A capacity analysis of the railway line Rotterdam-Dordrecht (NL)
Assessment of the future-proofing

Final report additional graduation work
July 16, 2012

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<table>
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This is the final report of my additional graduation work. The project is an elective course in the MSc-track Civil Engineering at Delft University of Technology and worth 10 points in the European Credit Transfer System. The thesis is about a capacity analysis of the railway line Rotterdam – Dordrecht in South Holland, the Netherlands in order to assess its future proofing.

I would like to thank my general supervisor Ir. P.B.L. Wiggenraad (TU Delft) and content supervisor Dr. Ir. A.A.M. Schaafsma (ProRail) for their help and support. Besides, I like to thank my family, friends and colleagues for their interest in my thesis. I hope the results of my research project are usefull for ProRail and maybe it is or parts of it are realized within a few years.

M.C.J. Schouwenaars, BSc.
Delft, June 2012.
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Separate document
Although the Dutch railway network is one of the busiest ones in Europe, it is still not completely future-proof; the limits of the current rail system are reached. In some cases major adaptions to the timetable require adjustments to the tracks themselves to come to a valid operating plan. Besides, the robustness of the network in case of disruptions is not yet satisfactory. To improve the future-proofing, the robustness and the reliability the Dutch Railway manager ProRail has initiated a program called “Robuust spoor”. The program has the objective to avoid future large disruptions and to control them better. As a part of this program a list is compiled with the top-50 stations and lines which need to be adjusted to improve the robustness and future capacity.

One of these lines is Rotterdam-Dordrecht. The introduction of PHS (Programma Hoogfrequent Spoorvervoer) in 2020 and the addition of the High Speed Line to the main railway network (HRN) in 2015 involve major changes to the current way of operating trains between Rotterdam and Dordrecht. This report has assessed the future proofing this line.

At first the current infrastructure is assessed based on the current timetable. This leads to the identification of some capacity issues. Next the future traffic demand and supply are determined. Research showed that train frequencies on the line will increase from 14 to 22 trains per hour per direction.

To assess the future proofing of the line, the match between future traffic demand and supply is analyzed. At certain points, especially in the Willemsspoortunnel, the future timetable is not feasible and adjustments need to be made. The suggested adjustments are the removal of cargo trains from the timetable in the Willemsspoortunnel during peak hours and a redistribution of train services over the available tracks.

While matching the future traffic demand and supply it became clear that the way of using the tracks between Schiedam and Rotterdam has large consequences for the train service routings on the Rotterdam Central station yard. If the trains use all four tracks between Schiedam and Rotterdam, a grade crossing must be built in order to make the future timetable robust (option 1). If only the two northern tracks are used, no issues showed up (option 2).

As long as the line Delft – Rotterdam is not completely rebuilt to four tracks, option 1 yields; no adjustments to the infrastructure are necessary to be able to operate the future timetable. Nevertheless it is advised to invest € 5,64 million in removing unused infrastructure. This makes the network less sensitive for interferences, implying a reduction in maintenance and disruption costs.

When in the future the timetable is more intensified and train services start to use four tracks between Delft and Rotterdam, it is advised to built the grade crossing. With almost no other adjustments to the Rotterdam Central station yard, the new timetable can then be operated without problems.
1 INTRODUCTION

1.1 MOTIVE

Although the Dutch railway network is one of the busiest ones in Europe, it is still not completely future-proof; the limits of the current rail system are reached. In some cases major adaptations to the timetable require adjustments to the tracks themselves to come to a valid operating plan. Besides, the robustness of the network in case of disruptions is not yet satisfactory. The complex timetable with interwoven train services functions well, but in case of failures or delays the consequences can be felt at great distances.

To improve the future-proofing, the robustness and the reliability the Dutch Railway manager ProRail has initiated a program called “Robuust spoor”. The program has the objective to avoid future large disruptions and to control them better. As a part of this program a list is compiled with the top-50 stations and lines which need to be adjusted to improve the robustness and future capacity.

One of these lines is Rotterdam-Dordrecht. The introduction of PHS (Programma Hoogfrequent Spoorvervoer) in 2020 and the addition of the High Speed Line to the main railway network (HRN) in 2015 involve major changes to the current way of operating trains between Rotterdam and Dordrecht. Therefore it is necessary to assess the future-proofing of this part of the network. Since the exact future timetable is unknown, the research has the aim to assess the line based on the future services and frequencies (instead of timetable) and to propose the required adjustments.

Figure 1.1-1: The line concerned
1.2 RELEVANCE OF THE PROJECT
The results from this research project exist of an assessment of the current railway line between Rotterdam and Dordrecht and, if necessary, the proposed adjustments to make the line future-proof. A final cost-benefit analysis checks the profitability of the adjustments.

The results can be used by the operator of the line, ProRail, in the consideration of implementing the proposed changes or to perform more research.

1.3 MAIN RESEARCH QUESTION
The above has led to the following research question:
“The railway line Rotterdam-Dordrecht faces major changes in the next 10 years, but how future-proof is the current line and what needs to be done to make these changes feasible?”

1.4 SUBQUESTIONS
- How does the current line look like (number of tracks, signals, safety system, junctions, origins and destinations)?
- What are the consequences of the addition of the HSL to the HRN for the line/timetable?
- What does PHS mean for the line/timetable (services, frequencies)?
- Which current infrastructure elements are necessary in order to meet the future demand?
- Which current infrastructure elements are not necessary in order to meet the future demand?
- Which new infrastructure elements are necessary in order to meet the future demand?
- What are the costs and benefits of the proposed adjustments?

1.5 STAKEHOLDERS
In Table 1.5-1 the stakeholders and their interests for this project are mentioned.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Example</th>
<th>Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>NS, NS Hispeed, Cargo-operators</td>
<td>A robust network so that they can run train services as planned.</td>
</tr>
<tr>
<td>Travelers</td>
<td>-</td>
<td>Easy, safe and comfortable traveling without disruptions and delays.</td>
</tr>
<tr>
<td>Residents</td>
<td>Residents along the line</td>
<td>Low noise and air pollution.</td>
</tr>
<tr>
<td>Grantor</td>
<td>Ministry of Infrastructure and Environment (I&amp;M)</td>
<td>A safe, robust and reliable railway network with high benefits for society and economy, but low costs.</td>
</tr>
</tbody>
</table>
1.6 STRUCTURE OF THE REPORT
The transport system can be seen as the so-called transport layer model. It consists of two sub models, the transport model and the traffic model.

If we look at the traffic model, we have on one hand traffic demand. Traffic demand is realized by transport services and needs vehicles to operate. On the other hand we have traffic supply. This supply is translated into infrastructure. The traffic market tries to achieve a match between the traffic demand and supply.

