Chapter 6

Alternative Capacity Scenarios (Part II): Infrastructure enhancement

6.1 Introduction

As presented in the previous chapter, the aim of the present chapter is to develop a strategic approach to analyse different infrastructure scenarios. As performed for the different signalling scenarios, a theoretical analysis is now carried out in order to come up with an approach that helps the task to be realized in Chapter 7.

So far railway operation is realized in a double-track line. Two main restrictions have to be considered from this configuration:

1. Operating density, or
2. Slowdown of fast trains

Judging from the results obtained in section 5.2 and section 5.3, a rather more substantial improvement of the railway capacity over the study area may require extensions of the existing infrastructure.

According to the existing infrastructure and signalling arrangements and taking into account the tuned planning for 1999, this section aims to analyze new capacity consumptions arising from different infrastructure configurations regarding extensions of a second track in both directions between Rijswijk and Rotterdam CS. In this sense, a theoretical analysis of the track occupation sensitivity to double-track enlargements is presented.

This chapter is developed in different sections treating different aspects dealing with the extensions to be done and analysed. Of course, each extension requires infrastructure management through RaiSys tool, thus modelling time. Therefore, first of all and according to the existing capacity situation and its constraints (for detailed analysis see Chapter 4), a suitable and representative *extension scenarios* are defined (in section 6.3) on the basis of the analysis of the existing bottlenecks (in section 6.2) detected through blocking time graphs provided in Chapter 4 for the Status Quo. In section 6.4, performed scenarios are evaluated by means of capacity analysis and compared to expectations by analysing the results obtained (section 6.5).

The chapter concludes with a short summary, not only on the assessments done during the analysis of the results, but also on the scope of a more spread and general framework.

6.2 Existing Critical Sections (Bottlenecks)

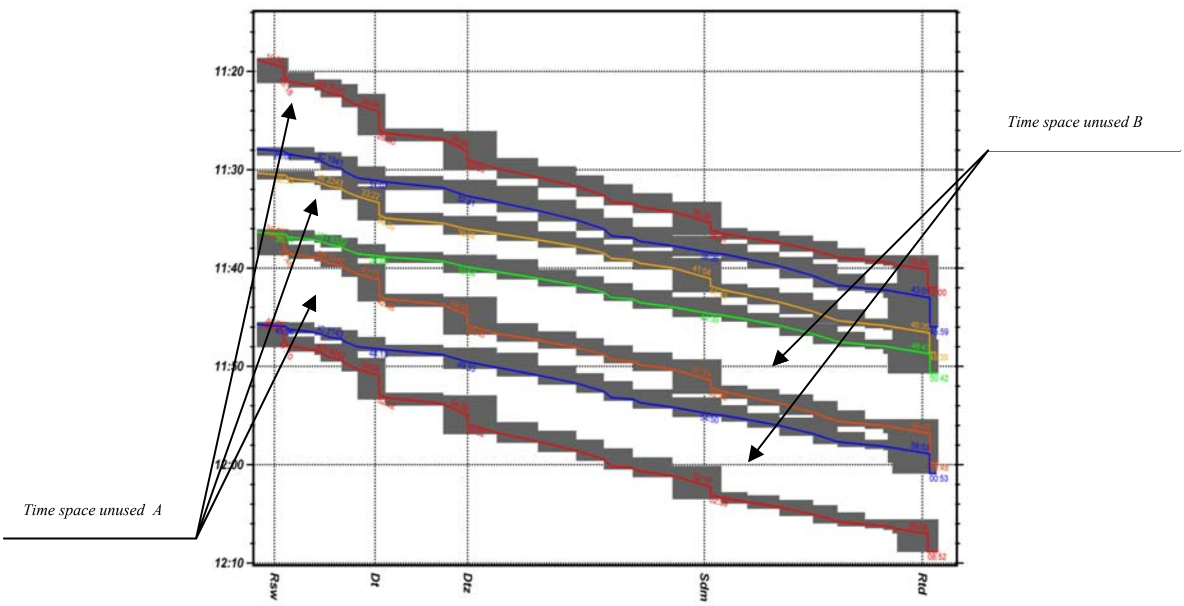
Capacity evaluation of the Status Quo operation showed 5 critical block sections determining timetable capacity (for detailed description see section 4.3). They are called to mind in Table 6.1.

