)
17	-	(2000,500,1700)	Freight	9800	If Freight train is moving	If TS=70 then 4: 9800 else 3: Freight
18	(2800,12500,12700)	-	-	-		Always 1: (2800,12500,12700)
19	(2800,12500,12700)	-	-	8800		If TS=70 then 4: 8800 else 1: (2800,12500,12700)
20	(2800,12500,12700)	-	-	9800		If TS=70 then 4: 9800 else 1: (2800,12500,12700)
21	(2800,12500,12700)	-	Freight	-	If Freight train is standing still	Always 1: (2800,12500,12700)
22	(2800,12500,12700)	-	Freight	-	If Freight train is moving	Always 3: Freight
23	(2800,12500,12700)	-	Freight	8800	If Freight train is standing still	If TS=70 then 4: 8800 else 1: (2800,12500,12700)
24	(2800,12500,12700)	-	Freight	8800	If Freight train is moving	If TS=70 then 4: 8800 else 3: Freight

Table C.1: SMD table of Utrecht central station for the direction Utrecht → Gouda, part 1

Nr	Track 1	Track 2	Track 3	Track 4	Details	Rule
25	(2800,12500,12700)	-	Freight	9800	If Freight train is standing still	If TS=70 then 4: 9800 else 1: (2800,12500,12700)
26	(2800,12500,12700)	-	Freight	9800	If Freight train is moving	If TS=70 then 4: 9800 else 3: Freight
27	(2800,12500,12700)	(2000,500,1700)	-	-		Always 1: (2800,12500,12700)
28	(2800,12500,12700)	(2000,500,1700)	-	8800		If TS=105 then 1: (2800,12500,12700) else 4: 8800
29	(2800,12500,12700)	(2000,500,1700)	-	9800		If TS=70 then 4: 9800 else 1: (2800,12500,12700)
30	(2800,12500,12700)	(2000,500,1700)	Freight	-	If Freight train is standing still	Always 1: (2800,12500,12700)
31	(2800,12500,12700)	(2000,500,1700)	Freight	-	If Freight train is moving	Always 3: Freight
32	(2800,12500,12700)	(2000,500,1700)	Freight	8800	If Freight train is standing still	If TS=105 then 1: (2800,12500,12700) else 4: 8800
33	(2800,12500,12700)	(2000,500,1700)	Freight	8800	If Freight train is moving	If TS=70 then 4: 8800 else 3: Freight
34	(2800,12500,12700)	(2000,500,1700)	Freight	9800	If Freight train is standing still	If TS=70 then 4: 9800 else 1: (2800,12500,12700)
35	(2800,12500,12700)	(2000,500,1700)	Freight	9800	If Freight train is moving	4: 9800 If TS=70. 3: Freight If $87 \leq TS < 105$. 1 (2800,12500,12700) If $TS \geq 105$

Table C.2: SMD table of Utrecht central station for the direction Utrecht → Gouda, part 2

Nr	Track 1	Track 2	Track 3	Details	Rule
1	-	-	-		Always 0
2	-	-	(12500, 12700, 2000)		Always 3: (12500, 12700, 2000)
3	-	-	(500, 1700, 2800)		Always 3: (500, 1700, 2800)
4	-	4000	-		Always 2: 4000
5	-	4000	(12500, 12700, 2000)	IC standing still	Always 2: 4000
6	-	4000	(12500, 12700, 2000)	IC is moving	Always 3: (12500, 12700, 2000)
7	-	4000	(500, 1700, 2800)	IC standing still	Always 2: 4000
8	-	4000	(500, 1700, 2800)	IC is moving	Always 3: (500, 1700, 2800)
9	-	9800	-		Always 2: 9800
10	-	9800	(12500, 12700, 2000)		Always 3: (12500, 12700, 2000)
11	-	9800	(500, 1700, 2800)	IC standing still	Always 2: 9800
12	-	9800	(500, 1700, 2800)	IC is moving	Always 3: (500, 1700, 2800)
13	Freight	-	-		Always 1: Freight
14	Freight	-	(12500, 12700, 2000)	FR at half speed	Always 1: Freight
15	Freight	-	(12500, 12700, 2000)	FR at full speed, IC standing still	If $TS \leq 92$ then 1: Freight else 3: (12500, 12700, 2000)
16	Freight	-	(12500, 12700, 2000)	In all other cases	Always 3: (12500, 12700, 2000)
17	Freight	-	(500, 1700, 2800)	FR is moving, IC is standing still	Always 1: Freight
18	Freight	-	(500, 1700, 2800)	IC is moving, FR at half speed	Always 1: Freight
19	Freight	-	(500, 1700, 2800)	In all other cases	Always 3: (500, 1700, 2800)
20	Freight	4000	-	If freight train is standing still	Always 2: 4000
21	Freight	4000	-	If freight train is not standing still	Always 1: Freight
22	Freight	4000	(12500, 12700, 2000)	IC and FR are standing still	If $TS \leq 92$ then 2: 4000 else 3: (12500, 12700, 2000)
23	Freight	4000	(12500, 12700, 2000)	FR is moving, IC is standing still	Always 1: Freight
24	Freight	4000	(12500, 12700, 2000)	IC at full speed, FR at half speed	Always 1: Freight

