Chapter 2

Estimated Timetable

2.1 Introduction

A suitable starting point from where to do capacity evaluation and further cogitate upon alternative upgraded scenarios ought to be defined. This chapter aims to estimate a timetable for 1999 following a stepwise procedure presented below according to the available data and available tools:

- Published Timetable by Dutch Railways: *Spoorboekje.*
- Detailed analysis applying blocking time theory (not possible by means of the *Spoorboekje* data).
- Calculation of blocking times: *RailSys.*
- Consistency of running time distributions (*Estimated Timetable*).
- Fine Tuning to deal with a suitable *Status Quo for 1999*.

This chapter contains three main sections, that is, section 2.2 presents the published timetable selected for the research; section 2.3 describes the timetable estimations done by the simulation tool based on blocking times, and section 2.4 where an analysis of the estimated timetable is carried out through location of planning conflicts. On a whole, the issues of the timetable estimation are presented and the appeared inconsistencies to be dealt in Chapter 3 analysed.

2.2 Selected Timetable: Spoorboekje 1999-2000

This section presents the scheduling task developed by Dutch Railways over the network based on running time and headway experience instead of using a blocking time approach. The customer demands are to determine a rough pattern; hence a timetable is published in minutes with trains per hour and line: the *Spoorboekje*. For the present case study referred to the line Den Haag HS – Rotterdam CS, it is assumed that a planning was built according to the following procedure:

1. Calculation of *minimum running* time between *Den Haag HS* and *Rotterdam CS*, including dwell times if necessary.
2. Addition of the standard *7% of time supplements* (time to cope with stochastic variations).
3. Addition of *extra time supplement* according to experience as well as to round-off values to minutes.

4. Sum of all these values to obtain the *scheduled running time* between *Den Haag HS* and *Rotterdam CS*.
5. Distribution of the scheduled running time between stations (in minutes).

In this context, a timetable was designed and published for a time horizon of one year (30 May 1999 to 30 May 2000)[1]. Figure 2.1 presents this timetable by means of the train movements over space and time: *train paths*.

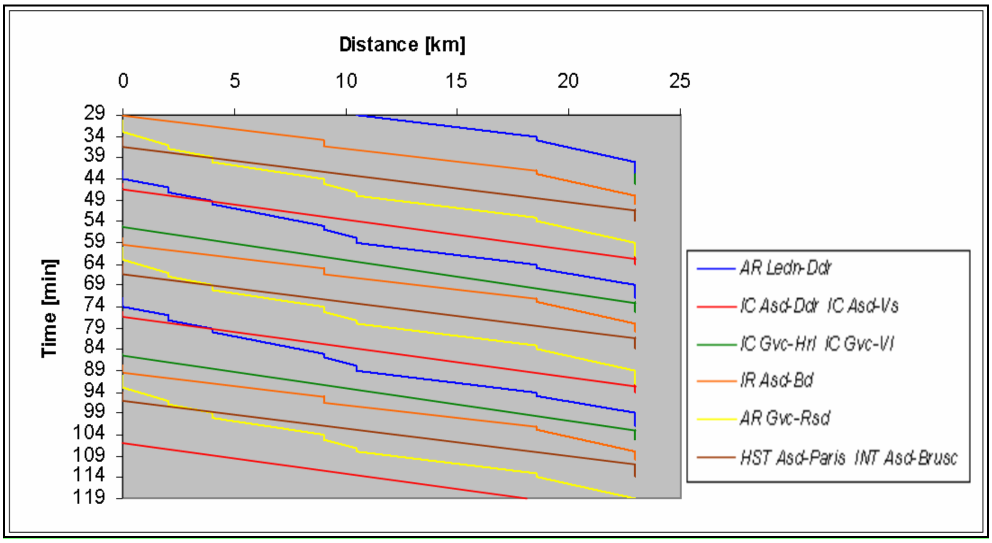

Figure 2.1: Graphical presentation of time-distance diagram for the published timetable *Spoorboekje 1999*

Numerical data concerning to the Spoorboekje timetable is given in tables in Appendix C.

However, the capacity research to be done requires a more precise approach of train paths considering more accurate running profiles between stations, especially for non-stopping trains from which only arrival and departure times at big terminals are provided. This chapter realizes this task applying the Blocking Time Theory. Further chapters will base their analysis according to this optimized approach.