Direction	Critical Block Section Nr.		
southbound	1	10	14
northbound	26	-	18

Table 6.1: Critical block sections causing capacity bottlenecks in both directions (Status Quo 1999)

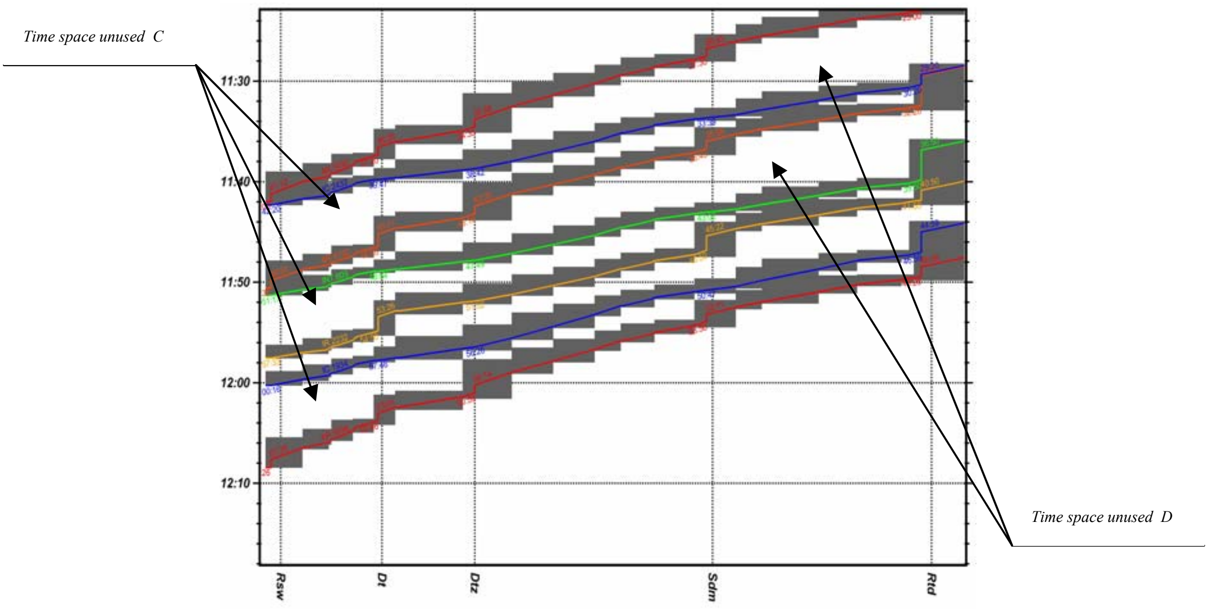
These bottlenecks created either by large dwell times at stopping locations or reduction form two to one track per direction can be visualized in Figure 4.6(b) and Figure 4.8(b). All of them are located within the double-tack corridor, and serve as a reference to define reasonable extension criteria.

The *time space unused* downstream or upstream caused by the capacity bottlenecks themselves as well as differences in speed profiles plays an important role to define extensions. Figure 6.1 and Figure 6.2 visualize the existing time space unused between blocking time graphs for the Status Quo approach.



Unused buffer time A downstream bottleneck number 1
Unused buffer time B upstream bottleneck number 10 or 14

Figure 6.1: Compressing of the blocking time graphs from the *Status Quo* timetable to visualize the unused buffer time due to capacity bottlenecks in southbound direction



Unused buffer time C upstream bottleneck number 26
Unused buffer time D downstream bottleneck number 18

Figure 6.2: Compressing of the blocking time graphs from the *Status Quo* timetable to visualize the unused buffer time due to capacity bottlenecks in northbound direction

In order to better understand this time space unused, it could be argued that it would not be so big in case of moving block implementation. In such a case, the track behind a train is cleared continuously leading to inexistent block lengths, thus the blocking time graphs might become continuous and the use of timetable capacity optimized. However, in a fixed block signalling, blocking graphs are not continuous and some time remains in between blocking times as shown in previous figures, where this fact is upgraded due to differences in running behaviours of trains.

In first instance, it seems logical to extend a second track per direction along the double-track corridor, either from Rotterdam CS or Rijswijk, including each conflict section to allow a closer blocking time graph, thus leading to lower track occupation. This would happen because blocking time stairways shift to different tracks avoiding overlapping. However, it has to be taken into account that every time a track is extended, new critical block sections appear somewhere along the line, especially for long enlargements. In other words, the previous existing bottlenecks could either disappear or remain and new ones appear, and this is hardly predictable before extending tracks and just estimations can be done according to the existing blocking time sizes.

Therefore, in order to define track extensions, the previously indicated critical sections are considered as potential candidates to be ending points for extensions in both directions. Besides, stopping locations where dwell times causes large blocking times are expected to be new critical sections every time an extension is done and do not include them, thus they will be also considered as extension endings to evaluate the development of track occupancy as well as gain in buffer time.

6.3 Selection and set up of the Extension Scenarios

For the study area, demand in each direction is relatively balanced over the whole timetable, thus it is reasonable to expect similar needs with regard to enhancement measures. Judging from the above argumentations, extensions are designed containing critical block sections at the same time the extra track used is designed as short as possible according to signalling constraints. In this sense, the procedure to be carried out per direction is based in the following stepwise sequence:

Step 1. First extension of a second track.

