Chapter 1

Introduction

1.1 Research motivation

This thesis is about a more sophisticated timetable compilation and capacity analysis for a selected Dutch railway line compared to the existing tools applied for these tasks. The research described does not focus on all variables involved in a complete management of these two fields, but performs a simple but rather acceptable approach to get several valid conclusions and recommendations.

The present work aims to analyse a certain timetable and to evaluate capacity upgrading of the railway line Den Haag HS (Hollands Spoornet) – Rotterdam CS (Centraal Station). The capacity of this railway line is limited by a double-track bottleneck in Delft and the mixed operation of intercity (IC-), fast (IR-) and local (AR-) trains along the line. Besides the railway line crosses the city of Delft on a viaduct since 40 years ago, forms a barrier for urban redevelopment and creates rather high noise and dust emissions on the adjacent buildings.

The government with the department of public works of the local authorities of Delft have decided to reduce the environmental and urban impact of the railway line in Delft by building a tunnel with an underground station. It remains unclear if such a large change could be also used to upgrade the capacity of the line by expanding it from 2 to 4 tracks through the tunnel. The question is whether an extension of the current network is the most suitable alternative to solve the capacity problems of the infrastructure according to an expected demand or if other solutions are more optimal. Moreover, such construction involving new tracks leads to higher costs and it is especially time-consuming (long-term project), besides external effects diverted to other transportation networks that would experience complete closures of certain links closed to the city centre, causing congestion, detours and delays. Therefore, this and other alternatives based on a rail infrastructure management should be assessed to be compared in the scope of a larger social cost benefit analysis.

The development of such an accurate analysis by means of computer-aided software might achieve a set of different possible alternatives and suggestions from which to support a more complete and extended analysis.
1.2 Research objectives

The main research objective of this thesis is the development of a set of alternative infrastructure and signalling scenarios on the basis of a theoretical approach and analyse their individual capacity contributions to support further measures.

In order to fulfil the main objective of the research, some tasks must be previously realized deriving the objectives formulated below:

- Fine timetable compilation and analysis on the basis of a real schedule by means of a scientific design approach.
- Performance of different alternative scenarios based on new signalling arrangements and technology and upgraded infrastructure configurations.
- Analysis of the effects on capacity utilization for the previously designed scenarios by means of an optimized capacity analysis.
- Validation of the theoretically obtained enhancements for new signalling systems or additional infrastructure on the scope of an upgraded demand scenario.

Specific research questions that are to be answered at the end:

- Can the current infrastructure deal with the future needs?
- What are the critical aspects/ conflicts to point out?
- How do signalling arrangements affect the operation of the line?
- Can capacity be improved by means of timetabling management to comply with the future demand situation?
- What is the most efficient timetable option in combination with the least costly infrastructure solution to deal with future traffic demand?

1.3 Research approach

The conceptual state-of-the-art approach applied in this thesis is based on the Blocking Time Theory to optimize timetable and capacity management of the selected line using a Fixed Block Signalling System. The following paragraphs give a short insight and general background regarding this theory in order to help comprehension of the work developed during the research (Pachl, J., 2002).

Fixed Block Signalling System and Blocking Time Theory

The purpose of such a signalling system is to ensure a safe train separation on lines with fixed block sections.
An automatic fixed block signalling system consists of lineside signals and train detection devices (axle counters). In its basic form, it uses fixed block sections, which are protected by signals. Signals allow control of the traffic on the network, and to avoid collisions among trains. In the Dutch case, a three-aspect signalling system is applied. In this sense, a block section is a track segment between two signals, which may be red, yellow or green. A red signal means either another train occupies the subsequent block or it is not in use, a yellow signal means that the subsequent block section is empty but the following block section is occupied, and a green signal means the next two block sections are empty ensuring the train ride without any obstruction. Thus, a train is allowed to occupy a certain block section either the signal released is green or yellow. The later indicates the train driver to decelerate to 40 km/h, keeping this “sight” speed until the next indication. Due to safety reasons, it is assumed that a block section must be at least as long as the braking distance required for a train running at the maximum allowed speed.

Travelling time in each block section is called block running time, calculated according to the physical characteristics of the railway infrastructure and rolling stock, and also the running time supplements added as scheduled running times to recover the planned operation. Besides, this running time can also include dwell time at stops and surrounding acceleration or deceleration times.

The headway is the interval between two following trains. The minimum headway on a line with a fixed block system depends on the blocking time, the time interval in which a section of track is exclusively allocated to a train and therefore blocked for all other trains. In this sense, the blocking times describe the occupation of the infrastructure sections. The blocking time is longer than the block running time, and it consists of:

- Time for clearing the signal
- Sight and Reaction time to view the signal aspect
- Approach Time between the signal that provides the approach indication and the entrance signal
- Time between block signals: Block Running Time
- Time to clear the block section, including safety margin of one train length
- Release time to “unlock” the block system

Figure 1.1 shows all these time intervals presented above making up the complete blocking time.
Times included in the blocking time can be categorised as *physical times* and *virtual times*. The earlier refers to the physical occupation of an infrastructure element, thus the time a train is physically inside the block section. It includes running time and release time, and serves enough for operational planning. The later are considered to fulfil the safety block requirements and includes all the rest. Both times are used to define the *minimum headway* between trains thus the track area associated defined as *block zone*. This theoretical times may change when a conflict occurs if time reserves are not able to deal with it, slowing down trains thus increasing blocking times.

