Chapter 7

Upgraded demand and infrastructure scenario

7.1 Introduction

This chapter will consider a case study based on the resulting demand forecasts for the year 2020 from ProRail. In order to extend the analysis done in Chapter 5 and Chapter 6, it examines the feasibility of those upgraded capacity scenarios in practical situations, to find suitable and consistent alternatives to meet the expected demand along the railway line Den Haag HS – Rotterdam CS.

Section 7.2 discusses the suitable selection of a forecasted scenario based on prognostics slightly adjusted to the thesis scope to reduce the degree of complexity. Then, once defined the upgraded demand scenario, section 7.3 deals with Train Path Management on the scope of a demand & supply analysis, and shows figures and results obtained through the simulation tool.

At the end of this assessment, conclusions and recommendations are drawn to prove that the realization of the planned project with regard to the tunnel construction presented in the research motivation could be used to extend the existing four-track from Rijswijk. However, from a capacity point of view other extension solutions would be also feasible as it will be analysed. Of course, other and largely detailed studies need to be done on the scope of other fields like dwell time optimization, to come up with an optimal analysis supporting a final decision-making (see section 7.4).

7.2 Travel Forecasts

To deal with the proper infrastructure and signalling measures, first of all it is necessary to know possible theoretical upgraded scenarios. In other words, travel forecasts have to be done to estimate the future travel demand, thus the number of trains to be integrated into the timetable.

Travel forecasts have been subtracted from ProRail studies (2004). These have been done regarding the impact of different projects planned for the coming years. Contrary to expectations, a huge increase of demand is not expected due to the impact of planning for railway services in the
Randstad area such as a high speed line (HSL) connection from Rotterdam CS to Schiphol Airport (planned for 2007) and a direct light rail connection between Rotterdam and Den Haag (Randstadrail).

As shown in Figure 7.1 these new infrastructure projects might cause a modal shift of the railway demand at that time to the different alternatives, decreasing the total load to the existing railway connection between Den Hag and Rotterdam that otherwise would have to meet.

By means of econometric models for simulation of travel behaviour, the number of passengers per day has been forecasted. The following table shows these values for different scenarios in time.

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2010</th>
<th>2020 (high)</th>
<th>2020 (low)</th>
</tr>
</thead>
<tbody>
<tr>
<td># passengers</td>
<td>62000</td>
<td>53000</td>
<td>70000</td>
<td>62000</td>
</tr>
</tbody>
</table>

Table 7.1: Demand prognostics in number of passengers forecasted for different future scenarios

Travel forecasts show a little or even no increase of travel demand depending on the conservatism of the approach. Assuming a high (conservative) scenario, an increase of 13% number of passengers should be expected, whereas in a less conservative scenario the demand would remain the same.

The following subsection gives more details about capacity use & occupation of this future demand scenario adapting the forecasted data to the capacity analysis requirements.
train of 4.45 min in the scheduled Status Quo approach. This value represents about 15% of the line occupation each half hour.

A more precise value with regard to the different train types running on the line within the defined cluster (for details see section B.2.3 in Appendix B) can be obtained by means of RailSys calculations. The occupation times of each train per half hour within a cluster of trains can be derived from the blocking time graph, and are strongly related to the relative order of trains. In this case, it is assumed the existing order according to the schedule, and track occupations are calculated per train type. As shown in the figure below, those values can be subtracted from the blocking time graph where minimum time headways between trains are determined.

From the minimum headways expressed in seconds in the diagram above, train’s occupations can be calculated. As commented before, these values depend on the existing order of trains and they would vary if a different distribution of trains is done due to different time headways. For simplicity, constant values will be assumed through the following approach. Table 7.3 depicts the average occupation values and average speeds for selected train series along the link Den Haag – Rotterdam according to the schedule worked out in previous chapters.