Step 2. Analysis of the resulting track occupation and newly bottlenecks turned up.

Step 3. Second extension starting from the already enlarged track.

Step 4. Analysis of the resulting track occupation and newly bottlenecks turned up.

Stepwise procedure until merge with the existing double-track per direction

Step 5. Completely two-track extension per direction between Rijswijk and Rotterdam CS.

Step 6. Separated analysis of the resulting occupations per track.

Since this will lead to a very large number of combinations, the number of second track extensions is restricted to 24 sub-scenarios which are considered representative for capacity evaluation. Forward and backward extensions are considered per direction due to the symmetrical location of the bottlenecks as shown in Figure 6.1 and Figure 6.2. For instance, a short backward extension in the northbound direction (East side) would deal with critical section number 26, gaining rather large amount of buffer time, whereas it would not improve the consequences from critical block section number 18. Besides, extreme situations with a line completely double-track per direction between Rijswijk and Rotterdam CS (four-track line) are analysed independently.

Each extension sub-scenario has a similar set up following a hierarchal procedure, starting from shorter extensions and finishing with the complete double-track line. As shown in Figure 6.3 and Figure 6.4, each subsequent extension also includes the previous one, so track occupation is expected to decrease continuously. However, due to the influence of newly critical sections, the decrease in track occupation may not be linear with the enlargements.

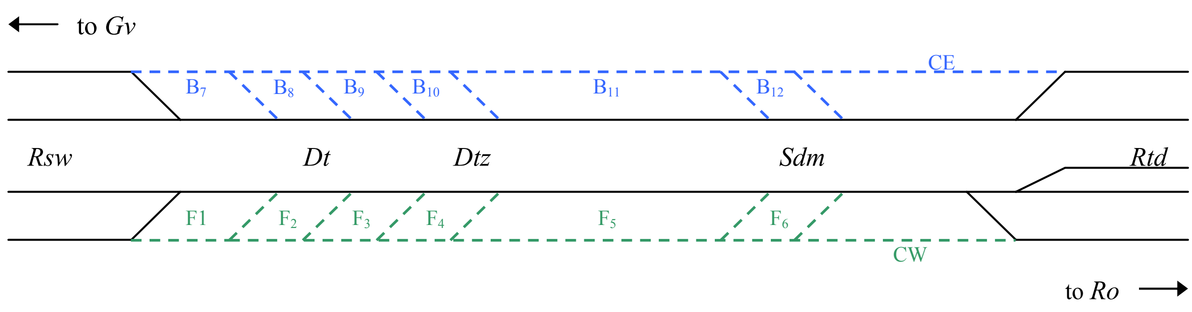


Figure 6.3: Schematized track layout for forward(F_i) and backward(B_j) extensions in southbound and northbound directions respectively and complete two-track extension per direction (CW and CE)

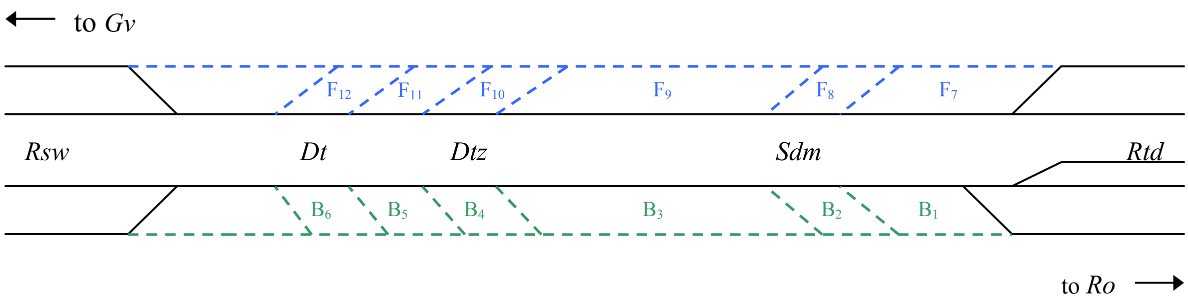


Figure 6.4: Schematized track layout for backward(B_i) and forward(F_j) extensions in southbound and northbound directions respectively.

To give an example regarding Figure 6.3, forward extension number 1 (F_1) in southbound direction would length as far as the entrance at Delft station (along the viaduct). Following extension, F_2, would include Delft station, thus an extra platform must be created. Further extensions would follow until completing a double-track direction (CW). The same logic is valid for the other configurations.