2.3 Timetable Compilation (by RailSys)

This section describes the available data used to represent a simplified network where to fit a timetable in the system's architecture of RailSys. First an overview is given to the data supply to be introduced both for infrastructure and rolling stock characteristics, followed by the scheduling of trains. As pointed out previously, this data served as a basis for other research project and was retrieved in part from its previous works.

[1] This past timetable was used instead of the current one because this analysis serves as basis for further comparison with empirical train detection data in the same period in the scope of another research project.

Section 2.3 describes the two-dimensional representation in space and time of the estimated timetable by RailSys, while section 2.4 deals with a conflict analysis to locate different conflicts arising from the estimations.

2.3.1 Data supply

Both infrastructure and train data collections are retrieved from a PhD research project being developed by Yuan, J. at the Faculty of Civil Engineering and Geosciences of Delft University of Technology.

Infrastructure Data

As stated in the introduction, the line under study (Den Haag – Rotterdam) is characterized by a double-track corridor with mixed operation. According to the available data, larger infrastructure was created and edited with a graphic tool through the *Infrastructure Module.* However, its effects on the study area will not be considered in this research, only focusing on the selected line.

Study area description The railway track under study is characterized by a capacity bottleneck from four to two tracks. This reduction leads to a double-tack line, making the operation of train services extremely sensitive if a conflict on a train occurs, spreading the disturbances over other train runs, without least possibilities of rectification. This infrastructure feature of the network also limits track capacity (it could also be affected by rolling stock, driver's behaviour, environmental conditions, etc.), thus any timetable design for this line has limited chances of track occupation optimisation. That is to say, the likelihood of further problems due to an increase of the train services to be operated is relatively high.

The following table and network section give an overview to the stations along the study area and the track layout of it as well as the relative location of stations.

Station Name	Station Abbreviation	
Den Haag HS	*Gv*	*(North)*
Den Haag-Moerwijk	*Gvmw*	
Rijswijk	*Rsw*	
Delft	*Dt*	
Delft Zuid	*Dtz*	
Schiedam	*Sdm*	
Rotterdam CS	*Rtd*	*(South)*

Table 2.1: Stations along the railway line *Den Haag HS – Rotterdam CS (22,4 km)*

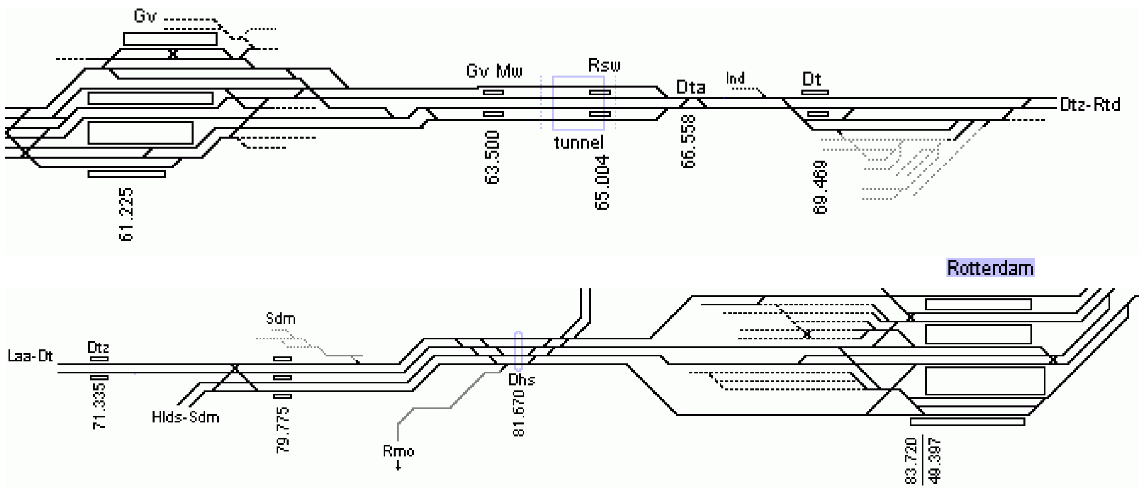

Figure 2.2: The railway section between *Den Haag HS* and *Rotterdam CS*
(source: Railverkeersleiding Automatisering & Middelen, 2001)

As shown in the above figure, a shift from quadruple- to double-track line (double- to single-track per direction) takes place between Rijswijk and Rotterdam CS. It is argued that this reduction leads to capacity bottlenecks as well as operation of train services rather sensitive to conflicts. In this sense, efforts should be focused to enhance operation along this part.