<table>
<thead>
<tr>
<th>Train Type</th>
<th>Average Speed [km/h]</th>
<th>Occupation Time [min]</th>
<th>Cluster occupation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1900/2500</td>
<td>75</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>IR</td>
<td>71</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>HST/ INT</td>
<td>90</td>
<td>4,2</td>
<td>14</td>
</tr>
<tr>
<td>AR5100</td>
<td>52</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>IC2400/2100</td>
<td>84</td>
<td>5,4</td>
<td>18</td>
</tr>
<tr>
<td>AR5000</td>
<td>52</td>
<td>4,3</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 7.3: Occupations and average speeds of each train series within a train cluster for the Status Quo schedule along the link Den Haag HS – Rotterdam CS (22.4 km)

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2 Southbound direction is taken as the reference to estimate the consumption of one additional train. The same value is assumed in northbound direction.
The results obtained in the above table have to be consistent with the track occupation values obtained before. Thus:

\[ 0.9 = \frac{t_{h}}{t_{p}} = \frac{\sum t_{h,i,j}}{t_{p}} = \frac{t_{h,IC2100} + t_{h,IC1900} + t_{h,AR5000} + t_{h,AR5100} + t_{h,IR2200} + t_{h,HST9300}}{t_{p}} \]

In words, the sum of all individual track occupations presented in Table 7.3 must be equal to the track occupation estimated in Chapter 4.

As pointed out before, the approach to be done is based on 2 extra AR-trains per hour or, which is the same, 1 extra AR-train per cluster (6+1), thus alternative signalling or infrastructure measures will have to be applied in order to deal with about 15% more track occupation. In this sense, according to the theoretical approaches analysed before, a new service scenario is to be proposed increasing the existing capacity of the line.

### 7.3 Train Path Allocation

The aim of this section is to do train path allocation according to the previous travel forecasts (demand) and enhanced scenarios analysed (supply). To deal with this task, firstly a scenario is chosen among all possibilities treated in previous sections. Secondly, some scheduling measures are suggested to handle the upgraded demand and come up with a properly constructed timetable. Of course not all factors taking part in this field are judged in the approach due to the complexity of this problem, and only capacity aspects are considered.

#### 7.3.1 Selected scenario

According to travel forecasts, a high demand scenario would require such an increase of capacity that none of the signalling scenarios performed in Chapter 5 could handle it. Bear in mind that those scenarios increased the capacity on average 7% which is not enough given the demand forecasts. Therefore, only second track extensions per direction are considered for the study case on the basis of the theoretical results obtained in Chapter 6.

To define a suitable scenario to meet the increased demand, different assumptions have to be taken into account. They are described below:

1. Acceptable Maximum Track Occupation.
2. Additional track occupation resulting from a new extra train path allocation.
3. Relationship between track occupation and second track extensions per direction.

Judging from the above, different scenarios could arise. In first instance, for the first assumption, a standard traffic flow 80% of the maximum capacity is considered (as stated by ProRail) once the upgraded operation takes place. This will be named as Case I. Besides, it is also analysed a second
case, where the existing values for track occupation (90% and 88% in southbound and northbound direction respectively) are accepted once the additional trains are inserted although traffic density stays high. This will be named Case II, following the same terminology. Also a third case regarding the UIC norm occupation standard (75%) could be analysed, but it has not been done in the present work.

With regard to the second assumption to be taken into account, it is assumed that each additional local train represents 15% more track occupation as indicated in Table 7.3 if the existing relative order is kept. This is quite non-realistic assumption if it is considered that once a new infrastructure scenario is applied, the amount of track occupation contributed per train type may change as well as the order of trains. However, assuming the existing contributions the approach is conservative, thus results are rather more robust.

The third assumption concerns to the estimations done in Chapter 6 and shown in Figure 6.6 and Figure 6.7.

With regard to the first assumption and given the two directions of the line, four cases are distinguished:

Case ISouth Maximum 80% of track occupation in southbound direction assuming one additional local train represents 15% of the occupation.

Case INorth Maximum 80% of track occupation in northbound direction assuming one additional local train represents 15% of the occupation.

Case II South Maximum 90% of track occupation in southbound direction assuming one additional local train represents 15% of the occupation.

Case II North Maximum 88% of track occupation in northbound direction assuming one additional local train represents 15% of the occupation.

To make a suitable choice for the different cases, a logic procedure is applied. For each case, it is easy to derive the optimal track extension if the maximum occupation to be constrained before adding an extra train is determined. Once it is calculated, it is possible to determine the optimal extension through the track occupation vs. extension diagram for the selected line direction. Appendix E details the procedure to determine the optimal extensions. Besides, the outline followed in the different cases is also presented.

