Performance of Crossovers in the Dutch Railway Network

Case Study for Amsterdam and Rotterdam

Master Thesis

Mirjam Hoeffelman

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Preface

This master thesis report is the final part of my graduation for the master Civil Engineering at Delft University of Technology. It is called: Performance of Crossovers in the Dutch Railway Network, case study for Amsterdam and Rotterdam. During the past nine months I have been working on this subject at two locations: RoyalHaskoningDHV and ProRail in Utrecht. I was lucky, to have had the opportunity of getting to know the two organizations in a short timeframe and I learned a lot from both of them. I would like to thank all the people: staff, friends and family who contributed to my final report and in particular I will mention the following people:

First of all, I would like to thank my daily supervisor from RoyalHaskoningDHV, Rob van Neerrijnen. I remember the first day I came to the office of DHV–in the meantime merged with RoyalHaskoning. I was very enthusiastic about the topic he presented me on crossovers and rescheduling; it was very topical and it still is. However, he told me that it was also a challenging subject and I got this confirmed during my research. Nevertheless, he supported me very well with this final report as a result.

Furthermore, I would like to thank my daily supervisor from ProRail, Alfons Schaafsma. Alfons helped me out with al the jargon and abbreviations which are common language if you are working in the railway sector for years but for me, as a newbie sometimes quite confusing. I really appreciate the opportunities ProRail gave me to visit the traffic posts of Amsterdam and Rotterdam. It was impressing to see daily work processes in real life. It helped me to better understand the rescheduling process.

I also would like to thank my daily supervisor from TU Delft, Rob Goverde for his support and feedback. I really appreciate the discussions we had which were an added value for my report. Furthermore, the other members of my thesis committee: Bart van Arem, Ingo Hansen and Michaël Steenbergen I would like to thank as well for their valuable feedback given which contributed to this final report.

Finally, I would like to thank Alwin Pot from RoyalHaskoningDHV. He helped me out with building the infrastructure in OpenTrack. And last but not least, I would like to thank my mom for the final editing of the report.

Mirjam Hoeffelman
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Summary

ProRail Traffic Control would like to have examined what the performance of crossovers for rescheduling is in case of partial obstructions. The need for quantitative information about the performance of crossovers in The Netherlands has grown. The research is intended to fill this knowledge gap by investigating the performance of crossovers in The Netherlands in a quantitative manner for two typical corridors. Therefore, the main research question is stated as follows:

What is the performance of crossovers with respect to reliability (benefits) and life-cycle costs when rescheduling takes place?

The focus in this research is on IVO switches (crossovers in between stations) that are only used for rescheduling. A crossover is a pair of switches that connects two parallel tracks and enables transfer from one track to the other track. The research question has been explored on two typical corridors in the Dutch railway network: corridor Amsterdam: Amsterdam Riekerpolder aansluiting (Asra) – Amsterdam Bijlmer ArenA (Asb)/Diemen Zuid (Dmnz) and corridor Rotterdam: Rotterdam Centraal (Rtd) – Gouda (Gd).

Several methods and tools have been used. First, a disruption analysis of the applied partial rescheduling (VSM: VerSperringsMaatregel) in 2011 has been done. The microscopic application TOON has been used to analyze disrupted train operations. Database MUIS contains manually added reports about rescheduling inputted by traffic controllers. With these two tools, similarities and differences between the applied VSM and the real processes and reports from traffic control have been analyzed. Furthermore, insight into the usage of crossovers during rescheduling has been obtained. To get insight into delays and the propagation, data from the Monitoringsystem has been used. The Monitoringsystem generates couplings between train delays.

Second, a simulation study of case study Rotterdam has been performed. The microscopic simulation tool OpenTrack has been used to analyze the rescheduling and crossover usage during partial obstruction between Rotterdam Noord Goederen (Rtng) and Nieuwerkerk a/d IJssel (Nwk) (VSM 25.070). Three scenarios have been analyzed: the reference situation: maintaining crossovers at Nieuwerkerk IVO wissels (Nwki) and Moordrecht overloopwissels (Mdo), scenario 1: a crossover at Capelle Schollevaar overloopwissels (Cpso) instead Nwki and scenario 2: both crossovers at Nwki and Mdo are removed. The scenarios have been evaluated through estimations of passenger-, operator- and infra manager costs.

Important conclusions that could be drawn from the analyses are that most disruptions that needed partial VSM were caused by defect trains rather than infrastructure related defects. Furthermore, the largest part of the rescheduling went according to the VSM. Although, some disruptions were too short and therefore rescheduling was partly executed according to the VSM. In both case studies crossovers were frequently used during rescheduling. Especially during the first phase–when trains are trapped–crossovers are needed to quickly remove and prevent trains to enter. This will speed up the implementation of the VSM either if partial or complete VSM is used. Moreover, crossovers were also frequently used to couple and abduct 'defect' trains to stations/yards and allow implementation of a VSM at once which is the case of delayed anticipated maintenance.

With regard to disturbance of crossovers, crossovers do influence the performance of the railway system i.e. according to ProRail's Asset Management database crossovers lead to a small number of TAOs. Delays and its propagation depend on the severity of disruption. When disruption was shorter (< 3 hours) no other trains on other corridors within the area of Rotterdam and Utrecht were affected. When disruption took longer (> 3 hours) delays were propagated, affecting other trains on other corridors within the area.

Furthermore, it can be concluded from the simulation study that scenario 1: crossover at Cpso instead of Nwki resulted in shorter delays of the still operable SPR 4000-series. However, the simulation showed that adding an additional IC 2800-series did not improve the performance of rescheduling. In case of one disruption per year scenario 2: removing the crossovers by removing the tongue and frog has the lowest total costs (€210,557). Removing both crossovers is more expensive (€214,909) as well as maintaining the crossovers at Nwki and Mdo (€240,422) or replacing the one at Nwki by a new one at Cpso (> €240,422). When more than one disruption per year occurs, remaining crossovers at Nwki and Mdo results in lower costs than removing them. Therefore, it can be concluded that with regard to corridor Rotterdam (six disruptions in 2011) maintaining the crossovers at Nwki and Mdo is the most cost-effective.

Finally, some recommendations are given with respect to further research. To get reliable data about the performance of crossovers that are applicable to the whole railway network more case studies should be done and different disruptions should be simulated. Moreover, a network-wide analysis of costs and benefits needs to be done to get reliable results for decision making. With respect to ProRail's new rescheduling philosophy it is questionable whether it is still sufficient in the long term. New technologies in the railway system such as decision support systems that give optimal rescheduling based on real-time delays are promising. Perhaps this could be explored in advance.

Also some recommendations are given with respect to the tools that have been used. Reporting the rescheduling process is arbitrarily done in MUIS if compared with the eventually executed rescheduling process obtained from TOON. This makes analyzing disruptions more complex. Therefore, it might be useful to integrate these two systems. With regard to disturbances of crossovers, data of ProRail Asset Management database did not always match with data of TOON and MUIS reports. It could be beneficial for research purposes to couple these databases. A disadvantage of the Monitoringsystem is that not all couplings are being made. A comparable system, TNV-Conflict would be recommended for follow-up studies since it has very accurate data (to the nearest second) about delays and its propagation. Finally, with the help of user-friendly applications such as a convertor that automatically imports the Infra Atlas in OpenTrack, simulation studies become less time-consuming and therefore more accessible.

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1 Introduction

Worldwide the Dutch railway system performs well–especially given the fact that it is also one of the busiest networks in the world. Still there is the ambition for further improvements of the system. Future growth of rail traffic but also higher requirements imposed by the government and the higher expectations of passengers trigger this ambition of ProRail and train operators. Crossovers are traditionally important links in the railway network but are also frequently the cause of delays in the increasingly complex train operations of today. This chapter describes the problem definition in Paragraph 1.1, followed by the research objectives and question explained in Paragraph 1.2. The constraints are described in Paragraph 1.3. The research approach is described in Paragraph 1.4 and in the last paragraph the report format is explained.

1.1 Problem Definition

The context in which the master thesis is conducted is briefly described. First, the performance of the current Dutch railway system is given. Subsequently, the complexity of the network (Subparagraph 1.1.2) and the function of crossovers (Subparagraph 1.1.3) are explained.

1.1.1 Current Railway System

The number of passenger kilometers in the Dutch railway system has grown over the years. In 2010 the total number of kilometers traveled was 16.4 billion (NS, 2010). According to ProRail and NS, the number of passenger kilometers will continue to grow: the prognosis is a growth of 20 to 40% which is 19 to 22 billion in 2020 (Hansen et al., 2012). The Netherlands have already one of the busiest railway systems in the world–only the Japanese railway system has a higher number of passenger kilometers per network kilometer (Hansen et al., 2012). A higher train frequency is also presenting a more fragile railway system. The risk of disturbances will increase–especially in combination with a complex railway network (rail infrastructure). If a disturbance occurs, it often results in disruption that affects a large part of the railway system. The reliability of the train service–measured in The Netherlands as the punctuality–is then at stake. Data from ProRail shows that the punctuality has increased in 2011 compared to 2010: 94.7% versus 92.5% (ProRail, 2012a). This is partly explained by the milder autumn and winter and even though the train frequency has increased in recent years, the punctuality has not deteriorated.

One of the key objectives that both ProRail and NS aim at for the future is to further improve the reliability of the railway system and simultaneously meet the projected demand (by increasing train frequencies) (ProRail, 2010a). To address higher train frequencies there is need for more capacity. The possibility for additional rail infrastructure is limited because of the high investment costs. Besides, the past ten years ProRail already invested billions of euros in developing new rail infrastructure. Therefore, their focus is more on leveraging the current rail infrastructure and one of the possible solutions is reducing the complexity of the railway network.

1.1.2 Complexity of the Railway Network

The railway network in The Netherlands is historically developed. Late 19th century there was a desire for rail transit between large cities and as the number of passengers grew more connections emerged between urban areas. Railway companies were mostly private and had their own rail infrastructure and exploitation. Large cities had several stations that once after the consolidation to one public railway company (NS) proved to be inefficient, for example the combination of The Hague Central (railway company: Maatschappij tot Exploitatie van Staatsspoor) and The Hague Hollandsspoor (railway company: Hollandsche IJzeren Spoorweg Maatschappij). There was little or no thought about synergy and optimization of the whole. The consequences are still present today. In addition, the railway network was even more complex due to the long list of demands for implementing new rail infrastructure.

1.1.3 Switches and Crossovers

The Dutch railway network contains many switches–an amount of 7,342 (ProRail, 2012b). The idea behind it was that more switches provide more connections for new infrastructure and provide more opportunities in making a regular timetable. In addition, switches make rescheduling possible in the event of disturbances and during scheduled maintenance. But switches themselves are a major cause of failures in the railway network which often results in delays. And through the increasing train frequencies, these disturbances will occur more frequently and decrease the availability of the railway network and consequently the reliability of the train service. Within the current railway network a balance must be found to realize a reliable railway system (Figure 1.1).

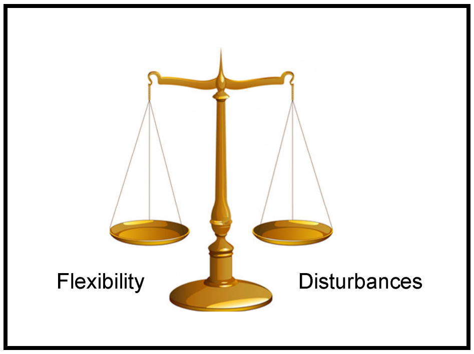


Figure 1.1 Balance switches/crossovers

A crossover consists of two switches that enable transfer to the opposite direction on a two-track section (Figure 1.2). In general crossovers can be divided into two groups according to their function in the railway network (Figure 1.3).

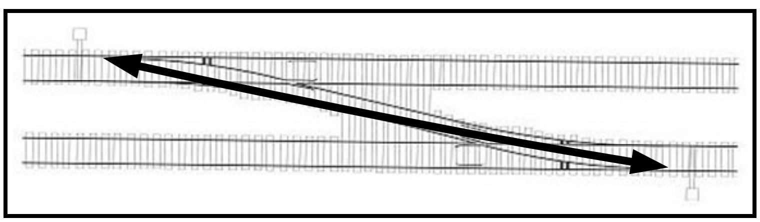


Figure 1.2 Crossover

The first group of crossovers, used for the regular timetable and for rescheduling in case of disturbances or scheduled maintenance is located at stations or near stations. They are used to separate arrival and departure of trains at a railway platform and make it possible for trains to return at stations. Because they are also used for the regular timetable they cannot be easily missed. The second group of crossovers, used only for rescheduling in case of disturbances or scheduled maintenance, is situated in between stations. They are used in case of a partial obstruction (disruption in one direction) on a two-track section. The crossover ensures that the limited capacity can be used in both directions because transfer is possible (single-track grids). These crossovers are also known as IVO (InfraVoorziening voor Onderhoud) switches. IVO switches are primarily intended for (re)scheduling during scheduled maintenance but are also used in case of disturbances.

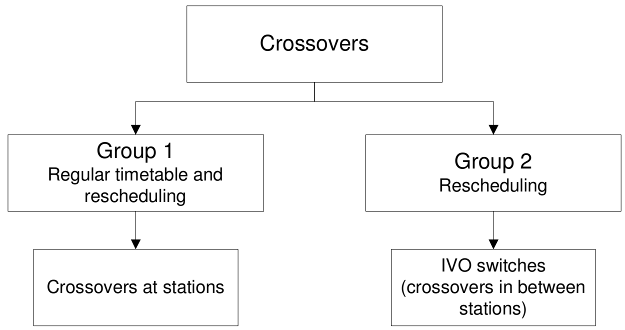


Figure 1.3 General classification of crossovers

1.2 Research Objectives and Question

As a follow-up of the problem definition, research objectives (Subparagraph 1.2.1) and question (Subparagraph 1.2.2) have been derived.

1.2.1 Research Objectives

ProRail–in particular the department of Traffic Control–would like to have examined what the performance of crossovers for rescheduling is in case of partial obstructions. This, in order to achieve a reliable railway system at minimum life-cycle cost; to be able to process higher train frequencies in the future and conform to the higher requirements that are imposed on punctuality. Therefore the research objective is as follows.

Get insight into the performance of the current crossovers in the Dutch railway network by focusing on specific case studies.

In developing a generic approach it is important taking into account the wishes of other stakeholders since it determines the success of the policy. It is in any case important that both, NS and ProRail agree with the generic approach but also statements of other stakeholders, for example freight train operators have to be taken into account. Proponents and opponents of crossovers base their judgments on 'good feelings' and qualitative data. To gain insight into the performance of crossovers a quantitative study has been performed. Based on this research, conclusions can be drawn if it has sufficient clarity for future policy.

1.2.2 Research Question

Following from the research objectives, the research question can be derived.

What is the performance of crossovers with respect to reliability (benefits) and life-cycle costs when rescheduling takes place? This question has been explored on two typical corridors in the Dutch railway network: case studies Amsterdam and Rotterdam.

The research question can be divided into a number of sub questions:

i. What criteria affect a reliable railway system? (Chapter 3)
ii. What stakeholders are involved? (Chapter 3)
iii. In which processes do crossovers play an important role? (Chapter 4)
iv. What is the current performance of rescheduling and crossovers? (Chapter 5)
v. Which case studies that include crossovers can be used as characteristic? (Chapter 6)
vi. What is the performance of rescheduling and crossovers for these case studies? (Chapter 7)
    - The comparison between the applied rescheduling and the VSM (VerSperringsMaatregel)?
    - The usage of crossovers during rescheduling?
    - The consequences: initial and knock-on delays on train operations?
vii. What is the effect of different scenarios of crossovers (trans-locating or removing) on the capacity of the rescheduling for a specific case study? (Chapter 8)
viii. What are the costs and benefits of these scenarios? (Chapter 8)

1.3 Constraints

There are however some constraints in the research. First, the scope of the research is explained and then some risks are addressed.

Function of crossovers. The focus of this research is on crossovers that are only used for rescheduling. At this time, ProRail is reorganizing its disruption management process and therefore the function of crossovers will change. There will be a distinction between:

- Crossovers on major stations–the decoupling points (ontkoppelpunten)–used for the regular timetable and rescheduling.
- Crossovers on small stations/yards (no decoupling points)–used for the regular timetable.
- Crossovers in between stations–IVO switches–used for rescheduling.

Therefore, the research is focused on the performance of IVO switches (Figure 1.4). The reasons behind it are:

- IVO switches will only be used for rescheduling due to scheduled maintenance (and also in case of disturbances). They are not used for the regular timetable.
- In the future during partial or complete obstruction, rescheduling will only take place at decoupling points and no longer at small stations/yards (ProRail and NS, 2011).
- Crossovers at decoupling points are used for rescheduling and for the regular timetable. Therefore in the current and future policy of ProRail these crossovers are indispensable.

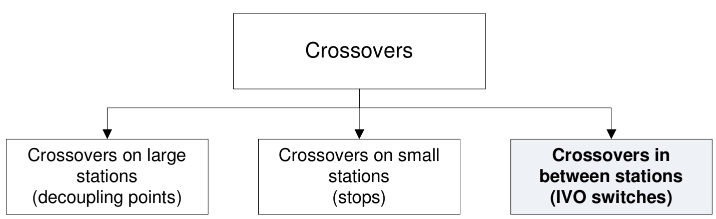


Figure 1.4 New classification of crossovers

Two-track sections. The research focuses only on crossovers on two-track sections (four-track sections will not be included).

Disturbances and scheduled maintenance. The added value of crossovers will be mainly investigated in relation to rescheduling due to disturbances that lead to partial obstructions (affecting the train service). However, minor attention will be given to scheduled maintenance since crossovers play an important role in the planning and execution of maintenance.

Case studies. For the performance analyses, a number of case studies are identified because it is impossible, given the limited time to analyze the effect of all crossovers in the Dutch railway network.

Stakeholders and quality of data. Finally, there are several risks. First, the performance of crossovers is a sensitive topic for different stakeholders: ProRail has other thoughts than NS. It is desirable to come up with a generic approach that is supported by both ProRail and NS (and perhaps other stakeholders). To accomplish this it is important that cooperation of the stakeholders is granted to get the necessary information. Second, the availability and quality of data is of importance to generate useful conclusions. If some parts are not well quantified assumptions are made that affect the results.

1.4 Research Approach

To answer the research question several methods and tools have been used. First, a disruption analysis of the applied partial rescheduling in 2011 has been done. ProRail has several databases and tools from which data has been extracted. MUIS archives reports of disruptions set up by traffic managers and traffic operators. Information of the kind of disruption: complete or partial, which kind of VSM has been used, the date, the start and end time of disruption and VSM, and the cause of disruption can be found. With the microscopic application TOON train operations over sections during disruption can be visualized. More specifically it is possible to analyze the applied partial VSM and which crossovers have been used. To get more insight into initial delays and the propagation of such delays (knock-on delays) the Monitoringsystem has been used. The Monitoringsystem generates couplings between train delays. It contains only trains that have a delay and an increasing delay (differences between the 'new' delay and the previous delay) of at least three minutes.

Furthermore, a simulation study of corridor Rotterdam has been executed. The microscopic simulation tool OpenTrack is very useful for capacity studies of specific train corridors. With a simulation program it is possible to analyze 'what if' situations. The effect on the train service (dispunctuality of trains and capacity) can be measured when disruption (VSM) is handled with and without crossovers at specific locations. Finally, the scenarios have been evaluated through costs and benefits. Benefits are the gain in passenger delays caused by disruptions. Costs are life-cycle costs: investment, maintenance, restoring costs of disturbances etc.

1.5 Report Format

In Figure 1.5 a schematic overview of the report format is given. The report is divided into four main parts. Part A describes the problem analysis; in Chapter 1 the introduction of the research topic is given, followed by a literature review in Chapter 2 and finally a description of the railway system in Chapter 3. Part B contains the process and performance analysis. The processes of rescheduling and crossovers are explained in Chapter 4. Chapter 5 describes the performance of rescheduling and crossovers on a national level. From Chapter 6 onwards, the research focuses on two specific case studies: corridor Amsterdam (Amsterdam Riekerpolder aansluiting [Asra] – Amsterdam Bijlmer ArenA [Asb]/Diemen Zuid [Dmnz]) and corridor Rotterdam (Rotterdam Centraal [Rtd] – Gouda [Gd]) (Part C). It starts with describing the choice process of the case studies and also explains the applied research methods and tools in more detail (Chapter 6). The performance of rescheduling and crossovers for the characteristic corridors Amsterdam and Rotterdam is analyzed by using historical data (Chapter 7). In Chapter 8 a simulation study is done for corridor Rotterdam. Furthermore, costs and benefits are estimated for different scenarios. In the last part–Part D–conclusions and recommendations are given (Chapter 9).

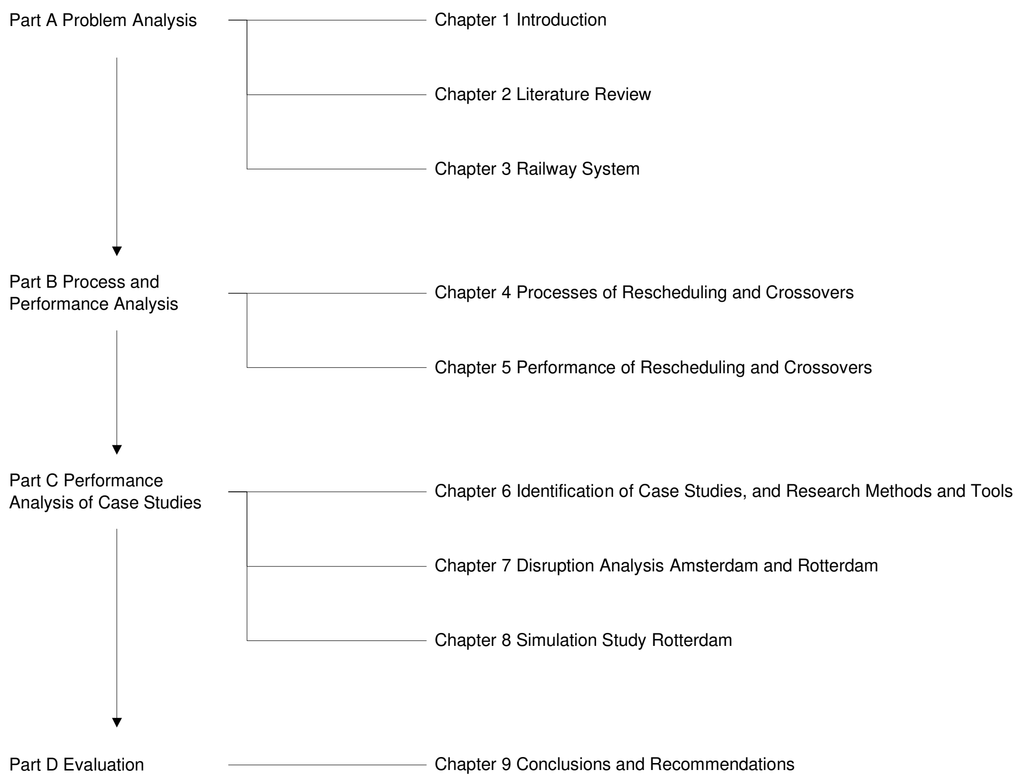


Figure 1.5 Report format

2 Literature Review

Increasing capacity, reliability and robustness of the railway system are important aspects in today's railway operations. In the literature there are different opinions in how to achieve these goals for the Dutch railway system. To emphasize this, a comparison has often been made between different countries in particular the ones that perform well such as Japan and Switzerland. The rail infrastructure and operations concerned are one of the aspects that determine the performance of a railway system. A short overview of current thoughts about this–Weeda et al. (2010) and Hansen et al. (2012)–is given in the first part (Paragraph 2.1). Furthermore, the performance of crossovers in the railway network is of interest. Two specific studies about crossovers have been found in the international literature: Veit (2006) and Steinborn et al. (2007). A brief summary of these studies is given in the second part (Paragraph 2.2). Paragraph 2.3 describes recent research done by Penders et al. (2011) to the impact of crossover locations on bus bridging in Australia. Finally, some conclusions are given in Paragraph 2.4.

