

# Contents

<b>1 Basic Terms of Railway Operation</b> .....	1
1.1 Classification of Railway Systems .....	1
1.2 Basic Track Elements .....	3
1.3 Basic Signal Arrangements .....	13
1.4 Movements of Railway Vehicles.....	27
1.5 Modes of Operation.....	33
1.5.1 Signal-controlled Operation .....	34
1.5.2 Non Signal-controlled Operation .....	35
<b>2 Dynamics of Train Movements</b> .....	37
2.1 Tractive Effort .....	37
2.2 Resistances .....	38
2.2.1 Line Resistance.....	38
2.2.2 Train Resistance .....	42
2.3 Grade-Speed Diagram .....	43
2.4 Running Time Calculation .....	44
<b>3 Spacing Trains</b> .....	49
3.1 Theory of Train Separation .....	49
3.1.1 Train Separation in Relative Braking Distance .....	49
3.1.2 Train Separation in Absolute Braking Distance .....	51
3.1.3 Train Separation in Fixed Block Distance.....	52
3.2 Non Signal-controlled Operation .....	52
3.2.1 Timetable and Train Order (T & TO).....	53
3.2.2 Radio-Based Occupation Control Systems.....	54
3.2.2.1 Track Warrant Control (TWC).....	54
3.2.2.2 Direct Traffic Control (DTC) .....	56

3.3	Signalled Fixed Block Operation .....	56
3.3.1	Basic Rules of Fixed Block Operation .....	57
3.3.2	Blocking Time and Headway Theory .....	58
3.3.3	Signals for Train Movements .....	65
3.3.3.1	Principles of Signalling .....	65
3.3.3.2	Signalling of Short Block Section .....	71
3.3.4	Block Systems .....	74
3.3.4.1	Control Logic of Block Systems .....	75
3.3.4.2	Manual Block .....	78
3.3.4.3	Automatic Block.....	87
3.3.4.4	Absolute Permissive Block (APB) .....	99
3.4	Automatic Train Protection .....	100
3.4.1	Intermittent ATP.....	101
3.4.2	Continuous ATP.....	104
3.4.3	European Train Control System (ETCS).....	108
3.4.4	Positive Train Control (PTC) .....	115
<b>4</b>	<b>Interlocking Principles.....</b>	<b>117</b>
4.1	Interlocking Routes .....	117
4.1.1	Interlocking between Points and Signals.....	120
4.1.2	Route Locking .....	123
4.1.3	Conflicting Routes.....	127
4.1.4	Flank Protection .....	128
4.1.5	Crosslock .....	133
4.1.6	Overlaps.....	134
4.1.7	Intermediate Points.....	138
4.1.8	Common Interlocking Areas .....	138
4.1.9	Command Interlocking.....	139
4.1.10	Track Clear Detection.....	140
4.1.11	Automatic Working of a Route .....	141
4.2	Signals in Interlocking Areas .....	142
4.2.1	Interlocking Signals for Train Movements.....	142
4.2.2	Shunting Signals.....	144
4.2.3	Signalling of Converging Terminal Tracks .....	147
4.3	Internal Logic of Interlocking Systems .....	148

4.3.1	Tabular Interlocking .....	149
4.3.1.1	Cascade Locking .....	149
4.3.1.2	Route-related Locking .....	151
4.3.2	Geographical Interlocking .....	153
4.4	Interlocking Systems .....	156
4.4.1	Mechanical Interlocking .....	156
4.4.2	Electric and Electro-pneumatic Interlocking .....	159
4.4.3	Relay Interlocking .....	161
4.4.4	Computer-based Interlocking .....	163
4.4.5	Interlocking Appliances for Hand Throw Points.....	164
4.5	Blocking Time in Interlocking Areas .....	166
<b>5</b>	<b>Capacity Research .....</b>	<b>169</b>
5.1	Dividing a Railway Network in Different Parts for Capacity Research.....	169
5.2	Basic Theory of Capacity Research .....	171
5.2.1	Waiting Time Diagram.....	171
5.2.2	Recommended Area of Traffic Flow.....	175
5.3	Research Methods .....	178
5.3.1	Capacity of Lines.....	180
5.3.1.1	Analytical Methods .....	180
5.3.1.2	Simulation .....	190
5.3.2	Capacity of Interlocking Arrangements .....	192
5.3.3	Capacity of Terminal Tracks .....	200
5.4	Improving Capacity .....	202
<b>6</b>	<b>Scheduling .....</b>	<b>209</b>
6.1	The Role of Scheduling in Traffic Control .....	209
6.2	Traffic Diagrams .....	210
6.3	Scheduled Running Time .....	212
6.4	Headways and Buffer Times .....	215
6.5	Cyclic Timetables.....	219
6.6	Scheduling Methods .....	222
6.6.1	Manual Scheduling.....	223

6.6.2	Computer-based Scheduling.....	225
6.7	Quality Assessment in Scheduling .....	227
<b>7</b>	<b>Traffic Control.....</b>	<b>231</b>
7.1	Traffic Control with Local Operators.....	231
7.1.1	Non Signal-controlled Lines.....	231
7.1.2	Signal-controlled Lines .....	232
7.1.3	Dispatcher Sheets .....	234
7.2	Centralised Traffic Control.....	235
7.3	Automation Technologies .....	236
7.3.1	Train Describers .....	237
7.3.2	Automatic Route Setting .....	240
7.3.3	Computer-based Dispatching .....	245
7.4	Control Centres.....	247
	<b>Symbols in Diagrams.....</b>	<b>251</b>
	<b>Glossary.....</b>	<b>253</b>
	<b>References .....</b>	<b>270</b>
	<b>Index .....</b>	<b>272</b>

Selected illustrations were provided by:

Bodo Schneider (4.43)

Holger Koetting (4.38)

Reinhard Schumacher (4.41)

Thomas White (4.35, 4.39, 4.40, 7.2)

All other illustrations by the author. For illustrations with screenshots of British control screens, the signalling simulation software SimSig was used with kind permission by the owner of [www.simsig.co.uk](http://www.simsig.co.uk).