Table 7.4 summarizes values the output obtained from this analysis by means of forward and backward extension enlargements (in kilometres) presented in section 6.3 and the hypothetical track occupation estimated that might arise running only the existing services in 1999 (without any additional local train).
7.3 Train Path Allocation

<table>
<thead>
<tr>
<th>Case</th>
<th>Extension</th>
<th>Length [km]</th>
<th>Track Occupation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISouth</td>
<td>F4</td>
<td>5.2</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td>12</td>
<td>62</td>
</tr>
<tr>
<td>ISouth</td>
<td>F10</td>
<td>12.5</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>B10</td>
<td>4.5</td>
<td>64</td>
</tr>
<tr>
<td>ISouth</td>
<td>F2</td>
<td>3.2</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>11.5</td>
<td>73</td>
</tr>
<tr>
<td>INorth</td>
<td>F8</td>
<td>4.4</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>B9</td>
<td>3.1</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 7.4: Optimal forward and backward extensions scenarios per case and their estimated track occupation before adding extra AR-train

Presuming enough capacity supply for all of the presented forward and backward extensions as well as under the respective threshold in each case, the shorter extensions are selected as the most suitable and efficient infrastructure scenarios where to fit an upgraded timetable handling additional train paths. Therefore, the final proposal for an optimal capacity extension for each case is presented in the following table:

<table>
<thead>
<tr>
<th>Case</th>
<th>Extension</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISouth</td>
<td>F4</td>
<td>including Delft Zuid</td>
</tr>
<tr>
<td>ISouth</td>
<td>B10</td>
<td>including Delft Zuid</td>
</tr>
<tr>
<td>ISouth</td>
<td>F2</td>
<td>including Delft</td>
</tr>
<tr>
<td>INorth</td>
<td>B9</td>
<td>including Delft</td>
</tr>
</tbody>
</table>

Table 7.5: Selected extension scenarios for the defined cases

Of course, decisions on extensions that have been done assuming the shorter the extension the lower the investment costs might not necessarily be like this and other costs depending on the area where to extend a second track (tunnel, open air, geography) would also play an important role. This is especially sensible for this case study where, according to the selected extensions indicated in the table above, all second track enlargements both in southbound and northbound direction would start from Rijswijk, conflicting with the urban area involving the Delft viaduct where a tunnel construction is planned.

7.3.2 Scheduling

The task of scheduling is to determine the route the additional train is guided on through the line, its arrival and departure times at stations and its speed profile. Besides, the movement of an additional train on the line where other trains running on it are scheduled may also change the existing pattern.

In principle, scheduling includes (Pachl, J., 2002:177-184):

- **Scheduled running time** consisting on running time between stops, dwell time, recovery time and scheduled waiting times.

- **Scheduled headway** consisting on a minimum headway plus a buffer time depending on the required quality of traffic.
To simplify calculations, running dynamics and individual schedule characteristics for the additional AR-train to be fit every half hour are assumed the same as for the existing local trains. In such a case, shapes of the time-distance curves of the other train services do not change and they are just displaced (re-scheduling), if necessary, in order to generate the buffer that is required to allocate an additional train path. Of course, it seems wise to operate enhanced stopping train services instead of the existing ones (as will probably be done in the future) provided with better rolling stock in terms of operational speeds and boarding and alighting of passengers at stations (it will be discussed in section 7.4), but it is not considered in the present approach.

Figures 7.3 to 7.6 visualize a possible allocation of an additional local train path per cluster in each direction according to the relative order of trains presented in the previous section (leading to 15% occupation) and the selected infrastructure scenarios in the different cases analysed. Track occupations ($\rho$), minimum buffer times and minimum signal headways estimated are indicated in minutes and seconds ([min:sec]) regarding the blocking time graphs.

Figure 7.3: Time-distance diagrams before and after allocation of an additional local train (Case ISouth)

Figure 7.4: Time-distance diagrams before and after allocation of an additional local train (Case INorth)
7.3. Train Path Allocation

a) Timetable with buffer time ($\rho=72\%$)  

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure7.5}
\caption{Time-distance diagrams before and after allocation of an additional local train (Case II\textsubscript{South})}
\end{figure}

\begin{itemize}
\item Min. Signal Headway: 01:41
\item Min. Buffer Time: 00:09
\end{itemize}

b) Timetable with additional train allocated ($\rho=86\%$)

\begin{itemize}
\item Min. Signal Headway: 00:28
\item Min. Buffer Time: -01:39
\end{itemize}