This report is completely built up as the two lower layers in the system above. Chapter 2 discusses the current traffic demand (train services) and chapter 3 discusses the current traffic supply (infrastructure). In chapter 4 the current traffic market is analyzed. Is there a good match between demand and supply? What are the issues and how are the solved?

To come to the future traffic model chapter 5 analysis the future traffic demand. Here all future service changes are discussed. In chapter 6 the future traffic infrastructure is analyzed. Subsequently chapter 7 analyzes the future traffic market; the match between traffic demand and supply. If there is no good match, adjustments to the demand and supply are taken into consideration.

If there are adjustments suggested in chapter 7, the costs and benefits of these adjustments are discussed in chapter 8.

Finally, chapter 9 draws some conclusions from the research.
2 CURRENT TRAFFIC DEMAND

2.1 INTRODUCTION
In order to assess the current traffic market, it is necessary to analyze the current traffic demand. This demand consists of all the services on the line. This demand, the timetable 2012, is discussed in paragraph 2.2.

2.2 TIMETABLE 2012
On December 12th 2011 the new timetable of the Dutch Railways was launched. For the line Rotterdam – Dordrecht there were some important changes. Rotterdam Lombardijen became a station for local trains only. On the other hand, Rotterdam Blaak became an intercity-stop.

In Table 2.2-1 the current timetable for passenger trains is shown.

<table>
<thead>
<tr>
<th>Train series</th>
<th>Type</th>
<th>Route (v.v.)</th>
<th>Stops</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>IC</td>
<td>Amsterdam - Rotterdam</td>
<td>Rtd</td>
<td>1x/hour</td>
</tr>
<tr>
<td>900</td>
<td>HST</td>
<td>Amsterdam - Breda</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>1900</td>
<td>IC</td>
<td>The Hague - Venlo</td>
<td>Rtd, Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>2100</td>
<td>IC</td>
<td>Amsterdam - Vlissingen</td>
<td>Rtd, Rtb, Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>2200</td>
<td>IC</td>
<td>Amsterdam - Dordrecht</td>
<td>Rtd, Rtb, Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>2800</td>
<td>IC</td>
<td>Rotterdam - Amersfoort</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>4000</td>
<td>LT</td>
<td>Rotterdam - Uitgeest</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>4100</td>
<td>LT</td>
<td>Hoek van Holland - Rotterdam</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>4200</td>
<td>LT</td>
<td>Maassluis - Rotterdam</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>5000</td>
<td>LT</td>
<td>The Hague - Breda</td>
<td>Rtd, Rtb, Rtz, Rib, Brd, Zwd, Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>5100</td>
<td>LT</td>
<td>The Hague - Roosendaal</td>
<td>Rtd, Rtb, Rtz, Rib, Brd, Zwd, Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>9200</td>
<td>INT</td>
<td>Amsterdam - Brussels</td>
<td>Rtd, Ddr</td>
<td>1x/hour</td>
</tr>
<tr>
<td>9300</td>
<td>HST</td>
<td>Amsterdam - Paris</td>
<td>Rtd</td>
<td>1x/ hour</td>
</tr>
<tr>
<td>9700</td>
<td>LT</td>
<td>Rotterdam - Gouda</td>
<td>Rtd</td>
<td>2x/hour</td>
</tr>
<tr>
<td>12500</td>
<td>IC</td>
<td>Rotterdam - Leeuwarden</td>
<td>Rtd</td>
<td>1x/hour (peak-only)</td>
</tr>
<tr>
<td>12700</td>
<td>IC</td>
<td>Rotterdam - Leeuwarden</td>
<td>Rtd</td>
<td>1x/ hour (peak only)</td>
</tr>
<tr>
<td>14100</td>
<td>LT</td>
<td>Vlaardingen - Rotterdam</td>
<td>Rtd</td>
<td>4x/ hour (peak only)</td>
</tr>
<tr>
<td>20500</td>
<td>IC</td>
<td>Rotterdam - Leeuwarden</td>
<td>Rtd</td>
<td>1x/ hour (non-peak)</td>
</tr>
<tr>
<td>21700</td>
<td>IC</td>
<td>Rotterdam - Enschede</td>
<td>Rtd</td>
<td>1x/ hour (non-peak)</td>
</tr>
<tr>
<td>36700</td>
<td>LT</td>
<td>Dordrecht – Geldermalsen</td>
<td>Ddr</td>
<td>2x/hour</td>
</tr>
<tr>
<td>36800</td>
<td>LT</td>
<td>Dordrecht - Gorinchem</td>
<td>Ddr</td>
<td>2x/hour</td>
</tr>
</tbody>
</table>

There are also some cargo series running. Most of these train only run on certain days and times. Since the timetable is the same every work-day every hour (BUP = BasisUurPatroon), Table 2.2-2 only shows the reserved cargo paths during peak hours. Again, not every path is used every hour every day.
Table 2.2-2: Reserved cargo train paths within the system boundary

<table>
<thead>
<tr>
<th>Path number</th>
<th>Route (v.v.)</th>
<th>Infra used</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gouda - Kijfhoek</td>
<td>(Gouda -) Rotterdam - IJsselmonde</td>
<td>2x/hour</td>
</tr>
<tr>
<td>2</td>
<td>Kijfhoek – Breda/Loosendaal</td>
<td>Kijfhoek – Dordrecht (- Dordrecht Zuid)</td>
<td>6x/hour</td>
</tr>
</tbody>
</table>

There is a possibility for running extra cargo trains, but these trains are fitted in the timetable manually.

2.3 CONCLUSION

As we can see in paragraph 2.2, a lot of trains make use of the line Rotterdam – Dordrecht. About half of the mentioned trains use Rotterdam Central Station or Dordrecht as a final stop, the rest uses the line between Rotterdam and Dordrecht. Here we have 2 (international) high-speed trains, 1 international train, 6 intercity trains, 4 local trains and at maximum 6 cargo trains per hour.
3 CURRENT TRAFFIC SUPPLY

3.1 INTRODUCTION
On the downside of the traffic market we have the traffic supply. The traffic supply is represented by infrastructure, which is analyzed in this chapter.

3.2 GENERAL
The line Rotterdam – Dordrecht is part of the so-called ‘Staatslijn 1’ from Rotterdam to Breda. The part Dordrecht – Rotterdam Zuid was in opened in 1872 and the part Rotterdam Zuid – Rotterdam Centraal in 1877. The line was electrified in 1950.

In 1994 the northern part of the line was reorganized due to the opening of the new Willemsspoortunnel through the city centre of Rotterdam.