However, due to the schedule of intercity and other fast non-stopping trains at intermediate stations along the line, also infrastructure from Rijswijk to Den Haag HS has to be considered in the study although four-tracks exist between them.

Availability and use of data To estimate a timetable by means of RailSys, first of all it is needed to input the suitable infrastructure data of the selected study area. Information about basic data structure was selected to build up a simplified network where to operate different services. For this task, Dutch network databases were used: OBE maps, provided by ProRail.

According to the needs of the study not all details were represented, but only those that are sensitive to the output to be obtained. In this sense, sidings at stations, switches and other track issues were neglected leading to a simplified but representative network layout.

Infrastructure Characteristics The simulation tool provides the user with a wide range of facilities to abstract the infrastructure to linear railway lines (sequence of track sections and switches). Within the module, the signals, the switches, the stops, the speed variations and further characteristics of the infrastructure are modelled by nodes and links individually created and edited.

Besides, the safe working system is characterized. The one for this line is based on automatic *main signal fixed block signalling system*. In other words, basically it is a fixed block signalling system where the main signals have a both a main signal function and approaching function. Section B.1 in Appendix B contains the relevant data for the two-track part of the line with regard to signal location, block lengths and design speeds.

Finally, *routes* of trains along the line are edited and represented by sequence of nodes, platforms and edges, representing a sequence of sections for a train to find its way on a line.

Once all infrastructures are inputted in the software, *lines* are edited and added to a predefined network. Figure B.1 in Appendix B gives a more clear idea of the infrastructure mapping of the line represented in RailSys. The two-track part of the line is clearly represented as well as stop and signal locations.

Train Data

Through the *Timetable Manager* module, train types and patterns as well as timetable characteristics are edited to further estimate a timetable that fits the defined infrastructure.

Dynamics of train movement To define the running dynamics of the different trains to be scheduled, the following traction unit data was needed:

- Basic data: maximum speeds, lengths, mass, etc.
- Acceleration/ Deceleration rates, derived from the tractive force-speed curve
- Rolling resistances

More extended and numerical data concerning to traction units relative to the train series (see table 2.2) is given in section B.2 in Appendix B.

Timetable Timetable inputs were edited according to Spoorboekje data. Basically, they are characterized by the following parameters:

- Train series/ train patterns
- Train routes
- Fixed arrival and departure times as well as indicated dwell times

Trains scheduled are grouped in train series depending on their type of operation over the network (only passengers trains). Table 2.1 indicates the different train types and train series numeration operated along the line under study as well as their line origin and destination.

Line		Train Type		Train Series
Den Haag CS - Roosendaal	*Gvc-Rsd*	*Stop Train*	*AR*	*AR5100*
Leiden - Dordrecht	*Ledn-Ddr*	*Stop Train*	*AR*	*AR5000*
Amsterdam - Paris	*Asd-Paris*	*High Speed Train*	*HST*	*HST9300*
Amsterdam - Dordrecht	*Asd-Ddr*	*Intercity Train*	*IC*	*IC2400*
Amsterdam - Vlissingen	*Asd-Vs*	*Intercity Train*	*IC*	*IC2100*
Den Haag CS - Heerlen	*Gvc-Hrl*	*Intercity Train*	*IC*	*IC2500*
Den Haag CS - Venlo	*Gvc-Vl*	*Intercity Train*	*IC*	*IC1900*
Amsterdam - Bruxelles	*Asd-Brusc*	*International Train*	*INT*	*INT600*
Amsterdam - Breda	*Asd-Bd*	*Fast Train*	*IR*	*IR2200*

Table 2.2: Mixed operation of train series running along the railway track between Den Haag HS and Rotterdam CS, passing through the two-track bottleneck

All lines indicated in the table above pass through the corridor under study, hence have to be taken into account for the research study. However, freight trains running on the line were not inputted to the software due to a lack of information concerning to those train movements and their scheduling. To develop a realistic and complete study approach they should be taken into account.