As shown in the above figures, the blocking time stairways play an important role to model the succession of trains along the line in a correct manner. However, for these cases it is just proved how one additional train per cluster fits into the timetable handled by the Den Haag HS – Rotterdam CS line, without going into detail in such constraints like the quality assessment of scheduling (stability & robustness) and other factors taking part in scheduling processes like demand & supply structure, preferred order of trains, and influences all over the network. These and other factors would have to be considered to compile a properly schedule. However, only supervision and suggestions not to have negative buffer time are roughly considered in this case study, and a complete rescheduling task is left out of the scope of this thesis.
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Figure 7.3(a) shows the timetable with buffer time for Case ISouth. As Figure 7.3(b) indicates, in case of one additional AR-train has to be fit within a cluster, re-scheduling of the existing services is not needed. As shown in the graph, an AR-blocking time stairway fits between INT-train and IC-train (this is the necessary relative order at Gv to keep to be consistent with the 15% occupation) without overlapping of blocking times and the other train paths do not have to be displaced (pattern is maintained). From a capacity point of view this situation is acceptable, but remaining buffer times between blocking time graphs of the indicated trains are too small from a stability point of view. In this sense, rescheduling of all trains to get a more harmonized blocking time graph would lead to better operation. Figure 7.7 gives a possible rescheduling of train services for Case ISouth where minimum buffer times are slightly increased, improving the quality of operation.

Figure 7.7: Alternative train path allocation for case ISouth resulting in a more harmonized conflict-free timetable

The same reasoning as in this case is valid in the opposite direction regarding Case INorth if Figure 7.4, both (a) and (b), are assessed.

Figure 7.5(a) shows available buffer for Case IISouth. As Figure 7.5(b) indicates, it is not possible to fit an additional local train without overlapping of blocking times if no rescheduling is done. To remove the arising conflicts and get a harmonized planning, rescheduling by means of either displacement of train paths or even reordering of trains would be needed. As stated earlier, many factors constraint this task which are not treated here. Figure 7.8 gives a rough insight to an alternative possible re-scheduling of trains resulting in a more harmonized timetable at the same time the overlapping of blocking times due to an additional train disappears. Nevertheless remaining buffer is almost zero, which might lead to stability problems.
7.3. Train Path Allocation

Min. Signal Headway: 02:25
Min. Buffer Time: 00:07
Track occupation (ρ): 86%

Figure 7.8: Alternative and necessary train path allocation for case II_{South}
resulting in a more harmonized and conflict-free timetable

The same reasoning as in this case is valid with regard to Case II_{North} if Figure 7.6 is assessed.

Track occupations arising from each of the above upgraded cases (with an extra AR-train) are summarized in Table 7.6. It can be checked how those values per direction remain under the assumed threshold in each of the analysed cases (case I and case II).

<table>
<thead>
<tr>
<th>Case</th>
<th>Admissible Track Occupation [%]</th>
<th>Extension R_{Sw} to</th>
<th>Length [km]</th>
<th>Track Occupation [%]</th>
<th>Reschedulling</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_{South}</td>
<td>90</td>
<td>Delft (F_2)</td>
<td>3.2</td>
<td>86</td>
<td>necessary</td>
</tr>
<tr>
<td>I_{North}</td>
<td>88</td>
<td>Delft (B_9)</td>
<td>3.1</td>
<td>83</td>
<td>necessary</td>
</tr>
<tr>
<td>ISouth</td>
<td>80</td>
<td>Delft Zuid (F_4)</td>
<td>5.2</td>
<td>76</td>
<td>advisable</td>
</tr>
<tr>
<td>INorth</td>
<td>80</td>
<td>Delft Zuid (B_{10})</td>
<td>4.5</td>
<td>73</td>
<td>advisable</td>
</tr>
</tbody>
</table>

Table 7.6: Estimated track occupations in both directions (S, N) extending from Rijswijk

It is also interesting to check how track occupations in cases I and cases II differ about 10%, which may represent the additional station platform (Delft Zuid) involved in cases I_{South} and I_{North} as mentioned in section 6.5.

As indicated in subsection 7.3.1, track extensions could be required from Rotterdam due to different construction issues. In this situation, track occupations arising from the above presented cases are also summarized in the following table.
Case | Admisible Track Occupation [%] | Extension Rtd to | Length [km] | Track Occupation [%] | Rescheduling |
--- | --- | --- | --- | --- | --- |
\( \text{Case I South} \) | 90 | bfr. Delft Z. (B1) | 11,5 | 87 | necessary |
\( \text{Case I North} \) | 88 | Schiedam (F1) | 4,4 | 84 | necessary |
\( \text{Case II South} \) | 80 | Delft Zuid (B4) | 12 | 77 | necessary |
\( \text{Case II North} \) | 80 | Delft Zuid (F10) | 12,5 | 65 | necessary |

Table 7.7: Estimated track occupations in both directions (S, N) extending from Rotterdam

### 7.4 Speed Harmonization and Dwell Time optimization measures

In this section it is commented the impact of increasing the average speed of AR-trains on track occupations and minimum buffer times presented in the previous section.