Railway stations along the line nowadays are:
- Rotterdam Centraal
- Rotterdam Blaak
- Rotterdam Zuid
- Rotterdam Stadion (only used in case of soccergames at Feyenoord)
- Rotterdam Lombardijen
- Barendrecht
- Zwijndrecht
- Dordrecht

Between Barendrecht and Zwijndrecht the biggest railway yard of the Netherlands is located. Kijfhoek is an important link in the cargo-flows from the Rotterdam harbor to the mainland and vice versa. It is connected to the railway line Rotterdam – Dordrecht, the Rotterdam harbor line and the Betuweroute.

Just south of Rotterdam Lombardijen the HSL-Zuid (High Speed Line) is connected to the line.

3.3 DETERMINING THE SYSTEM BOUNDARY
To perform a line-assessment it is necessary to determine a system boundary. The way trains enter the stations of Rotterdam Central station and Dordrecht is important for the analysis. Therefore the system boundary is enlarged to the tracks just before the stations. The connections with Kijfhoek are part of the system, but Kijfhoek itself is placed outside the boundary to make the analysis less complex. The station platforms and tracks in the direction of Utrecht at Rotterdam Central station and Geldermalsen at Dordrecht are also placed outside the system boundary to reduce the complexity.

Important tracks entering/exiting the system boundary are:
- To/from Schiedam Centrum – Hoek van Holland
To/from Schiedam Centrum – Delft
To/from Schiphol (High Speed Line)
To/from the Rotterdam harbor line
To/from Breda (High Speed Line)
To/from Kijfhoek Noord
To/from Kijfhoek Zuid
To/from Lage Zwaluwe – Breda/Roosendaal

The system boundary can be found in the schematic rendering of the trajectory in appendix 1.1.

### 3.4 Switches and Safety System
Between Rotterdam and Dordrecht the line consists of at least four tracks. These tracks are interconnected with switches at numerous places.

There are four types of switches:
- Ratio 1:9 Maximum speed allowed when passing in deviated position: 40 km/h;
- Ratio 1:12 Maximum speed allowed when passing in deviated position: 60 km/h;
- Ratio 1:15 Maximum speed allowed when passing in deviated position: 80 km/h;
- Ratio 1:34.7 Maximum speed allowed when passing in deviated position: 140 km/h.

The safety system on the line is ATB-EG. This is the primary Dutch Automatic Train Protection system. Train drivers receive information about maximum allowed speed through light signals and signs along the track. When the train driver doesn’t obey the signals and signs, the ATP brings the train to a halt.

The way light signals and points (switches) are used along the line is an interlocking principle. Safe routing is achieved by interlocking between points and signals, route locking, locking conflicting routes, flank protection and track clear detection.

On the HSL-Zuid and the Rotterdam harbor line the European Railway Train Management System (ERTMS) is installed. For this analysis only the transition areas are important, since the HSL-Zuid and Rotterdam harbor line are located outside the system boundary.

All tracks, switches, signals and signs can be found in the schematic rendering of the trajectory in appendix 1.1.

### 3.5 Peculiarities
There are several sections on the line where special infrastructure influences the timetable of the passing trains.

#### 3.5.1 Willemsspoortunnel Rotterdam
The Willemsspoortunnel in Rotterdam has got steep slopes of 27‰, causing extra risks for cargo trains. If a cargo train comes to a halt inside the tunnel, there is a chance that the train cannot get out of the tunnel on its own force. Another risk is a snap in the train. If this happens on an upward slope, the loose end of the train would roll back towards the next train in the tunnel and cause a crash.
To reduce these risks a safety regime was launched when the tunnel opened, the so-called X/G-regime. The X/G regimes prevent a cargo train from entering the tunnel when it is not completely free. Another measure is that other trains can only enter the tunnel when the cargo train has left it. Last measure are special step-by-step speed signs along the track that show the ideal speed for cargo trains.

3.5.2 Grote Brug Dordrecht
For the Grote Brug in Dordrecht (Railway bridge) yields the same as for the Willemsspoortunnel. The steep slopes of the bridge can cause problems for cargo trains if they have to stop halfway. An L/H-regime (comparable with an X/G-regime) stops cargo trains before the slope if it is not completely free.

Another peculiarity of the bridge are the opening times, because the bridge is part of the standing mast route. On working-days the bridges opens every 2 hours for about 5 minutes. In the weekend during summer the bridge opens every hour for 5 minutes.

3.5.3 Double slip switches east of Rotterdam Central station
East of Rotterdam Central station a lot of double slip switches with ratio 1:12 are applied. With use of these switches trains can enter Rotterdam Central station with a speed of 60 km/h. These double slip switches are only applied in Rotterdam and therefore very rare. Maintenance of these switches requires special attention and implies extra costs.

3.6 SCHEMATIC RENDERING OF THE TRAJECTORY
As mentioned before, in appendix 1.1. a schematic rendering of the trajectory can be found. This rendering includes all tracks, signals, speed signs, switches and stations within the system boundary. This rendering will be used and referred to throughout the whole assessment.
4 ASSESSMENT OF THE CURRENT TRAFFIC DEMAND-SUPPLY MATCH

4.1 INTRODUCTION

This chapter discusses the traffic market. In other words: is there a match between the current traffic demand and the traffic supply derived from the chapters 2 and 3? To assess the match, the trainservices (demand) are placed on top of the infrastructure (supply) by means of a blocking time diagram. Capacity issues are then visualized by overlapping blocks. The track occupancy is also calculated to get a good view on the line capacity consumed by the current timetable.

4.2 ASSESSMENT OF THE DIRECTION NORTH-SOUTH

The corridor in the direction of Dordrecht consist of two tracks (leaving sidings aside). Although both tracks have platforms at every daily used station, the inner track is most commonly used for local trains, the outer track for intercity services. In the capacity analysis both tracks are observed individually.

The 2100-intercity service uses the inner track between Rotterdam and Rotterdam Stadium and the outer track after that point. Halfway the line, the connections to the HSL-Zuid and Kijfhoek are located. To identify the current capacity issues, the basic hour pattern is drawn in appendix 2.1.1, based on\(^1\). In this pattern, at critical points the blocking times are shown to check for problems.

4.2.1 Outer track

As said the outer track is used for intercity services. Since there is an easy connection to Kijfhoek from this track, cargo trains use it too. By drawing a Blocking Time Diagram (see appendix 2.1.2) it is easy to observe the timetable and to find the bottlenecks and capacity issues.