Based on a train pattern hierarchy, previous works fixed departure times and other fixed time points per train route considered were inputted to the software per train series. Running the simulation tool, different points in time were estimated according to infrastructure and train data. Further on, those times were modified to match with the fixed scheduled times from the Spoorboekje.

The following sub-section deals with RailSys architecture to come up with an *Estimated Timetable*.

2.3.2 Timetable estimation

As stated previously, the simulation tool RailSys is used in the scope of this project as a tool for running time and blocking time calculation. It does not apply an analytical approach based on user defined delay distributions and waiting time estimations like other systems (*e.g. ANKE*), but considers predefined running times derived on the basis of tractive force vs. speed diagram of the rolling stock implemented. In other words, RailSys leads to deterministic train path and blocking time graphs resulting from a use of characteristic acceleration and deceleration rates of the existing trains in the form of standard running time and braking distance, time loss, and rate of acceleration (Hansen, I.A. et al., 2003:89), given the distances between stopping locations.

This procedure is applied per train type according to rolling stock characteristics previously defined as well as the scheduling fixed by the timetable inputted. The output obtained may not match exactly with reality, thus train paths cannot be trust as in real operation. However, it helps to estimate a rather acceptable conflict-free timetable to define the Status Quo for 1999.

Appendix A shows a more detailed conceptual scheme of the planning task developed by RailSys system with regard to timetable construction. Besides, in this appendix it is presented another RailSys utility non-used for the study referring to simulation of stochastically introduced delays to trains. Defining perturbations by means of empirical or exponential distributions, a Montecarlo Simulation is done leading to development of delays as well as propagation to other trains. It is not used in the scope of this project due to differences between train protection systems for Dutch and German operation. The German case uses longer blocking distances combined with specific approach distances, and a train begins to stop when the distance to the preceding train becomes critical. In the Dutch case, the three-aspect signalling system indicates that when a train encounters a yellow signal it has to start braking to 40 km/h if the block section ahead is still occupied. A train protection system (ATP) controls the train to run at 40 km/h. Not to obtain non-realistic results, it was decided not to apply the tool for simulation purposes (see section A.3 in Appendix A).

Train Paths

To estimate train paths, running times between locations are calculated and added to earlier prefixed times. *Minimum Running Time* is calculated compiling different deterministic speed-time values, derived from the tractive-effort diagram, for a specific distance between stop locations. In this way, the movement of the train is characterized by a sequence of the following modes: *acceleration*, *constant speed*, *coasting* and *braking* (see Figure 2.3).

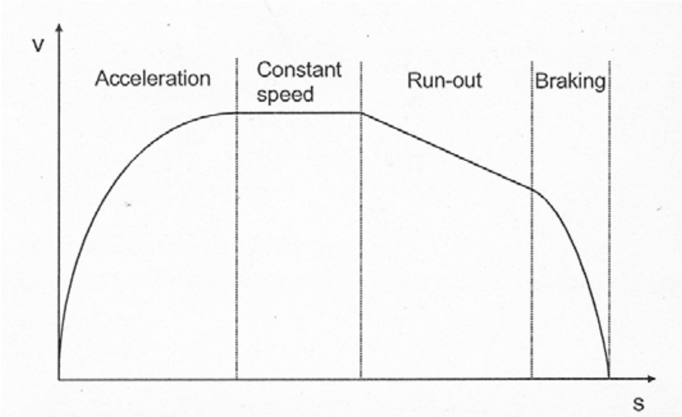

Figure 2.3: Elements of a Train Movement between two stops (Pachl, J., 2002:34)

However, the *scheduled running times* over different distances are estimated by adding up to the minimum running time a certain *time margin* (time supplement) as a percentage of it used to recover the schedule if a small conflict occurs. Then, the scheduled running time is characterized as,

$$SchRT = MinRT + \%MinRT$$

where,

SchRT : scheduled running time
MinRT : minimum running time

A standard time margin of 7% to be spread over the train path was assumed in previous works, as well as minimum dwell times at stations. Given this settings, the system calculates running times between predefined points with accuracy of seconds. In order to meet the scheduled fixed times, if necessary extra running time is automatically added at the end of the train run, increasing the time supplement provided.

According to these calculations, train movements are defined as a function of time and the timetable is represented in a space-time diagram by train paths (see Figure 2.4).