On lines with mixed traffic the minimum headways depend significantly on the speed differences between trains. On the other hand, on lines where all trains run with rather similar speed, the critical block sections are usually the block sections in which blocking time includes the dwell time at stops (Pachl, J., 2002:50). In first instance the situation in this study case is clearly defined by a mix operation of local, fast and high speed trains, hence it seems logical to harmonize speeds. However, as it has been concluded in Chapter 6, dwell times at stations are determinant to achieve a better capacity scenario. Then, measures in both fields should be applied.

According to the reference timetable presented in section 3.3 (Hansen, I.A., 2003), speed for local trains is increased about 8.5% regarding the existing one. Then, assuming a round-off value for an increased speed of AR-trains by 10% due to different reasons like better acceleration and deceleration rates or less train weight, among others, train paths for local trains can be harmonized to the fastest ones.

Another factor influencing speed of stopping trains as well as a need of avoiding critical sections at intermediate stations of the railway link Den Haag – Rotterdam is to reduce large dwell times that take place. If it is intended to reduce about 50% the scheduled dwell time, it would be necessary to apply measures optimizing the boarding and alighting times at platforms. This could be achieved by means of more efficient rolling stock provided with an increased number of wider doors allowing higher volume of passengers through them in less time, or reducing the entrance and exit levels at platforms among others.

Rough estimations have been done for the application of these measures leading to a 10% velocity increase and 50% reduction of dwell times. The two upgraded cases in southbound direction analysed before (Case I\text{South} and Case II\text{South}) in order to give to the reader an overview to their improvements by means of track occupancy and minimum buffer time. Table 7.8 indicates the estimations as regards these values.

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3 This proposal differs to the one done during the tuning of the estimated timetable to find out a feasible Status Quo because it would imply different arrival and departure times not according to the Spoorboekje, thus timetabling task would have to be done.
7.5. Summary and conclusions

<table>
<thead>
<tr>
<th>Cases</th>
<th>Track Occupation [%]</th>
<th>Min. Buffer Time [sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Case I&lt;sub&gt;South&lt;/sub&gt;</td>
<td>70</td>
<td>62</td>
</tr>
<tr>
<td>Percentage difference to the base case</td>
<td>-6</td>
<td>+14</td>
</tr>
<tr>
<td>Enhanced Case II&lt;sub&gt;South&lt;/sub&gt;</td>
<td>79</td>
<td>41</td>
</tr>
<tr>
<td>Percentage difference to the base case</td>
<td>-7</td>
<td>+34</td>
</tr>
</tbody>
</table>

Table 7.8: Improvement achieved by speed harmonization and dwell time optimization measures

The above presented values must be treated cautiously because they have still not been confirmed by computation. However, they are rough estimations from the author of this thesis according to RailSys calculations and experience on the timetable, indicating the wise application of such set of measures demanding a more accurate analysis in further research.

7.5 Summary and conclusions

This chapter basically shows the applicability of the theoretical results obtained in previous chapters for management in a future scenario. In this chapter an upgraded demand scenario is introduced according to travel forecasts developed by ProRail. Analysis of prognostics showed how in a high demand scenario for the line under study might lead to two additional trains per hour running along the line. The applicability of these results to the thesis framework has been done by assuming one additional local train inserted in each predefined train cluster in order to reduce complexity of the problem, instead of considering a totally new running of services based on a new pattern consisting of two train types which might better improve the capacity situation.

With respect to the results obtained for the different alternative capacity scenarios analysed in Chapter 5 and Chapter 6, it is concluded that only an extension of a second track per direction might deal with the increase of demand, but not signalling improvements. According to Figure 6.6 and Figure 6.7, an analysis of two different cases based on different track occupation assumptions is done per line direction. This analysis leads to optimal second track enlargements per direction able to meet the additional demand at the same time the maximum fixed occupation standards are obeyed.