2.1 International Benchmark

Weeda et al. (2010) have made a comparison of the railway network between Japan and The Netherlands. Their conclusions are described in Subparagraph 2.1.1. Hansen et al. (2012) did an international benchmark about the performance of the railway system of different–mostly European countries–which is summarized in Subparagraph 2.1.2.

2.1.1 Simplicity of the Japanese Railway System

Weeda et al. (2010) did a comparison between the Japanese and Dutch railway system. Japan is number one in terms of reliability of the railway system worldwide. Therefore, often the Japanese railway system is an example to others. Although The Netherlands do not perform bad–third place behind Switzerland–the difference with number one is still considerable. According to Weeda et al. the main difference is the simplicity of the Japanese railway network. The railway network is linear of structure. In most cases there are direct connections between city pairs and the number of nodes which create interference and bundling train flows is minimal. The focus lies with the main function that has to achieve high capacity with the highest possible speed. Rescheduling is limited because the premise is to prevent rescheduling rather than facilitate it. The more possibilities for rescheduling, the more vulnerable the railway network will be since the chance of failure of these possibilities is higher. Hence, they have shorter signal distances, no left track signaling and less switches/crossovers which allow higher frequencies with minimal disturbance.

To get insight into the difference of simplicity between Japan and The Netherlands, Weeda et al. investigated the number of switches (not specifically crossovers) on both main stations. In Table 2.1 the difference in the amount of switches between Utrecht Central Station and Tokyo Main Station is depicted. At Utrecht Central Station there are ten times as many switches while the number of trains per hour is three times as low as at Tokyo Main Station. According to Weeda et al. this indicates that it is possible to use fewer switches–and thus less rescheduling–and achieve a high frequency in combination with a high punctuality.

Table 2.1 Comparison switches

	Utrecht Central Station	**Tokyo Main Station**
Amount of switches	280	28
Train frequency (trains/hour)	60	180

Weeda et al. (2010)

2.1.2 Benchmark International Railway Systems and Improvements

Recently, independent research–commissioned by de Dutch parliament–about coping with (future) capacity problems of the Dutch railway system was done by Hansen et al. (2012). In one of the two researches a benchmark with several European railway systems had been performed: Belgium, Denmark, Sweden and Switzerland and the Japanese railway system as well. The important conclusions are summarized.

With respect to maintenance, Hansen et al. conclude that there is an underinvestment or inefficient use of the maintenance budget which affects the reliability of the Dutch rail infrastructure. It has led to a higher amount of rail infrastructure related defects which were frequently the cause of long delays in recent years. In general the life-cycle of rail track/switches is approximately 40 years. This implies that approximately 175 kilometers track and 180 switches (2.5%) per year have to be replaced. ProRail replaced 100 kilometers track (1.4%) and 130 (1.8%) switches per year (average of the last five years) while SBB (Switzerland) replaced 190 kilometers track (2.5%) and 320 switches (2.2%) per year. Moreover, The Netherlands have besides Belgium and Sweden the lowest investments in maintenance: approximately €6.7 per train kilometer. In Switzerland two times as much is spent for maintenance (€12.5 per train kilometer).

Compared to Japan, the railway systems of all investigated European countries have a significant lower capacity. Hansen et al. investigated the Chuo-Line from JR East which connects the western agglomeration Takao with the center of Tokyo (Tokyo station). The line has 24 stations and 104 switches (approximately two switches per kilometer). At nine stations there are opportunities for trains to overtake and for passengers to transfer. Furthermore, there are 12 locations on the line where trains can overtake or reverse in case of disruption. Efficient operations are possible because Japan has separate train lines and almost every train has the same stop pattern and the same in-vehicle time/operational speed. Freight trains are not allowed on high utilized train routes or only at evening/nighttime or in weekends. In The Netherlands and other European countries there is mixed train traffic: IC-trains, regional trains and freight trains on the same corridor. Furthermore, the timetable is more complex–for example long haul passengers do not have to transfer at stations as it is the case in Japan. To enable these processes the railway network contains also more switches. The European vision to cope with capacity problems is by implementing four-track sections, by separating the exploitation of IC- and regional trains and by introducing new techniques: the signaling system ERTMS/ETCS that allows shorter headways. Hansen et al. conclude that the European countries are further ahead with respect to ERTMS/ETCS compared to The Netherlands; ProRail focuses in particular on the optimization of the current signal system by decreasing the distance between signals and by eliminating switches/crossovers. Hansen et al. argue that these measures are less helpful.

Hansen et al. believe that in order to get a higher capacity in the railway system focus has to be on improvement of current train operations and techniques rather than simplifying (disruption management) processes and the railway network (eliminating switches/crossovers). One of their recommendations is that freight transport should be limited to one train path per hour per direction till 19:00 hour (like Japan) since freight transport highly determines the feasibility of higher train frequencies. Furthermore, in order to realize the desirable high frequent train service of six IC- and six SLT-trains plus one freight train path, ERTMS/ETCS is necessary otherwise reliability and punctuality of the train service will be in danger. Finally, instead of simplifying the current disruption management process, investments in intelligent information and decision support systems should be done in order to accurately inform passengers and freight train operators about disruptions and quickly detect and solve disruptions/delays to increase capacity while a high reliability and punctuality is guaranteed.

2.2 Optimal Distance between Crossovers

Veit (2006) and Steinborn et al. (2007) looked at the optimal distances between crossovers. Veit (2006) took Austria and Steinborn et al. (2007) took Germany as case study. A brief summary of these researches is given in the following subparagraphs.

2.2.1 Optimal Distance between Crossovers in Austria

Veit (2006) has investigated the optimal distance between crossovers on a two-track section. He simulated three different corridors in Austria. The corridors have mixed train traffic (IC-train, regional train and freight train) with speeds between 80 and 160 km/hour. Each corridor has a different train frequency (Table 2.2).

Table 2.2 Corridors and characteristics Austria

Corridor	**Section**	**Train frequency (trains/day/track)**	**Train frequency (trains/hour/track)**
West Vienna-Germany	Pöchlarn-Amstetten	150	6
South Vienna-Italy	Wiener Neustadt-Gloggnitz	100	4
North Vienna-Czech Republic	Gänserndorf-Hohenau	50	2

Veit argues that the optimal distance between crossovers is determined by the investment and maintenance costs on one hand, and the operational costs on the other. More crossovers cause higher investments and maintenance costs but have lower operating costs because they provide rerouting possibilities during scheduled maintenance. The optimum is determined by a balance between these costs.

The operational costs are estimated on the basis of various delays caused by disruption of 24-, 8- and 4-hours during daytime and 4-hours during nighttime due to scheduled maintenance. Figure 2.1 gives an overview of the duration of such delays for different distances between crossovers in case of a 24-hour disruption. The total delay is the sum of the delays of the specific train services which were simulated on the corridor with a train frequency of 6 trains/hour/track. It is striking that the difference in delay in case of a follow-up distance of 5 and 7.5 kilometers is not long compared to that of 15 kilometers. There is a big difference between 20 and 30 kilometers (from approximately 5,500 to approximately 8,500 minutes). The delay is monetized according to the cost method of the Austrian Railways (ÖBB).

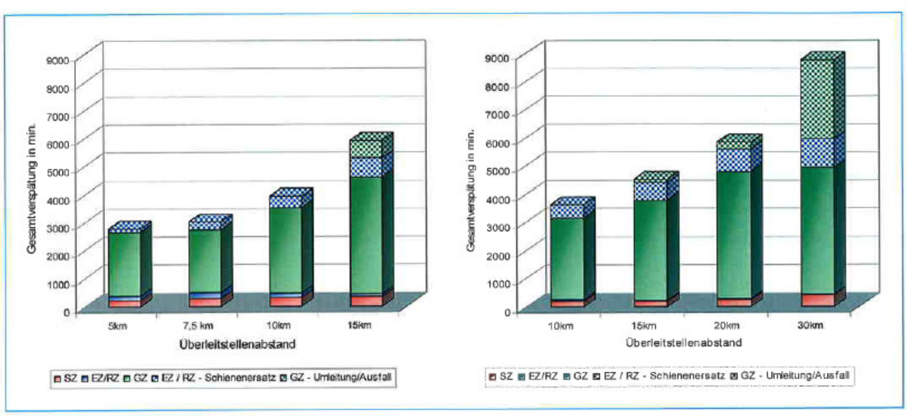


Figure 2.1 Delay at different distances between crossovers (Veit, 2006)

In Figure 2.2 the depreciation, maintenance and operational costs for the corridor with a train frequency of 6 trains/hour/track are listed and plotted against the distance between crossovers. The minimum is the optimum follow-up distance.

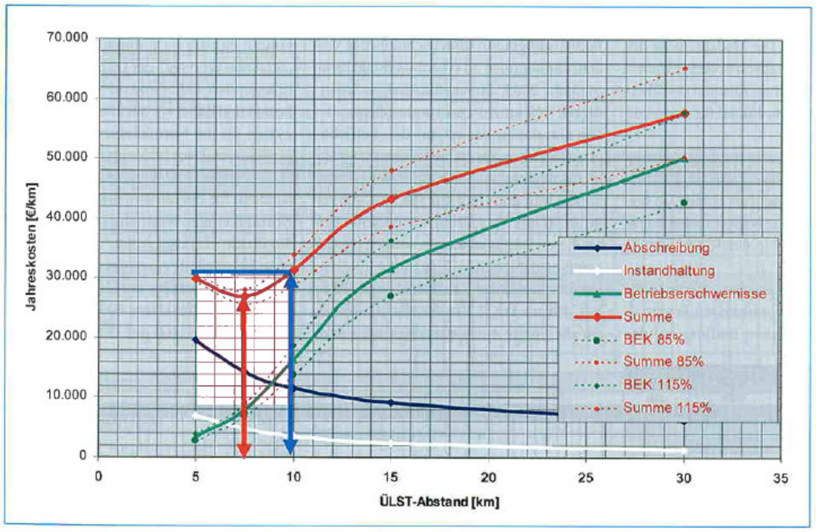


Figure 2.2 Annual total costs at different distances between crossovers (Veit, 2006)

Veit concludes that the optimum is dependent on the train frequency. In case of 6 and 4 trains/hour/track the optimal distance between crossovers is 7.5 kilometers (Figure 2.2). For a train frequency of 2 trains/hour/track this value appears to be approximately 10 kilometers. It is not always possible to implement crossovers at exactly these distances because of the different distances between stations. Therefore, Veit recommends implementing crossovers in case of a train frequency of 6 trains/hour/track, a follow-up distance of no more than 10 kilometers and for a train frequency of 4 trains/hour/track, a follow-up distance of 13 kilometers.

2.2.2 Optimal Distance Between Crossovers in Germany

A similar study was conducted by Steinborn et al. (2007) but applied to two-track sections in Germany. Their study is more extensive than that of Veit because more corridors were analyzed and except for different train frequencies also different types and combinations of train services were analyzed. Table 2.3 gives an overview of the four characteristic corridors.

Table 2.3 Corridors and characteristics Germany

Corridor	**Train service**	**Max. speed (km/hour)**	**Train frequency (trains/hour/track)**
Berlin-Spandau-Oebisfelde (P300)	High speed line passenger transport	300	7
Berlin-Anhalter-Bitterfeld (P230)	Mainly passenger transport	230	5
Halle-Großheringen (M160)	Mixed train traffic	160	5
Halle-Sangerhausen (G120)	Priority freight transport	120	5

According to the study of Steinborn et al. delay increases exponentially with an increasing distance between crossovers. This is assumed for an average train frequency of 5 trains/hour/track (mixed train traffic) during a 1-hour disruption (Figure 2.3).

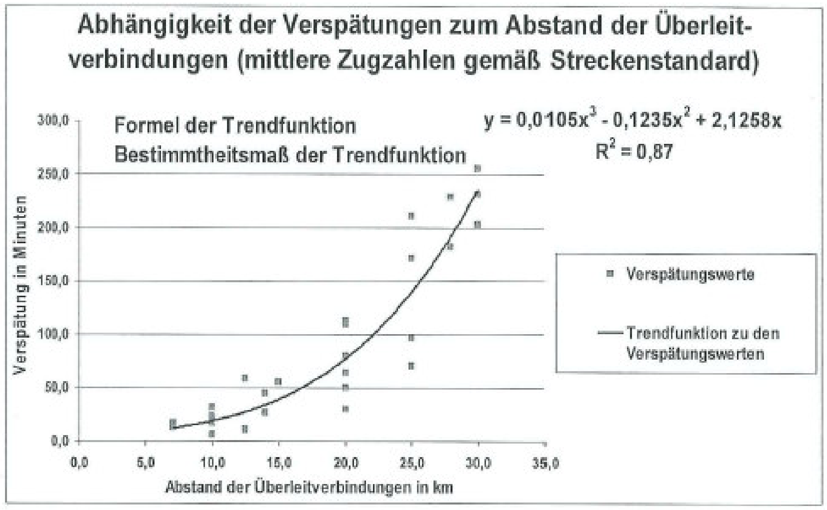
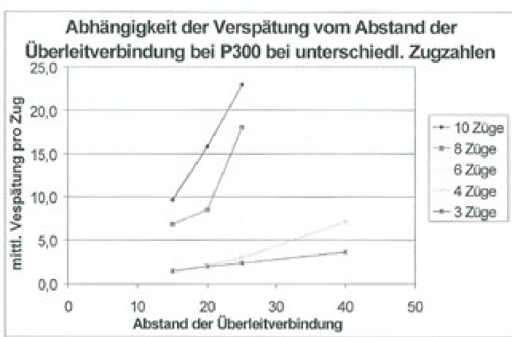


Figure 2.3 Delay at different distances between crossovers (Steinborn et al., 2007)

Steinborn et al. conclude that in the case of disruption with a maximum duration of 1-hour a distance of maximal 10 kilometers between crossovers creates an acceptable increase in delay. For a lower train frequency longer follow-up distance–a maximum of 14 kilometers–is acceptable. These values are comparable with the results of Veit's research.

In Figure 2.4a the influence of different train frequencies can be seen. Just as Veit concludes in his research, Steinborn et al. conclude that a higher train frequency causes a larger delay. The longer the distance between consecutive crossovers the larger the delay will be in case of a 1-hour disruption. It is noteworthy that the difference in delay between 3 and 4 trains/hour/track is not very big compared to the difference between 8 and 10 trains/hour/track.



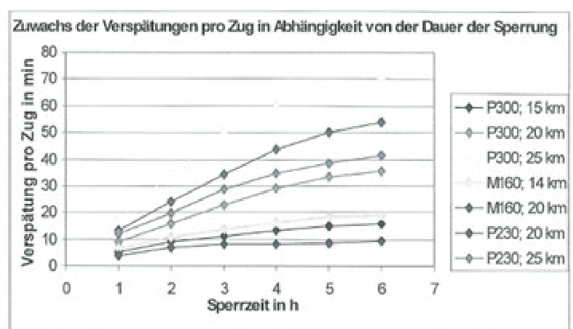


Figure 2.4a Different train frequencies Figure 2.4b Difference duration of disruption
(Steinborn et al., 2007)

The effect of different distances between crossovers for different duration of disruption for several train services is shown in Figure 2.4b. According to Steinborn et al., disruptions that last 1-hour are the most common. They conclude that the longer the disruption the larger the delay. This delay is larger when the follow-up distance of crossovers is longer. For crossovers on every 20 and 25 kilometers the delay increases faster–especially between disruptions of 1- and 4-hours–rather than crossovers on every 15 kilometers. In the latter, the difference in delay between disruptions of 1- and 6-hours is less pronounced.

Steinborn et al. have also investigated the case that there are no crossovers–called the 'Japanese method'. Then, in the event of disruption in one direction (partial obstruction), train service cannot be rerouted in the opposite travel direction. The impaired direction must wait until disruption has been dissolved.

It can be concluded that a follow-up distance of 30 kilometers is the limit. If the spacing is shorter than 30 kilometers then the use of crossovers will provide a smaller delay (in the case of a mixed train service with a frequency of 6 trains/day/track). If the follow-up distances are longer than 30 kilometers then the 'Japanese method' delivers a smaller delay.

To monetize the effect of crossovers Steinborn et al. have defined the costs as follows:

- Delay costs without crossovers–'Japanese method'
- Delay costs with use of crossovers
- Infrastructure costs for investment and maintenance of crossovers
- Delay costs due to malfunction of the crossovers

In Figure 2.5 the costs are depicted. In the case of a longer distance between crossovers, the expenditure (Aufwand) will first decrease and then increase. While the yields (Nutzen) continue to decrease when the distance between crossovers becomes longer. The intersection is approximately at 14 kilometers. When the distances between crossovers are shorter, the infrastructure costs are higher and the result (Ergebnis) is negative. At long distances between crossovers, the revenues are lower than in case of the 'Japanese method' and therefore provide also a negative result.

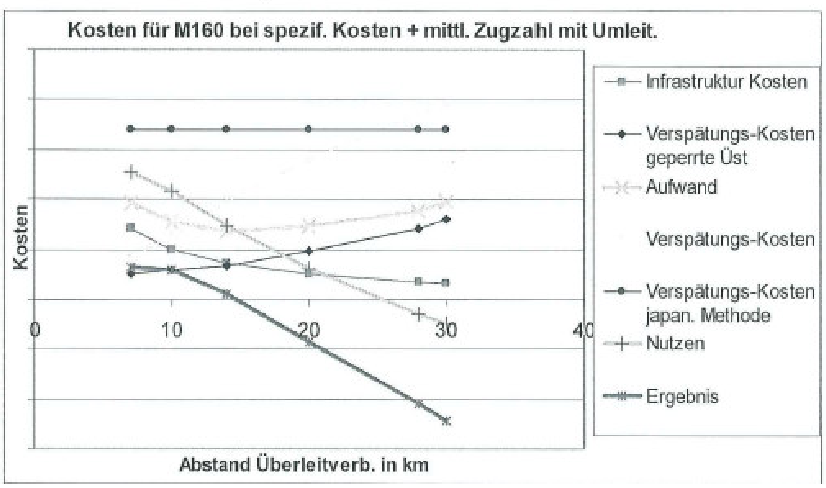


Figure 2.5 Costs and result (Steinborn et al., 2007)

Steinborn et al. add that prolonged disruptions lead to high delay costs. In fact it is worthwhile placing crossovers at smaller distances. In the current situation, crossovers are placed at a longer distance from one another.

2.3 Impact of Crossover Locations on Bus Bridging in Australia

Recent research has also been done about the impact of crossover locations on bus bridging in case of disruption. Pender et al. (2011) analyzed the Sandringham Line (Sandringham-Melbourne City v.v.) on the Metropolitan rail network in Melbourne, Australia. It is not common practice in the Metropolitan area of Melbourne to use left track (on double track sections) in case of disruption because of safety and logistical issues. Instead, alternative public transit is used to replace train operations, so-called bus bridging. Therefore, crossovers are used to return trains at the station that acts temporary as a terminus while bus bridging is used between stations on the disrupted corridor.

To investigate the impact of crossover locations, Pender et al. (2011) modeled three scenarios wherein a disruption between Elsternwick and Sandringham occurred. In the current situation (base case) there is bus bridging between Elsternwick and Sandringham. Train operations are still possible between Elsternwick and Melbourne City because at Elsternwick a crossover is available. In the three scenarios, one crossover was added on three different stations in between Elsternwick and Sandringham (not cumulative). Subsequent, the scenarios were compared with the base case. The estimations are based on Net Present Values of user costs of bus bridging (extra travel time), operator costs of bus bridging (bus services) and costs of new crossovers (capital and installation costs).

The authors conclude that when an additional crossover is implemented, user and operator costs reduce and that the closer a new crossover is located to the disruption, the larger the user and operator benefits (1.8 million Australian dollar over 30 years and with a discount rate of 3%). Hence, additional crossovers that assist bus bridging result in a win-win improvement for users and operator.

Furthermore, they did a sensitivity analysis which contains different disruption frequencies, passenger volumes and disruption locations along the corridor Elsternwick-Sandringham. At least three unplanned disruptions per year are needed for a positive Cost Benefit Analysis (CBA) for all three scenarios. If there is only one unplanned disruption it is not beneficial for any of the scenarios. With regard to passenger volume, they conclude that if 60% or more of a train is loaded, it is beneficial. If the load is 20% or less, it is not beneficial for any of the scenarios. The latter reinforces the conclusion that the closer a crossover is placed at the disruption, the higher the cost benefit ratio.

Finally, Pender et al. (2011) argue that adding more crossovers also increases the chance of disruptions which is an important reason why a majority of railway operators are careful in implementing crossovers. Moreover, in Australia it is common practice to remove crossovers once they reach the end of life-cycle instead of replacing them.

2.4 Conclusions: Literature Review

In the literature there are different opinions in how to achieve a higher capacity, reliability and robustness of the Dutch railway system. Weeda et al. focus on simplifying the railway network while Hansen et al. focus more on technical improvements such as implementing information and decision support system and the signaling system ERTMS/ETCS. It is disputable which of the solutions are the most efficient, but that is not the objective of this research. This research contributes in solving capacity and reliability problems of the Dutch railway system by focusing on the performance of specific switches i.e. crossovers in the railway network.

But some care has to be taken in comparing different railway systems and removing switches on basis of those conclusions. With regard to the article of Weeda et al. (2010), Utrecht Central Station is a different station compared with Tokyo Main Station. Utrecht Central Station is an important separate central node in the Dutch railway network. The station is divided into two parts which functions as a terminus (commuter trains) but also as a stop and transfer for continuing lines (long haul trains). Because of more entry and exit points there are a lot of bundled train flows/crossing trains. Therefore switches are needed at the entry and exit points of the station area.

In Figure 2.6 it can be seen that Tokyo Main Station functions as a stop for processing unbundled commuter and long haul trains (Shinkansen). But the station is one of the many stations along the rail beltway. All together they contribute to the railway performance of the Tokyo Metropolitan Area. The separate stations may have fewer switches than Utrecht Central Station but taking the rail beltway as a whole it does have more switches and also need those switches. These switches are situated at the entry and exit points of the rail beltway. Therefore, it is not correct to compare Utrecht Central Station with Tokyo Main Station only. Moreover, the Tokyo Metropolitan Area is a different railway system, it functions like a metro system and therefore train frequencies are much higher than at Utrecht Central Station.

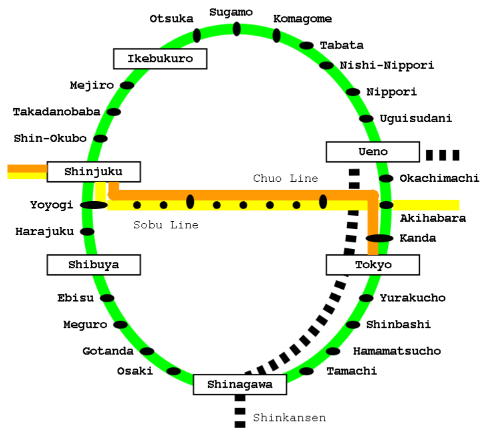


Figure 2.6 Rail beltway of Tokyo

Veit (2006) and Steinborn et al. (2007) developed a cost algorithm to determine the optimum distance between crossovers. The studies were performed in different countries (Austria and Germany) and the results correspond. They conclude in their researches that the optimal distance between crossovers is dependent on the train frequency and that when these distances are longer than 30 kilometers, delays are larger than if no crossovers are used. Besides, Pender et al. (2011) conclude from their research to the impact of crossover locations on bus bridging, when an additional crossover is implemented, user and operator costs reduce. Furthermore, the closer a new crossover is located to the disruption, the larger the user and operator benefits. But they also address the pitfall of implementing more crossovers: it increases the chance of disruptions due to crossover failures.

Yet, there is caution to say that these findings also apply to the Dutch situation. No similar studies have been found that apply to The Netherlands, while the need for quantitative information about the performance of crossovers in The Netherlands has grown. The question arises if crossovers that are only used in case of disruption need to be removed. This research is intended to fill this knowledge gap by investigating the performance of crossovers in The Netherlands for two typical corridors.