Enlargements of the infrastructure have been designed by means of RailSys Infrastructure module. So far, new links and turnouts (switches) to the existing track are assumed to be built as well as additional signals and block section, assuming:

1. Physical characteristics of links (length, design speed, etc.) equal to the parallel track in the same side of the extension.

2. Switches to the existing track according to design speed in extension area and the following standards:

Common Turnouts		
angle of intersection	Length [mm]	Speed [km/h]
1:34.7	99332	140
1:15	47277	80
1:15	42706	70
1:12	38320	60

Table 6.2: Survey of some common turnouts (Esveld, C., 2001:346)

3. A symmetrical fixed block signalling system with the same block lengths as in the existing infrastructure.

Table 6.3 and Table 6.4 give approximate extension values in kilometres of track regarding the previously proposed scenarios.

	Rsw	*Dt**	*Dt*	*Dtz**	*Dtz*	*Sdm**	*Sdm*	*Rtd*
Rsw	0	2,1	3,2	4,3	5,2	12,8	13,5	16,6
Rtd	16,6	13	14	11,5	12	3,4	4	0

Dt means "before Delft station according to extension"*
Dt means "including Delft station according to extension"

Table 6.3: Track extensions from *Rsw* (forward) and *Rtd* (backward) in kilometres (southbound direction)

	Rsw	*Dt**	*Dt*	*Dtz**	*Dtz*	*Sdm**	*Sdm*	*Rtd*
Rsw	0	2,2	3,1	3,9	4,5	12,4	13,1	17
Rtd	17	13,5	14,2	11,7	12,5	3,7	4,4	0

Table 6.4: Track extensions from *Rsw* (backward) and *Rtd* (forward) in kilometers (northbound direction)

With regard to the routing of trains and timetable planning, the following statements are assumed:

1. Minimum changes done to the existing routing of trains. Departure and arrival stations are kept while after track extensions still remain certain double track part. On the other hand, when double track per direction is reached, routing has to be slightly modified. Figure 6.5 gives an overview to tracks and platforms involved.

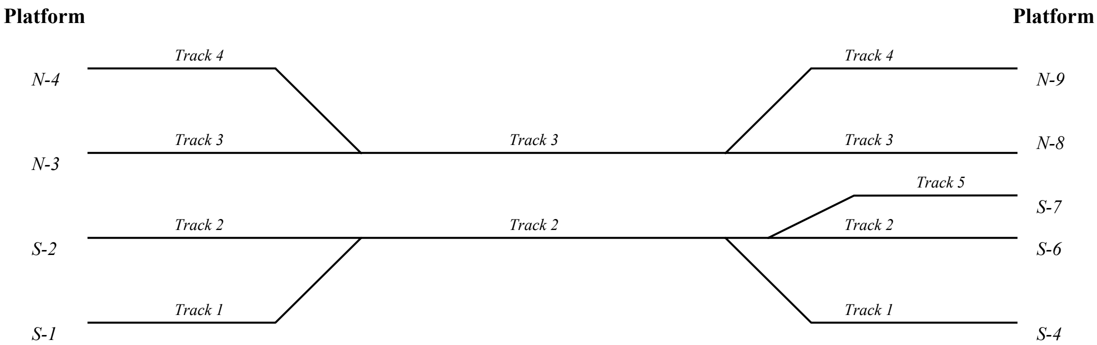


Figure 6.5: Existing track and station layout handling the train routes through this part of the line

For instance, if a train route is defined through platform *S-1* in Rijswij*k* (track 1), once the expansion of this track is done the route would keep on running in the enlarged track 1 until the turnout, and then developed as it used to. Table B.6 in Appendix B summarizes the existing routing kept at the different extensions.

However, once extensions reach double-track per direction (quadruple-track) between Rijswijk and Rotterdam CS, in order to get a smooth operation it is proposed to operate using dedicated tracks: one exclusively allocated to intermediate stopping and slow cluster of trains (*AR*-, *IR*-) whereas the other would be used by fast non-stopping cluster of trains (*HST-, INT-, IC-*). In such situation, both highly dense and rapid service could be optimized. Such kind of speed fleeting measure is done from a capacity utilization point of view; robustness may not be improved so clearly and it could even be critical if more trains are fitted into the schedule. Table B.7 in Appendix B gives insight to changes in routing with regard to the original pattern.

2. The same scheduled arrival and departure times for all trains planned in the Status Quo approach.

From the proposed extension scenarios it is expected a continuous increase of line buffer allowing fitting more trains in the timetable. Lower track occupation running the same train services (optimized capacity utilization) should be achieved every time a critical block section is included in an extension. In particular this is expected in station block sections, due to the influence of dwell times judging from blocking time diagrams, but also at reduction from two to one track.