Table C.3: SMD table of Woerden station for the direction Utrecht → Gouda, part 1

Nr	Track 1	Track 2	Track 3	Details	Rule
25	Freight	4000	(12500, 12700, 2000)	IC and FR are running half speed	If $TS \leq 92$ then 1: Freight else 3: (12500, 12700, 2000)
26	Freight	4000	(12500, 12700, 2000)	In all other cases	Always 3: (12500, 12700, 2000)
27	Freight	4000	(500, 1700, 2800)	FR at half speed	Always 1: Freight
28	Freight	4000	(500, 1700, 2800)	FR at full speed, IC standing still	Always 2: 4000
29	Freight	4000	(500, 1700, 2800)	In all other cases	Always 3: (500, 1700, 2800)
30	Freight	9800	-	If freight train is standing still	Always 2: 9800
31	Freight	9800	-	If freight train is not standing still	Always 1: Freight
32	Freight	9800	(12500, 12700, 2000)	FR is moving, IC is standing still	Always 1: Freight
33	Freight	9800	(12500, 12700, 2000)	IC at full speed, FR at half speed	Always 1: Freight
34	Freight	9800	(12500, 12700, 2000)	IC and FR are running half speed	If $TS \leq 92$ then 1: Freight else 3: (12500, 12700, 2000)
35	Freight	9800	(12500, 12700, 2000)	In all other cases	Always 3: (12500, 12700, 2000)
36	Freight	9800	(500, 1700, 2800)	FR is moving, IC is standing still	Always 1: Freight
37	Freight	9800	(500, 1700, 2800)	IC is moving, FR at half speed	Always 1: Freight
38	Freight	9800	(500, 1700, 2800)	In all other cases	Always 3: (500, 1700, 2800)

Table C.4: SMD table of Woerden station for the direction Utrecht → Gouda, part 2

Nr	Track 1	Track 2	Details	Rule
1	-	-		Always 0
2	Freight	-		Always 1: Freight
3	-	some train		Always 2
4	Freight	some train		Always 1: Freight

Table C.5: SMD table of Oudewater for the direction Utrecht → Gouda

Nr	Track 1	Track 2	Track 3	Track 4	Details	Rule
1	-	-	-	-		Always 0
2	-	-	-	(9700, 4000)		Always 4: (9700, 4000)
3	-	-	Freight	-		Always 3: Freight
4	-	-	Freight	(9700, 4000)	FR is standing still	Always 4: (9700, 4000)
5	-	-	Freight	(9700, 4000)	FR is running	Always 3: Freight
6	-	(12500, 12700, 2800)	-	-		Always 2: (12500, 12700, 2800)
7	-	(12500, 12700, 2800)	-	(9700, 4000)		If TS=IC then 2: (12500, 12700, 2800) else 4: (9700, 4000)
8	-	(12500, 12700, 2800)	Freight	-	FR is standing still	Always 2: (12500, 12700, 2800)
9	-	(12500, 12700, 2800)	Freight	-	FR is running	Always 3: Freight
10	-	(12500, 12700, 2800)	Freight	(9700, 4000)	FR is standing still	Always 4: (9700, 4000)
11	-	(12500, 12700, 2800)	Freight	(9700, 4000)	FR is running	Always 3: Freight
12	(2000, 500, 1700)	-	-	-		Always 1:: (2000, 500, 1700)
13	(2000, 500, 1700)	-	-	(9700, 4000)		If TS=IC then 1: (2000, 500, 1700) else 4: (9700, 4000)
14	(2000, 500, 1700)	-	Freight	-	FR is standing still	Always 1: (2000, 500, 1700)
15	(2000, 500, 1700)	-	Freight	-	FR is running	Always 3: Freight
16	(2000, 500, 1700)	-	Freight	(9700, 4000)	FR is standing still	Always 4: (9700, 4000)
17	(2000, 500, 1700)	-	Freight	(9700, 4000)	FR is running	Always 3: Freight
18	(2000, 500, 1700)	(12500, 12700, 2800)	-	-		Always 1: (2000, 500, 1700)
19	(2000, 500, 1700)	(12500, 12700, 2800)	-	(9700, 4000)		If TS=IC then 1: (2000, 500, 1700) else 4: (9700, 4000)
20	(2000, 500, 1700)	(12500, 12700, 2800)	Freight	-	FR is standing still	Always 1: (2000, 500, 1700)
21	(2000, 500, 1700)	(12500, 12700, 2800)	Freight	-	FR is running	If TS=Freight then 3: Freight else 1: (2000, 500, 1700)
22	(2000, 500, 1700)	(12500, 12700, 2800)	Freight	(9700, 4000)	FR is standing still	Always 4: (9700, 4000)
23	(2000, 500, 1700)	(12500, 12700, 2800)	Freight	(9700, 4000)	FR is running	If TS=Freight then 3: Freight else 4: (9700, 4000)