3 Railway System

The railway system is a broad concept. Different stakeholders are active who all have their own objectives and measures to obtain their goals. It is important to distinguish the contradictions and ambiguity in order to understand the performance of the railway system and the different thoughts about the role of crossovers in the railway system. Therefore, first the organization of ProRail i.e. Traffic Control department, is described (Paragraph 3.1) followed by the explanation of several important factors in Paragraph 3.2. In Paragraph 3.3 the subsystems of the railway system are elaborated. Then, in Paragraph 3.4 the processes and relations–in particular the role of crossovers–within the railway system are explained. In Paragraph 3.5 the network of stakeholders is described. Finally, in Paragraph 3.6 some conclusions are given.

3.1 Organization ProRail and Traffic Control

This research is performed for ProRail–in particular the department of Traffic Control. ProRail is the owner and manager of the rail infrastructure in The Netherlands and acts on behalf of the Dutch State. ProRail is responsible for construction, maintenance and management of rail infrastructure covering 7,002 kilometers (ProRail, 2012b) and includes tunnels, railroad crossings, catenaries, signals, switches/crossovers and stations. In addition, ProRail is responsible for the allocation of rail infrastructure capacity by delivering train paths. It participates together with other rail stakeholders in generating solutions to mobility issues (ProRail, 2010b). Recently, ProRail repelled its travel information department which was adopted by NS. Figure 3.1 shows the organizational chart of ProRail.

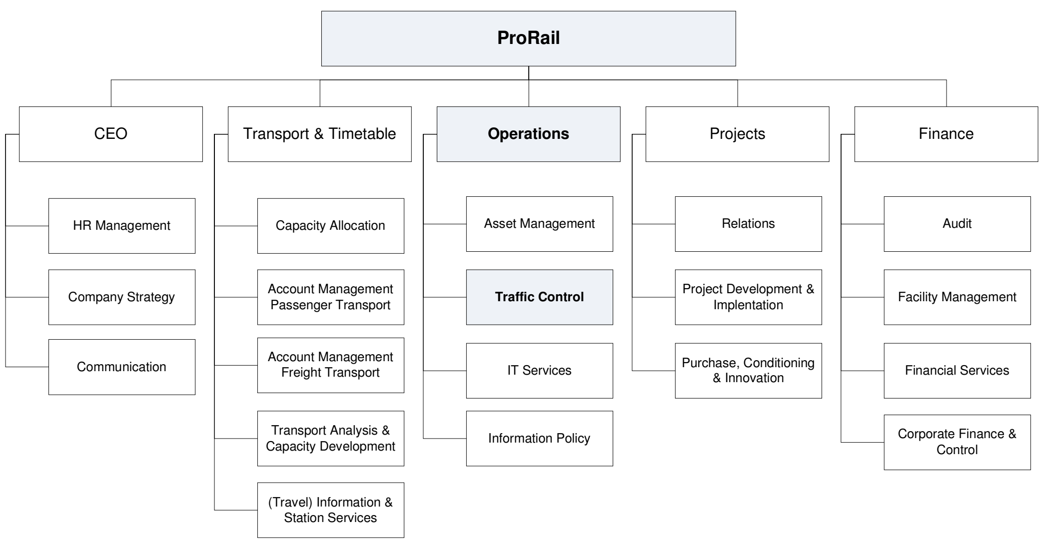


Figure 3.1 Organizational chart of ProRail

ProRail's Traffic Control department is responsible for the operational division of the rail infrastructure. Its tasks include the following (ProRail, 2010b):

- Assign rail infrastructure capacity in the last hours (within 36 hours) before execution.
- Adjust the allocation of rail infrastructure capacity in case of disturbances.
- Disclose rail infrastructure capacity by means of safe routes and time-space paths according to the (adjusted) rail infrastructure allocation.
- Coordinate and direct disruptions on and around the track (including preparation and evaluation).
- Inform train operators about the current operations in the railway network.

- Provide information in an objective and neutral manner that arise from the cooperation between government, railway manager and train operators.

The execution of these processes is organized in a structured form consisting of the LVL (Landelijke Verkeersleiding) and the DVL (Decentrale Verkeersleiding). Traffic managers (verkeersleiders) are spread over the LVL and several DVL's. Traffic operators (treindienstleiders) are spread over 13 Traffic Control Posts (Table 3.1).

Table 3.1 Traffic Control locations

Regions	**LVL**	**DVL/Traffic Control Posts**
Till 2010	Utrecht (together with the OCCR)	Alkmaar (Amr)
- Northeast (NO)		Amersfoort (Amf)
- Randstad North (RN)		Amsterdam (Asd)
- Randstad South (RZ)		Arnhem (Ah)
- South (Z)		Den Haag (Gvc)
		Eindhoven (Ehv)
From 2010		Groningen (Gn)
- Randstad (RN & RZ)		Kijfhoek (Kfh) (originally from KeyRail)
- Region (NO & Z)		Maastricht (Mt)
		Roosendaal (Rsd)
		Rotterdam (Rtd)
		Utrecht (Ut)
		Zwolle (Zl)

The LVL optimizes the operations (control and rescheduling) within the last 36 hours on national level. The DVL optimizes the operations (control and rescheduling) within the last 36 hours in its control area. In fact, the LVL determines measures on a strategic level while the DVL determines measures on a tactical and operational level. The LVL can overrule decisions of the DVL (ProRail, 2010b). In Figure 3.2 depicts the organizational structure of Traffic Control. The dotted lines are hierarchical relations while the other lines are operational relations.

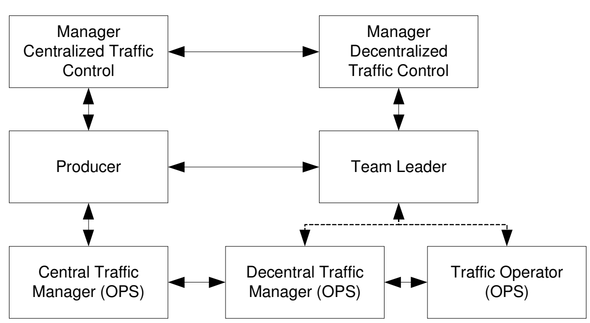


Figure 3.2 Organizational structure of ProRail Traffic Control (ProRail, 2010b)

Recently, the OCCR (Operationele Controle Centrum Rail) was founded. There was need for better cooperation between different train operators (and railway manager) in case of disruptions. It is more efficient if all stakeholders work together at one location. The OCCR is located in the same building as the LVL and handles disruptions on 24/7 basis. ProRail Incident Management is a division of ProRail Traffic Control located in the OCCR.

3.2 Reliability and Robustness

Reliability and robustness of the railway system are frequently used terms. The question arises what is meant by a reliable and robust railway system. Moreover, reliability is often being associated with robustness. In literature several explanations are given, which are discussed briefly.

Reliability. Hansen and Pachl (2008) have a general definition of reliability which is: the ability of a system or component to perform as designed. Immers et al. (2004) look at passenger reliability. According to them, reliability is the extent to which travelers can estimate their travel time with some certainty. Certainty is determined by the expected travel time, the variation of travel time, the stability of travel time, the available travel information and the alternatives the traveler has. Van Oort and Boterman (2009) argue that reliability is the agreement between the promised service (according to the timetable) and the offered service (real-time operation). Increasing reliability can be done by either adapting the timetable or adapting the operations. For instance, adapting the timetable by means of increased in-vehicle times, results in a higher reliability since the occurrence of a delay will be minimized. But it will decrease the average in-vehicle speed which results in lower utilization of the railway network (lower frequency). This is not always desirable because capacity is scarce while demand is growing. Eventually, they state that there is a closed loop relation between reliability and demand: a higher reliability leads to a higher demand since unreliability leads to a decrease of passengers. Besides the in-vehicle travel time, the waiting time is also of importance for a reliable railway system. In case of delay the waiting time will increase. One minute waiting time will be experienced as 1.5 minute in-vehicle time. Hence, Van Oort and Boterman (2009) conclude that waiting time has a stronger effect on reliability and should therefore be included.

Robustness. Savelberg and Bakker (2010) argue that there are two ways of interpreting the robustness: from a supply (railway manager and train operator) or demand (passenger) point of view. From a supply viewpoint they use the definition: making the network less vulnerable for disturbances. Important factors are to prevent disturbances that lead to disruptions and to minimize the effects of disruptions. From a demand viewpoint they use as definition of robustness: the extent to which extreme travel times–caused by incidents–are prevented. Therefore, they state that robustness is part of reliability. Since large disturbances frequently lead to train failure, availability is synonymous with robustness according to Savelberg and Bakker (2010). Hansen and Pachl (2008) have a more formal but comparable definition of robustness: the ability of a system or component to withstand model errors, parameter variations or changes in operational conditions.

It can be concluded that the explanation of reliability and robustness highly depend on the kind of (sub)system it is intended for. Finally, reliability and robustness are also more and more seen from a demand (passenger) perspective and not only from a supply (railway manager and train operator) perspective. The next paragraph describes the subsystems and terms for each subsystem are further explained.

3.3 Subsystems: Infrastructure, Timetable and Operations

The railway system can be divided into three subsystems. Reliability and robustness are used in all subsystems but have different consequences. In addition, since the separation of rail infrastructure (ProRail) and exploitation (different train operators such as NS, Arriva etc.) the subsystems got different responsible stakeholders, while before there was only one integrated railway company (NS) which was responsible for all subsystems. Figure 3.3 depicts the subsystems and its relations, including the responsible stakeholder for each specific task.

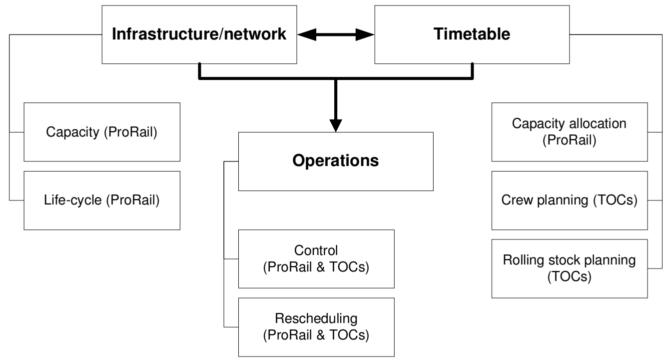


Figure 3.3 Railway system

ProRail is solely responsible for the rail infrastructure or railway network. The timetable or the scheduled processes in the railway network consists of the capacity allocation which is done by ProRail and the planning of crew and rolling stock which is done by different train operators. The operations or the real-time processes in the railway network can be divided into the control (daily operations) and rescheduling (disruption management) in case of incidents. ProRail is responsible for traffic control (control and rescheduling) but there is close collaboration with train operators (control and rescheduling of crew and rolling stock).

In Figure 3.4 important terms of the different subsystems are depicted. The blue colored blocks are terms concerned with ProRail and are further elaborated in the next three subparagraphs. The other terms primary concern train operators but they will also determine the performance of the railway system and therefore are briefly explained as well.

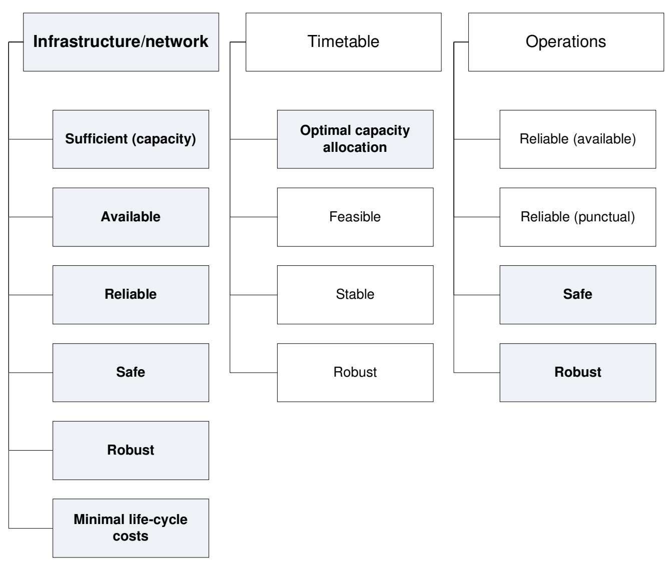


Figure 3.4 Objectives of the subsystems

3.3.1 Infrastructure/Network

Sufficient (capacity). It is necessary to have sufficient rail infrastructure (capacity) in order to fulfill the demand of train operators (timetable). Capacity is defined as the maximum number of trains per hour or per day per track. Capacity is mainly dependent on the rail infrastructure but also on the timetable and the characteristics of the rolling stock (Hansen et al., 2012). There is a difference between the theoretical and practical capacity. The theoretical capacity is defined by the minimum headway time between consecutive trains. The practical capacity takes account of timetable pattern, time supplements and buffer times (slack in the timetable). If the railway network does not meet the demand it must be reorganized. There are two ways to increase capacity. Obvious, new infrastructure increases capacity but requires high investments. An optimal utilization of the current rail infrastructure is a more feasible option and requires rescheduling of all subsystems: redesigning the railway network and/or adjusting allocation of rail infrastructure and/or train operators adjusting their timetable etc.

Safe. The safety of the railway network is dependent on the quality of the railway track, interlocking and signaling system. Failure of these systems can lead to major accidents in the railway network but the interlocking and signaling system is designed according to fail safe principles and therefore safety is preserved well. Preventive maintenance (on-time and frequent maintenance) will lower the chance of failure of these systems. Driver behavior mainly in station areas causes more unsafe situations.

Available. There is a clear distinction between the availability and the reliability of rail infrastructure. Availability and reliability of the railway network are often used interchangeably while measuring is slightly different. Availability is defined as the percentage of time that the railway network is available for train services as a result of rail infrastructure related disturbances or exceeded scheduled times for maintenance. From 2005 on, the availability is above 99% (Hansen et al., 2012).

Reliable. ProRail defines reliability of rail infrastructure as the percentage of delivered train paths from the originally scheduled train paths. In 2010 the reliability was 97% (Hansen et al., 2012).

Robust. A robust railway network is a rail infrastructure with minimum disturbances. Another important factor that creates robustness of the railway network is flexibility. A railway network is flexible when there are possibilities to reroute trains in order to minimize delays in case of disruption. Switches and crossovers allow rerouting. In particular crossovers create single-track grids such that trains on the affected track are able to continue on the opposite track.

Minimum life-cycle costs. ProRail aims at realizing its processes with minimum life-cycle costs. Minimum life-cycle costs are the costs from beginning to end of life of railway network elements: minimum development and realization costs, minimum maintenance and depreciation costs and eventually minimum costs for removal.

3.3.2 Timetable

Optimal capacity allocation. With respect to the timetable, an optimal allocation of train paths is necessary in order to satisfy the requests of train operators and ensure daily operations. ProRail measures the quality of capacity allocation as the number of allowed train paths from the total number of requested train paths. From 2007, the allowed percentage is 99.7% (Hansen et al., 2012). In case of disruption of the requested train path, ProRail will offer an alternative such as train paths on other corridors or times. The percentage of alternative train paths is set on 60% for 2011 (Hansen et al., 2012).

Feasible. Timetables are designed by train operators. A timetable should be designed such that train operations are feasible. This implies that the constraints must not be violated. If the timetable is not feasible–for example too many trains scheduled on a particular corridor–then train operation is impossible without delays and dangerous situations caused by the timetable itself (and not by disruptions).

Stable. According to Hansen and Pachl (2008) the definition of stability is the ability of the timetable to compensate for delays and return to the desired state (normal operations). In case of disruption, the initial delay can settle in a finite time without adjusting the timetable. This can be realized by building some slack in the timetable through optimal scheduled time supplements and buffer times (Goverde, 2008).

Robust. First, to have a robust timetable it must be stable as described above. Furthermore, a timetable that has many bundling train flows i.e. many interdependencies, is more vulnerable and affects its robustness as well. Weeda et al. (2006) concluded that 55% of the non-punctual arrivals on the corridor Rotterdam-Dordrecht are caused by knock-on delays. Apart from unbundling of train flows/crossing trains, also effective crew and rolling stock scheduling contribute to a robust timetable.

3.3.3 Operations

Reliable (available). Reliability of train operations has different meanings and thus can be measured in two different ways: reliability in the sense of availability of trains operations and reliability in the sense in the sense of punctuality. Reliability of train operations according to NS is the percentage of trains that was actual operational from the total trains according to the timetable (availability). This percentage is around 98% (Hansen et al., 2012). But this is only determined in case of disturbances and not in case of an adapted timetable through scheduled maintenance.

Reliable (punctual). Another way of quantifying the reliability of train operations is done by the (train) punctuality. Train punctuality is the extent in which departure and arrival times correspond to the timetable. In The Netherlands this is measured by the percentage of trains that arrive within five minutes at 35 stations (Savelberg and Bakker, 2010), the method by NS. This method has the following shortcomings:

- Passenger load is not taken into account.

The measuring is based on the number of trains and not on the number of passengers. The passenger load of a train in peak hour is higher than outside peak hour. In peak hour the occurrence of a delay is higher. Therefore, punctuality will be less if passengers are taken into account instead of trains.

- Differences in value of time for passenger are not taken into account.

A large part of the passenger flows in peak hour are home-work/school related. Therefore, their travel time rate is higher than that of passengers outside the peak hour (more leisure travel).

- Does not include the effects on the door-to-door travel time of travelers.

Travelers could miss their connection and therefore their overall delay will become longer (waiting time). The waiting time should be included to measure reliability (van Oort and Boterman, 2009).

- Does not include trains that are cancelled due to disruption (availability).

When delays become too long, the respective train is often cancelled which means that it does not count in the punctuality statistics (but in the availability statistics).

- Does not include all stations.

The ProRail Monitoringsystem measures punctuality at 300 locations only.

The first three shortcomings could be solved by taking passenger instead of train punctuality. Actually, a new performance indicator for punctuality based on passenger punctuality is applied from 2011. The performance indicator is the percentage of successful train operations weighted by the number of affected passengers and the measured connections by transit passengers (Hansen et al., 2012).

Safe. Besides the physical/technical aspects (rail infrastructure) operational aspects determine the safety of the railway system. To have optimal train operations (control and rescheduling) ProRail must have an efficient internal (between the different traffic controllers) and external line of communications (towards train operators) which is an important aspect to avoid accidents and aggravation of accidents.

Robust. Operations that are robust can recover from disruption repeatedly and quickly (Immers et al., 2004). To have resilient train operations, the timetable must be stable. The resilience is determined by:

- The effectiveness of the disruption management process (chosen rescheduling).
- The response speed on disruption (quick and adequate measures). ProRail measures this by the FHT (Functie Herstel Tijd) which means the time necessary to recover from disruption and train operations are possible according to the timetable.

As mentioned earlier, a flexible railway network facilitates resilient train operations because by using switches (and alternative routes) to remove trains from the disrupted area, recovery time is less. Furthermore, a timetable with some slack through time supplements and buffer times can absorb small disturbances and can avoid or minimize delays in train operations. Therefore, it can be concluded that the terms of the subsystems highly depend on each other.

3.4 Process and Relations

It is necessary to get more insight into the influence of the railway network on the railway system– particularly the function and performance of crossovers, since they are primarily used for rescheduling. In order to do so, the following process has been put in place (see the conceptual diagram in Figure 3.5). The diagram is partly based on a diagram for car traffic designed by Immers et al. (2004) but is adapted and extended for train traffic. Factors that are italic are external factors for ProRail.

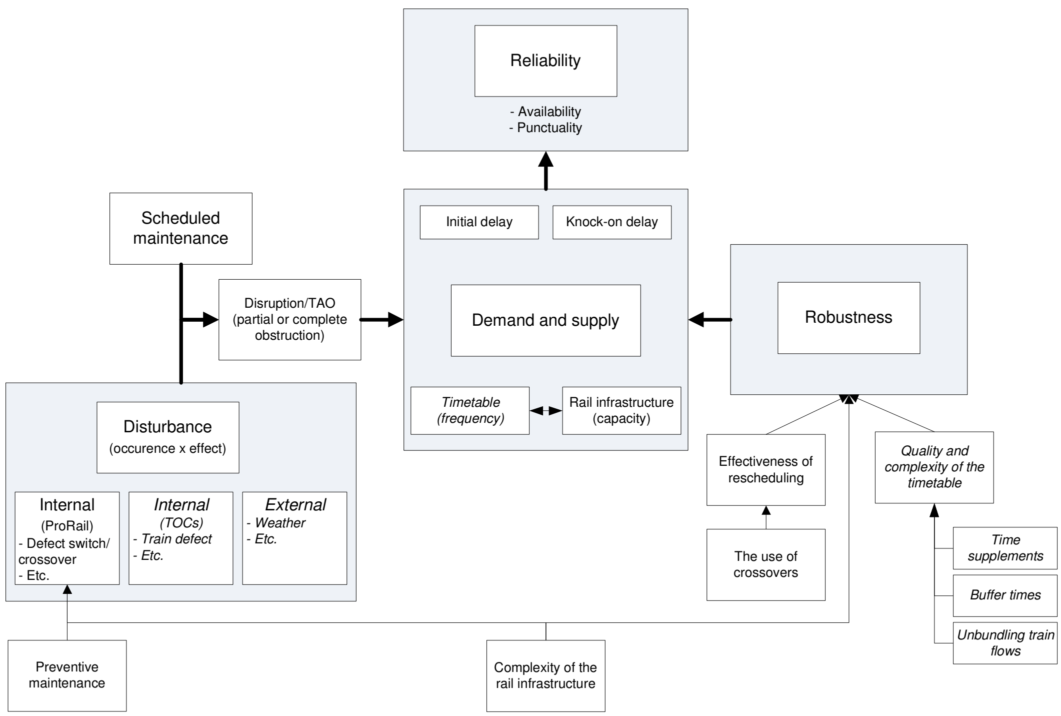


Figure 3.5 Railway system processes

Main process: disturbance/scheduled maintenance-demand/supply-robustness-reliability. A reliable railway network means high availability of train paths and time that the rail infrastructure is available for train operations. Disturbances and scheduled maintenance are factors that influence supply (availability of rail infrastructure). When the supply is insufficient to process the demand (timetable), reliability (availability and punctuality of the train service) will decrease. The robustness of the railway system determines what the effect (size and duration) of the disturbance or scheduled maintenance is on the ratio demand/supply and thus the reliability of the railway system. Important factors that determine the robustness of the railway system are the effectiveness of rescheduling, preventive maintenance, the complexity of the rail infrastructure and the quality and complexity of the timetable.

Disturbance and scheduled maintenance. Disturbance can be quantified as the occurrence of a disturbance multiplied by the effect of a disturbance. The occurrence of a disturbance can be divided into disturbances which ProRail and train operators can be accounted for and therefore can be influenced/prevented by ProRail (this is rail infrastructure related as failure of switches/crossovers and signals etc.) and by train operators (defect train etc.). The second group is disturbances caused by external circumstances (weather etc.). In most cases disturbances and scheduled maintenance lead to disruptions which affect the train service (Treindienst Aantastende Onregelmatigheid/TAO).

The effect of a delay can be divided in size and duration. Small disturbances do not always lead to delays or only small delays that do not have a high impact on the railway system. For example a train that departs a few minutes late. Often, these small disturbances do not lead to delays at all because they could be absorbed by the timetable (time supplements and buffer times). In some cases the disturbance only affects one train (initial delay) or following trains (small knock-on delay) and could be solved by the timetable itself or by light dispatching measures. Large disruptions such as signal failure lead to high initial and consequently high knock-on delays (trains on other corridors are affected as well). Large disruptions need heavy dispatching measures/rescheduling such as cancelling, reversing and rerouting trains. The duration is also much longer. In case of scheduled maintenance the effect is predictable and rescheduling can be done at an earlier stage. It depends on the size of disruption which kind of rescheduling would be necessary.

Partial and complete obstructions. Disturbances and scheduled maintenance often cause disruptions (TAOs). There are two forms of disruptions: partial obstruction–disruption in one direction, caused for example by signal failure, broken train etc.; complete obstruction–disruption in both directions. In this case train traffic is impossible. For example, a train collision or scheduled maintenance of a crossover (depending on the type) causes a complete obstruction. But a temporary speed restriction (TSR) caused by someone who walks along the track is also a disruption.