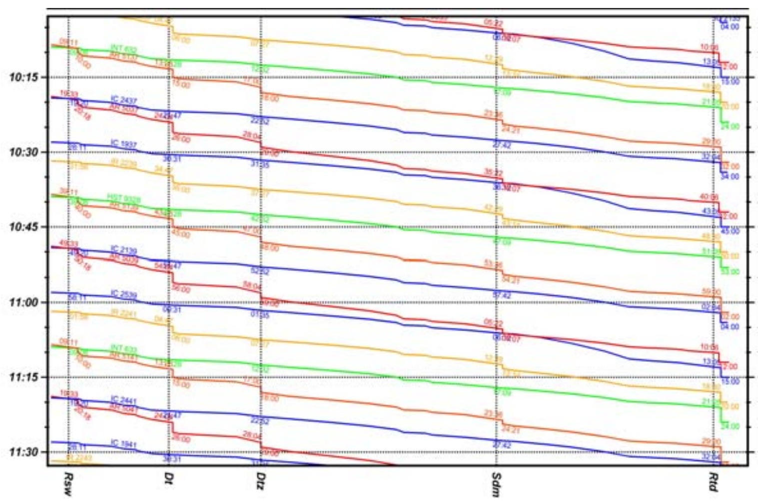

Figure 2.4: Graphical *Estimated Timetable* by RailSys. Representation of train paths for the different train series inputted in southbound direction

Numerical data concerning to this Estimated Timetable is available in Appendix C.

Blocking Times

Individual blocking time calculation leads to *blocking time graphs.* Blocking times depend basically on predefined running profiles of trains as seen in the previous point as well as signalling arrangement and its settings as presented in the research approach: clearing points, block spacing, blocking time components, etc. According to these variables, the simulation tool provides the user with a blocking time diagram for all trains scheduled, where individual blocking times and blocking time "stairways" are represented. Besides, it visualizes overlapping of blocking times if they occur. Figure 2.5 presents the estimated blocking time graphs of scheduled trains according to the Estimated Timetable.

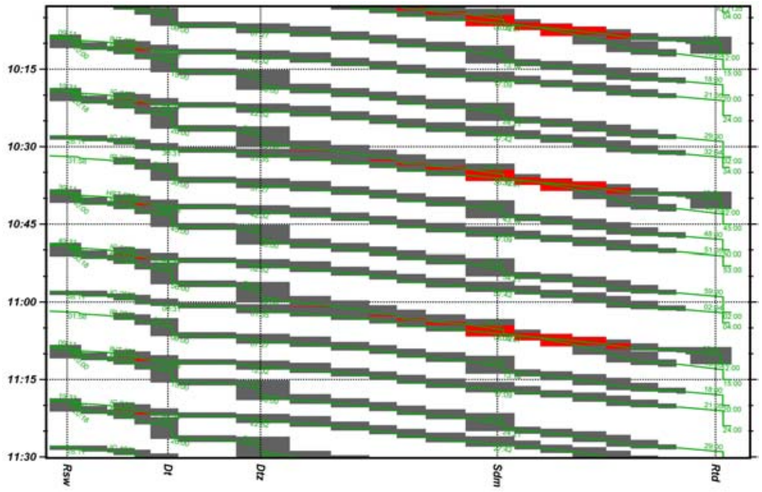

Figure 2.5: Blocking Time Diagram &Train Paths for the Estimated Timetable in southbound direction

From the resulting blocking time diagram, *train headways* and *buffer times* can be determined as well as other relevant values concerning to the train run like track occupations and platform occupations. Further chapters go into detail to extract the necessary information form it.

Theoretically, both the planned timetable (Spoorboekje) and the estimated timetable (RailSys) should match. However, some differences exist due to non-accurate planning, system inconsistencies or the uncertainty of the real operation (for numerical details check tables in appendix C). This situation could lead to non-feasible time-distance profile estimation to define the Status Quo for 1999*,* thus an extended analysis is needed*.*

2.4 Analysis of the Estimated Timetable

Through the blocking time diagrams estimated per direction, several *conflicts* are detected represented by overlapping of blocking times. In blocking time terminology, a conflict arises when two trains require a block section at the same time and one of the trains involved has to change its speed profile in order to avoid automatic braking due to a yellow or red signal encountered. In other words, the remaining time between the starting time of a block and the end of the previous one, the *buffer time,* is negative. This means that the minimum headway distance between header and following trains is not satisfied by train separations, leading to train movement with hinder (deceleration of the following train necessary), thus a planning fault.