Ergo, a block signal must only be cleared when the entire control length of the signal (referred to the blocking time) is clear and a train ahead is protected by a stop signal. In automatic block systems, track clear detection devices realize this task.

![Figure 1.2: Control Length of Signals in a Fixed Block Line without block overlaps (Pachl, J., 2002:46)](image)

Connecting all blocking times for a train run leads to the *blocking time stairway*/*blocking time graphs*, which allows determining graphically the *buffer times* as well as *minimum time headway* between trains, concepts strongly related to capacity consumption of the infrastructure by the train paths, thus capacity evaluation (for more details see section 4.2).

According to this approach, blocking times are used as the central modelling element for the case study presented in this thesis. In practical applications, blocking times are still not applied by the Dutch infrastructure managers (neither *ProRail* nor *NS*), thus railway management is hardly optimized. Research done by means of this theoretical approach may lead to better improvements and optimized scenarios for railway operation.

To undertake this wide range of management tasks and performance of scenarios, the infrastructure & timetable optimisation system *RailSys* is applied. This software supports the user from railway planning analysis on the basis of blocking times, and is used in this thesis to perform different computational experiments.

### About RailSis 3.0

The timetable and infrastructure management program *RailSys* is a computer-based software system for analysis, planning and optimization of operational procedures in railway networks developed for the German case by RMCON Rail Management Consultants. This microscopic detailed database leads to a very efficient way of optimizing proposed infrastructure and timetabling (scheduled operations). A detailed planning of both infrastructure and timetable aspects for several variants created can be carried out by means of this system, including tools for running time calculation, infrastructure mapping, timetable construction and evaluation and the planning of vehicle rosters.
1.4 Thesis contributions

All these characteristics make this tool suitable in different application fields like timetable construction and modelling, planning of capacities, infrastructure planning, scheduling and planning of different traffics, validation and investigation of timetables, disposition of strategies in case of delays or operational disturbances or checking of operational quality and punctuality.

Basically, RailSys consists of four basic modules or system components:

- Infrastructure Manager
- Timetable Manager
- Simulation Manager
- Evaluation Manager

Since the existing differences in signalling environment and operation rules for German and Dutch railway networks, this simulation system is only applied in the scope of this thesis as a tool to calculate running times and blocking times on the basis of predefined running times, thus constructing but not simulating a timetable. Calculated values are assessed and used for further external analysis. In this sense, Simulation and Evaluation Manager modules are not used due to uncertainty that may arise from the results to be obtained.

A more detailed description of these system components is attached in Appendix A.

1.4 Thesis contributions

The main scientific contribution of the research described in this thesis is the improvement achieved by means of an analysis based on blocking times. Different views of train operations, signalling and train protection systems, train types and timetable alternatives are assessed as well as proposed according to previously estimated railway transport demand and development. Furthermore, an extensive analysis of timetables, running times, blocking times, track occupations, buffer times and headways are also assessed to succeed with a proper output. In this sense, comparison of the strengths and weaknesses of the different aspects stated above are investigated.

Nevertheless, some constraints influencing the research from a network level have not been considered due to the complexity arising from them. Different assumptions and simplifications are done along the study to frame the research in a more theoretical and simplified environment. In this sense, different aspects like operation of freight trains or the interrelations between the isolated study area and surrounding stations and lines out of it are not analysed.

1.5 Outline of the thesis

The research presented in this thesis could be split into three parts, namely according to the contents of the chapters, timetable compilation and capacity analysis of the Status Quo for 1999, alternative capacity scenarios, and upgraded demand and infrastructure validation.

First, a selection of the most appropriate infrastructure and timetable databases is done to carry on a complete study through the selected computational system chosen for the analysis. The performed study focuses on the timetable for 1999 along the railway line between Den Haag HS and Rotterdam CS as presented in the research motivation. Once establishing the tool and acquired the necessary knowledge to better represent on it the selected data, a timetable is estimated. An assessment of it is done to check whether it fits to a feasible and suitable scheduling.
As indicated in the research approach, the software architecture used works based on blocking times but its application may not lead to the suitable approach to be used for capacity analysis. In this sense, Chapter 3 aims to tune the estimated timetable approach by the system to get a more suitable one defining a Status Quo for the study case selected.

Based on the Status Quo description of the timetable by means of time-distance graphs and blocking time diagrams, capacity analysis is performed in Chapter 4.

The second part of the thesis concerns an alternative scenario construction and evaluation. Different cases are discussed within two chapters based on new signalling approaches and infrastructure configuration. Chapter 5 deals in first instance with the location of signals and spacing between them, thus block lengths, and try to validate the consequences of reducing these lengths from a capacity point of view. Besides, it also analyzes the application of an upgraded signalling technology named Automatic Train Control system (ATC) to check whether it leads to significant capacity improvements. As a second block, Chapter 6 performs a number of infrastructure scenarios based on different extensions of a second track per direction along the critical corridor of the line, and evaluates the trend of track occupations.

The resulting theoretical scenarios are applied under the scope of a hypothetical upgraded scenario characterized by an increased transport demand forecasted for 2020 by ProRail, public infrastructure manager and traffic controller. The applicability of the best alternative selected to meet the increased demand is demonstrated and results obtained with regard to line occupation. Chapter 8 summarises findings and conclusions for the whole research described in this thesis.