Quality and complexity of the timetable. A complex timetable influences the robustness of the railway system. A complex timetable is a train service of high frequencies (needing more frequent maintenance of rail infrastructure), many bundled train flows/crossing trains as a result of current rail infrastructure and complex crew and rolling stock scheduling. The unreliability will be higher if the timetable is complex since the robustness will be lower. Improving the quality of the timetable through an optimal allocation of time supplements and buffer times may improve the robustness of the timetable but only against small disturbances/disruptions (Kroon et al., 2008). In case of large disruptions, disruption management is needed.

Effectiveness of rescheduling. In case of disruption the effectiveness of rescheduling becomes very important. It has influence on the robustness (resilience). The effectiveness of the disruption management process is determined by the coordination between the different stakeholders and the effectiveness of the chosen rescheduling. Important factors are the speed of the response on the disruption and the possibility of rerouting trains (infrastructure related).

Preventive maintenance. Timely and frequent maintenance on the rail infrastructure minimizes the chance of disturbance. In Japan they apply preventive maintenance (higher maintenance costs) to minimize the occurrence of disturbance cause by defect rail infrastructure. A trade-off is made by extra (preventive) maintenance costs on one hand and costs caused by disturbances on the other.

Complexity of the rail infrastructure. The second factor that influences the chances of disturbance is the complexity of the rail infrastructure. Switches and crossovers are sensitive for disturbances compared to only straight forward rails. Moreover, they require maintenance more frequently which costs more. The more switches/crossovers, the higher the chance of disturbance. A simple rail lay-out is more resistant for disturbances (availability). In most cases failure of a switch results in delay–affecting the train service (TAO). The time of failure is also a factor that determines the delay. When a failure happens at night time, the repair can be done before morning peak hours. On the other hand, a complex rail infrastructure is more flexible (robust) because in case of disruptions rerouting is possible.

The use of crossovers. Finally to come to the role of crossovers in the process, a clear dilemma exists. A simple physical network–a network with few crossovers–is more resistant to disturbances that are caused by defect rail infrastructure and improves the reliability and availability of the railway network and system. Besides, it has lower maintenance costs. But less crossovers gives few opportunities to reroute trains in case of disruption and therefore negatively affect the robustness (flexibility) and consequently the reliability of the railway system.

It can be concluded that the subsystems highly depend on each other and determine together the quality of the railway system. The complexity of rail infrastructure is strongly related to the complexity of the timetable. Herrmann (2006) concludes in his research conducted in the region of Bern (Switzerland) that the more complex a timetable becomes (tighter), the more important is the lay-out of the railway network (suitable track topologies) with respect to reliable and robust operations. Unfortunately, he does not explain how suitable rescheduling in rail infrastructure is obtained. Finally, there is a trade-off in having a complex or simple rail infrastructure (amount of crossovers): the chance of rail infrastructure related disturbances versus having flexibility in the handling of disruptions.

3.5 Network of Stakeholders

In the development of a generic approach for crossovers in the railway system it is important to take the objectives of other stakeholders into account since it determines the success of the policy. In the following subparagraphs stakeholders and their formal relationships are discussed; the internal conflicting objectives of ProRail are explained and finally, the external conflicting objectives of other stakeholders are described.

3.5.1 Stakeholders and Formal Relationships

Since 1995, the ownership and exploitation of the Dutch railway system has been gradually separated according to European guideline 91/440. The idea behind that is that more competition on and about the railway can be realized (Figure 3.6). Before, the railway system was owned and exploited by one railway company NS. From then on, ownership and management (traffic control) of the railway network was placed in a new organization ProRail (in 2003) which got a concession for 10 years (in 2005). The exploitation was transferred to public and private train operators (TOCs). NS–an independent public train operator–got the exploitation for the main railway network for 10 years (in 2005). The remainder of the railway network was divided amongst three other private train operators: Arriva, Connexxion, Syntus and Veolia Transport. Furthermore, there are some international train operators using the main railway network (Fyra, Thalys, ICE) in which NS has a share. Finally, there are 15 private freight train operators using the railway network and a few train operators related for maintenance.

Figure 3.6 Train operators in The Netherlands (ProRail, 2010a)

In Figure 3.7 the stakeholders and their formal relationships are depicted. The so-called constitutional triangle is the relation between the Ministry of Infrastructure and Environment (I&E) (Dutch State), ProRail (owner and manager) and NS (train operator). The Ministry of I&E acts on behalf of the society and ensures that there is sufficient access to public transit, that it is affordable for people and that it is efficient, safe and reliable by means of concessions. It is controlled by the parliament (regulations) and the European Union (guidelines).

ProRail and the Ministry of I&E. The Ministry of I&E establishes the (main) requirements for management of the railway network and delegates management concession for a certain period of time (10 years). ProRail processes the requirements in a management plan that must be approved and will be monitored by the Ministry. These requirements are measured through key performance indicators such as availability, punctuality etc. of the railway network. Furthermore, ProRail is subsidized by the Ministry. Thus there is a hierarchical and control relation.

NS and the Ministry of I&E. The same holds for the relationship with NS. The Ministry of I&E establishes the (main) requirements for exploitation of the main railway network and delegates transport concession for a certain period of time (10 years). NS processes the requirements in a transport plan that must be approved and will be monitored by the Ministry (control relation). NS also gets some subsidies from the Ministry but the relation is less hierarchical because it is an independent (public) train operator. These requirements are measured through key performance indicators such as availability, reliability etc. of the train operations. Regional authorities do the same but then for the regional railway network and regional train operators.

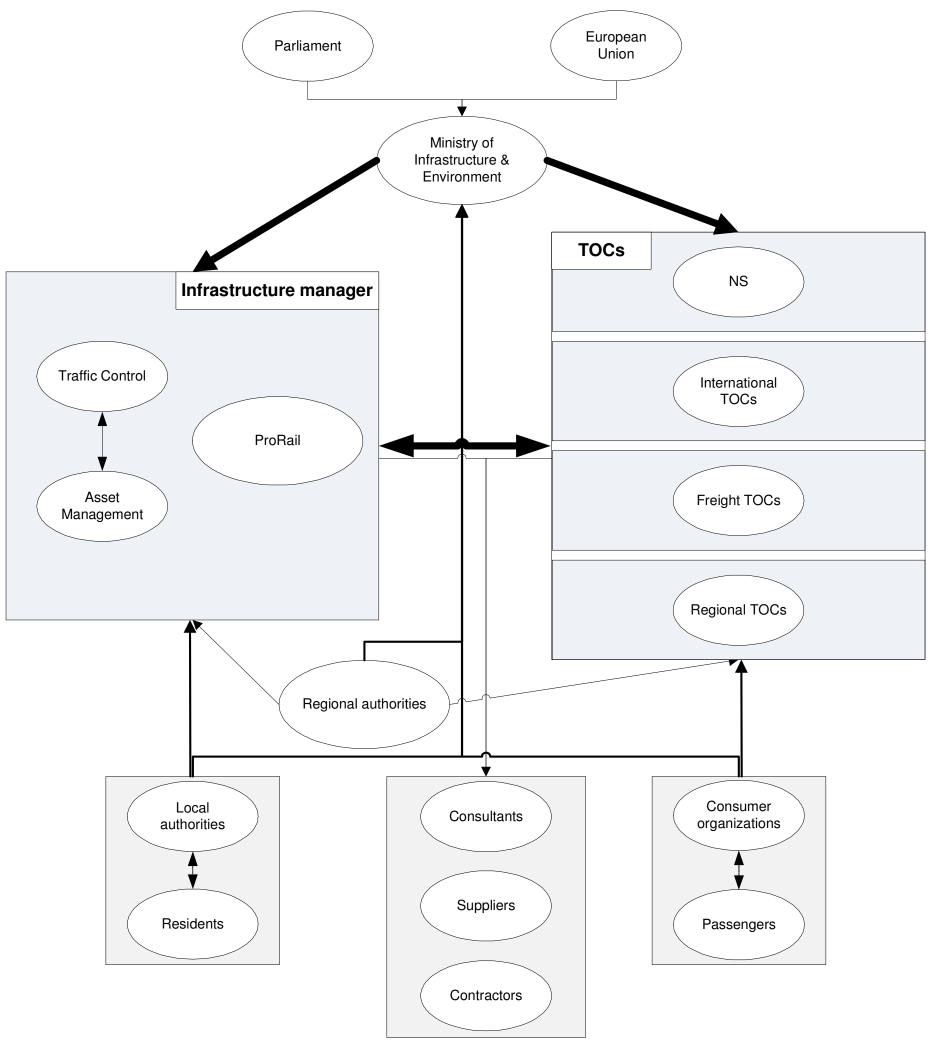


Figure 3.7 Stakeholders and their formal relationships

ProRail and NS (and other train operators). ProRail gives access agreements to the various train operators and allocates the capacity on the railway network. This is in close collaboration with train operators. NS has to share the main railway network and the regional train operators have to share the regional railway network with some freight train operators. Train operators have to pay users fees to ProRail. There is an influence relation between the stakeholders wherein grandfather rights also determine the allocation of the capacity.

Other formal relationships with ProRail. Relationship between ProRail and passengers is official through consumer organizations such as ROVER (which have a representative relation with passengers). Consumer organizations participate in discussions about station environment such as accessibility of platforms, quality of the travel information panels etc (control relation). Complaints about the quality of travel information are now addressed to NS since ProRail repel their travel information department to NS. Local authorities act on behalf of residents (representation relation) and have a control relation with ProRail. Local authorities participate in the planning for the surroundings in case of maintenance and in case of dangerous situations etc. Furthermore, regional authorities, local authorities and consumer organizations have a control relation with the Ministry of I&E. Finally, ProRail gives orders to consultants, suppliers of rail infrastructure and contractors through procurement (influence relation). However, in the latter case ProRail acts frequently in cooperation with TOCs.

3.5.2 Internal Conflicting Objectives

The main objectives of ProRail are to have sufficient and safe rail infrastructure that is available, reliable and robust to ensure efficient train operations (control and rescheduling) against minimum life-cycle costs. Because of the need for higher train frequencies more capacity is necessary and a better utilization of the railway network might be a feasible solution. There is increased interest in reducing the complexity of the current rail infrastructure. Since a major part of the crossovers are not used for the regular timetable, crossovers might be the first that can be removed without negative consequences for the railway system.

But there are some internal contradictions about this issue. The Asset Management department (Figure 3.1) that is involved in the management of switches argues that crossovers cause higher life-cycle costs. They require more often maintenance since they are more sensible for disturbances. Moreover, crossovers that have a failure affect the availability of the railway network which pay-off the requirements in the management plan. They also create flexibility for ProRail Traffic Control. In case of a disruption they could be used so delays can be prevented or be minimized and/or be solved quicker. Furthermore, without crossovers–specific IVO switches–the scheduling of maintenance is more complex and safety issues play a role as well for ProRail Asset Management. There are also costs for removing them and when a crossover is removed, it cannot easily be placed back without extra costs (purchase and implementing costs). It can be concluded that the internal contradictions are caused by the knowledge gap with respect to the performance of crossovers in the railway network.

3.5.3 External Conflicting Objectives

ProRail and NS. ProRail and NS aim at further improvement of the reliability of the railway system while meeting the projected increasing demand. But they have different opinions in how to achieve these goals. With respect to crossovers there is a clear contradiction. While ProRail aims at simplifying their railway network by removing crossovers, NS aims at retaining the crossovers since they create flexibility for the timetable and for operations, especially in disruption management of their crew and rolling stock (NS Transportbesturing/Transport Control). ProRail Traffic Control works in close collaboration with Transport Control of NS and other train operators. These also have influence in the choice for rescheduling because they have to fit their crew, rolling stock and also passengers.

ProRail and freight train operators. Freight train operators also want to operate during nighttime since the major part of their train paths are at night. They will be affected if scheduled maintenance is always during nighttime.

ProRail and other stakeholders. For passengers it is understandable that riding a crossover is not very comfortable. For residents in the surroundings of the track, trains that pass a crossover cause more noise. But these complaints are minor compared to the other objectives.

3.6 Conclusions: Railway System

Reliability and robustness of the railway system are frequently used terms. It can be concluded that the explanation of reliability and robustness highly depend on the kind of (sub)system it is intended for. The railway system can be divided into three subsystems: infrastructure/network, timetable and operations which are the responsibility of different stakeholders: ProRail and several train operators. Furthermore, it can be concluded that the subsystems highly depend on each other and determine together the quality of the railway system. The complexity of rail infrastructure is strongly related to the complexity of the timetable. Finally, there is a trade-off in having a complex or simple rail infrastructure (amount of crossovers): the chance of rail infrastructure related disturbances versus having flexibility in the handling of disruptions.

The most important stakeholders are the so-called constitutional triangle which is the Ministry of Infrastructure and Environment, ProRail and NS. Not only external conflicting objectives are presented between these stakeholders but also conflicting objectives within ProRail (for example ProRail Traffic Control vs. ProRail Asset Management) determine the vision regarding crossovers for rescheduling.

4 Processes of Rescheduling and Crossovers

In this chapter the primary process of rescheduling is explained (Paragraph 4.1) followed by an explanation of crossovers and its importance for rescheduling (Paragraph 4.2). Finally, Paragraph 4.3 gives a summary of the processes.

4.1 Rescheduling Process

Rescheduling or disruption management is the process of managing train operations in case of disruption (disturbances and scheduled maintenance)–in particular due to disturbances because it needs quick anticipation while scheduled maintenance can be managed in advance. Rescheduling of operations is executed by ProRail Traffic Control (Paragraph 3.1) in order to ensure optimal train operations and minimum delays. In Subparagraph 4.1.1 general rescheduling is explained while in Subparagraph 4.1.2 the process of applying VSM is explained. The new rescheduling philosophy of ProRail and NS is described in Subparagraph 4.1.3 and reviewed in Subparagraph 4.1.4. At last Subparagraph 4.1.5 summarizes rescheduling caused by scheduled maintenance.

4.1.1 General Rescheduling

When trains do not run according to the scheduled timetable rescheduling is often necessary. It depends on the severity of disruption which kind of rescheduling will apply. The classification of rescheduling is shown in Figure 4.1 according to Schaafsma (2001).

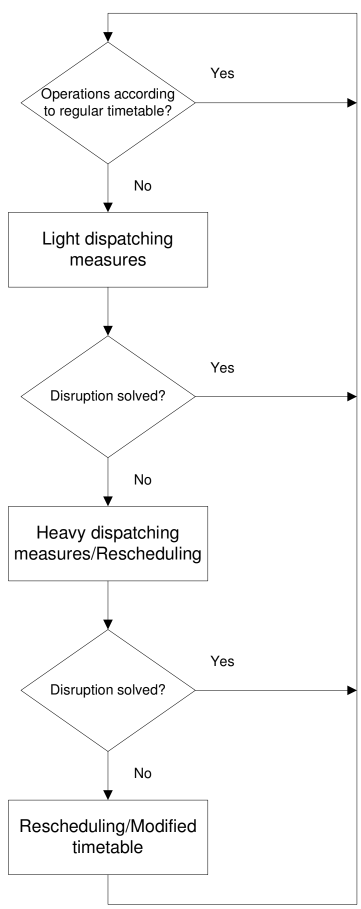


Figure 4.1 General rescheduling

If train operations differ from the timetable, first light dispatching measures will be implemented such as changing the train sequence. These kinds of measures are taken and implemented by ProRail Traffic Control and do not have any consequences on the quality of operations. If these measures are insufficient, heavy dispatching/rescheduling is necessary. The operations according to the timetable will be affected–for example connections between trains do not fit any longer. This kind of rescheduling is prearranged by ProRail Traffic Control and train operators (NS) in the so-called TAD (TreindienstAfhandelingsDocument). In case these kinds of rescheduling are not helpful because disruption is too severe, a temporarily modified timetable will be implemented as the most radical rescheduling. This is done by applying typical VSM. For most common disruptions VSM are made in collaboration with train operators (NS).

4.1.2 VSM Process

VSM has standardized the rescheduling which leads to faster implementation than when the choice is made by a convention of different stakeholders: ProRail Traffic Control and train operators (NS). Every corridor has a typical VSM-series. Annex A gives an overview. Furthermore, each corridor has different VSM depending on the kind of disruption that occurs on the particular corridor: complete or partial obstruction and at which location.

In case of disruption the traffic manager of the affected Traffic Control Post (DVL), or in the case of a larger area the traffic manager of the LVL, reports an IFB (InFrastructuurBeperking) in the ISVL5 system. ISVL5 is the general system to which stakeholders have access and make reports about the progress of disruption. In consultation with the traffic manager, the train operator (NS) indicates if and when a VSM starts. The traffic operators of the affected Traffic Control Post and other concerned Traffic Control Posts execute the VSM. In the remainder of the report the term traffic controller will be used as a synonym for traffic manager and traffic operator. Only if there is a specific difference a distinction is made.

If a complete obstruction occurs at a location on the corridor, the disruption can only be processed with a VSM that is designed for a complete obstruction. For partial obstructions however, there is a choice of processing it as partial obstruction, or as complete obstruction with the associated partial or complete VSM. Hence, there is flexibility in handling a partial obstruction for rescheduling (Figure 4.2).

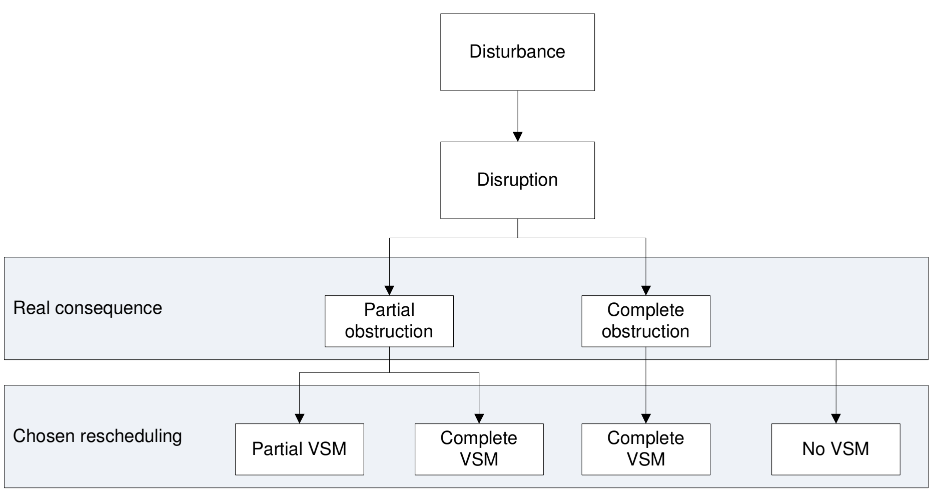


Figure 4.2 Consequence and rescheduling

After disruption occurs three different chronological phases can be distinguished. This is the so-called bathtub model (Figure 4.3):

- First phase
- VSM
- Reoccupation phase

First phase. When disruption occurs, first a call is made in the ISVL5 system. The severity of the disruption is estimated and which kind of measure should be taken: partial or complete VSM depending on the kind of obstruction. Sometimes no VSM is chosen. This is the case if disruption is not severe enough and other rescheduling: light or heavy dispatching is sufficient. If there is no appropriate VSM frequently another similar VSM will be applied (VSM with adjustments). The first phase is the most critical phase. It depends on the location and time but especially if the affected corridor and surroundings have a high train frequency it is a complete chaos. Appropriate and quick actions to remove trapped trains should be taken by traffic controllers before VSM can be implemented. Besides, experience of the traffic controller and also the track lay-out (availability of crossovers, return track etc.) which determines the possibilities to reroute and return trains, is a determining factor for efficient processing of the first phase. In some events there is no first phase. This is in case of scheduled maintenance or delayed scheduled maintenance–when daily train operations start.

VSM. Actually a VSM can be implemented correctly if trapped trains are removed from the site. If the VSM is implemented train operations run according to a modified timetable. In most events rescheduling is applied exactly according to the VSM. Sometimes it differs: if there is no correct VSM for the situation (VSM with adjustments). But mostly these adjustments are made by train operators (NS). During the VSM, trains can be operational (sometimes as a shuttle service), cancelled, rerouted, modified or inserted. When disruption is solved a call is made in the ISVL5 system and the reoccupation phase starts. Sometimes it is decided to continue the VSM long after disruption is solved. One of the reasons could be logistic problems of train operators during rescheduling.

Reoccupation phase. In the reoccupation phase, the disruption and the VSM are finished and normal train operations are slowly starting. This is gradually done; for example a train series that normally operate two times per hour is–in first instance–operational only one time per two hours and so on till normal schedule. This is done because of logistic problems of train operators during the reoccupation phase. Crew and rolling stock are frequently uneven divided over the railway network. It takes a while before the equilibrium is reached.

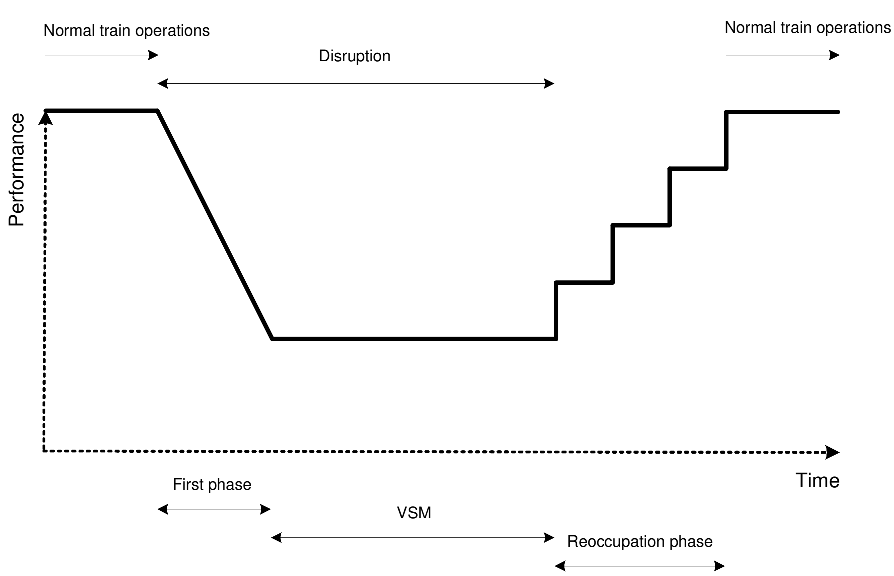


Figure 4.3 Bathtub model

4.1.3 New Rescheduling Philosophy

In recent years the strategy of ProRail and NS in case of disruption was to reschedule the operations such that a maximum of trains can continue the services according to the timetable. Nowadays it is difficult to maintain this strategy due to higher utilization of the railway network. As a consequence–even with rescheduling–more trains were cancelled and initial and knock-on delays became larger and longer. Frequently, rescheduling increased the problem instead of reducing it. Therefore, ProRail and NS developed a new strategy to tackle these problems (ProRail and NS, 2011). An overview of the philosophy can be seen in Table 4.1.

Table 4.1 Rescheduling philosophy (ProRail and NS, 2011)

Goal	Philosophy	Principle	Consequence
Careless journey	Prevent rescheduling	- Robust timetable - Minimum disturbances - Short FHT	
Quick solution in case of problem	Rescheduling to ensure optimal performance of a corridor	- Corridor control is responsible for processes on corridor - On time decision for rescheduling - Match demand (frequency) and supply (capacity) - Update control goals	- Cancel trains (preventive) - Order acceptation (rerouted trains, empty trains) - Overview actual train paths (disturbances, scheduled maintenance)
Constrained hindrance	Isolated delays (prevent knock-on delays)	- No corridor mixing when applying rescheduling that is normally handled differently - No rerouting of trains (only international trains) - Trains will not depart or only depart according to schedule - Rescheduling only at decoupling points	
	Focus rail infra on main function	- Rescheduling should not hinder the main function	
	Investments in rail infra for rescheduling only if Cost Benefit Analysis (CBA) is positive	- Rescheduling should use rail infra that is applied for the main function - Rescheduling only at decoupling or at bifurcations	

Decoupling points. When a disturbance occurs it often results in disruption. Rescheduling of operations is only done at decoupling points (ontkoppelpunten) which are large stations. In case of disruption IC- and stop train (sprinter) services will start and end at these stations. The disruption will be isolated and the recovery time will be shorter. Trains operate according to the regular timetable outside the disrupted area and trains that already entered the disrupted area (between two decoupling points) are terminated in most cases.