In the first case, Case I, an 80% of maximum track occupation is assumed. Both directions are analysed under this assumption and optimal forward and backward extensions are determined. Assuming a criteria “the shorter the extension the better it is”, 5.2km forward extension including Delft Zuid might lead to the best solution in southbound direction leading to a track occupation of 76% once the additional train is inserted. If the same reasoning were applied northbound direction, the optimal scenario would be a 4.5km backward extension including Delft Zuid that might lead to a track occupation of 73%, also in the upgraded scenario. Then, although different extensions provide sufficient capacity, starting enlargements from Rijswijk both for southbound and northbound directions seems to be the optimal alternative.

Moreover, if the existing Status Quo occupation is considered as an acceptable capacity situation (Case II), the same reasoning leads to the same result but shortening the enlargements. In other words, forward and backward extensions might be optimal solutions for southbound and northbound directions respectively, but enlargements would be shortened to 3.2km in the West track, including Delft station, and 3.1km in the South track also including Delft. Such scenario might lead to track occupations of 86% and 83% respectively, although re-scheduling would be needed in order to frit trains without conflicts.
Then, as it is implicitly presented here, starting extensions from Rijswijk both for southbound and northbound directions seems to be the optimal alternative. In this sense, the planned tunnel construction could be developed at the same time four tracks are extended from Rijswijk although they are not necessary from a short term planning. However, this situation might not be the optimal if construction costs play a role because track extensions under a tunnel construction represent about 10 times higher costs compared with open air construction. In this sense, as it has been analysed and presented in numerical values, larger extensions from Rotterdam could also meet the capacity requirements at the same time they would imply less costs due to their open air construction.

Additionally, a comment is given on the impact of increasing the speed of local trains by a 10% due to higher open track speeds as well as broadening and alighting measures that might lead to lower dwell times at stations (about 50%), reducing track occupations estimated so far.

The final comment concerns to the scheduling task. As indicated before in the different graphs, the remaining buffer time at critical sections is in general too small in order to perform a reliable operation of trains, especially in cases II. In this sense, it is suggested to the reader to avoid such kind of planning and try to develop a more robust scheduling of trains or to increase more the capacity through the different measures analysed in this report. This chapter does not go into deep on these fields and just it is indicated that a more accurate scheduling based on different variables could improve even more the presented scenarios. The rough approach applied in this reasoning aims to indicate that additional train paths fit into the timetable once the other trains are re-scheduled in a suitable manner.
7.2. Travel Forecasts

7.2.1 Number of trains to be fit in the timetable

According to the defined Status Quo, successive clusters of 6 trains were running every 30 minutes of the studied timetable in each direction. In other words, 12 trains per hour were supposed to be running along the whole line. Table 7.2 gives an idea of the maximum number of trains per hour of the different forecasted scenarios as well as their distribution among the different train series.

<table>
<thead>
<tr>
<th></th>
<th>ProRail</th>
<th>Thesis Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
<td>2010</td>
</tr>
<tr>
<td>INT/ HST</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>IC</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>IR</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>AR</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Cargo</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Max trains/ h</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 7.2:** Maximum number of trains per hour in each direction forecasted for the different scenarios

From the above table it is easy to check the new approach assumed by ProRail: the number of trains is increased from 12 to 14 in the high scenario (2020), but a planning of services is also considered excluding IC-train series, getting a timetable with only two different train series. In this situation, more homogeneous train paths might arise due to a reduced mixed operation, leading to an increase of the available capacity or in other words, an optimization of the capacity use.

To simplify the approach to work with and make it more appropriate to the following subsection and to the available data used in previous chapters, it is assumed an upgraded scenario considering 2 more local/ stopping trains running along the line each hour; equivalently it is considered 1 additional AR-train per train cluster repeated each half hour. The number of train services remains the same (three) as shown in the last column of the above table. In this planning, just two stopping trains are selected per hour and not one intercity and one local train or two intercity trains. This can be argued with regard to the expected infrastructure projects in developments indicated above. A new high speed line located in this area would provide a new “intercity service” for those “intercity passengers” using the existing line, thus they might be shifted to it. In this sense, it seems logical and more realistic according to the infrastructural supply scenario expected to add extra stopping trains at the existing link Rotterdam CS- Den Haag HS. Of course, the acceptability of this assumption depends on the relative traffic volume of intermediate stations compared to Delft, which is not accurately assessed in the approach.

7.2.2 Extra occupation

As a start, before applying any measure to increase the capacity to meet the demand increase, it is necessary to know how much extra occupation an additional local train will approximately represent. Based on previous capacity calculations and the estimated 90% of line occupation and 6 trains per cluster every 30 minutes (see Figure 4.5), it leads to a rough average occupation time per