<table>
<thead>
<tr>
<th>Issue number</th>
<th>Location</th>
<th>Concerned train services</th>
<th>Issue description</th>
<th>Current solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS-O1</td>
<td>Willemsspoortunnel</td>
<td>1900 - Cargo</td>
<td>Cargo trains can only enter the Willemsspoortunnel when the tunnel track is completely free. In this case the 1900-intercity is in the last tunnel section when the cargo train is scheduled to enter the tunnel. Headway is ~30 seconds.</td>
<td>After the cargo train there is no train schedule for that track for about 15 minutes. A delay of a few minutes for the cargo train solves the problem.</td>
</tr>
<tr>
<td>NS-O2</td>
<td>Willemsspoortunnel</td>
<td>1900 – Cargo - 9200</td>
<td>Same issue as in NS-O1, but now a train is scheduled right after the cargo train. The cargo train wants to enter the tunnel when the 1900-intercity is still inside the tunnel. The 9200-intercity wants to enter the tunnel when the cargo train has not completely cleared it.</td>
<td>Delays will definitely occur here. The issue is solved by not using the cargo path.</td>
</tr>
<tr>
<td>NS-O3</td>
<td>Grote Brug Dordrecht</td>
<td>1900 - Cargo</td>
<td>Cargo trains can only go up the slope of the Grote Brug in Dordrecht when the upward part is completely free. In this case the 1900-intercity has cleared it 8 seconds too late when the cargo-trains want to enter.</td>
<td>It is very likely that the trains won’t always run on time, so the 8 seconds delay can be recovered later.</td>
</tr>
</tbody>
</table>

The track occupation of the outer track is 65%.

\(^1\) (ProRail, Basis uur patroon Rotterdam - Dordrecht ochtendspits, 2011)
4.2.2  Inner track
The inner track is used by local trains only. As the Blocking Time Diagram in appendix 2.1.3 shows, no capacity issues occur at this track. The track occupation of the inner track is 72%.

4.3    ASSESSMENT OF THE DIRECTION SOUTH-NORTH
The corridor in the direction of Rotterdam consists throughout the whole line of two tracks (leaving sidings aside). Although both tracks have platforms at every daily used station, the inner track is most commonly used for local trains, the outer track for intercity services. Halfway the line, the connections from the HSL-Zuid and Kijfhoek are located. The basic hour pattern for this direction is drawn in appendix 2.1.4.

4.3.1  Outer track
The outer track is again used by intercity, high speed and cargo trains. By producing the blocking time diagram (see appendix 2.1.5) one issue is identified.

Table 4.3-1: Capacity issues in current situation in south-north direction on outer track

<table>
<thead>
<tr>
<th>Issue number</th>
<th>Location</th>
<th>Concerned train services</th>
<th>Issue description</th>
<th>Current solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN-O1</td>
<td>Willemsspoortunnel</td>
<td>1900 - Cargo</td>
<td>Cargo trains can only enter the Willemsspoortunnel when the tunnel track is completely free. In this case the 1900-intercity is in the last tunnel section when the cargo train is scheduled to enter the tunnel. Headway is -10 seconds.</td>
<td>After the cargo train there is no train scheduled for that track for about 15 minutes. A delay of 4 minutes for the cargo train solves the problem.</td>
</tr>
</tbody>
</table>

The track occupation of the outer track is 68%.

4.3.2  Inner track
The inner track is used by local trains only. As the Blocking Time Diagram in appendix 2.1.6 shows, no capacity issues occur at this track. The track occupation of the inner track is 71%.

4.4    USAGE IN THE EVENT OF DISTURBANCES
In case of disturbances the line is (or parts of it are) still used. Based on where the disruption is situated, local trains continue to a tail track as far as possible. From the north this is Rotterdam Lombardijen (Rlb). From the south, this is the station of Zwijndrecht (Zwd) (see Figure 4.4-1). Intercity and high speed trains turn at the two major stations, Rotterdam Central station (Rtd) and Dordrecht (Ddr).

Figure 4.4-1: Usage of the line in the event of disturbances
If for an example all tracks are blocked between Rotterdam Lombardijen and Barendrecht, the next scenario will be applicable:

![Figure 4.4-2: Example of scenario in case of disturbance](image)

All intercity trains travelling south will turn at Rotterdam Central station. Intercity trains travelling north will turn at Dordrecht. Local trains continue to a tail track as far as possible, which is going south Rotterdam Lombardijen and going north Zwijndrecht. The station of Barendrecht is unreachable by train for passengers in this situation.

### 4.5 CONCLUSION

From the analysis above we can derive that small capacity issues occur at the line, but overall it functions well. The track occupancy is summarized in the table below:

<table>
<thead>
<tr>
<th>Direction</th>
<th>Track</th>
<th>Track occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-South</td>
<td>Outer</td>
<td>65%</td>
</tr>
<tr>
<td>North-South</td>
<td>Inner</td>
<td>72%</td>
</tr>
<tr>
<td>South-North</td>
<td>Outer</td>
<td>68%</td>
</tr>
<tr>
<td>South-North</td>
<td>Inner</td>
<td>71%</td>
</tr>
</tbody>
</table>

Recommended limit for consumed capacity in the UIC Code 406 (UIC 2004) for mixed traffic lines during peak hours is 75%. From the table we can see that all four tracks stay within this limit, but not much capacity is left.
5 FUTURE TRAFFIC DEMAND

5.1 INTRODUCTION
The line Rotterdam – Dordrecht will face some major changes in the future. The line is part of the plan ‘Programma Hoogfrequent Spoor’. This plan includes increasing train frequencies on the line. In some alternatives of this plan both local and intercity trains have higher frequencies than in the current situation. Another future change is the addition of the HSL-Zuid to the main railway network of the Dutch Railways. This means that new high-speed train services will be introduced and the current high-speed plan will be adjusted.

To assess the future traffic market for the line, this chapter analyzes the future traffic demand.

5.2 ADDITION OF THE HSL-ZUID TO THE HRN
After building the HSL-Zuid, HSA (an collaboration of NS and KLM) received the concession for running trains via the HSL from the ministry of Transport. The concession runs from 2009 till 2024. Because of the high concession fee and disappointing results there was a risk HSA would go bankrupt. In favor of the passengers, the minister proposed a construction where the HSL-Zuid will be combined with the main railway network (HRN) in a new concession. In February 2012 the Dutch government agreed with the plans.

From December 2014 on, the HSL-Zuid is officially part of the HRN. The concession runs until December 2024 (NS, 2011).

5.2.1 Initial plans for the use of the HSL-Zuid
When the initial concession for the HSL-Zuid was forgiven, the plan for running trains was as follow:

- 2 trains per hour Amsterdam Central Station – Rotterdam Central Station
- 2 trains per hour Amsterdam Central Station – Breda
- 1 train per hour Amsterdam Central Station – Brussels South Station
- 1 train per hour Amsterdam Central Station – Paris North
- 1 train per 2 hours The Hague Central Station – Rotterdam Central Station
- 1 train per 2 hours The Hague Central Station – Breda – Brussels South Station

![Figure 5.2-1: Initial HSL-Zuid train service scheme](image-url)
As can be seen from Figure 5.2-1, the frequency of high-speed trains between Rotterdam and Dordrecht (Barendrecht HSL connection) is at maximum 5 trains per hour per direction.