6.4 Capacity Evaluation

Once each of the previous sub-scenarios has been modelled, RailSys estimates the time-distance diagrams with train paths and their blocking times. Compressing the diagram without buffer time, line occupations and remaining line buffers are calculated. The following tables give the track occupation for each of the proposed track extensions assuming the same services are operated.

		Rsw	*Dt**	*Dt*	*Dtz**	*Dtz*	*Sdm**	*Sdm*		*Rtd*
Rsw		90	84	71	71	62	61	59	50 [2]	33 [1]
Rtd	50 [2]	33 [1]	62	50	73	62	87	77		90

Table 6.5: Track Occupations [%] in southbound direction arising from forward (from *Rsw*) and backward (from *Rtd*) extensions. Complete double track line in south direction leads to two different track occupations for each track:

[1] *Fast train series track*
[2] *Slow train series track*

		Rsw	*Dt**	*Dt*	*Dtz**	*Dtz*	*Sdm**	*Sdm*		*Rtd*
Rsw		88	84	70	70	64	60	59	53 [2]	29 [1]
Rtd	53 [2]	29 [1]	55	44	70	57	77	73		88

Table 6.6: Track Occupations [%] in northbound direction arising from backward (from *Rsw*) and forward (from *Rtd*) extensions.

The above occupation estimates can be represented graphically in order to get a better insight to the behaviour of the track occupation for each individual track extension.

6.5 Analysis of the results

Both southbound and northbound directions are analyzed with regard to different extensions. The comments given in the following paragraphs would be better followed by checking Figure 6.1 and Figure 6.2.

Southbound direction

Capacity evaluation provided different track occupation rates from different extension scenarios in southbound direction as shown in Table 6.5. As Figure 6.6 indicates, track occupation tends to decrease as extension lengths are increased.

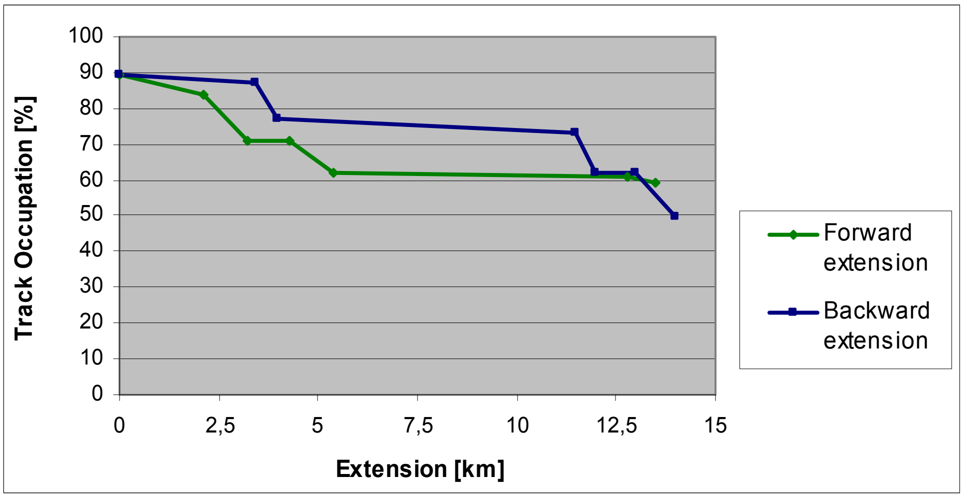


Figure 6.6: Effect of forward and backward extensions on West track occupation in southbound direction

The graph above shows expected development of track occupation depending on the amount of kilometres extended. Just deterministic values (points in the graph) are estimated and it would not be convenient to extrapolate them to the straight curves plotted. However, it gives a rather acceptable outlook to the theoretical development of track occupation according to the location of bottlenecks and blocking time structure (see Figure 6.1). Plotted points as shown in the graphs represents track occupation estimations obtained through RailSys calculations referring to the previously defined extensions focusing on halts, where bigger differences in track occupation were expected and now are graphically indicated. Complete extension to double-track from *Rsw* to *Rtd* is not considered in the graph because track occupation is split up in two.

Every time a second track is extended including an intermediate station, thus a new platform, between 10% and 15% of track occupation is reduced with regard to the previous extension (see Table 6.5). This happens both for backward and forward extensions. However, the later, regarding block section number 10 (Schiedam station) included in extension F_6, leads much less reduction (about 2%). This could be explained by the fact that such a large extension would already develop new dwell time bottlenecks at halts between trains running through the extended track, making the improvement rather small although blocking times at Schiedam station are not critical.

This particular situation is not detected for large backward extensions including Delft and Delft Zuid stations, which still cause capacity improvements as shown in Figure 6.6.

