Chapter 8

Conclusions

This final chapter summarizes the conclusions and gives recommendations for the implementation of the ideas outlined in this thesis in further research. First, the contents of this thesis are summarized to give a brief overview to the problem studied. The second section summarizes the main conclusions and recommendations of the research done. In the third section, recommendations are given with respect to further research on evaluation of upgrading the capacity of the line.

8.1 Short Summary

The main purpose of this work has been to do an accurate timetable analysis and evaluation of upgrading the capacity of a certain railway line by means of different alternative scenarios in order to get an insight to the most efficient solution. In this thesis, research has been done according to a state-of-the-art analysis methodology based on the Blocking Time Theory. Regarding to this approach, the computational system RailSys has been applied as a support tool for design, calculation and analysis of the different performed scenarios.

The allocation of an uncertain future demand within the existing railway infrastructure between Den Haag and Rotterdam is one of the major issues in future railway operation of this line. The current transport supply situation does not allow meeting an increased demand due to the existing capacity bottlenecks created by the mixed operation of trains on the double-track corridor characterizing this line. In order to solve this situation, different measures with respect to capacity increase have to be set out according to the transport needs of the line. Nevertheless, it has been decided to construct a tunnel at Delft station responding to environmental and urban reasons under the scope of a large project with a time horizon of 15 years. Then, the remaining question is whether this project could be enlarged by means of four-track extensions through the tunnel at Delft. However, travel forecasts and newly planned railway infrastructure projects might change the situation and make some minds think about other more suitable and optimal alternatives to upgrade the capacity in this line in a sufficient way.

Timetable data regarding the planning of one year (1999) at the Dutch railway network has been used to perform all computational experiments. Under these conditions, the first step in the development of a theoretical framework to analyze capacity optimization has been the specification
of a suitable base timetable (Status Quo), which defines a reliable scheduling for 1999. The most significant problem faced in the timetable compilation made by the simulation tool was to define suitable running time supplements over all train series, especially for intercity trains, to remove the existing overlapping of blocking times and obtaining a conflict-free schedule. This problem has been solved by tuning the train paths redistributing running time supplements which were concentrated at the end of the train runs and spreading them over the whole train paths, resulting in a more harmonized time-distance diagram. Then, capacity evaluation through the conflict free blocking time graphs has been done to obtain the track occupation percentages used as reference values for further upgraded scenario analysis.

The main objectives of Chapter 5 and Chapter 6 have been to extend the theoretical approach of blocking time theory to the performance of new capacity scenarios based on modified signalling arrangements as well as extended infrastructure alignments. The new signalling scenarios have been differentiated in two types according to different measures: variation of the block section lengths according to minimum braking distances and implementation of ATC technology. Moreover, the first one has resulted in two scenarios, Scenario A which considers maximum capabilities of trains as the main design criteria and yields inadmissible track occupations, and Scenario B, which considers capacity and economic efficiency.

The second approach presented is based on a set of double-track extensions per line direction. These infrastructure scenarios have been designed on the basis of blocking time (stairways) graphs and location of the existing capacity bottlenecks. Since it is not known a priori, the development of critical sections every time the track is extended (extensions before station stops and including them) have been considered to check whether the influences of dwell times and single track bottlenecks are significant or not. Computational design and experiments of those sub-scenarios have been performed to obtain a track occupation vs. extension length graphs per direction serving as theoretical approach for implementation in Chapter 7, where a suitable infrastructure scenario is to be found according to travel forecasts.

8.2 Main conclusions and recommendations

Having briefly reviewed the contents of this thesis, the next step is to summarize the conclusions arising from the qualitative and quantitative results obtained. Three main fields of conclusions are discussed in this section regarding the three levels this thesis consists on: Timetable compilation, Alternative capacity scenarios, and Upgraded demand scenario.

Timetable compilation

The most important finding from setting a suitable Status Quo refers to a need of homogenizing the speed profiles of trains in order to get a more suitable and harmonized timetable approach avoiding planning conflicts. It has been proved that the best operation of the line capacity is only achieved by planning a timetable in which train runs are harmonized without large speed differences. Nevertheless, a trade off has to be done to also provide the required reserves in time according to a reasonable timetable stability and robustness.