5.2.2  Changes in the concession
As said, in 2015 the HSL-Zuid will officially become part of the HRN. This implies that national non-high-speed trains can use the HSL-Zuid to provide faster train services. After the minister of Transport received permission for the plans, the Dutch Railways announced their view on the future train services.

5.2.3  Future plans for the use of the HSL-Zuid
From 2015, NS wants to run the following train services:

- 2 trains per hour Amsterdam Central Station – Breda
- 1 train per hour Amsterdam Central Station – Brussels South Station
- 1 train per hour Amsterdam Central Station – Paris North
- 2 trains per hour The Hague Central Station – Eindhoven (- Dusseldorf)
- 2 trains per hour (Zwolle -) Almere Centrum – Amsterdam South – Rotterdam Central Station
- 1 train per hour Breda – Brussels South Station

As you can see from Figure 5.2-2, the frequency of trains between Rotterdam and Dordrecht (Barendrecht HSL connection) is now at maximum 6 trains per hour per direction. Although the plans are made public, the future train services are still subject to changes and adjustments.

5.3  IMPLEMENTATION OF PROGRAMMA HOOGFREquent SPOOR (PHS)
Programma Hoogfrequent Spoorspoor, in short PHS, is a program from ProRail, NS and several cargo operators which searches for possibilities to increase train frequencies within the current railway network. Main target is to run 6 intercity trains and 6 local trains per hour on the main corridors of the network. The program was initiated after the government announced their wishes for the public transport in the Netherlands (Projectteam, 2009).

In January 2011 ProRail defined 5 corridors for which the project applies:
- Alkmaar – Amsterdam
- Amsterdam – Utrecht – Eindhoven
- Schipol – Utrecht – Arnhem/Nijmegen
- Den Haag – Rotterdam – Breda
- Breda – Eindhoven

The line Rotterdam - Dordrecht is part of Den Haag – Rotterdam – Breda, and thus also affected by PHS. This chapter discusses the plans and changes inherent to the implementation of PHS for the line concerned.

5.3.1 Preferred service scheme

Based on transport demand analyzes, ProRail, Dutch Railways and KNV came up with two main proposals. The so-called “6/customized”-variant and the “6/6”-variant (ProRail, Programma Hoogfrequent Spoornetwerk, 2010). In July 2010 the government announced its preferred decision for PHS. Initially the 6/6-variant seemed to be infeasible within the budget, but after an extensive optimalisation process between ProRail, Dutch Railways and KNV they announced that they preferred the 6/6-variant. If, due to certain circumstances, the next cabinet wants to limit the available PHS-budget, it should also be possible to fallback to variant 1 ‘6/customized’ (MinVenW, 2010).

**Passenger trains**

In variant ’6/6’ at least six intercities and six local trains per hour run on the busiest routes in the larger Randstad. This variation in the corridor planning studies corresponds to the ambition of the minister as stated in the policy ‘Network Approach’. This means that on the busiest routes in the Randstad up to six intercities per hour run combined with customization for Sprinters.

For the line Rotterdam – Dordrecht this variant involves the following train services:

- 4 IC’s The Hague – Rotterdam – Breda – Eindhoven;
- 2 Local trains The Hague – Rotterdam – Dordrecht – Roosendaal;
- 2 Local trains The Hague – Rotterdam – Dordrecht – Breda;
- 2 Local trains The Hague – Rotterdam – Dordrecht;

In variant 2 the intercity trains between The Hague and Eindhoven can use the HSL-South infrastructure between Rotterdam and Breda in case of capacity problems on the conventional line.

**Cargo trains**

Currently 2 cargo trains per hour use the northern part of the line (Rotterdam Central Station – Kijfhoek North) and 6 cargo trains per hour use the southern part (Kijfhoek South – Dordrecht). Since the Betuweroute is in use, every year more and more cargo trains use this route instead of the conventional routes. With the introduction of PHS, the cargo routings are reorganized as well, to provide extra infrastructure capacity for passenger trains and to decrease nuisance in urban areas.

For the southern part of the Netherlands cargo-routings are planned via the Betuweroute. Only 2 trains per hour are allowed via the Brabanroute.
Trains to the north can use conventional tracks or the Betuweroute as well. In PHS the frequency on conventional tracks is limited to 2 trains per hour on the line between Kijfhoek and Rotterdam Central Station.

5.4 CONCLUSION
To get an overall view of all the projected trains on the line, it is necessary to merge the plans for the HSL-addition and PHS. At first, neglecting potential capacity issues on the line, we get the train service scheme as in Figure 5.4-1.

The scheme shows that on the northern part of the line 22 trains per hour run. After the HSL-connection, 14 trains per hour (after Kijfhoek South 16 trains per hour) continue to Dordrecht.
6 FUTURE TRAFFIC SUPPLY

6.1 INTRODUCTION
Next to the planned changes on the demand side of the traffic model, the supply side faces some changes too. This chapter discusses other plans and projects which may have any influence on the line in dispute.

6.2 REBUILDING THE HOEKSE LIJN TO METRO TRACK
In 2008 the metropolitan council of Rotterdam introduced plans for rebuilding the Hoekse Lijn (Rotterdam – Hook of Holland) to metro track. After working out the plans, in 2011 the council sent the project proposal to the minister of Transport. When she gives her agreement, the tracks of the current line between Rotterdam Central Station and Schiedam Centrum will become available for trains between Rotterdam and Delft in 2016. It is not decided yet if and how this extra capacity is going to be used. There is a possibility trains keep running over the current two tracks.

Besides of the extra track capacity, extra platform capacity becomes available at Rotterdam Central Station when the Hoekse Lijn is rebuilt. (Stadsregio, 2011).

6.3 INTRODUCTION OF ERTMS
In June 2012, the minister of Transport declared that the Dutch railway network will be equipped with ERTMS widely. Because the implementation will take at least ten years, it is likely that the introduction of ERTMS on the line Rotterdam-Dordrecht won’t take place before 2020. This implies that the future traffic demand derived in chapter 5 yields for the line with and without ERTMS.

ERTMS is a different safety system which can increase the capacity on existing lines. For the line Rotterdam – Dordrecht, ERTMS may be able to increase the capacity inside the Willemsspoortunnel. A separate research must be carried out to assess the possibilities of ERTMS for increasing the capacity inside the tunnel.

6.4 DENSIFICATION OF THE X/G-REGIME IN THE WILLEMSSPOOR_TUNNEL
As said in chapter 3.5.1 in the Willemsspoortunnel an X/G-regime is installed. To make an increase in capacity possible, ProRail has investigated a possible densification of the X/G-regime in the Willemsspoortunnel.