Another comment referring to Figure 6.6 refers to the rather big difference between track occupations achieved by large forward and backward extensions before completing double-track (F_6 and B_6). It might be expected a smaller difference caused by different little remaining single-track lengths to Rotterdam CS and Rijswijk in forward and backward extensions respectively. Nonetheless, whereas the backward extension B_6 leads to track occupation of 50%, a forward extension with similar length until Schiedam, F_6, would lead to a track occupation of 59%. From this point, extending F_6 to a complete dedicated double-track might reduce the track occupation as expected from 59% to 50% and 33% per track for slower train track and faster train track respectively (see Table 6.5 to check track occupation values). On the other hand, a similar extension to the already extended track B_6 might not lead to the same behaviour according to estimations because it would shift from the 50% already achieved to the same double-track occupations per dedicated track.

This 9% difference (50% vs. 59%) as estimated seems to be too large and might give a rough idea of the critical capacity halts along the line to build up a suitable enhancement measure. Nevertheless, through the analysis of the train paths in both cases, the reason for such a difference is found in the routing assumptions done previously to define extensions. Extensions are done keeping the original routing along the track extended; this causes different dwell time bottlenecks in individual tracks, leading to higher or lower track occupations. That is the case of extension F_6, where Schiedam station remains as a critical block section due to close routing of trains in time through the same track as well as the existing dwell time scheduled at this halt. Such situation does not happen in the case of extension B_6, leading to lower track occupation.

Drops in track occupation due to extending two tracks along the reduction from 2 to 1 track after Rijswijk or before Rotterdam CS can also be checked through Figure 6.6. The output is quite surprising regarding expectations, and only the bottleneck number 1 (Delft viaduct) is rather significant. It is graphically indicated in the Figure 6.6 and numerically in Table 6.5, a decrease of 6% in track occupation is expected once this area is extended with a double-track. Nevertheless, reduction from 2 to 1 tracks before Rotterdam CS and especially in open track generated by the different extensions, both represent rather low or null drop in capacity occupation although some of the are key locations to globally profit from capacity improvements at stations included in the extensions.

These and other issues can be better understood through Appendix D that shows the development of existing critical sections taking as a reference the existing situation.

Northbound direction

As done in southbound direction, Figure 6.7 indicates the effect of both forward and backward extensions to track occupation but this time in northbound direction. The same reasoning is valid for the analysis in this case using Table 6.6 and the extension layout in northbound direction.

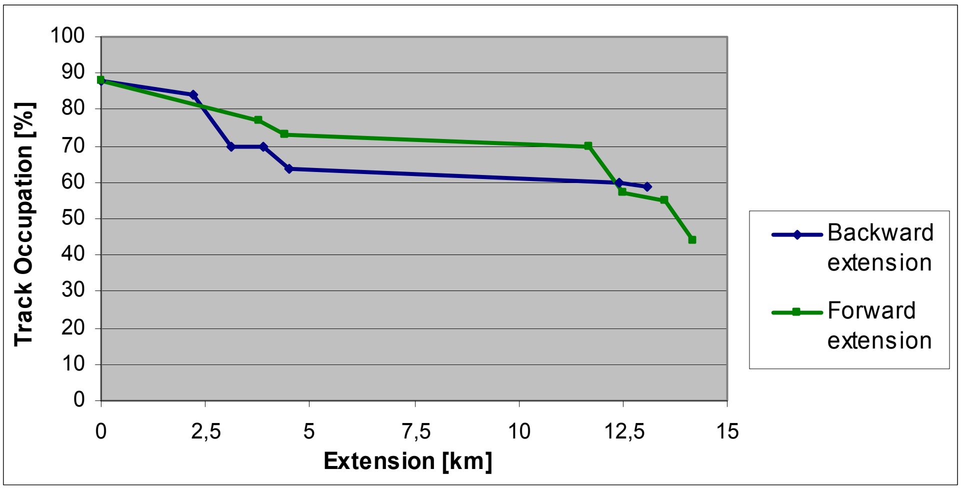


Figure 6.7: Effect of forward and backward extensions on East track occupation in southbound direction

Figure 6.7 indicates similar shapes as in southbound direction, obviously due to numerous infrastructure and signalling similarities of both directions. It shows how capacity use is mostly lost at station block sections instead of double-track reductions. As a rule, between 11% and 14% of track occupation is reduced at stations excluding Schiedam where, as commented before, lower gain is achieved and just 1% and 4% is reduced by extending backward and forward respectively.

Extensions along the open-track do not improve the capacity utilization in this direction. Besides, a similar difference appears between backward and forward extensions before extending them up to double-tack per direction. The same argumentation serves as before and only numerical values slightly differ from the previous ones. In this sense, forward extension F_{12} until Delft might expect to reach a track occupation about 44%, whereas backward extension B_{12} until Schiedam again an occupation of 59%. Once the whole double track is completed, the occupation of each dedicated track would be expected to rise to 53% and 29% for slower and faster trains respectively.