There are three types of decoupling points: decoupling points for IC-trains, for sprinters and reverse stations (note: stations that are no decoupling points i.e. small stations, are called stops) (ProRail, 2011a). A station that is defined as an IC-decoupling point (IC station) must be able to process IC-trains and sprinters in case of disruption while a station that is defined as a sprinter decoupling point (only sprinter station) must be able to process sprinters in case of disruption. Therefore a decoupling point for IC-trains is automatically a decoupling point for sprinters too. A reverse station is either an IC or sprinter station that must be able to process sprinters in case of disruption. However, it has fewer functions compared to the other two decoupling points. Freight trains will be adjusted through freight corridors if possible and otherwise they will be rerouted–only if they are on a primary freight route, in case of a secondary freight route they have to wait. It must be prevented that freight trains enter the mixed railway network in case of disruption. International trains will be rerouted. The tasks that the three types of decoupling points have to fulfill are depicted in Table 4.2.

Table 4.2 Functions of decoupling points (ProRail, 2011a)

	IC-decoupling point	**Sprinter decoupling point**	**Reverse stations**
Complete obstruction	- Receive passengers - Receive/return train crew - Reverse ending trains or a part of the trains while other trains proceed to the next (sprinter) decoupling point - Store of stranded/defect trains	- Receive passengers - Receive/return train crew - Reverse ending trains or a part of the trains while other trains proceed to the next (sprinter) decoupling point or reverse station	- Reverse part of the trains
Partial obstruction	- Transfer of a part of the trains to opposite track (single-track grids) - Reverse other trains	- Transfer of a part of the trains to opposite track (single-track grids) - Reverse other trains	n/a
Platform track obstruction	- Trains stop at another platform track of the same platform	- Trains stop at another platform track of the same platform	n/a
Larger delays	- Cancel/terminate trains (preventive) - Insert of new trains - Prepare trains - Change sequence of trains (slow trains will be overtaken by fast trains)	- Change sequence of trains (slow trains will be overtaken by fast trains)	n/a

An example of rescheduling. An example of such rescheduling is shown in the figures that follow. Figure 4.4a shows normal operations in both directions according to the timetable. The blue lines are IC-trains and the red ones are sprinters. IC-trains stop only at Station A and Station C whereas sprinters stop at all three stations and stops I, II, III, IV and V. When disruption occurs–in this example a complete obstruction between stop III and IV–Stations A and C function as an IC-decoupling point (Figure 4.4b). IC-trains reverse at these two stations. Passengers at Station A have the option of transferring to sprinters. These trains will continue with the same frequency towards Station B which functions as a sprinter decoupling point. In Figure 4.4c there are even shuttle services (lower frequency) that serve stop III and IV, just before the bottleneck. Passengers who want to travel beyond station A or C must take a detour with other train lines. A maximum of one hour is maintained for a detour. If the detour takes longer, passengers are transported to the last uncoupling point. From there they can choose to take alternative public transit or wait until disruption has been solved. Since some of the passengers will take a detour it is possible to continue to the last uncoupling point with lower train frequency (ProRail and NS, 2011).

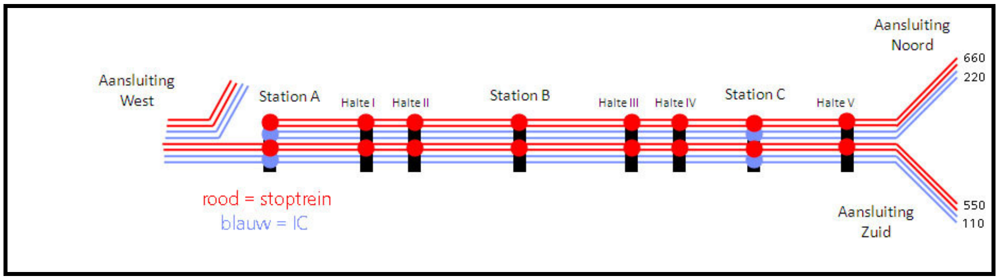


Figure 4.4a Normal train operations (ProRail and NS, 2011)

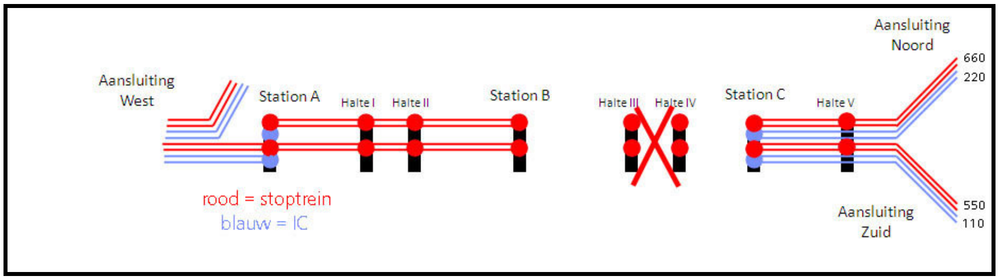


Figure 4.4b Complete obstruction between stop III and IV (ProRail and NS, 2011)

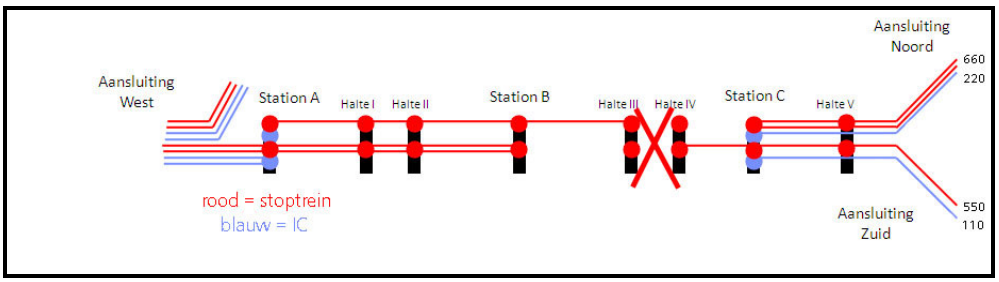


Figure 4.4c Complete obstruction with shuttle services to stop III and IV (ProRail and NS, 2011)

4.1.4 Review of the New Rescheduling Philosophy

It is questionable whether the new rescheduling philosophy is still sufficient in the long term. In the short term it has advantages above the current disruption strategy. However, in future utilization of the railway network will further increase and the new disruption management process might become unsuitable i.e. it needs to be adapted continuously. Introduction of new technologies (automation) in the railway system such as decision support systems in controlling and executing disruption management might be very helpful. Decision support systems give continuous feedback on actual train positions and optimal rescheduling to the traffic controller (Kecman et al., 2011). A decision support system is flexible and therefore more efficient as long term solution. Moreover, decision support systems give optimal solutions for rescheduling individual events and this information is instantly available to the traffic controller.

4.1.5 Rescheduling due to Scheduled Maintenance

Apart from disturbances scheduled maintenance also leads to disruptions in the railway network. The advantage of disruptions caused by scheduled maintenance is that the effect of disruption is more or less predictable and rescheduling can be organized at an earlier stage. A complete closure of the corridor creates the safest working conditions for contractors but this is–especially during daytime–not desirable since train operations have to be cancelled. Therefore, often partial closure of one direction is performed wherein limited train operations are possible by the use of crossovers–especially IVO switches (crossovers in between stations). If there are no crossovers at the specific corridor, rescheduling can be performed according to the new rescheduling philosophy. A disadvantage of the latter is that it is more complex because of fewer possibilities i.e. less flexibility.

4.2 Crossovers

First, the general classification of rail infrastructure is explained in Subparagraph 4.2.1 because with the new rescheduling philosophy the usage of crossovers will be different. Second, different types of crossovers are explained (Subparagraph 4.2.2). Furthermore, in Subparagraph 4.2.3 the advantages and disadvantages of crossovers in the railway network are explained. Finally, in Subparagraph 4.2.4 examples of rescheduling using crossovers are describe while in Subparagraph 4.2.5 the distribution of crossovers used for rescheduling are explained.

4.2.1 General Classification of Rail Infrastructure

With the new rescheduling philosophy the classification of rail infrastructure also changed. ProRail makes distinction between 'black', 'yellow', 'red' and 'blue' infrastructure (ProRail and NS, 2011). This classification will be implemented in the so-called 'Functional Map' (Functionele Kaart) but this tool is still in progress. 'Black' infrastructure is the infrastructure that is necessary to fulfill normal operations (according to the timetable, including shunting and access to/from yards). Additional infrastructure for rescheduling in case of a complete obstruction is called 'yellow' infrastructure. For partial obstructions, infrastructure that is necessary–besides 'black' and 'yellow' infrastructure–is called 'red' infrastructure. Ultimately, there is 'blue' infrastructure, necessary for platform track obstructions.

Typical rail infrastructure is necessary to reschedule train operations such as: crossovers, left track signaling, tracks for overtaking etc. For example, trains must be able to reverse through a platform track, crossover, or on the yard behind the decoupling point. Therefore crossovers are of importance at decoupling points. Crossovers are divided over all infrastructure categories but the majority is 'yellow' and 'red' infrastructure because crossovers are mainly used for rescheduling purposes. Figure 4.5 shows an example of rescheduling infrastructure in case of a complete obstruction between stop III and IV. Besides the 'black' infrastructure several 'yellow' infrastructure elements are necessary.

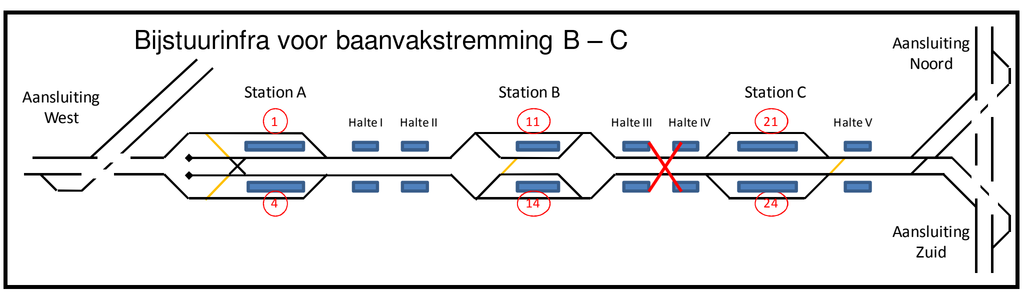


Figure 4.5 Potential rescheduling infrastructure for a complete obstruction between stop III and IV (ProRail and NS, 2011)

The new disruption management philosophy gives the opportunity to modify rail infrastructure. Crossovers that are not situated at decoupling points may be redundant. Removing underutilized and sensitive rail infrastructure results in a less complicated railway network–less costly and well focused on high frequent railway traffic. As a consequence removing these implies modification of rescheduling. However, there is a chance that removed crossovers are needed again when utilization of the railway network increases in the future.

4.2.2 Types of Crossovers

Function. A crossover is a pair of switches that connects two parallel tracks and enables transfer from one track to the other track (Figure 4.6). In most of the crossovers, the two switches are operating together at the same time and are indicated by the same number that consists of A or B.

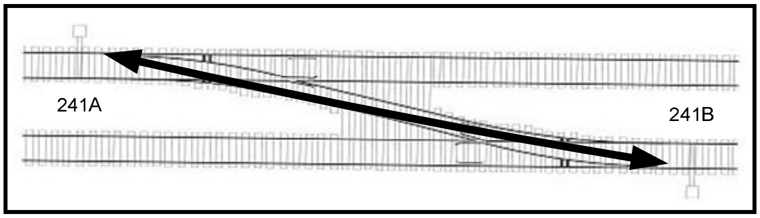


Figure 4.6 Pair of switches i.e. crossover

A disadvantage of these coupled switches is that if one of the switches does not work, the other does not work either–fail safe principle. The new generation of crossovers has two independently operating switches which have a unique number each. The advantage of the latter is that in case of a failure of one of the switches, the opposite switch can still function i.e. it only works in straightforward direction and trains on that particular track are able to continue their service–there is only a partial obstruction instead of a complete obstruction.

In general crossovers can be divided into two groups according to their function in the railway network. The first group of crossovers is used for the regular timetable and for rescheduling (in case of disturbances and scheduled maintenance); located at stations or near stations. They are used to separate arrival and departure of trains at a railway platform and make it possible for trains to reverse at stations. Because they are also used for the regular timetable they cannot be easily missed. The second group of crossovers is only used for rescheduling (in case of disturbances and scheduled maintenance) and is situated in between stations. They are used in case of a partial obstruction on a two-track section. The crossover ensures that the limited capacity can be used in both directions because transfer is possible (single-track grids). These crossovers are also known as IVO switches. IVO switches are primarily intended for rescheduling during scheduled maintenance but are also used in case of disturbances. Figure 4.7 shows this classification.

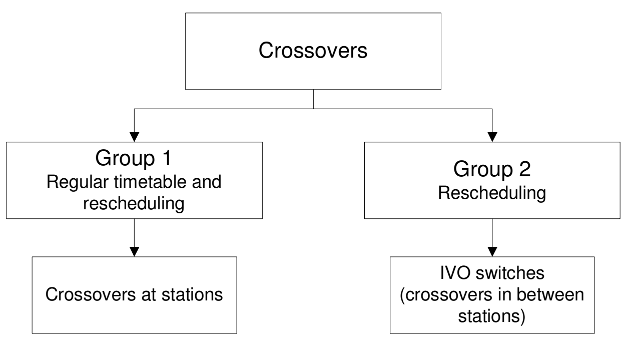


Figure 4.7 Old classification of crossovers

In the new rescheduling philosophy the classification of crossovers will change (Figure 4.8). Stations are divided into decoupling points (large stations) and stops (small stations). Small stations/yards do not have a decoupling function (anymore) and crossovers that are now used for rescheduling (‘yellow’, ‘red’ and ‘blue’ infrastructure) tend to be redundant. Hence, the focus in this research is on IVO switches (crossovers in between stations) that are only used for rescheduling (in case of disturbances and scheduled maintenance). In the remainder of the report with a crossover, an IVO switch is meant unless otherwise stated.

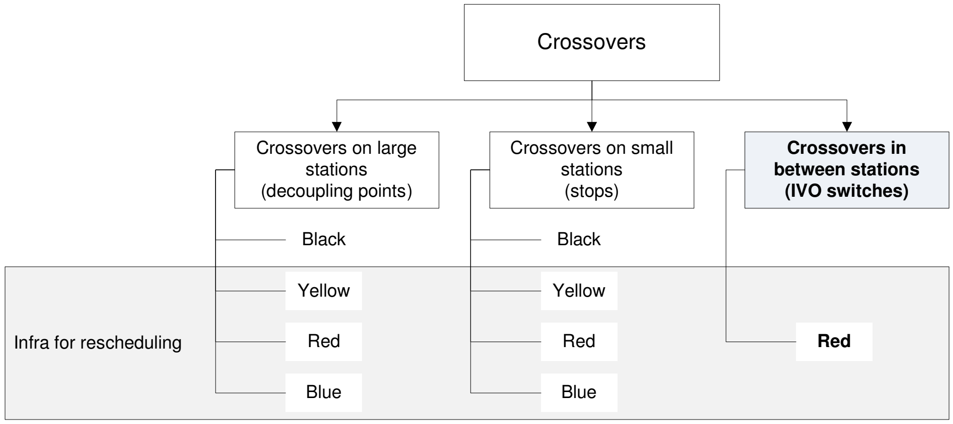


Figure 4.8 New classification of crossovers

An example of the two different groups of crossovers can be seen in Figures 4.9a and b.

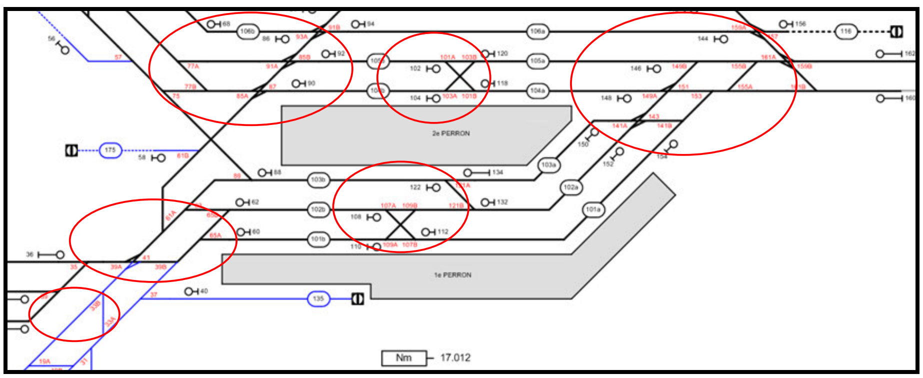


Figure 4.9a Crossovers of the first group at Nijmegen (Nm)

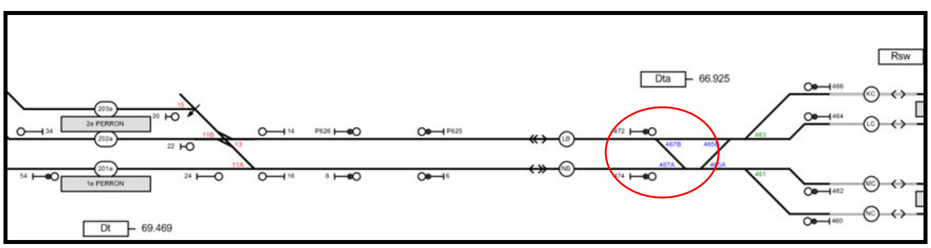


Figure 4.9b Crossovers of the second group between Delft (Dt) and Rijswijk (Rsw)

Configurations. Crossovers exist in various configurations. Figure 4.10a shows a (single) crossover that consists of two switches that enables transfer to the opposite direction. Mostly there are two (single) crossovers–a double crossover–close to each other to go from right to left and from left to right. The majority of this configuration is situated in between stations because there is enough space. If the crossover is not used (straightforward direction) the operational speed can be maintained. In Figure 4.10b a scissors crossover (combined crossover) is shown. A scissors crossover is mostly located at stations because of the limited space. It is more expensive than two single ones. Sometimes a specific combined crossover is used at stations/yards–a double slip switch (Figure 4.10c). A double slip switch takes less space than a scissors crossover but is also more sensitive for disturbances. Both require a lower speed in straightforward position because of possible derailment.

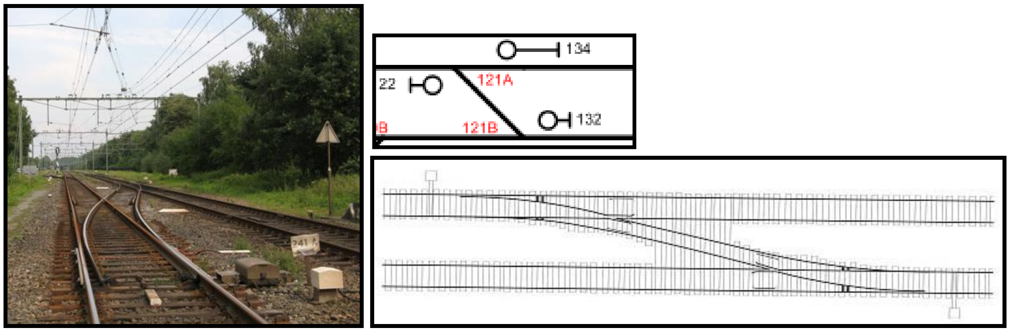


Figure 4.10a (single) Crossover

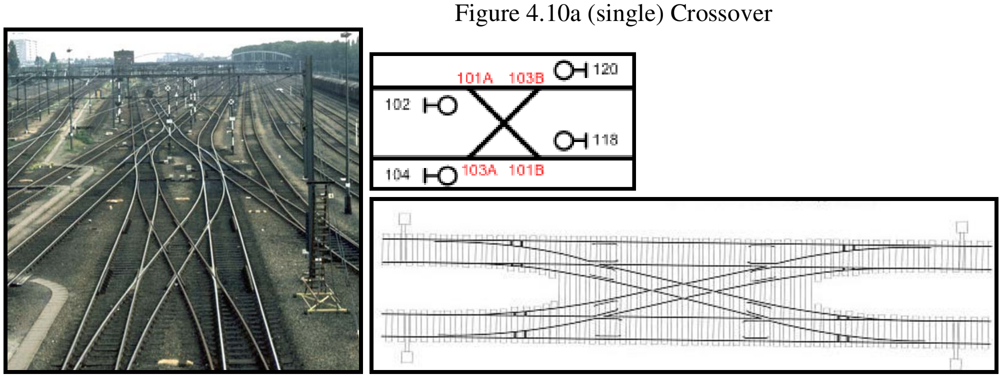


Figure 4.10b Scissors crossover (combined crossover)

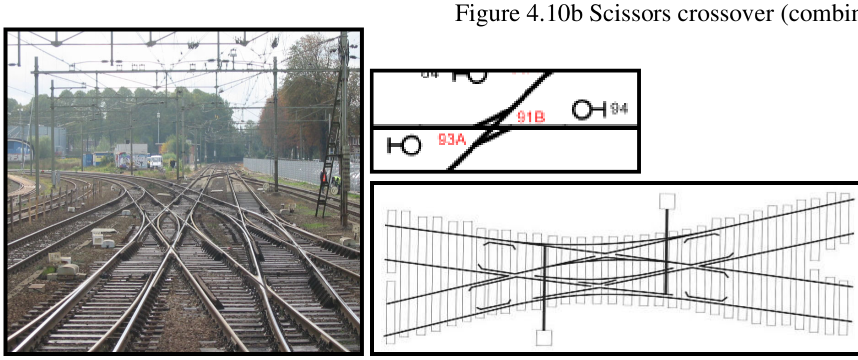


Figure 4.10c Double slip switch (Engels wissel)

Crossovers in between stations (IVO switches) are almost always placed in a double configuration. Scissors crossovers or double slip switches are only found at stations/yards. An overview of the allowed speeds for different types and different angles of switches can be found in Annex B.

4.2.3 Advantages and Disadvantages of Crossovers

In Table 4.3 an overview of the pros and cons of crossovers is given. The advantage of crossovers is an increase in flexibility and resilience of the railway network. In the event of a disruption in one direction of a two-track section (partial obstruction), there is transfer to the other–not obstructed–direction and the train service does not have to be reversed or rerouted. They also provide flexibility during scheduled maintenance and in designing the timetable. But having crossovers in the railway network has also some disadvantages. A major disadvantage is that they are frequently the cause of a disturbance (Paragraph 5.2). Also they take up space and consequently there is limited choice for placement of signaling. In addition, speed must be decreased at crossovers (curved direction) for safety reasons. Finally, there are additional costs for construction and maintenance and there is nuisance such as noise, vibration and comfort. Because a large part of the crossovers are usually only used for rescheduling, they are less frequently used than other rail infrastructure elements. Yet, they must be used regularly to prevent rusting. Corrosion creates disturbances in the ATB-EG. In the timetable rust riding (extra process) must be included or auxiliary axle counters should be implemented.

Table 4.3 Pros and cons of crossovers

Advantages	**Disadvantages**[1]
- Flexibility/resilience of disturbances	- Less availability (disturbances/failure)
- Flexibility of scheduled maintenance	- Spacious (restrictions for signal placement)
- Flexibility at stations in designing the timetable	- Speed limitation (curved direction)
	- Low punctuality
	- Unsafe (collisions, derailment etc.)
	- Costly (investment and maintenance)
	- Nuisance (sound, vibrations, comfort etc.)

[1]Weeda et al. (2010)

4.2.4 Examples of Rescheduling Using Crossovers

Crossovers in between stations (IVO switches) are mostly used for partial obstructions. In this regard there are three possible rescheduling options whereby crossovers can be used (Figure 4.11a). The traffic operator could choose from:

- An IVO switch before the obstruction to redirect trains on the impaired direction to the opposite direction. There is train traffic in both directions on one track but the capacity is limited.
- Crossovers at decoupling points to redirect trains on the impaired direction to the opposite direction. There is train traffic in both directions on one track but the capacity is more limited than if using IVO switches–the distance on the opposite track is longer.
- Crossovers at decoupling points to reverse trains. The partial obstruction will be handled as if it is a complete obstruction.