It is difficult to anticipate how trains really behave during operation along the line due to dependency on many stochastic variables not predictable such as train driver behaviour, weather conditions, delays of trains, etc. Dutch railways published a timetable made up in a standard and macroscopic manner where time distributions at intermediate stations are not indicated, especially
for non-stopping trains like intercity trains. Only after assuming an optimal distribution of those uncertain running time supplements through the simulation tool a complete running profile can be found, turning to be close to real operation. Then, the new redistribution of the scheduled waiting times applied, especially to IC-trains shifting their speed profiles closer to slower trains, lead to a conflict-free scheduling between conflicting trains series. Although the resulting time supplements seem to be larger than the standard values, they must be accepted to define a reliable operation without conflicts.

Comparing both the published timetable (Spoorboekje) and the new detailed approach it has been observed that some local trains’ running times differ, especially between Delft Zuid and Schiedam stations, where the difference found is about one minute less for the official schedule. This might be caused by the fact that real planning process did not consider a precise running time distribution, leading to not correct times that in this case might lead to passengers waiting at Schiedam platform.

A last comment regarding the scheduling refers to larger time supplements located at the end of train runs, especially before large transport nodes like Den Haag HS or Rotterdam CS. Such scheduling is done not only to have relatively small recovery time in case a small delay occurs and provide trains with enough extra time, but also to provide transfer buffer time at platforms, to reach the planned connections with other trains.

Capacity evaluation of the existing scenario has indicated extremely high values for track occupations along the line regarding the existing standards. It has been proved that not only the double-track corridor limits the capacity but also other factors as the mixed operation of trains basically, which presents too many differences in running profiles. Then, it is clear that the existing line capacity is over-consumed, which does not mean that is optimally used. In other words, the existing available capacity might be improved by means of enhancement measures that not only provide additional capacity but also exploit the unused one due to bottlenecks.

Alternative capacity scenarios

For a number of reasons, it is desirable to analyse different improved scenarios to deal with possible future capacity problems of the line. Firstly, soft measures concerning to signalling system just achieve light track occupation reductions that might improve the timetable stability of the mixed operation but that may have difficulties to meet an extra demand of trains. A completely new reallocation of all signals would not be economically feasible neither efficient for a short-term planning, and only reducing some of the existing block lengths might lead to an acceptable scenario. However, it has been proved that even when optimal block section lengths or ATC system are applied in this line, the infrastructure and signalling system yield not enough capacity enhancements as to meet additional train paths. Bear in mind that the block sections were optimized/ reduced so far and little shortenings might be achieved, which limits the blocking time improvements obtained.

Secondly, it appears that second track enlargements would be much better to achieve a significant increase of the capacity. It has been shown that extending a second track either from Rijswijk or Rotterdam both in southbound and northbound directions leads to a continuous increase of capacity, not linear but concentrated at station block sections. The track occupation results obtained per track extension indicated that both Delft and Delft Zuid stations mainly represent the capacity bottlenecks of the double-track corridor. Hence for short enlargements, extensions from Rijswijk yield lower track occupations compared to extensions from Rotterdam especially in southbound direction. Then, omitting other components influencing a construction decision, capacity achieved
with short extensions is optimized and more trains could be fit in the timetable if extensions start from Rijswijk than if they do so from Rotterdam CS.

Open track extensions and reductions from two to one track per direction nearly do not contribute to improve capacity so much. In this sense, selective slot allocations of extra track in terms of sidings at stations to allow overtaking or dwell time reductions would be less costly solutions at the same time similar improvements might be achieved. This assumption emphasises the fact that dwell time bottlenecks at stations represent the main capacity constraint of this railway line. However, critical block sections indicate that although most buffer time is gained by removing station bottlenecks, critical double-track bottlenecks at the edges of the corridor (e.g. Delft viaduct) must be removed in advance in order to exploit any gain achieved at station sections, otherwise the track occupation would still remain critical.