Some comments on oddness in northbound direction are treated more in deep. In this sense, it is interesting to analyze the first forward extension (F_7), involving the track reduction from 2 to 1 at Rotterdam CS. It leads to rather large decrease of track occupation due to the location of bottlenecks and the blocking time graph structure (see Figure 6.2) contrary to what happened in southbound direction. Once critical block section number 18 is removed, large buffer time is recovered due to those characteristics. Such situation is not expected in southbound direction due to a different blocking time structure of the graphs as shown in Figure 6.1.

Appendix D shows the development of the existing critical block sections every time an extension includes a station block, as done in the opposite direction.

6.6 Summary and conclusions

This chapter performed a set of alternative capacity scenarios based on upgraded infrastructure supply by means of second track enlargements per direction along the double-track corridor between Rijswijk and Rotterdam CS. These scenarios are suggested from an analysis of the existing critical sections overviewed in the blocking time diagrams obtained in Chapter 4, basically caused by reduction from two to one track per direction and dwell time spent at station halts. Keeping the same characteristics of the existing tracks, enlargements of tracks are performed by extending them until certain representative locations merging to the existing track by implementation of suitable turnouts.

Computational experiments are carried out to determine the capacity scenarios arising from the designed infrastructure layouts. Existing hierarchy of extensions leads to a quantitative and qualitative theoretical approach of development of track occupation every time an extension is done. The following tables summarize those track occupations as well as the relative capacity improvements achieved per extension indicating the percentage difference to the existing situation as well as to the standard track occupations. Results concerning to complete double-track extension per direction are not indicated here due to their inconsistency with the research aims; however they can be checked in tables Table 6.5 and Table 6.6.

Capacity Utilization	**Forward Estensions**						**Backward extensions**					
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Improved track occupation [%]	84	71	71	62	61	59	87	77	73	62	62	50
Percentage difference to Status Quo [%]	-6	-19	-19	-28	-29	-31	-3	-13	-17	-28	-28	-40
Percentage difference to UIC [%]	9	-4	-4	-13	-14	-16	12	2	-2	-13	-13	-25
Percentage difference to ProRail [%]	4	-9	-9	-18	-19	-21	7	-3	-7	-18	-18	-30

Table 6.7: Relative increases in Track Occupation [%] arising from forward (from *Rsw*) and backward (from *Rtd*) extensions, regarding the existing track configuration in southbound direction and standards.

Capacity Utilization	**Forward extensions**						**Backward extensions**					
	F7	**F8**	**F9**	**F10**	**F11**	**F12**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**
Improved track occupation [%]	77	73	70	57	55	44	84	70	70	64	60	59
Percentage difference to Status Quo [%]	-11	-15	-18	-31	-33	-44	-4	-18	-18	-24	-28	-29
Percentage difference to UIC [%]	2	-2	-5	-18	-20	-31	9	-5	-5	-11	-15	-16
Percentage difference to ProRail [%]	-3	-7	-10	-23	-25	-36	4	-10	-10	-16	-20	-21

Table 6.8: Relative increases in Track Occupation [%] arising from backward (from *Rsw*) and forward (from *Rtd*) extensions, regarding the existing track configuration in northbound direction and standards.

Some conclusions arise from discussion of the above results. First of all, the output obtained from capacity evaluation per extension scenario was qualitatively expected (shape of the track occupation curves) but not quantitatively (sensitivity of track occupation to station bottlenecks seems to be much bigger than two to one track reductions bottlenecks). Besides, it can be concluded that according to the track occupation estimations, both Delft and Delft Zuid stations mainly represent the capacity constraints for the double-track part of the line due to mix operation of trains. Most time space unused is gained by including those critical bottlenecks to the extensions.

Regarding construction aspects, for short enlargements extensions from Rijswijk lead to lower track occupations compared to extensions from Rotterdam, especially in southbound direction. In other words, the use of available capacity is better optimized and more trains would be able to be fit in the timetable if short extensions were done from Rijswijk and Rotterdam CS in southbound and northbound directions respectively.

Also shown in figures 6.6 and 6.7, subsequent extensions lead to decrease of track occupation, even though the relation is not linearly. This indicates how open track extensions nearly do not contribute directly to improve line capacity. In this sense, it could be interesting to consider other scenarios where just additional sidings where critical sections appear are used by fast trains to overtake slower ones. Similar improvements at the same time costs are reduced might be achieved with such kind of measures. This assumption emphasises the fact that station dwell times represent the main capacity constraint of the railway line between Den Haag HS and Rotterdam CS, leading to another possible capacity measure regarding dwell time reductions at stations. However, both measures would not have the desired effect, at least in southbound direction, if first the bottleneck number 1 at Rijswijk (reduction from 2 to 1 track before Delft viaduct) is not solved. Removing it and the others created along the surrounding open tracks, track occupation is not reduced that much but it represent a key location to profit from the gain achieved at stations by means of the presented measures. In other words, such track reduction at open track bottlenecks do not improve capacity directly but indirectly by allowing to profit the gain expected at stations, otherwise minimum buffer time might still appear in those locations and capacity would not be enhanced.