Table C.6: SMD table of Gouda station for the direction Gouda → Utrecht

Nr	Track 1	Track 2	Details	Rule
1	-	-		Always 0
2	-	some train		Always 2
3	Regional train	-		Always 1
4	Regional train	some train		Always 2

Table C.7: SMD table of Gouda Goverwelle station for the direction Gouda → Utrecht

Nr	Track 1	Track 2	Details	Rule
1	-	-		Always 0
2	some train	-		Always 1
3	-	Freight		Always 2: Freight
4	some train	Freight		Always 2: Freight

Table C.8: SMD table of Oudewater for the direction Gouda → Utrecht

Nr	Track 1	Track 2	Track 3	Track 4	Details	Rule
1	-	-	-	-		Always 0
2	-	-	-	FR_{ut}		Always 4: FR_{ut}
3	-	-	-	FR_{hmla}		Always 4: FR_{hmla}
4	-	-	4000	-		Always 3: 4000
5	-	-	4000	FR_{ut}	If FR is standing still	Always 3: 4000
6	-	-	4000	FR_{ut}	If FR is moving	Always 4: FR_{ut}
7	-	-	4000	FR_{hmla}	If FR is standing still	Always 3: 4000
8	-	-	4000	FR_{hmla}	If FR is moving	Always 4: FR_{hmla}
9	-	9800	-	-		Always 2: 9800
10	-	9800	-	FR_{ut}	If FR is standing still	Always 2: 9800
11	-	9800	-	FR_{ut}	If FR is moving	Always 4: FR_{ut}
12	-	9800	-	FR_{hmla}	If FR is standing still	Always 2: 9800
13	-	9800	-	FR_{hmla}	If FR is moving	Always 4: FR_{hmla}
14	-	9800	4000	-		If TS=70 then 2: 9800 else 3: 4000
15	-	9800	4000	FR_{ut}	If FR is standing still	If TS=70 then 2: 9800 else 3: 4000
16	-	9800	4000	FR_{ut}	If FR is moving	Always 4: FR_{ut}
17	-	9800	4000	FR_{hmla}	If FR is standing still	If TS=70 then 2: 9800 else 3: 4000
18	-	9800	4000	FR_{hmla}	If FR is moving	Always 4: FR_{hmla}
19	8800	-	-	-		Always 1: 8800
20	8800	-	-	FR_{ut}	If FR is either standing still or running full speed	Always 1: 8800
21	8800	-	-	FR_{ut}	If FR is runnig half speed	Always 4: FR_{ut}
22	8800	-	-	FR_{hmla}	If FR is either standing still or running full speed	Always 1: 8800
23	8800	-	-	FR_{hmla}	If FR is runnig half speed	Always 4: FR_{hmla}
24	8800	-	4000	-		Always 1: 8800

Table C.9: SMD table of Woerden station for the direction Gouda → Utrecht, part 1

Nr	Track 1	Track 2	Track 3	Track 4	Details	Rule
25	8800	-	4000	FR_{ut}	If FR is either standing still or running full speed	Always 1: 8800
26	8800	-	4000	FR_{ut}	If FR is runnig half speed	Always 4: FR_{ut}
27	8800	-	4000	FR_{hmla}	If FR is either standing still or running full speed	Always 1: 8800
28	8800	-	4000	FR_{hmla}	If FR is runnig half speed	Always 4: FR_{hmla}
29	8800	9800	-	-		Always 1: 8800
30	8800	9800	-	FR_{ut}	If FR is either standing still or running full speed	Always 1: 8800
31	8800	9800	-	FR_{ut}	If FR is runnig half speed	Always 4: FR_{ut}
32	8800	9800	-	FR_{hmla}	If FR is either standing still or running full speed	Always 1: 8800
33	8800	9800	-	FR_{hmla}	If FR is runnig half speed	Always 4: FR_{hmla}
34	8800	9800	4000	-		Always 1: 8800
35	8800	9800	4000	FR_{ut}	If FR is either standing still or running full speed	Always 1: 8800
36	8800	9800	4000	FR_{ut}	If FR is runnig half speed	Always 4: FR_{ut}
37	8800	9800	4000	FR_{hmla}	If FR is either standing still or running full speed	Always 1: 8800
38	8800	9800	4000	FR_{hmla}	If FR is runnig half speed	Always 4: FR_{hmla}

Table C.10: SMD table of Woerden station for the direction Gouda → Utrecht, part 2

Nr	Track 1	Track 2	Details	Rule
1	-	-		Always 0
2	-	8800		Always 2: 8800
3	-	9800		Always 2: 9800
4	-	Freight		Always 2: Freight
5	IC	-		Always 1: IC
6	IC	8800	IC is running	Always 1: IC
7	IC	8800	IC is standing still	Always 2: 8800
8	IC	9800	IC is running	Always 1: IC
9	IC	9800	IC is standing still	if TS=70 then 2: 9800 else 1: IC
10	IC	Freight		Always 2: Freight

Table C.11: SMD table of Harmelen aansluiting for the direction Gouda → Utrecht