



## UvA-DARE (Digital Academic Repository)

### Dynamic delay management at railways: a Semi-Markovian Decision approach

Al Ibrahim, A.

**Publication date**  
2010

[Link to publication](#)

#### **Citation for published version (APA):**

Al Ibrahim, A. (2010). *Dynamic delay management at railways: a Semi-Markovian Decision approach*. Thela Thesis.

#### **General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

#### **Disclaimer/Complaints regulations**

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

# Contents

Dankwoord (Acknowledgements in Dutch)	v
<b>1 General introduction and overview</b>	<b>1</b>
1.1 Introduction	1
1.2 Practical motivation	3
1.3 The research in a broader perspective	5
1.4 Performance measures	6
1.5 The railway network and decomposition	7
1.6 Scheduling and Rescheduling in The Netherlands	8
1.7 Literature overview	11
1.7.1 Tactical scheduling	12
1.7.2 Operational scheduling	14
1.7.3 Rescheduling	16
1.7.4 Stochastic approaches	19
1.7.5 Other related models	22
1.7.6 Final remarks	23
1.8 The Semi-Markovian Decision technique	24
1.8.1 Introduction to SMD	24
1.8.2 Solving the SMD model	26
1.8.3 SMD as an application for railways	28
1.9 Main goals	29
1.10 Thesis outline	30
<b>2 Model preliminaries</b>	<b>33</b>
2.1 A typical junction	33
2.2 The SMD railway framework	34
2.2.1 Arrival track	35
2.2.2 The arrival process of trains	36

2.2.3	Time jumps and train movement on arrival tracks . . . . .	38
2.2.4	Destination track . . . . .	39
2.2.5	Function of blocks in discretized destination track . . . . .	41
2.2.6	Headway time and block length on the destination track . . . . .	41
2.2.7	Train movement on the destination track . . . . .	43
2.2.8	Externality costs . . . . .	44
<b>3</b>	<b>Detailed modelling of the Fork<sub>R</sub> junction</b>	<b>47</b>
3.1	States . . . . .	48
3.2	Decisions . . . . .	49
3.3	Decision moments . . . . .	50
3.4	Transitions . . . . .	50
3.4.1	The destination track phase . . . . .	51
3.4.2	The junction crossing phase . . . . .	51
3.4.3	The arrival process . . . . .	54
3.4.4	Summary of the transitions . . . . .	54
3.5	Costs . . . . .	55
3.6	State space reduction . . . . .	57
3.7	Computational complexity . . . . .	59
3.8	Trains with different destinations . . . . .	60
<b>4</b>	<b>Results of the Fork<sub>R</sub> model</b>	<b>63</b>
4.1	Basic scenario . . . . .	64
4.2	Relevant states at the destination track . . . . .	66
4.3	SMD strategy for the basic scenario . . . . .	67
4.4	Simulation technique . . . . .	69
4.5	The heuristics . . . . .	70
4.6	Results of the basic scenario . . . . .	71
4.7	Variations of the basic scenario . . . . .	74
4.7.1	Freight train acceleration . . . . .	75
4.7.2	System load . . . . .	76
4.7.3	Shorter headway . . . . .	78
4.7.4	The passenger-freight train ratio . . . . .	79
4.7.5	Train type priorities . . . . .	80
4.7.6	Other robustness tests . . . . .	82
4.8	Conclusions . . . . .	83

<b>5</b>	<b>Modelling a Bidirectional junction</b>	<b>85</b>
5.1	Physical differences . . . . .	86
5.2	Model changes . . . . .	87
5.2.1	States . . . . .	88
5.2.2	Decisions . . . . .	88
5.2.3	Time advance . . . . .	89
5.2.4	Transitions . . . . .	89
5.2.5	Costs . . . . .	90
5.2.6	State space reduction . . . . .	90
5.3	Results . . . . .	91
5.3.1	Strategies . . . . .	91
5.3.2	Basic scenario . . . . .	93
5.3.3	SMD strategy of the basic scenario . . . . .	94
5.3.4	Results of the basic scenario . . . . .	97
5.3.5	Variations of the basic scenario . . . . .	98
5.4	Conclusions . . . . .	102
<b>6</b>	<b>The SMD track speed model</b>	<b>105</b>
6.1	Reasons for an alternative approach . . . . .	105
6.2	Modelling changes . . . . .	107
6.2.1	TrackSpeed variable $ts$ . . . . .	107
6.2.2	Changes to the state space . . . . .	108
6.2.3	Changes to transitions . . . . .	108
6.2.4	Changes to costs . . . . .	111
6.3	Computational complexity . . . . .	112
6.4	Results . . . . .	114
6.4.1	Structure of the $SMD_{ts}$ strategy . . . . .	114
6.4.2	Performance of the $SMD_{ts}$ strategy . . . . .	117
6.4.3	Aggregation of track speeds . . . . .	119
6.5	Conclusions . . . . .	120
<b>7</b>	<b>Railway networks</b>	<b>123</b>
7.1	Networks and SMD . . . . .	123
7.2	Decomposition and the scope of junctions . . . . .	124
7.3	A network of three Fork <sub>2</sub> junctions . . . . .	126
7.4	A network of seven Fork <sub>2</sub> junctions . . . . .	129
7.5	A network containing a bidirectional junction . . . . .	131

7.6	Conclusions . . . . .	133
<b>8</b>	<b>SMD in practice</b>	<b>135</b>
8.1	Line segment Utrecht - Gouda . . . . .	136
8.1.1	Lay-out of the line segment . . . . .	137
8.1.2	Timetable . . . . .	139
8.1.3	Historical delays data . . . . .	142
8.2	The TAD conflict resolution rules . . . . .	144
8.3	The modelling . . . . .	144
8.3.1	Utrecht to Gouda . . . . .	146
8.3.2	Gouda to Utrecht . . . . .	153
8.4	Simulation study . . . . .	158
8.4.1	Simulation and the difference with the SMD model . . . . .	158
8.4.2	Scenarios . . . . .	161
8.4.3	Strategies . . . . .	161
8.4.4	Results Utrecht to Gouda . . . . .	162
8.4.5	Results Gouda to Utrecht . . . . .	165
8.5	SMD decisions and the usage in practice . . . . .	167
8.6	Conclusions . . . . .	171
<b>9</b>	<b>Epilogue</b>	<b>173</b>
9.1	General discussion and summary . . . . .	173
9.2	Limitations of the thesis and recommendations for further research . . . . .	176
	<b>Summary</b>	<b>179</b>
	Summary in English . . . . .	180
	Nederlandse samenvatting (summary in Dutch) . . . . .	184
	Краткое содержание (summary in Russian) . . . . .	188
	مختصر الأطروحة (summary in Arabic) . . . . .	195
	<b>Appendices</b>	<b>203</b>
	<b>A Definitions</b>	<b>205</b>
	<b>B TAD rules of the Utrecht-Gouda line segment</b>	<b>209</b>
	<b>C SMD tables of the Utrecht-Gouda line segment</b>	<b>213</b>
	<b>Bibliography</b>	<b>221</b>