According to a reasonable planning, the time-distance diagram should not have any conflict. This chapter aims to analyze the conflicts outcome from the estimated timetable within the study area to further remove them by fine-tuning measures, obtaining a feasible Status Quo.

Conflicts from the Estimated Timetable

Conflicts detected occur between fast and slow trains involved in a following train movement. Those conflicts, here named as *following conflicts,* are analysed below and can be easily located through the blocking time diagrams presented in this sub-section.

Three overlapping of blocking times for trains running in the same direction have been detected. The following gives an overview of the nature of those conflicts. They are located through figures limited to a selected period of time to facilitate their visualization. However, repetition of conflicts takes place over the whole timetable every time the same train series involved are running again, thus cyclically (with reference to train clusters in section 4.3).

Following conflict 1 As presented in Figure 2.6, the blocking time diagram shows a large overlapping of blocking times (marked in red) between intercity (*IC*-) and local (*AR*-) trains specially concentrated at Schiedam station and developed around it, between Delft Zuid and Rotterdam CS in southbound direction (West track).

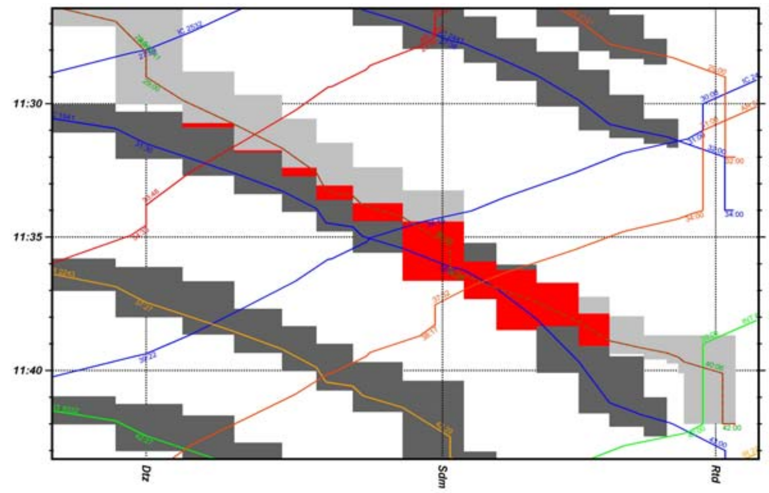

Figure 2.6: Overlapping of blocking times between preceding train series *AR5000* and following train series *IC1900/IC2500*

Table 2.3 gives some representative values related to the conflict and block sections involved and shown in the previous figure.

Block Section (*)	Block Length [m]	Blocking Time [sec]	Buffer Time [sec]
5	1327	142 [1]	-10
		118 [2]	
6	1381	129	-4
		98	
7	1393	129	-19
		99	
8	1334	128	-32
		103	
9	1202	121	-40
		111	
10	1203	203	-73
		122	
11	513	69	-111
		126	
12	680	82	-94
		147	
13	936	98	-97
		202	
14	895	111	-73
		224	

(*) see Appendix B related to signalling system, to understand the block section numbering

Table 2.3: Blocking times for preceding train series *AR5000* [1] and following train series *IC1900/IC2500* [2] overlapping, resulting in negative buffer times.

Judging from this table, block sections number 11, 12, 13 and 14 indicate a meaningful decrease in the speed profile for *IC*-trains, running slower than *AR*-trains contrary to what happens in previous block sections. Of course, this situation is not desirable from a planning perspective neither realistic because *IC*-trains run faster, thus it must be rejected.

Following conflict 2 As shown in Figure 2.7, the blocking time diagram visualizes a small conflict due to a slightly overlapping of blocking times between local and faster trains along Delft viaduct in southbound direction (West track).