After the study the results were judged and approved by the inspection of Transport and implemented. Further densification is not allowed by the inspection (ProRail, Programma Hoogfrequent Spoorvervoer, 2010).
7 ASSESSMENT OF THE FUTURE TRAFFIC DEMAND-SUPPLY MATCH

7.1 INTRODUCTION
In this chapter the future traffic demand (as found in chapter 5) will be projected on the future traffic supply (as found in chapter 6) to identify potential capacity issues. Afterwards measures which may solve these issues are discussed.

7.2 SUMMARY OF THE TRAFFIC DEMAND
In Table 7.2-1 all train services using the line Rotterdam – Dordrecht are listed.

<table>
<thead>
<tr>
<th>Train service</th>
<th>Frequency at Rtd-Ddr line</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cargo train</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>2 Cargo train</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>3 High Speed Train</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>4 High Speed Train</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>5 High Speed Train</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>6 High Speed Train</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>7 Intercity</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>8 Intercity</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>9 Local Train</td>
<td>6x/hour</td>
<td>10'-10'-10'-10'-10'-10'-10'</td>
</tr>
</tbody>
</table>

7.3 RUNNING TIMES
To identify potential capacity issues it is necessary to project the train series on the line. To do this, running times are necessary to get a good view of the track occupation. Below for each train service mentioned above the running times are calculated, with respect to the design standards provided by ProRail. These include:

- As a basis for calculating running times with respect to the material composition, the maximum possible composition will be used for the calculations.
- Running time supplement for passenger trains is 5%, calculated between two main stations (in this case Rotterdam Central Station and Dordrecht).
- Dwell time at stops: determined by the category of the station. Rotterdam: 3 minutes minimum; Dordrecht: 2 minutes minimum; rest: 1 minute.

The running times calculation sheet can be found in appendix 5.1

<table>
<thead>
<tr>
<th>Train service</th>
<th>From/stop to (v.v.)</th>
<th>Running time (supplement included)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cargo train</td>
<td>Rotterdam Ijsselmonde</td>
<td>4 min 53, 5 min 8</td>
</tr>
<tr>
<td>2 Cargo train</td>
<td>Kijfhoek South Dordrecht</td>
<td>4 min 53, 5 min 8</td>
</tr>
<tr>
<td>3 High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>4 min 40, 4 min 55</td>
</tr>
<tr>
<td>4 High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>4 min 40, 4 min 55</td>
</tr>
</tbody>
</table>
7.4 SERVICE DISTRIBUTION

7.4.1 Option 1

Between Rotterdam and Kijfhoek only the outer track grants direct access to Kijfhoek North (via IJsselmonde) and the HSL-South. From the inner track access is only possible after crossing the outer track at ground level.

Based on the situation of the connections to Kijfhoek and the HSL-South, it is likely to let Cargo and High Speed Trains run on the outer tracks between Rotterdam and Dordrecht. Intercity trains and local trains can use both tracks. The same yields for the vice-versa direction.

If we combine the frequency patterns (local trains + high speed trains 6x/hour and intercity trains 4x/hour), we can distribute the trains as below:

Table 7.4-1: Projection of trains on outer track (option 1)

<table>
<thead>
<tr>
<th>Train service</th>
<th>Type</th>
<th>From/stop/to (v.v.)</th>
<th>Frequency at Rtd-Ddr line</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cargo train</td>
<td>Rotterdam IJsselmonde</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>2</td>
<td>Cargo train</td>
<td>Kijfhoek South Dordrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>3</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>4</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>5</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>6</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>9</td>
<td>Local Train</td>
<td>Rotterdam Centraal Rotterdam Blaak Rotterdam Zuid Rotterdam Lombardijen Barendrecht Zwijndrecht Dordrecht</td>
<td>6x/hour</td>
<td>10'-10'-10'-10'-10'-10'</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td>14x/hour</td>
</tr>
</tbody>
</table>
A quick analysis shows that running 14 trains per hour on the outer track is infeasible. The cargo trains consume a lot of capacity in the Willemsspoortunnel, which leaves not enough capacity for 6 high speed trains.

### 7.4.2 Option 2

The option above indicated that it is not possible to run all the planned trains through the Willemsspoortunnel. Suggestion is therefore to ban cargo trains from the line during peak hours. Cargo trains use a lot of capacity in the Willemsspoortunnel. Moving cargo trains to the off peak or rerouting them to the Betuweroute is in line with the capacity analysis carried out by ProRail (ProRail, Programma HoogfrequentSpoorvervoer, 2010). The two planned cargo trains per hour from Kijfhoek to the south can still run in this distribution option.

### Table 7.4-2: Projection of trains on inner track (option 1)

<table>
<thead>
<tr>
<th>Train service</th>
<th>Type</th>
<th>From/to (v.v.)</th>
<th>Frequency at Rtd-Ddr line</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Intercity</td>
<td>Rotterdam Dordrecht</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>8</td>
<td>Intercity</td>
<td>Rotterdam Centraal Rotterdam Blaak Dordrecht</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td>8x/hour</td>
</tr>
</tbody>
</table>

### Table 7.4-3: Projection of trains on outer track (option 2)

<table>
<thead>
<tr>
<th>Train service</th>
<th>Type</th>
<th>From/stop/to (v.v.)</th>
<th>Frequency at Rtd-Ddr line</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Cargo train</td>
<td>Kijfhoek South Dordrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>3</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>4</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>5</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>1x/hour</td>
<td>60'</td>
</tr>
<tr>
<td>6</td>
<td>High Speed Train</td>
<td>Rotterdam HSL connection Barendrecht</td>
<td>2x/hour</td>
<td>30'-30'</td>
</tr>
<tr>
<td>9</td>
<td>Local Train</td>
<td>Rotterdam Centraal Rotterdam Blaak Rotterdam Zuid Rotterdam Lombardijen Barendrecht Zwijndrecht Dordrecht</td>
<td>6x/hour</td>
<td>10'-10'-10'-10'-10'-10'-10'</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td>12x/hour</td>
</tr>
</tbody>
</table>

### Table 7.4-4: Projection of trains on inner track (option 2)

<table>
<thead>
<tr>
<th>Train service</th>
<th>Type</th>
<th>From/to (v.v.)</th>
<th>Frequency at Rtd-Ddr line</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Intercity</td>
<td>Rotterdam Dordrecht</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>8</td>
<td>Intercity</td>
<td>Rotterdam Centraal Rotterdam Blaak Dordrecht</td>
<td>4x/hour</td>
<td>15'-15'-15'-15'</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td>8x/hour</td>
</tr>
</tbody>
</table>
7.5 NEED FOR INFRASTRUCTURE IN UNDISTURBED SITUATIONS

The way trains arrive from Delft/Schiedam (see paragraph 6.2) is very decisive for the route choice at the Rotterdam Central station yard. Since the definite way of arriving is not chosen yet, this paragraph deals with both possibilities.