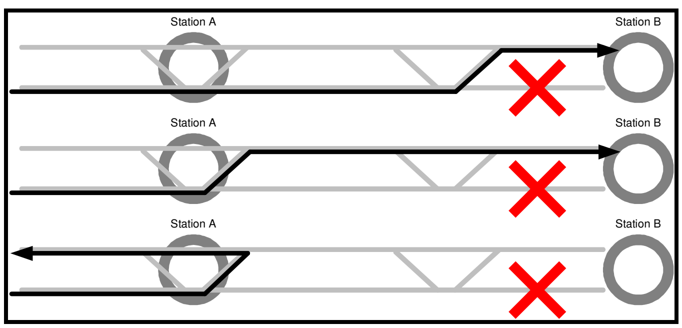


Figure 4.11a Rescheduling measures using crossovers

Two options in which crossovers will not be used are: the train stops at the decoupling point until the disruption is solved, or the train reverses on the same track (Figure 4.11b).

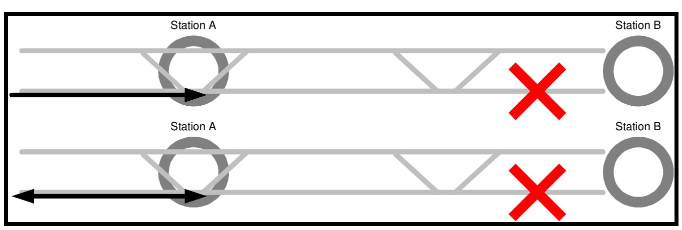


Figure 4.11b Rescheduling measures without using crossovers

4.2.5 Distribution of Crossovers Used for Rescheduling

According to ProRail there are 94 'potentially redundant' crossovers (IVO switches) on the Dutch railway network. This data has been obtained from the Kern Infra Manager. The Kern Infra Manager gives an overview of the switches which are necessary to fulfill regular train operations (according to BUP [Basis Uur Patroon]) and minimum train operations, for example in case of extreme weather conditions. This is divided into different phases. Infra phase 1 gives a list of 'potentially redundant' crossovers (Annex C). Figure 4.12 shows the division over the four regions: Northeast (NO), Randstad North (RN), Randstad South (RZ) and South (Z). As can be seen from this figure, the major part of the 'potentially redundant' crossovers is situated in the region Randstad North, followed by the region Randstad South. The peripheral regions Northeast and South have less 'potentially redundant' crossovers.

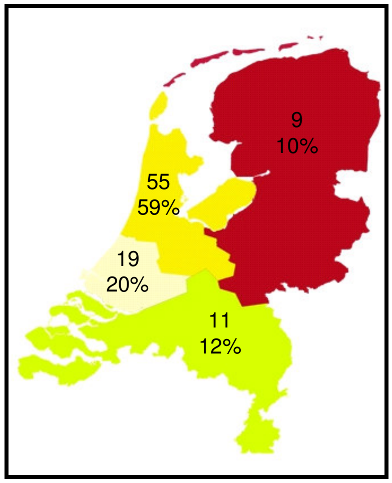


Figure 4.12 Division of crossovers (region)

Figure 4.13 shows the subdivision in Traffic Control Posts. In region Randstad North (RN) the largest part of crossovers is located at Amsterdam (Asd) and Utrecht (Ut) followed by Amersfoort (Amf). In Maastricht (Mt) and Rotterdam (Rtd) there are less 'potentially redundant' crossovers.

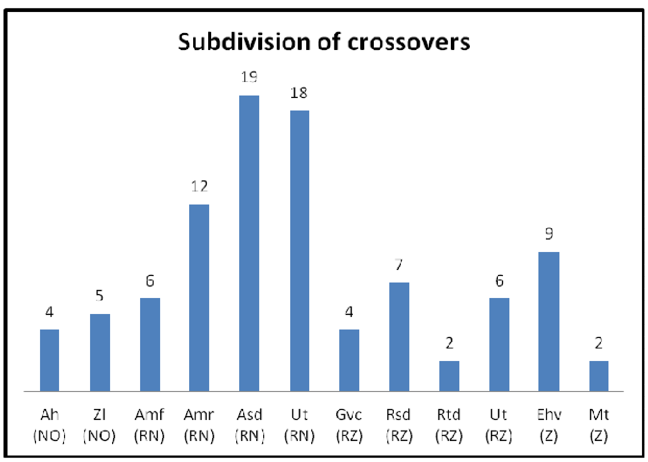


Figure 4.13 Subdivision of crossovers (post)

4.3 Conclusions: Processes of Rescheduling and Crossovers

If disruption is too severe typical VSM is applied. VSM is a temporary modified timetable and standardize the rescheduling which must result in faster implementation. These are made in collaboration with train operators (NS).

Three different chronological phases can be distinguished between when disruption occurs and when normal train operations can be resumed. This is the so-called bathtub model which consists of the first phase, the VSM and the reoccupation phase. The first phase is the most critical phase, trapped trains are to be removed and it must be prevented that more trains enter the affected area. During the VSM, trains are processed according to a modified timetable. Trains can be operational, cancelled, rerouted, modified or inserted. In the reoccupation phase normal train operations are slowly started. This is mostly done gradually because of logistical problems of train operators. Crew and rolling stock are frequently uneven divided over the railway network.

Nowadays, it is difficult for ProRail and NS to maintain the current rescheduling process because of higher utilization of the railway network. Therefore, they developed a new strategy: only at important stations–decoupling points–rescheduling takes place. This has some consequences for the current track lay-out. Decoupling points must have crossovers to make rescheduling possible. But at small stations–stops–these crossovers may be redundant. ProRail investigated if it is possible to have less switches and crossovers. However, there is a chance that removed crossovers are needed again when utilization of the railway network increases in the future.

A crossover is a pair of switches that connects two parallel tracks and enables transfer from one track to the other track. The focus in this research is on IVO switches (crossovers in between stations) that are only used for rescheduling. According to ProRail there are 94 ‘potentially redundant’ crossovers (IVO switches) on the Dutch railway network. The case studies are concentrating on this aspect.

5 Performance of Rescheduling and Crossovers

The performance of rescheduling and crossovers over the last years is discussed in this chapter. The first paragraph explains the distribution and causes of rescheduling. Paragraph 5.2 gives some insight into disturbances of crossovers that lead to disruption and consequently rescheduling. Furthermore, in Paragraph 5.3 some figures about rescheduling through the use of crossovers are shown. Finally, in the last paragraph a summary of the performance is given.

5.1 Distribution and Causes of Rescheduling

ProRail quantifies disruption through a TAO which needs rescheduling, in most cases according to a VSM. As discussed in Subparagraph 4.1.1 there is a difference in the kind of disruption (TAO) that occurred (complete or partial obstruction) and how it had been treated by traffic controllers (as a complete or partial obstruction, complete or partial VSM). Data of the latter has been analyzed in this paragraph. Because there is a freedom in handling a partial obstruction, partial obstructions that happened in reality could be handled as a complete obstruction (complete VSM) and therefore this data is not accurate to draw conclusions from the distribution of disruptions that occurred in reality. Unfortunately, only extended data from 2009 is available. The original data file can be seen in Annex D.

Rescheduling. Figure 5.1 depicts distributions of rescheduling in partial and complete VSM. From the first column it can be seen that 56% of disruptions were solved with a partial VSM (687 measures). Hence, the distribution of rescheduling is in favor of partial VSM. Basically, the majority of disruptions occur at one side of the track. Another interesting detail is the distribution of the duration of rescheduling. ProRail quantifies the duration of disruption through the FHT which means: the time it takes to recover from disruption to allow train operations in line with the timetable. The second column shows that 44% of the total duration of rescheduling is from partial VSM. Although partial VSM is applied more often, its duration is less than applying complete VSM.

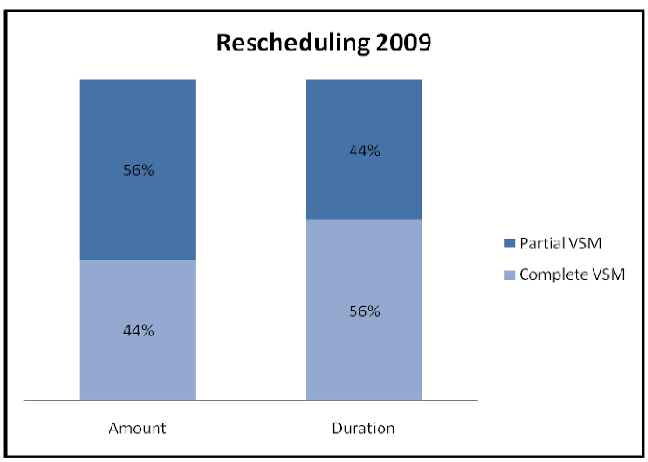


Figure 5.1 Rescheduling 2009

Rescheduling caused by disturbances of switches/crossovers. Figure 5.2 shows the distribution of rescheduling in case of disruptions caused by failure of switches/crossovers. It is stated that 83% of disruptions caused by failure of a switch/crossover was processed according to a partial VSM (124 measures). In the second column, 76% of the total duration of rescheduling caused by failure of switches/crossovers is from partial VSM. Compared with the amount of rescheduling, the duration is less than complete VSM which still counts for 24%.

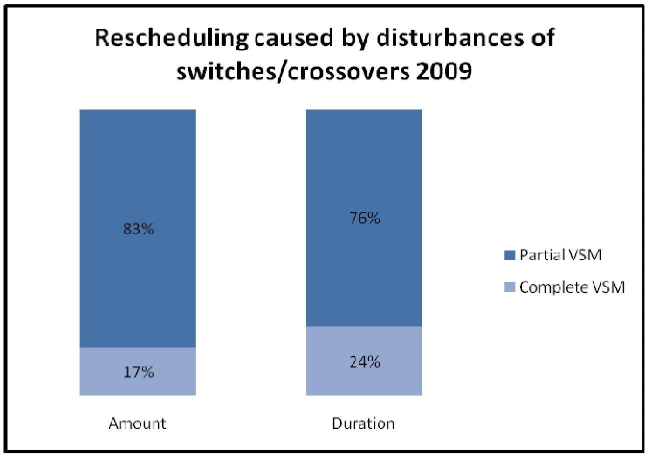


Figure 5.2 Rescheduling caused by disturbances of switches/crossovers 2009

Rescheduling to cause. To get insight into the share of infrastructure related disruptions on rescheduling, the distribution is shown in Figure 5.3. It is divided into infrastructure, external related factors and a small part of unknown factors. External related factors are factors which ProRail has no influence on such as a defect train, weather, passenger behavior etc. In Annex D an overview of infrastructure and external related factors is presented. It is remarkable that the total share of infrastructure related disruptions is less (41%, 508 measures) than disruptions caused by external factors such as train related disturbances (54%, 662 measures). Weeda et al. (2006) concluded in their research that only 35% from the non-punctual arrivals (three or more minutes delayed) is caused by disruptions due to rail infrastructure and external factors (train related). Moreover, the largest part (65%) of delays is caused by a mismatch in the planning and the actual operations (quality and complexity of the timetable) of which even 55% is caused by knock-on delays. Infrastructure related disruptions are not taking place as frequent as has been assumed.

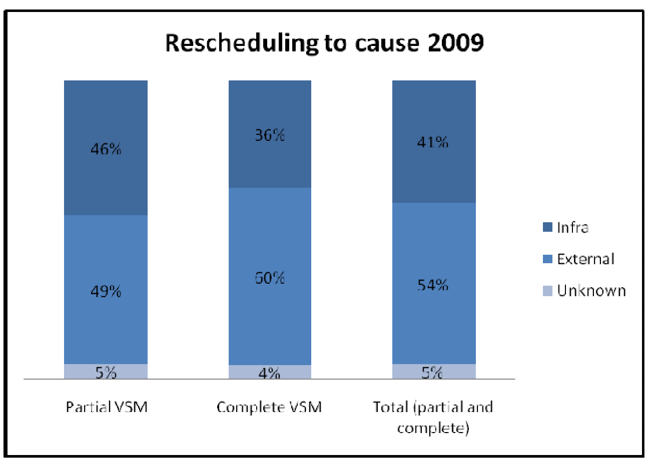


Figure 5.3 Rescheduling to cause 2009

When looking at the average duration of rescheduling it can be said that a disruption caused by infrastructure failure takes longer time than disruption caused by external factors (Table 5.1). Despite that the unknown factors have a low share (5%) it must be said that the average duration is notably high: 861 minutes. This high average duration is mainly presented in events with complete VSM. Probably these causes differ too much, were exceptional (heavy impact) and could not be classified and/or identified by the traffic controllers and therefore grouped under unknown factors. But it leads to a higher total average and therefore the reliability of the distribution is questionable.

Table 5.1 Average duration of rescheduling

	Total (partial and complete)		
	Infra	*External*	*Unknown*
Average duration (min)	300/309	268/309	861/309

Share of rescheduling caused by disturbances of switches/crossovers. Figure 5.4 shows the share of rescheduling caused by disturbances of switches/crossovers i.e. 12% (150 measures) of the total rescheduling. This share is 30% of rescheduling related to failure of infrastructure.

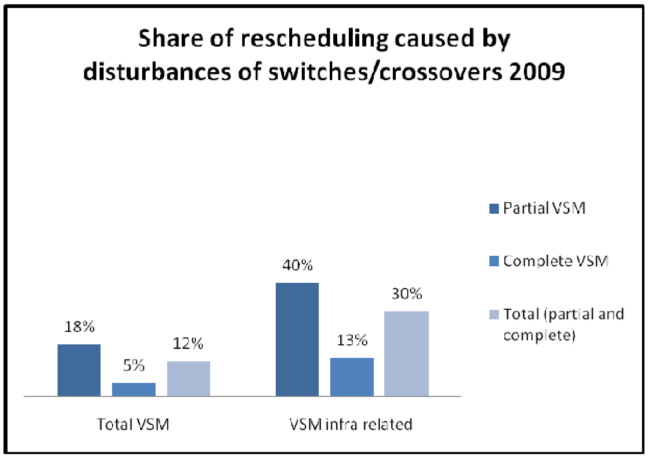


Figure 5.4 Share of rescheduling caused by disturbances of switches/crossovers 2009

5.2 Disturbances of Crossovers

In Figure 5.5 an overview is shown of disturbances of the 94 'potentially redundant' crossovers (infra phase 1) from 2008 till 2010. Two remarkable conclusions can be drawn from this figure. In that timeframe there were more disturbances of crossovers which did not cause disruptions (TAOs) and a small part–approximately one third of disturbances of switches–caused disruptions which needed rescheduling. First of all, it must be said that the recording of a TAO is also partly a subjective process by traffic controllers. Another factor is that for the regular timetable crossovers will only be used for rust riding. If this is not possible, train operations can continue as normal (straight forward direction is not affected, only the turnover does not work) and therefore there is no TAO.

Apart from that, the figure shows an increase in the amount of disturbances of crossovers. Probably this is caused by the extreme winters of 2009 and 2010–there was a higher utilization of crossovers for rescheduling. Furthermore, because of the higher amount of rescheduling in that period, the availability of crossovers for rescheduling were probably also more often checked. This also does not lead to a TAO. At least it could be due to less maintenance over recent years.

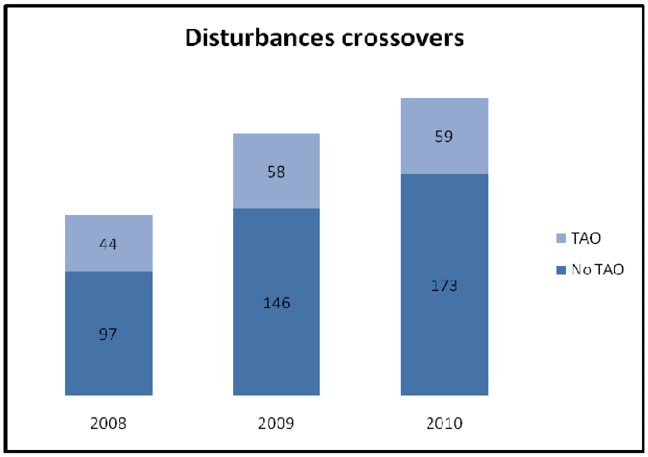


Figure 5.5 Disturbances crossovers

The share of disturbances at the 94 crossovers that resulted in a disruption in 2009 is depicted in Figure 5.6. The figure shows that 39% of disruptions caused by switches are due to disturbances of crossovers. The remainder is caused with other type of switches. It can be said that this is a high proportion given the limited use in train operations.

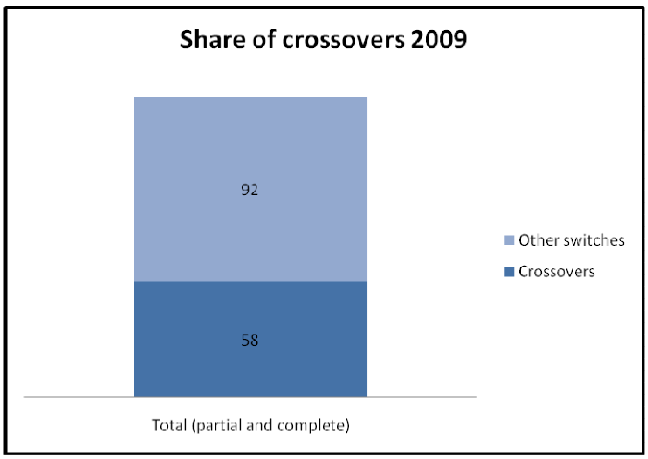


Figure 5.6 Share of crossovers 2009

5.3 Rescheduling Using Crossovers

Crossovers are used for partial obstructions and that are consequently handled with partial VSM. Figure 5.7 shows in the first column the amount of partial VSM over the four regions in 2010 which are 492 measures. Looking at the distribution of partial VSM over the four regions it can be seen that Randstad North (RN) has the most partial VSM but is also the busiest region, followed by Randstad South (RZ). South (Z) has the least partial VSM.

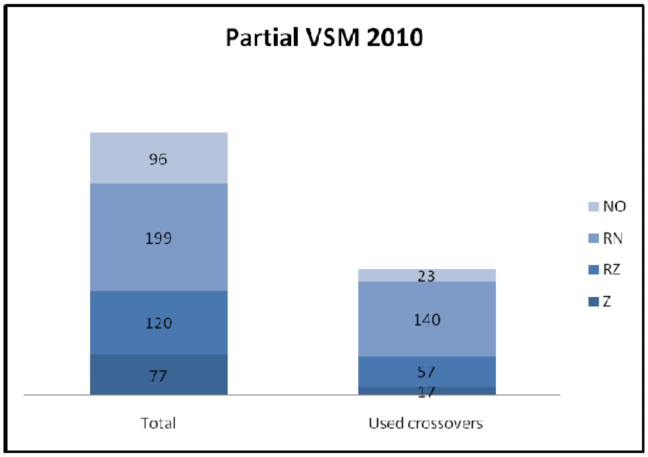


Figure 5.7 Partial VSM 2010

The second column shows the amount of partial VSM wherein crossovers were used (397 measures). This is a share of 48% of the total amount of partial VSM. Basically, about half of the partial VSM that were applied in 2010 did use crossovers (Figure 5.8).

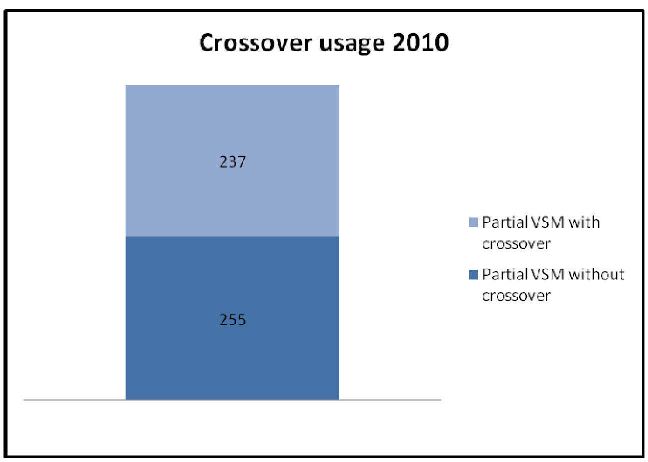


Figure 5.8 Crossover usage 2010

5.4 Conclusions: Performance of Rescheduling and Crossovers

Five important conclusions can be drawn from the performance related to crossovers which are also shown in Figure 5.9.

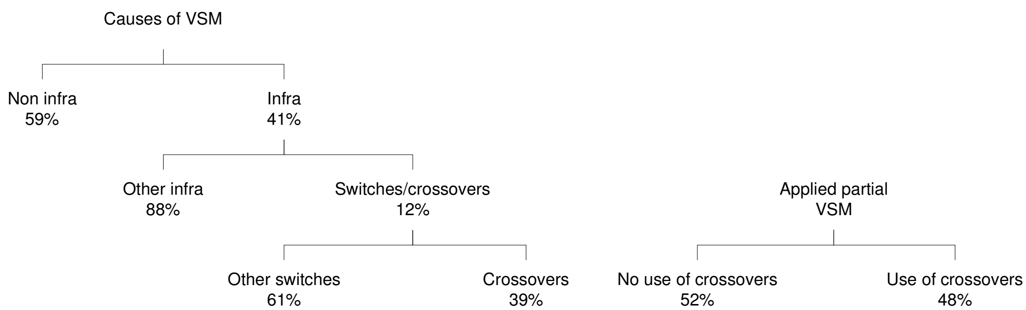


Figure 5.9 Conclusions of performance rescheduling and crossovers

Distribution and causes of rescheduling

1. From data of rescheduling in 2009 it can be concluded that the share of infrastructure related disruptions (41%) is a significant part of the total disruptions and consequently delays in the railway system. But it does not have the greatest influence on disruptions. The majority of disruptions are caused by external factors such as train related factors (54%).
2. The share of failure of switches/crossovers is 12% of the total rescheduling. When looking at infrastructure related failures, failure of switches/crossovers is counted for 30% of the total rescheduling. Simplicity of the railway network by removing crossovers will probably lower the chance of disruptions. Still, the largest part of the causes of disruptions i.e. external factors will not be solved.

Disturbances of crossovers

3. With respect to disturbances due to crossovers it can be concluded that for 2008 till 2010, there were more disturbances of crossovers which did not cause disruptions (TAOs). Only a small part, approximately one third of disturbances of switches caused disruptions (TAOs) which needed rescheduling.
4. The share of disturbances of crossovers is 39% of the total disruptions caused by switches. This is quite a large part given the limited use in train operations. Besides, there is an increase in disturbances of crossovers over 2008, 2009 and 2010. This is probably caused by the extreme winters of 2009 and 2010 and less maintenance over recent years.

Rescheduling using crossovers

5. The share of partial VSM that use crossovers in 2010 is 48%.

6 Identification of Case Studies, and Research Methods and Tools

In Paragraph 6.1 the assessment criteria are explained that are used to generate case studies. The process of choosing case studies is described in Paragraph 6.2. Paragraph 6.3 explains the research methods and tools. Finally, a summary is given in Paragraph 6.4.

6.1 Assessment Criteria

In choosing specific case studies, assessment criteria are helpful. In Table 6.1 an overview of the chosen assessment criteria is given. The location is an important criterion (starting point) to get various case studies. A common Dutch division is the Randstad area (Randstad) and the periphery (Region). The train frequency is related to the location because highly occupied corridors are mostly situated in the Randstad. Besides, the corridor must include different type of stations according to the new rescheduling philosophy of ProRail. It must include at least one decoupling point (IC or sprinter) and at least one stop. The determination of the type of stations is still an ongoing process between ProRail and NS. For this research the current state is assumed. The last two criteria are obvious. The corridor must include at least one crossover that belongs to infra phase 1 since these crossovers are subject of interest. Furthermore, the corridor must have at least one crossover that has been used in the partial VSM of 2011, so that historical performance can be analyzed.

Table 6.1 Assessment criteria

1	Location
2	Train frequency
3	Type of stations
4	Crossovers (infra phase 1)
5	Partial VSM (in 2011)

6.2 Case Studies

Looking at the first criterion it is understandable that at least one corridor of the Randstad and at least one corridor of the Region are depicted but because of limitations in research time and available (simulation) data only the Randstad is further investigated. Besides, the Randstad has a higher train occupancy which needs frequently rescheduling and crossover usage.