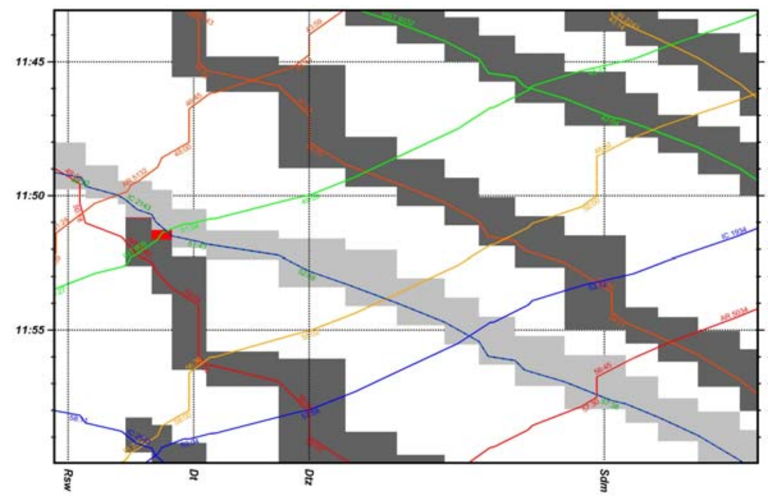

Figure 2.7: Overlapping of blocking times between preceding train series *HST93000/INT600* and *IC2100/IC2400* and following train series *AR5100* and *AR5000* respectively

Table 2.4 gives some representative values related to the conflict and the block sections involved shown in the previous figure.

<table>
<tr><th>Block Section</th><th>Block Length [m]</th><th>Blocking Time [sec]</th><th>Buffer Time [sec]</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">1327</td><td>108</td><td rowspan="2">-24</td></tr>
<tr><td>130</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">1327</td><td>111</td><td rowspan="2">-21</td></tr>
<tr><td>142</td></tr>
</table>

Table 2.4: Blocking times for preceding train series *HST93000/INT600* and *IC2100/IC2400* and following train series *AR5100* and *AR5000* overlapping respectively, resulting in negative buffer times.

Following conflict 3 The blocking time diagram in Figure 2.8 shows an important overlapping of blocking times between fast trains and intercity trains, also along Delft viaduct in northbound direction (East track)

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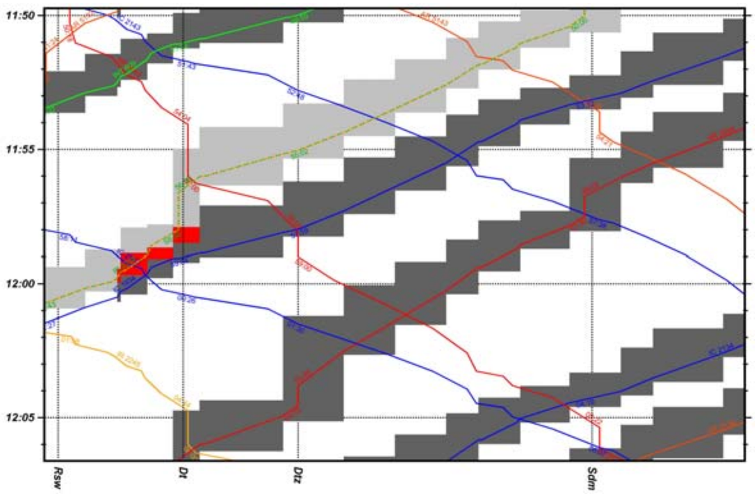

Figure 2.8: Overlapping of blocking times between preceding train series *IC1900/2500* and following train series *IR2200*

Table 2.5 gives some representative values related to the conflict and the blocks involved in the previous figure. In this case, overlapping also appears outside the double-track part of the line.

Block Section	Block Length [m]	Blocking Time [sec]	Buffer Time [sec]
2	329	211	-35
		79	
1	927	77	-25
		67	
#	1165	106	-49
		92	
#	1190	93	-31
		94	

: means a block out of the double track corridor

Table 2.5: Blocking times for preceding train series *IR2200* and following train series *IC1900/IC2500* overlapping, resulting in negative buffer times.

In all three cases the overlapping of blocking times would cause delays to trains during operation, which is a clear indicator of infeasibility of the blocking times for a train run without hinder, thus it must be rejected from estimations. A suitable Status Quo for 1999 which to work with must be free from these conflicts from a quality point of view. In this sense, the estimated timetable has to be tuned, putting special attention to the earliest conflict presented above due to its size. This task is developed in the subsequent chapter.