7.5.1 Option 1: four tracks between Schiedam and Rotterdam

In this option all four tracks between Schiedam and Rotterdam are used for traffic from/to Delft. Intercity trains run on the inner tracks, local trains on the outer tracks. Rotterdam Central station can be visualized as a black box with incoming trains from three different directions:

![Diagram showing the layout of the Rotterdam Central station yard with four tracks and incoming trains from three directions.](image)

Figure 7.5-1: “Black box” Rotterdam central station

If the in- and output is projected on the schematic rendering of Rotterdam Central station, Figure 7.5-2 shows a possible option for routings through the station.

![Schematic rendering of the Rotterdam Central station yard with four tracks and incoming trains from three directions.](image)

Figure 7.5-2: Schematic rendering of the Rotterdam Central station yard

---

2 Trains from Gouda and Utrecht are neglected, since this connection is located outside the system boundary.
The figure shows a potential bottleneck east of the station (red dotted circle). All trains going south, which implies 20 trains per hour, make use of this part of infrastructure. Rules and guidelines concerning headway times and robustness make it impossible to run trains in this situation. Therefore an alternative is introduced. Since there is no space for a grade-separated crossing east of the station, traffic needs to be bundled differently already at the west of the station. Here, enough space is available for a grade-separated crossing of the innertrack coming from Schiedam and the high speed track coming from Schiphol. With use of this new crossing, no more level-crossings occur at Rotterdam Central station, which makes train services independent from each other and therefore operation very robust.

![Figure 7.5-3: Schematic rendering of the Rotterdam Central station yard without capacity issues](image)

A scale drawing of the new fly-over can be found in appendix 3.1.

As mentioned before, east of Rotterdam Central station high speed and local trains use the outer tracks, intercity trains the inner tracks. Just north of Rotterdam Lombardijen the high speed trains enter and exit the high speed line. South of Rotterdam Lombardijen all local and intercity trains continue to Dordrecht on the same tracks as north of Rotterdam Lombardijen.
For Dordrecht the same strategy as with Rotterdam Central station can be applied. By considering Dordrecht as a black box, the input and output can be schematized:

![Figure 7.5-4: “Black box” Dordrecht](image)

A projection of the input and output on the schematic rendering of Dordrecht station gives the following figure:

![Figure 7.5-5: Schematic rendering of the Dordrecht station yard](image)

According to this rendering all turning train services (local and intercity) use platform 3 for this purpose. To enter and to exit this turning track, trains have level crossings with each other.

For the turning trains yields:

- An turning intercity train
  - Crosses no paths when arriving
  - Crosses no paths when departing
- An turning local train
  - Crosses an intercity path when arriving (2x per hour)
  - Crosses an intercity path when departing (2x per hour)

Based on the frequency of occurrence, no further action is necessary in this case.
7.5.2 Option 2: two tracks between Schiedam and Rotterdam

In this option only the two current tracks between Schiedam and Rotterdam are used for traffic from/to Delft. Rotterdam Central station can be visualized as a black box with incoming trains from three different directions:

![Black box Rotterdam central station](image)

**Figure 7.5-6: "Black box" Rotterdam central station**

If the in- and output is projected on the schematic rendering of Rotterdam Central station, Figure 7.5-7 shows a possible option for routings through the station.

![Schematic rendering of the Rotterdam Central station yard](image)

**Figure 7.5-7: Schematic rendering of the Rotterdam Central station yard**

Since the figure shows no level crossings, train services are very independent from each other and therefore operation is very robust.

South of Rotterdam, option 2 is not different from option 2.

---

3 Trains from Gouda and Utrecht are neglected, since this connection is located outside the system boundary.
7.5.3 Conclusion
It can be concluded that extra infrastructure is only necessary at Rotterdam Central station when all four tracks between Rotterdam and Schiedam are used. In the case of option 2, all train services run without level crossings. The absence of level crossings makes operation very robust.

7.6 NEED FOR INFRASTRUCTURE IN DISTURBED SITUATIONS
In case of disturbances between Rotterdam and Dordrecht it is not possible to run trains as planned. In some situations traffic is completely blocked at some point, in other situations only one track is out of service. To be prepared for these situations it is necessary to make scenarios for the timetable of how to adjust the timetable to a suitable format. These plans may need other pieces of infrastructure then those used in undisturbed situations. For all of the cases below, the extra infrastructure needed is colored grey in appendix 1.2 and 1.3.

Table 7.6.1: Scenarios in case of disturbances

<table>
<thead>
<tr>
<th>#</th>
<th>Location of disturbance</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schiedam – Rotterdam Central station</td>
<td>Trains coming from Schiedam cannot reach Rotterdam Central station. Trains in the direction of Schiedam and Delft turn at Rotterdam Central. Trains to Utrecht and HSL continue undisturbed.</td>
</tr>
<tr>
<td>2</td>
<td>HSL – Rotterdam Central station</td>
<td>Trains coming from the HSL cannot reach Rotterdam Central station. High speed trains to the HSL turn at Rotterdam Central station (or use conventional infrastructure to Schiphol).</td>
</tr>
<tr>
<td>3</td>
<td>Rotterdam Central Station – Rotterdam Blaak</td>
<td>At Rotterdam central station several cases may be possible: a platform may be blocked by a broken train or technical problems with switches or signals can cut off certain parts of the yard. To reduce the impact of such disruptions, alternative routings and platforms are provided in grey in appendix 1.2/1.3.</td>
</tr>
<tr>
<td>4</td>
<td>Rotterdam Central Station – Rotterdam Blaak</td>
<td>In this case all trains from Schiedam turn at Rotterdam Central Station. Local Trains from the south turn at Rotterdam Lombardijen. Intercity trains at Dordrecht. High speed traffic to Breda is not possible. Rotterdam Central station, Blaak, Zuid and Lombardijen are still connected via metro or tram traffic.</td>
</tr>
<tr>
<td>5</td>
<td>Rotterdam Blaak – Rotterdam Zuid</td>
<td>All trains from Schiedam turn at Rotterdam Central Station. Local Trains from the south turn at Rotterdam Lombardijen. Intercity trains at Dordrecht. High speed traffic is not possible. Rotterdam Central station, Blaak, Zuid and Lombardijen are still connected via metro or tram traffic.</td>
</tr>
<tr>
<td>6</td>
<td>Rotterdam Zuid – Rotterdam Lombardijen</td>
<td>All trains from Schiedam turn at Rotterdam Central Station. Local Trains from the south turn at Rotterdam Lombardijen. Intercity trains at Dordrecht. High speed traffic is not possible. Rotterdam Central station, Blaak, Zuid and Lombardijen are still connected via metro or tram traffic.</td>
</tr>
<tr>
<td>7</td>
<td>Rotterdam Lombardijen – Barendrecht</td>
<td>Local trains from Schiedam continue to Rotterdam Lombardijen. Other trains turn at Rotterdam Central Station. Local Trains from the south continue to Zwijndrecht and turn at track JR. Intercity trains turn at Dordrecht. Barendrecht is not accessible by train.</td>
</tr>
<tr>
<td>8</td>
<td>Barendrecht - Zwijndrecht</td>
<td>Local trains from Schiedam continue to Rotterdam Lombardijen. Other trains turn at Rotterdam Central Station. Local Trains from the south continue to Zwijndrecht. Intercity trains turn at Dordrecht. Barendrecht is not accessible by train.</td>
</tr>
<tr>
<td>9</td>
<td>Zwijndrecht - Dordrecht</td>
<td>Local trains from Schiedam continue to Zwijndrecht. Other trains turn at Rotterdam Central Station. All Trains from the south turn at Dordrecht.</td>
</tr>
<tr>
<td>10</td>
<td>Dordrecht</td>
<td>At Dordrecht several cases may be possible: a platform may be blocked by a broken train or technical problems with switches or signals can cut off certain parts of the yard. To reduce the impact of such disruptions, alternative routings and platforms are provided in grey in appendix 1.2/1.3.</td>
</tr>
</tbody>
</table>
Figure 7.6-1 shows the turning possibilities for trains on the line. In both directions, turning is possible at Rotterdam Central station, Rotterdam Lombardijen, Zwijndrecht and Dordrecht.