As mentioned in section 5.1, combining proposed extensions with a suitable re-routing and scheduling of trains series, lower track occupations could be achieved. However, these additional variables have not been largely modified to clearly check the sensitivity of capacity to an upgraded infrastructure. Hence, an optimization problem arises with different parameters to be weighted to reach the most suitable solution.

The final comment refers to the applicability of the theoretical results obtained. Apparently, extensions just before a certain station and extensions including the previous station contribute to improve the capacity the same (see tables 6.5 and 6.6). The reason for that is the next station downstream the line, which leads to a new bottleneck constricting the capacity. Of course, if no improvement is achieved it makes no sense to waste extra track regardless the presented approach. Hence, the following figures summarize per line direction the feasible forward and backward extensions including station block sections and track occupations achieved assuming the Status Quo schedulling.

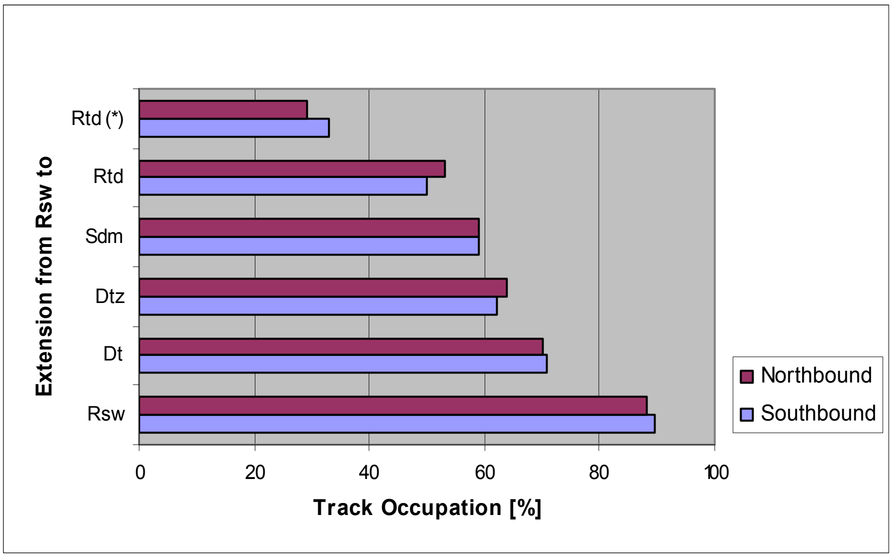


Figure 6.8: Track occupations in both directions extending the second track per direction from *Rijswijk*

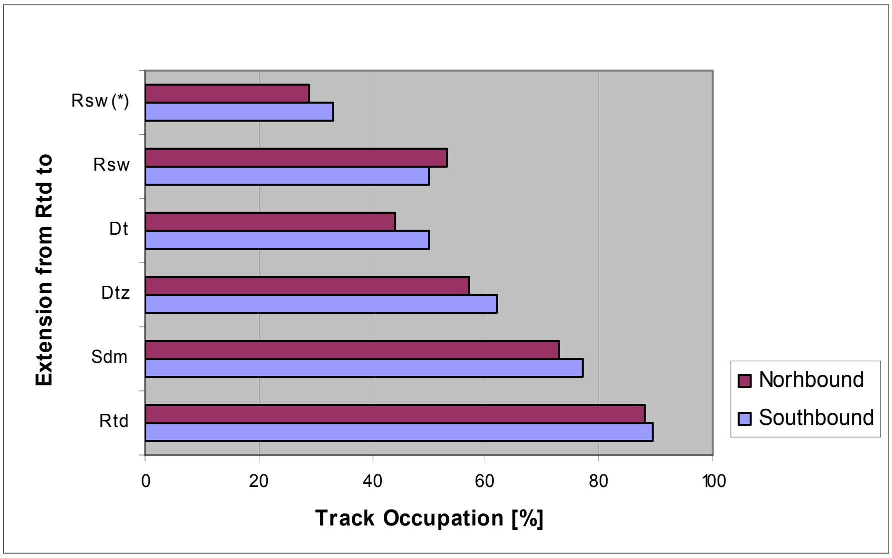


Figure 6.9: Track occupations in both directions extending the second track per direction from *Rotterdam CS*