Therefore, two corridors in the Randstad have been chosen using the remainder of the assessment criteria (Figure 6.1):

- Corridor Amsterdam: Amsterdam Riekerpolder aansluiting (Asra) – Amsterdam Bijlmer ArenA (Asb)/Diemen Zuid (Dmnz).
- Corridor Rotterdam: Rotterdam Centraal (Rtd) – Gouda (Gd).

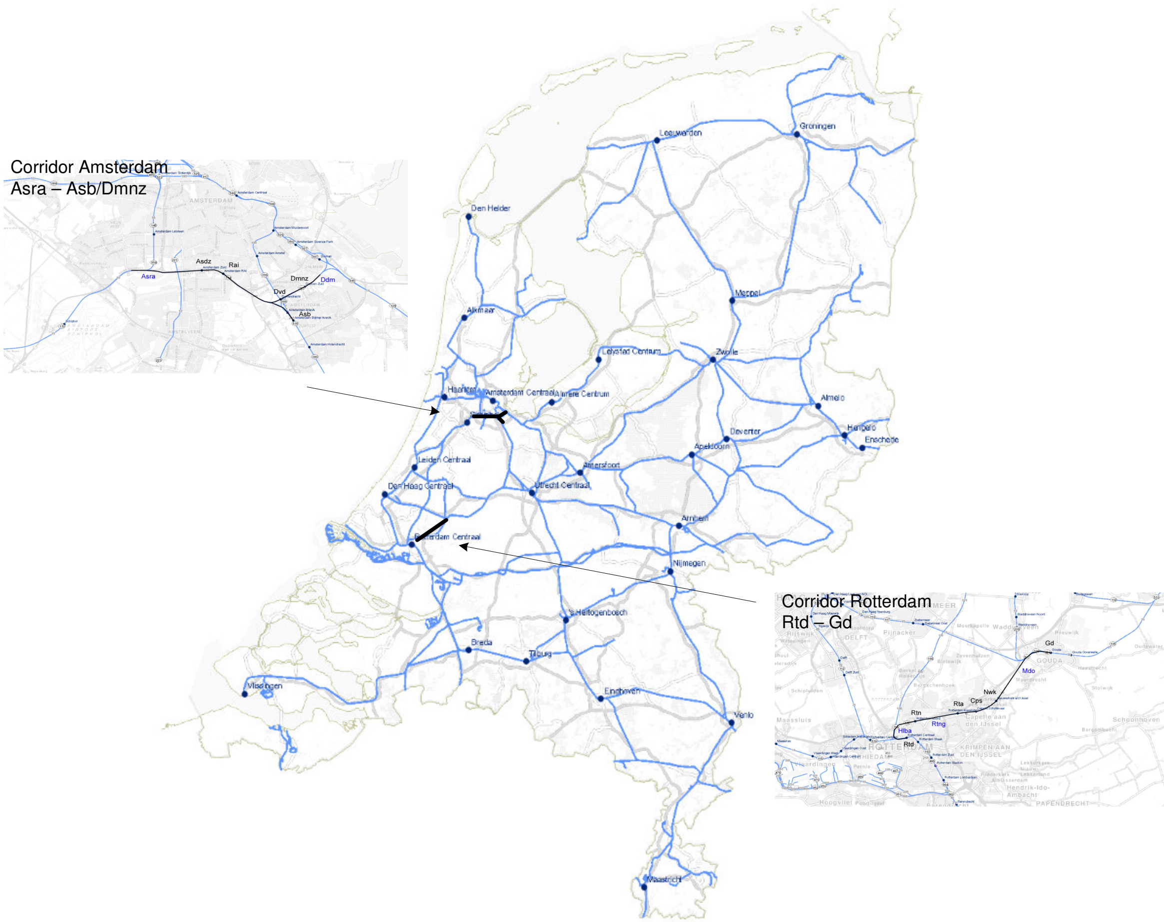


Figure 6.1 Corridors

Corridor Amsterdam is a higher occupied corridor than Rotterdam but both corridors are very important connections. Both corridors have several IC connections between the Randstad and the Region. Corridor Amsterdam has several international connections while corridor Rotterdam serves as an important route for freight trains that cannot use the Betuweroute. The corridors have different type of stations, both IC-DP/sprinter DP and stops. Finally, both corridors contain some crossovers from infra phase 1 and were used during partial VSM in 2011. The result of the selection process of the case studies is depicted in Table 6.2.

Table 6.2 Selection process corridors

Criterion		**Corridor Amsterdam** **Asra – Asb/Dmnz**	**Corridor Rotterdam** **Rtd – Gd**
Train frequency (trains per hour per track)		14 (peak hour)	8 (peak hour)
Type of stations		- Asdz (IC-DP) - Rai (stop) - Asb (stop) - Dvd (sprinter DP) - Dmnz (sprinter DP)	- Rtd (IC-DP) - Rtn (stop) - Rta (IC-DP) - Cps (stop) - Nwk (stop) - Gd (IC-DP)
Crossovers (group 2)		- 971 - 983 - 985 - 1165 - 1301 - 1303	- 251 - 253 - 271 - 273 - 281 - 283 - 293 - 295
Rescheduling/VSM (2011) crossovers	Used	- 971 - 983 - 985 - 1165 - 1301 - 1303	- 281 - 283 - 293 - 295
	Not used		- 251 - 253 - 271 - 273

6.3 Research Methods and Tools

The remainder of the research can be divided into two chapters. In each chapter specific methods and tools are used in order to answer the sub questions. This paragraph explains the methods and tools in more detail. In Figure 6.2 an overview of the applied methods and tools are shown including the sub question answered.

Chapter 7 contains a disruption analysis (partial obstructions) for case studies Amsterdam and Rotterdam. It consists of:

- The comparison between the applied rescheduling and the VSM.
- The usage of crossovers during rescheduling.
- The consequences: initial and knock-on delays on train operations.

The first two sub questions are applicable to both case studies. The tools MUIS and TOON have been used. The third sub question is only answered for case study Rotterdam because of time limitations. The tool Monitoringsystem has been used.

Chapter 8 contains a simulation study of case study Rotterdam. The simulation tool OpenTrack has been used. In the following three subparagraphs the tools are further explained.

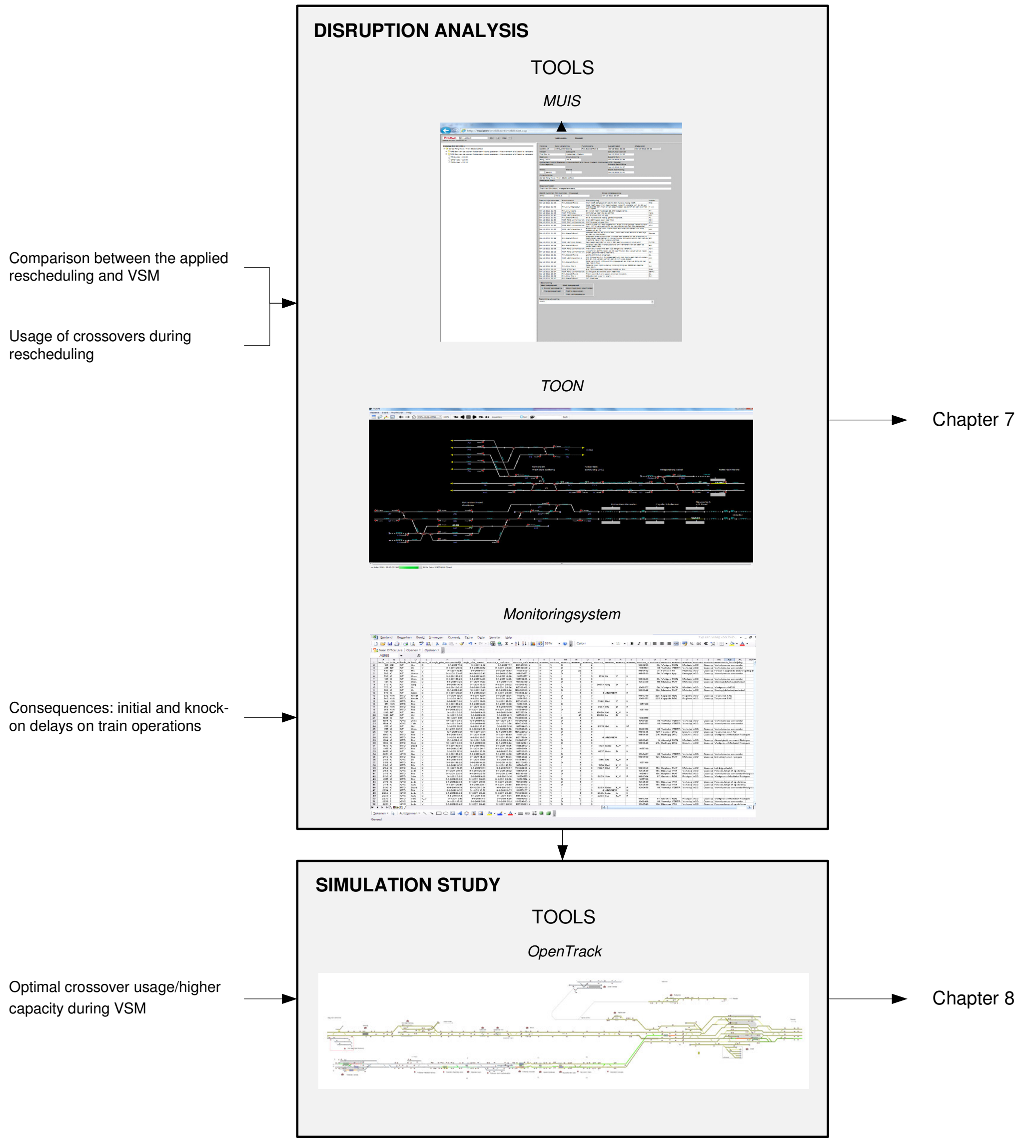


Figure 6.2 Research methods and tools

6.3.1 Tools MUIS and TOON

Data of disruptions were collected from database MUIS. MUIS contains data from the ISVL5 system (Informatie Systeem VerkeersLeiding) and includes all disruptions on the railway network that were reported by Traffic Control. It consists of calls that were handled with no VSM (light dispatching only), partial VSM or complete VSM. An example of a call in MUIS can be seen in Annex E. The comparison was done for all partial obstructions in 2011 on the corridors Amsterdam and Rotterdam.

MUIS contains manually added reports from traffic controllers about the rescheduling. A disadvantage of these reports is that they are arbitrary. Traffic controllers from different traffic posts but also train operators add information to the same reports. In ISVL5 (and MUIS) several fields have to be filled in case of disruption. This is done by different stakeholders: traffic controllers from different posts and train operators that are affected. First, they add an IFB and second if applicable they add a VSM. Finally, in the assessment field the traffic controller has to depict which kind of measure has been used: no VSM, VSM, VSM that has some adjustments etc.

Between these three fields there are frequently contradictions. This is unavoidable since different stakeholders are allowed to fill in these fields. But it makes it difficult to identify if either a partial or complete VSM was applied or not. As a consequence the data that was converted from MUIS to Excel was frequently incomplete. Therefore, it was necessary to check missing fields manually. This is a minor issue for the analysis of individual events but to get insight into totals (for example the number of partial VSM in 2011) this is a time-consuming effort. Hence, drawing conclusions only based on this method is unreliable.

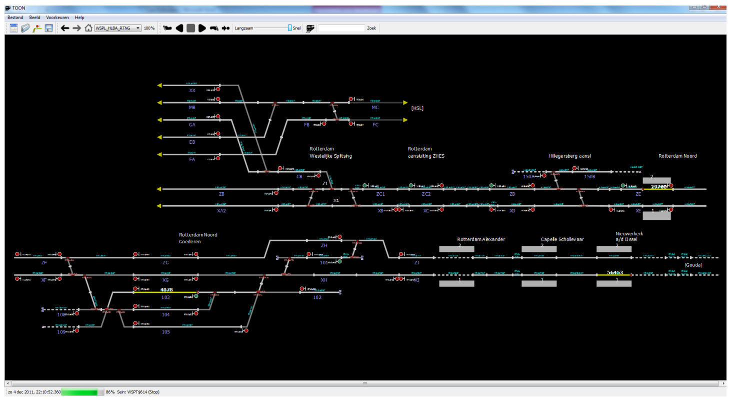


Figure 6.3 TOON

The train operations before, during and after disruption can be analyzed with TOON. TOON visualizes historical train operations which are based on TROTS log-files, exact information from signals and sections. A visualization of TOON can be found in Figure 6.3. It is an objective and clear method to check whether the rescheduling went according to the VSM. But a disadvantage of using TOON to compare the rescheduling with the VSM is that TOON only visualizes the processes, there are no explanations about why the rescheduling was different from the VSM. Insight in the usage of crossovers during the rescheduling is also obtained with TOON. TOON is a very reliable and additional source to analyze individual events. MUIS on the other hand gives a very useful explanation about why a certain measure was chosen. Therefore, both tools are used simultaneously which give the best insight into the rescheduling process.

6.3.2 Tool Monitoringsystem

To get insight into delays that are caused by disruptions, data from the Monitoringsystem has been used. The Monitoringsystem gets delay input from VKL (VerKeersLeidingsysteem). From all train delays (TA = Trein Afwijking) VKL only stores the explained train delays (TVTA = Te Verklaren Trein Afwijking) which are trains that have a delay and an increasing delay (differences between the 'new' delay and the previous delay) of at least three minutes.

The Monitoringsystem generates couplings between train delays. This can be direct and indirect couplings. Direct couplings are couplings between an explained train delay and the cause of this explained delay (initial delay). Indirect couplings are couplings between an explained train delay and the explained train delay that caused its delay (knock-on delay). These indirect couplings can be made automatically but it is done mainly by hand through traffic controllers. Using the Monitoringsystem more information about the consequences of the disruption can be obtained i.e. more insight into the initial delay and the propagation of such delay (knock-on delay) can be gained.

There are some weaknesses about the Monitoringsystem. The stored train delays in VKL have an inaccuracy that can sometimes be more than one minute because the measurements are based on the home and exit signal at stations instead of the real stop of the train at a station (Goverde, 2010). As a result it is possible that in reality a TA is no TVTA but according to VKL it is. The Monitoringsystem couples these wrong measurements. Also the opposite can occur: a TA is in reality a TVTA but not reported as such by VKL. Then the Monitoringsystem lacks explained train delays (Goverde, 2010). Therefore, the accuracy of interpreting the delays based on the Monitoringsystem has to be taken into consideration.

Furthermore, Goverde (2010) evaluated the accuracy of the Monitoringsystem. It is compared with a similar system, TNV-Conflict. TNV-Conflict has been developed by TU Delft and its delay data is based on TNV-log files which are very accurate (to the nearest second). Goverde (2010) concluded that particularly the percentage of incorrect indirect couplings is very high, 76%. Of this percentage 30% were incorrect indirect automatic couplings and 46% were incorrectly reported by traffic controllers. From the direct couplings still 22% are incorrect. Another option was to use TNV-Conflict to get more reliable data about delays. The reasons for using data from the Monitoringsystem are that it is already widely used and accepted within ProRail and that it is easier to obtain given the limited research time. TNV-Conflict is more complicated and time-consuming but it will be recommended for further research.

6.3.3 Simulation Tool OpenTrack

OpenTrack is a microscopic simulation tool that can be used for a wide range of rail related issues. It can be used for the consequences of new infrastructure variants; analyzing the capacity of train lines and stations, the timetable construction and its robustness, the effects of disruptions and delays, the signal system and so on (OpenTrack, 2012a). The simulation tool is made up of three parts: input, simulation and output (Figure 6.4). For the input data on rolling stock, infrastructure and a timetable are necessary. During the simulation train operations are visualized in detail. The output contains diagrams, train graphs, occupation and statistics depending on the research.

With respect to the infrastructure the largest part of corridor Rotterdam was already provided by DHV. But the part Rotterdam Centraal – Rotterdam Alexander (Rtd-Rta) was still missing which meant that this had to be provided prior to the simulation study. In addition, left track signaling had to be implemented to the whole corridor Rotterdam Centraal – Gouda (Rtd-Gd). There were two options: (1) designing the missing parts by hand or (2) using a prototype tool that automatically imports the Infra Atlas (OBE [Overzicht Baan en Emplacement] rail maps) into OpenTrack. This tool has been developed by DHV and OpenTrack, Switzerland and is still being developed (Tax, 2011). Its advantage is that it automatically imports the infrastructure data and the signals and routes as well, from Infra Atlas into OpenTrack. Because the converter is still under development there are some disadvantages as well. While importing the Infra Atlas some data is missing and some unnecessary data is also converted. Consequently, data has to be added or removed by hand in order to get a clear and less complicated model. To avoid this, in this research it was decided to import the missing parts of the network manually. But for the future this tool promises to be beneficial.

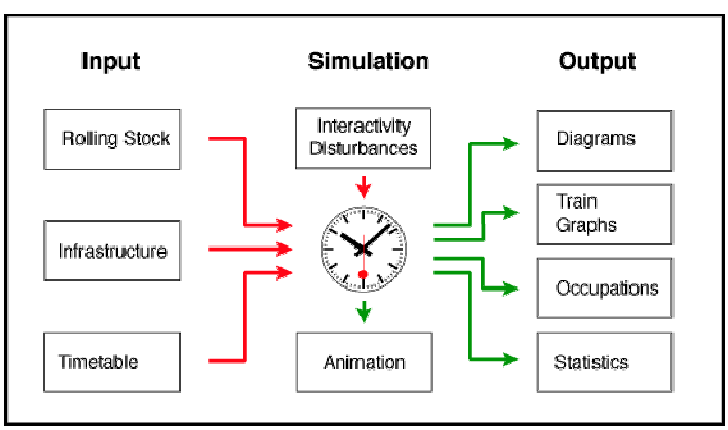


Figure 6.4 OpenTrack tool (OpenTrack, 2012b)

In this research, OpenTrack is used for analyzing the rescheduling and crossover usage during a partial obstruction. This is done for the case study Rotterdam–a partial obstruction between Rotterdam Noord Goederen (Rtng) and Nieuwerkerk a/d IJssel (Nwk) (VSM 25.070). The current crossovers at Nieuwerkerk IVO wissels (Nwki) and Moordrecht overloopwissels (Mdo) have a distance of 4.3 kilometers which is very short (i.e. inefficient) concluded from literature studies (Chapter 2) while between Rtng and Nwk (7.8 kilometers) there are no crossovers. With OpenTrack it can be analyzed whether the existing crossovers are needed and effective to handle more trains during the VSM. Furthermore, the effects of alternative VSM for train routing can be estimated.

6.4 Conclusions: Identification of Case Studies, and Research Methods and Tools

In choosing specific case studies assessment criteria were used. Two case studies in the Randstad have been chosen; corridor Amsterdam: Amsterdam Riekerpolder aansluiting (Asra) – Amsterdam Bijlmer ArenA (Asb)/Diemen Zuid (Dmnz) and corridor Rotterdam: Rotterdam Centraal (Rtd) – Gouda (Gd). Both corridors are important connections that are highly occupied and contain crossovers that may be redundant.

In the next chapter the corridors are analyzed. First, partial obstructions of 2011 were investigated. TOON has been used to analyze disrupted train operations which are based on TROTS log-files, exact information from signals and sections. MUIS contains manually added reports about rescheduling inputted by traffic controllers. TOON gives no explanation about adjustments made to the VSM while MUIS contains arbitrary reports. Therefore, both are needed to compare the applied rescheduling with the original VSM. To get insight into delays caused by disruptions, data from the Monitoringsystem has been used. Delays and the propagation are only analyzed for corridor Rotterdam. Interpreting delays based on the Monitoringsystem has to be taken into account since data from VKL is inaccurate (Goverde, 2010). Chapter 8 contains a simulation study of case study Rotterdam. OpenTrack is used to analyze the rescheduling and crossover usage during partial obstruction between Rotterdam Noord Goederen (Rtng) and Nieuwerkerk a/d IJssel (Nwk) (VSM 25.070).

7 Disruption Analysis Amsterdam and Rotterdam

In Paragraph 7.1 the amount and causes of rescheduling calls is explored for both case studies. In Paragraph 7.2 case study Amsterdam: Amsterdam Riekerpolder aansluiting (Asra) – Amsterdam Bijlmer ArenA (Asb)/Diemen Zuid (Dmnz) is described while in Paragraph 7.3 case study Rotterdam: Rotterdam Centraal (Rtd) – Gouda (Gd) is described. Finally, in Paragraph 7.4 conclusions are given. For ease of reading, in the remainder of this report the full names of stations are abbreviated. At the end of the report abbreviations are written in full.

7.1 Disruption Calls 2011

Figure 7.1 gives an overview of reported disruption calls by traffic control in 2011 collected from MUIS. As can be seen in the figure more than half of the calls finally resulted in no VSM. These calls were handled with light dispatching measures (Figure 4.1) or without VSM. As can be seen in Figure 7.2 the majority of the calls are due to defect trains. Frequently, these trains could continue after several minutes and therefore rescheduling was not necessary. According to Figure 7.1, corridor Amsterdam has the most reported disruption calls in 2011 (total of 45) followed by corridor Rotterdam (total of 30). Furthermore, corridor Amsterdam has the most applied partial VSM (total of 16) while corridor Rotterdam has 10 applied partial VSM.

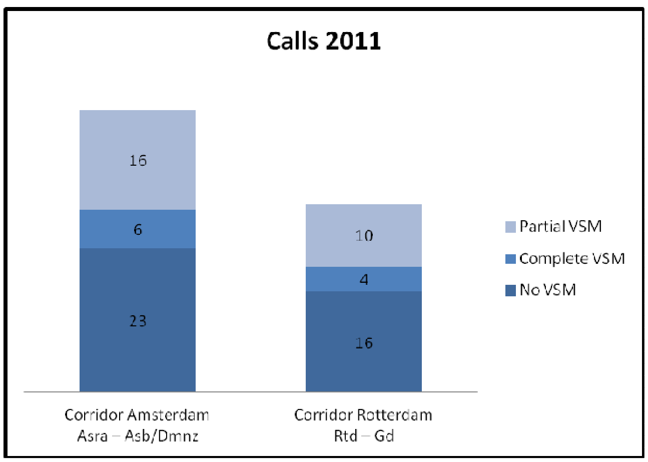


Figure 7.1 Calls 2011

In Figure 7.2 the causes of disruption in 2011 is shown. As mentioned earlier, the majority of calls in the corridors are due to external causes such as defect trains. Regarding corridor Amsterdam, 49% was caused by train defects while 31% was due to infrastructure failure. With regard to corridor Rotterdam 57% was caused by train defects while 20% was due to infrastructure failure. Surprisingly, the share of infrastructure related disturbances–especially, switches/crossovers is relatively low. But–and this cannot be seen in the figure–infrastructure related disturbances led to larger and longer disruptions for which rescheduling was necessary compared with external related disturbances. This is further elaborated in the next two paragraphs in which the corridors are analyzed separately.

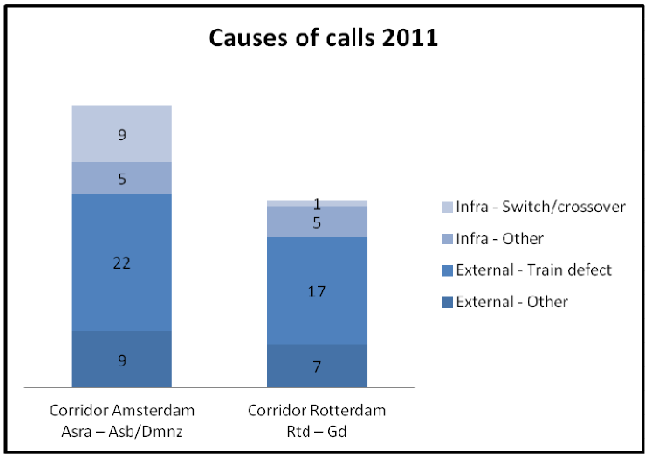


Figure 7.2 Causes of calls 2011

7.2 Corridor Amsterdam (Asra – Asb/Dmnz)

In Subparagraph 7.2.1 an explanation of the train series and the track lay-out (crossovers) is made. Then, in Subparagraph 7.2.2 a comparison is done between the applied rescheduling and the VSM. More in-depth research about the 'potentially redundant' crossovers can be found in Subparagraph 7.2.3, in which the entire annual crossover usage and usage during VSM are analyzed as well as the contribution of crossovers to the first phase and the VSM. Data of crossover disturbances is discussed in Subparagraph 7.2.4.