![Diagram of train routes]

**Figure 7.6-1: Visualisation of adjustment options**

### 7.7 OVERALL NEED FOR INFRASTRUCTURE

In the two analyses above it is determined which infrastructure is necessary for exploitation of train traffic in undisturbed and in numerous kinds of disturbed situations. The schematic rendering in appendix 1.2 and 1.3 shows in color which infrastructure is needed for basic service exploitation. Infrastructure colored grey is only necessary in disturbed situations (see example below).

![Example of schematic rendering]

**Figure 7.7-1: example of schematic rendering which shows the overall need for infrastructure**

### 7.8 EXCESS INFRASTRUCTURE

All infrastructure which is not colored in appendix 1.2 and 1.3 is theoretically useless and can be removed. To improve the robustness of the network, it is advised to do this. The less excess infrastructure, the less malfunctions can occur. Especially switches are very susceptible to interferences. When all the useless infrastructure is removed, we get the schematic rendering as in appendix 1.4 and 1.5.

### 7.9 CONCLUSION

The analysis carried out in this chapter assessed the match between the future traffic demand and supply. Based on developments of PHS outside the system boundary, two options are discussed: the use of four tracks between Delft and Rotterdam (option 1) and the use of two tracks between Delft and Rotterdam (option 2). For option 1 a new grade crossing has to be built at the Rotterdam Central station yard in order to achieve a match between future traffic demand and supply. For option 2 this is not necessary. For both options it is examined which infrastructure is needed in case of undisturbed and disturbed situations and which infrastructure can be removed.
8 COSTS AND BENEFITS

8.1 INTRODUCTION

This chapter discusses the effects of the project. Both costs and benefits are identified and, if possible, quantified.

8.2 DIRECT COSTS

To make the line Rotterdam – Dordrecht future proof, several measures were suggested in the previous chapter. The table below summarizes these measures. Costs are explained in the appendices.

Table 8.2-1: Investment costs

<table>
<thead>
<tr>
<th>#</th>
<th>Location of disturbance</th>
<th>Costs option 1 (mln €)</th>
<th>Costs option 2 (mln €)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leveled crossing west of Rotterdam</td>
<td>76.00</td>
<td>-</td>
<td>Determined by ProRail (ProRail, Programma Hoogfrequent Spoorvervoer, 2010)</td>
</tr>
<tr>
<td>2</td>
<td>Switch costs</td>
<td>5.48</td>
<td>5.50</td>
<td>See appendix 4.1</td>
</tr>
<tr>
<td>3</td>
<td>Track costs</td>
<td>0.60</td>
<td>0.04</td>
<td>See appendix 4.2</td>
</tr>
<tr>
<td>4</td>
<td>Safety system costs</td>
<td>0.15</td>
<td>0.10</td>
<td>See appendix 4.3</td>
</tr>
<tr>
<td>SUM</td>
<td>82.25</td>
<td>5.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8.3 BENEFITS

Especially the investments in removing unused infrastructure lead to a less sensitive network for interferences. This implies a decrease in maintenance costs and costs as a result of disruptions. On the other hand, more trains are running compared to the basic situation, so the replacement interval of the infrastructure becomes smaller. The decrease of maintenance and disruption costs is estimated at the same level as increase of replacement costs. It is expected that on the long term the investments in removing unused infrastructure are recovered. Additional research should be carried out to quantify these amounts and to validate the assumption.
9 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS
During the analysis of the line it became visible that its capacity limits are almost reached. Mainly due to the cargo trains running through the Willemsspoortunnel, there is very limited space to intensify the timetable for passenger trains during peak hours. To make this possible, cargo trains must be rerouted or rescheduled to off-peak hours and the type of trains services must be distributed over the available tracks in another way.

While matching the future traffic demand and supply it became clear that the way of using the tracks between Schiedam and Rotterdam has large consequences for the train service routings on the Rotterdam Central station yard. If the trains use all four tracks between Schiedam and Rotterdam, a grade crossing must be built in order to make the future timetable robust. If only the two northern tracks are used, no issues show up.

The main research question stated at the start of this project was:
“The railway line Rotterdam-Dordrecht faces major changes in the next 10 years, but how future-proof is current line and what needs to be done to make these changes feasible?”

The answer to this question depends on the way PHS is carried out between Schiedam and Rotterdam.
- Use of four tracks: the line is not future proof, a grade crossing is necessary.
- Use of two tracks: the line is future proof, the future timetable can be operated without adjustments to the infrastructure.

Another item is the disposal of unused tracks and switches. By limiting the number of switches, the annual maintenance costs and number of failures decreases. On the other hand, increasing train frequencies decrease the service life of switches. The decrease of maintenance and disruption costs is estimated at the same level as increase of replacement costs.

9.2 RECOMMENDATIONS
As long as the line Delft – Rotterdam is not completely rebuilt to four tracks, option 1 yields; no adjustments to the infrastructure are necessary to be able to operate the future timetable. Nevertheless it is advised to invest € 5,64 million in removing unused infrastructure. This makes the network less sensitive for interferences, implying a reduction in maintenance and disruption costs.

When in the future the timetable is more intensified and train services start to use four tracks between Delft and Rotterdam, it is advised to built the grade crossing. With almost no other adjustments to the Rotterdam Central station yard, the new timetable can then be operated without problems.
BIBLIOGRAPHY