**Upgraded demand scenario**

One of the main objectives of the theoretical research apart from serving as a rough indicative approach for further analysis was to apply the findings to a given demand scenario of the studied line forecasted for 2020. Although large demand load on this line could be expected, future boundary transportation alternatives of the study area made the prognosis not so conservative. In such a demand environment, two more local trains per hour are expected to be fit into the timetable in a time horizon of 15 years. Hence this additional load to the existing one will have to be handled by new proposed infrastructure extensions. None of the signalling improvements (less costly measures) would result in a sufficient increase of capacity, thus only track enlargements might cause the increase needed to reach a reliable operation of trains.

Capacity scenarios faced by this thesis would suggest an alternative infrastructure scenario based on shortest quadruple-track extensions from Rijswijk to Delft Zuid, in both directions, meeting the forecasted load at the same time track occupation remains below the common standards. Furthermore, if the existing capacity scenario is accepted, a suitable situation might be achieved by only extending double tracks until Delft, although stability of the timetable might remain critical due to small buffer times. In both cases, especially in the last one, re-scheduling tasks are suggested and may lead to improved quality of operations.

These extensions would not be needed for a short term planning. In the coming years, it is only necessary to find out an approach dealing with small capacity variations and stability of the timetable, at the same time a small investment is needed. In this sense a policy to optimize dwell times at stations or planning optimal timetable concepts could be some efficient ways to improve the existing scenario. However, assuming that a tunnel construction at Delft station will start in short due to environmental and urban reasons, it could be recommended to extend four tracks within this project. Nevertheless, if costs of such four-track tunnel project are too high, it is also possible to set out different alternatives extending from Rotterdam or combining three-track extensions from both sides. In this way, capacity needs are also reached and costs are reduced due to the open air construction of the railway track.

### 8.3 Recommendations for further research

This section provides suggestions for further research according to the issues outlined in this thesis, basically regarding the different alternative capacity scenarios and other measures discussed in the main report.
8.3. Recommendations for further research

With respect to the existing timetable, it would be interesting to see whether capacity is improved by means of a new timetable concept based on more harmonized speeds between the different train series. In this sense, it is recommended to make a detailed speed profile assessment (speed homogenization) and re-scheduling task of the different train series in combination with the presented measures in order to get a more harmonized timetable. Furthermore, the impact of increasing the speed of local trains by means of better rolling stock and/ or dwell time optimization at platforms should be deeply analysed due to its reliability and efficiency (see section 7.4). At it has been mentioned, dwell time management at stations as well as other conflict points could also be the goal of further research projects due to its proved influence in capacity issues in such a complex mixed operation. Station capacity and stability of train operations (Hansen, I.A., 2000) is an article researching on this field, as well as Application of computer simulation to rail capacity planning (Barter, W.M., 1998) which treats also dwell times among other issues in order to deal with capacity planning.

As commented in the infrastructure enhancement (Chapter 6), the presented set of track extension scenarios could be extended by means of additional computational design and analysis for implementation of sidings at stations in order to optimize the investment costs. Besides, other ideas like flexible operation on a complete triple-track line with a multiuse track should be deeply assessed as some research stated previously (Katsuta, K., 2000). Somehow, these additional approaches would have to deal with certain key locations like capacity bottlenecks not directly removed if track extensions are not applied, otherwise they would limit any of the improvements achieved.

A complete study regarding all these proposed measures as well as the scenarios presented in this thesis should be involved in a complete cost-benefit analysis regarding different alternatives. By this, the research would lead to a more complete approach to better supply with information for technical and economical evaluation (Jelaska, M., 1998) supporting the decision making process. As it is the case of the future situation forecasted for 2020, a part from extending four-tracks from Rijswijk within the tunnel construction as suggested in section 7.3, other alternatives like extending four tracks from Rotterdam or an intermediate solution extending three tracks from both Rotterdam and Rijswijk should be analysed due to their reduced costs in the tunnel construction.

To conclude it has to be pointed out that the research realized does not take into account neighbouring railway networks and freight train operations, simplifying the problem, thus the study developed must be placed in a wider network and operational framework. By this, new constraints and interdependencies may arise making the outputs obtained to change, thus the conclusions and recommendations presented. Nevertheless, this study serves as a rough indication for small scale analysis and must be understood according to its limitations and assumptions indicated.