7.2.1 Train Series and Track Lay-out

The corridor Asra-Asb/Dmnz is one of the busiest corridors in The Netherlands. Besides processing local (commuter) traffic within, from and to the capital city, it processes through-going traffic from the Randstad to the Northern, Eastern and Southern part of The Netherlands. Moreover, it connects the international airport Schiphol and it also processes international trains. In 2011, nine different train series were operational. Two of them are on the corridor Asra-Asb. These are IC-trains, the IC 3100- (Shl-Nm) and 3500- (Shl-Mt) series which connect the Southern part of The Netherlands. The other seven are on the corridor Asra-Dmnz: the IC 140-, 240- (international trains to Berlin), 700- (Shl-Gn), 1600- (Shl-Es), 3700- (Gvc-Lls) series and the SPR 4300- (Gvc-Lls) and 5700- (Ledn-Ut) series which connect the Northern and Eastern part of The Netherlands with the Randstad region cities The Hague and Leiden. The IC-trains serve the stations Asdz, Dvd and Asb while the sprinters stop at all stations in between (Asdz, Rai, Dmnz and Asb). Except the international trains (5 times a day) all train series operate twice per hour. Figure 7.3 shows an overview of the train series on the corridor. In Annex F more information about the train series can be found.

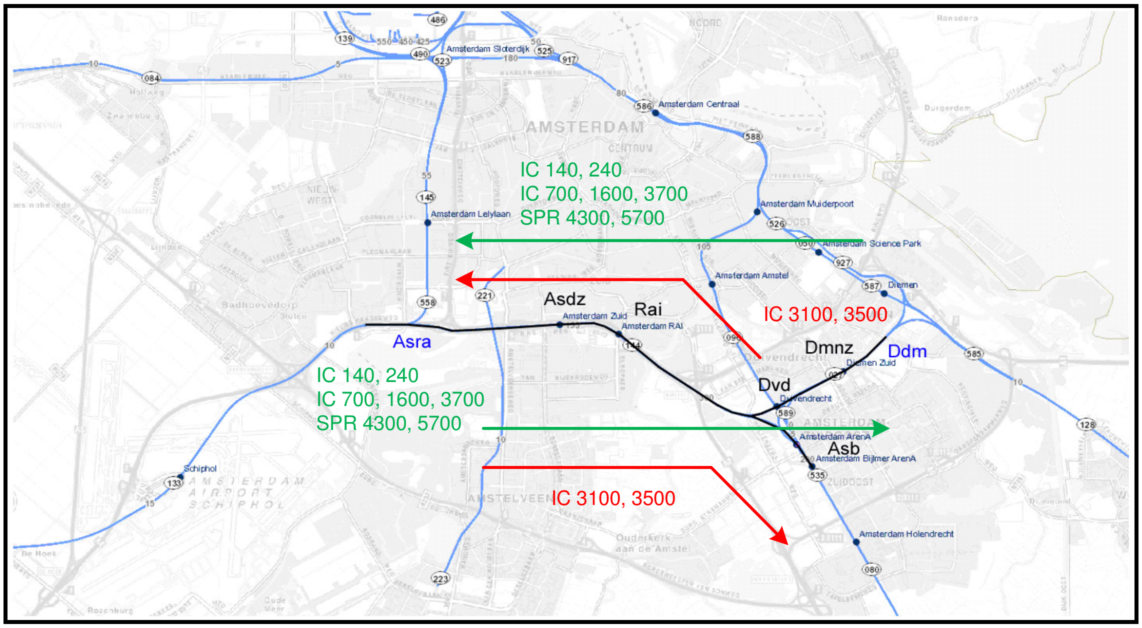


Figure 7.3 Trains through Asra – Asb/Dmnz

In Figure 7.4 an overview of the crossovers on the corridor can be seen. The red highlighted crossovers are crossovers that are 'potentially redundant' (from infra phase 1, ProRail). From left to right these are: 1303A/B, 1301A/B (Asra), 985A/B, 983A/B (Rai), 971A/B (Dmnz) and 1165A/B (Ddm). Besides these crossovers there are some indispensable and intensively used crossovers (black infra) which are 1021A/B, 1025A/B, 1005A/B and 1001A/B, used to divert trains to either Shl-Asdl or Shl-Asdz. Furthermore, there are crossovers (black infra) at stations Asdz and Asb to divert trains over different platform tracks, a crossover (yellow/red infra) at stations Asdz and Dmnz that enables turn movements. Finally, crossover 957A/B at Dmnz (black infra) is frequently used for freight trains between Dmnz and Asb.

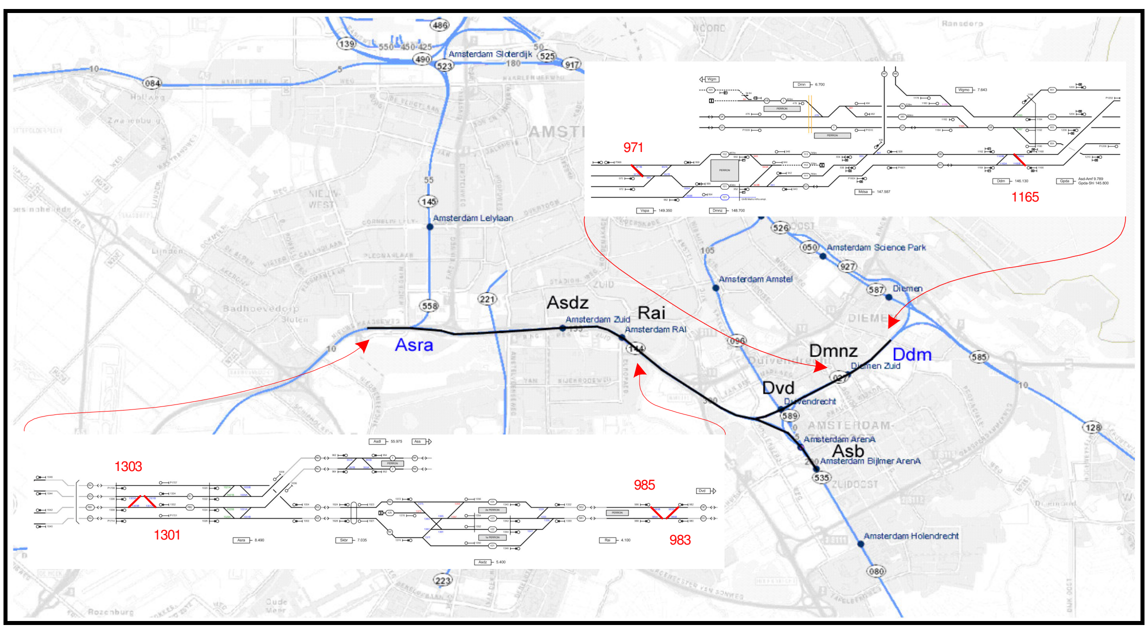


Figure 7.4 Crossovers at Asra – Asb/Dmnz

7.2.2 Comparison Applied Rescheduling and VSM

As only partial VSM is of interest in this research since crossovers (IVO switches) are used in partial obstructions exclusively, a list of these disruptions was obtained from traffic control (MUIS). The results can be seen in Table 7.1. The rescheduling (VSM no. 10) that is applicable to this corridor contains 19 different scenarios. In 2011, four out of 19 were used: VSM 10.041, 10.060, 10.101 and 10.120. More precisely, there were nine disruptions that were handled as partial obstruction: VSM 10.041 was used two times, VSM 10.060 and 10.120 were both used three times and VSM 10.101 was used once.

Table 7.1 Partial VSM 2011

Call	Corridor	VSM	Start	End	Duration	Cause
11240619	Dvd-Dmnz	10.041	14-6-2011 5:30	14-6-2011 13:27	7:57:24	Vandalism
11453442	Dvd-Dmnz	10.041	11-11-2011 7:12	11-11-2011 8:31	1:19:00	Train defect
11062020	Dvd-Dmnz	10.060	9-2-2011 13:50	9-2-2011 15:36	1:46:18	Switch/crossover
11062851	Dvd-Dmnz	10.060	10-2-2011 13:00	10-2-2011 14:10	1:10:26	Switch/crossover
11171001	Dvd-Dmnz	10.060	26-4-2011 13:42	26-4-2011 14:21	0:39:35	Train defect
11051464	Asdz-Rai	10.101	1-2-2011 22:40	1-2-2011 23:13	0:33:46	Train defect
11243462	Asdz-Asra	10.120	17-6-2011 14:05	17-6-2011 14:42	0:37:29	Train defect
11263924	Asdz-Asra	10.120	1-7-2011 7:49	1-7-2011 8:10	0:21:15	Train defect
11362477	Asra-Asdz	10.120	8-9-2011 7:40	8-9-2011 8:35	0:55:09	Train defect

It can be seen from the table that the causes and durations of disruptions were different. In Figure 7.5 the causes of partial VSM are visualized. The figure shows that train defects have the highest share (67%) while the share of disruptions due to failure of switches/crossovers is lower (22%). But short disruptions–some of them were solved within 30 minutes–were frequently due to defect trains while longer disruptions were caused by failure of rail infrastructure. The one that lasted almost eight hours was caused by vandalism due to copper theft.

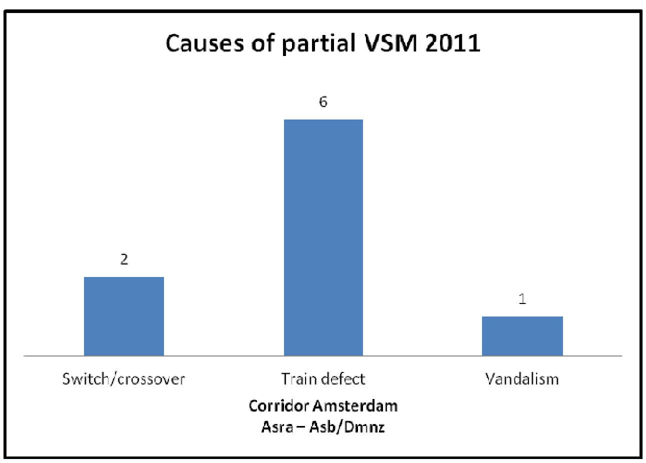


Figure 7.5 Causes of partial VSM 2011

In the remainder of this subparagraph disruptions and applied VSM on the corridor are analyzed with TOON and reports from MUIS. Similarities and differences between the applied VSM and the real processes (TOON) and reports from traffic control (MUIS) are discussed. Next, the usage of the crossovers during rescheduling is addressed. Because of the large number of disruptions, only VSM 10.041 is discussed in detail in the main report. The elaboration of the other VSM can be found in Annex H while its conclusions are described in the main report. Furthermore, in Annex I the TOON analysis is elaborated. The rail maps that have been used as support are derived from SporenplanOnline (2012) since the official OBE rail maps from ProRail are too detailed. The original VSM (VSM 10.041, 10.060, 10.101 and 10.120) can be found in Annex G.

VSM 10.041: right track between Dvd and Dmnz is obstructed. In 2011, VSM 10.041 was selected twice. The measure deals with partial obstruction between Dvd and Dmnz. The cause of the two disruptions was different. The one on June 14 was caused by copper theft which resulted in a disturbance at the section of crossover 971A/B. The affected track was out of service for almost eight hours. The second event, on November 11 was caused by a defect train at Dvd. Eventually–after approximately 1.5 hours–the train continued without help of a chartered loc resulting in less trouble. Table 7.2 shows the train processes of the measure.

Table 7.2 VSM 10.041

Operational	**Modified**	**Inserted**	**Cancelled**
SPR 4300 (returns at Dmnz)	70140, 70240 (Amf-Wgm)	29700 (Lls-Almo)	IC 140, 240, 700, 1600 (Amf-Shl)
74300			IC 3700 (Lls-Shl)
			SPR 5700 (Wp-Asdz)
			70700, 71600, 73700

June 14, 05:30-13:27. At 05:30 a disturbance at the section of crossover 971A/B (between Dvd and Dmnz) was reported. Since it was reported early in the morning, the frequency of train traffic was still low and therefore the first phase was solved quickly by letting all trains pass manually (slower) through the disturbed section. On top of that, one hour later SPR 4317 was defect at Dvd which ended up in delays for upcoming trains. From that point, the traffic controllers decided to intervene and rerouted the IC 700- and 1600-series through Asd instead of cancelling them according to the VSM. The already trapped IC 719 was directed left track through crossover 983A/B and back on right track through crossover 1165A/B. All other trains still passed the affected section (manually). At 09:49 the last SPR 5731 passed–thereafter repair work and the VSM started. The prognosis changed several times during the process: from 90 minutes to 150 minutes and finally it lasted 210 minutes. At 13:29 the repair work was done and train operations continued according to schedule. The IC 3100 and 3500-series to Asb were operational during disruption–they had less hindrance since switch 1985 was not affected. Remarkably, during the reoccupation phase IC 3549 and its consecutives were cancelled. In Figure 7.6 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. In the first phase, the IC 700- (IC 721-727) and 1600- (IC 1619-1633) series were rerouted to Asd but around 09:00, the traffic controllers followed the VSM and cancelled them between Amf and Shl. The IC 3700-series were cancelled according to the VSM. In the reoccupation phase the IC 700-, 1600- and 3700-series continued first once every two hours and then once every hour. The SPR 4300-series were directed through crossover 983A/B to left track and returned at Dmnz (shuttle train) as mentioned in VSM 10.041. In total there were seven shuttle trains between Dmnz and Gvc (SPR 4333-4347). On the opposite track the SPR 4300-series shuttled between Dmnz and Alm. The SPR 5700-series ended their service in Asdz and returned to Ledn. At the opposite direction the SPR 5700-series returned from Wp. In total there were eight SPR 5700 (SPR 5733-5747) that returned from Asdz.

Differences VSM and applied rescheduling. IC 147 was directed left track through crossover 983A/B and back on right track through crossover 1165A/B instead of being cancelled. IC 240 was rerouted to Asd and also had a stop at Asd instead of being cancelled. In MUIS they mentioned the adjustment: only rerouting towards Amf.

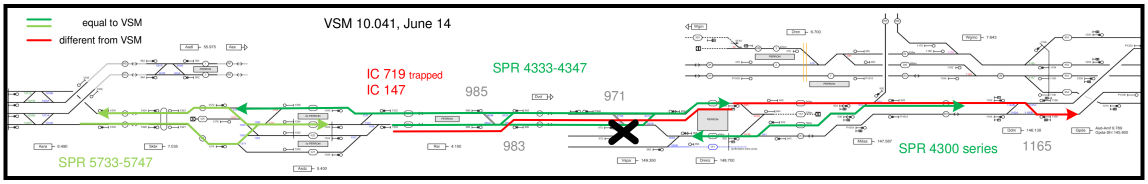


Figure 7.6 Applied rescheduling, June 14

November 11, 07:12-08:31. In the morning at 07:12, IC 141 had a defect at Dvd. In the first phase, SPR 4321 was already in the trap behind IC 141 and was returned and directed left track through crossover 985A/B and back on right track through crossover 971A/B to Dmnz. The opposite IC 716 was directed left track through crossover 983A/B because SPR 4321 was already on the left track. The second train, IC 3723 was directed left track through crossover 983A/B and back on right track through crossover 971A/B to Dmnz. At 08:29, IC 141 was able to continue without external traction. However, the traffic controllers decided to return IC 242 at Bh. The next IC 143 departed as scheduled from Shl. The IC 3100- and 3500-series to Asb were operational during disruption. In Figure 7.7 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 700- and 1600-series returned from Amf and the IC 3700-series were cancelled according to the VSM. The SPR 5700-series ended their service in Asdz and returned to Ledn. At the opposite direction the SPR 5700-series returned from Wp. In total there were three of the SPR 5700-series (SPR 5721-5725) which returned from Asdz.

Differences VSM and applied rescheduling. The SPR 4300-series were directed to left track (through crossovers 983A/B or Asdz) and back on right track (through crossover 971A/B). Compared to the VSM they did not return at Dmnz (shuttle trains). In total there were three SPR 4300 (SPR 4321-4325) that where directed left track to Dmnz. Maybe traffic controllers considered it as first phase. But in MUIS, it was reported as a VSM without adjustments.

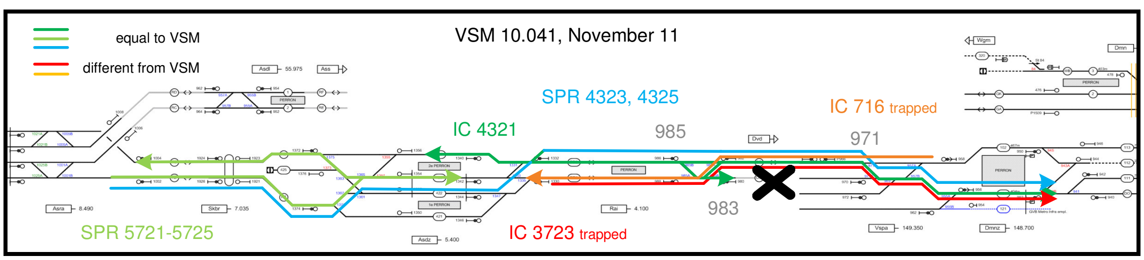


Figure 7.7 Applied rescheduling, November 11

Conclusions VSM 10.041. Table 7.3 summarizes the similarities and differences between VSM 10.041 and the applied rescheduling. The first event had quite a big impact because repair work took several hours. Since the occupation of the track was still low in the early morning the number of trapped trains was low and the VSM could be implemented fast. In the first phase, the traffic controllers used half of the measure: they only rerouted the IC 700- and 1600-series and still continued the remainder manually through the affected section. When repair work started around 10:00 they executed the whole measure. The IC 700- and 1600-series were cancelled but the IC 140 continued left track and IC 240 was rerouted to Asd. For the second event, the traffic controllers chose VSM 10.041 but eventually they executed the SPR 4300-series (no shuttle service) according to VSM 10.060. They could have thought that the defect train would be repaired very soon and therefore cancelled the more extensive shuttle service.

Table 7.3 Comparison VSM 10.041 and applied rescheduling

	VSM 10.041	June 14	November 11
Operational	SPR 4300 (shuttle)	SPR 4300 (shuttle) IC 140	SPR 4300 (no shuttle)
Cancelled	IC 140, 240, 700, 1600, 3700 SPR 5700	IC 700, 1600, 3700 SPR 5700	IC 700, 1600, 3700 SPR 5700
Rerouted	-	IC 240, 700, 1600	-
Not expected	n/a	-	IC 140, 240

Table 7.4 gives an overview of the crossovers that were used during disruption and the measure taken. Crossovers are important to excecute the measure but they are also important during the first phase. In this phase–before the measure can be executed–trains that are trapped need to be removed from the disrupted site.

Table 7.4 Crossover usage VSM 10.041 (total)

Crossover	June 14	November 11
First phase		
957A/B (Dmnz)	-	-
971A/B (Dmnz)	-	2
983A/B (Rai)	1	1
985A/B (Rai)	-	1
1165A/B (Ddm)	1	-
VSM		
957A/B (Dmnz)	1	-
971A/B (Dmnz)	-	2
983A/B (Rai)	8	1
985A/B (Rai)	-	-
1165A/B (Ddm)	1	-

Conclusions of the other VSM. VSM 10.060 was used three times and only in one of the events, the inserted 29700 between Lls and Almo was not applied according to the VSM. Furthermore, there were some differences from the VSM: some IC-series were cancelled or rerouted instead of being operational. In the last event on April 26 there was only some dispatching during the first phase to remove trapped trains, no VSM was executed. With regard to VSM 10.101 which was used one time, traffic controllers reported in MUIS that the measure was used but eventually the problem was solved with some dispatching/partly VSM. Finally, VSM 10.120 was chosen three times but all three disruption were too short and therefore rescheduling was partly executed according to the VSM. Furthermore, it can be concluded that crossovers were not only used during the VSM but also during the first phase.

7.2.3 Occupancy of Crossovers

To get some insight into the usage of the 'potentially redundant' crossovers in 2011 for corridor Amsterdam, Figure 7.8 shows the total trains that used the crossover (in curved direction). Annex J gives more details. First, it must be said that the ratio curved/straight direction of the crossovers is 1%/99%. It is clear that these crossovers are mostly used in straight direction. Hence, these crossovers are only used for rescheduling (and rust riding). The crossovers located near Rai are used less compared with the other crossovers. Further upstream there are crossovers at station Asdz where trains are returned in case of disruptions. More downstream crossover 971A/B located near Dmnz can be used as well. This crossover is also used for freight trains between Gpda and Asb during regular operations. Crossovers 1301A/B and 1303A/B are used most. Trains are able to switch to either Asdl or Asdz.

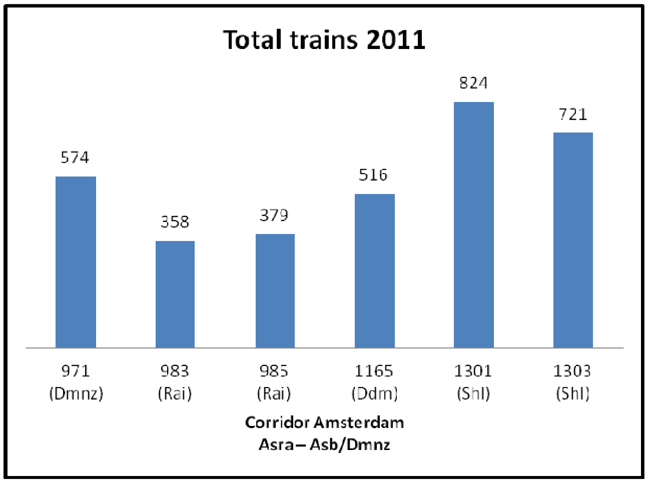


Figure 7.8 Total trains using crossover (curved)

In Figure 7.9 crossover usage during the total partial VSM in 2011 can be seen. Surprisingly, the amount is much lower compared to the total usage. These crossovers are not taken in the regular timetable but the greater part of usage in curved direction is for rust riding which must be done at least once every 24 hours. Furthermore, crossover 983A/B (Rai) is relatively often used in case of disruption between Rai and Dmnz. This has been discussed earlier. Because disruptions were solved relatively quickly fewer trains were directed left track during rescheduling.

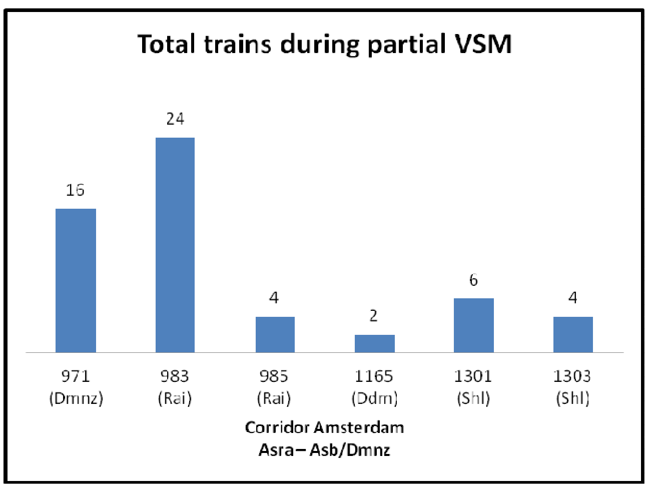


Figure 7.9 Total trains during partial VSM using crossovers (curved)

In Figure 7.10 the distribution of the 'potentially redundant' crossover usage during rescheduling can be seen. It can be stated that the first phase is important with regard to crossover usage. Traffic controllers need this typical rail infrastructure to remove trains from the disrupted area or prevent trains to enter. This accelerates the introduction of the VSM, where train operations stabilize through an alternative timetable. But from the figure it cannot be concluded that these crossovers are really needed. When crossovers are available, traffic controllers will use these as can be seen from the figure. But are they really indispensable or are there alternative solutions as well. There are some alternatives that can be used. For example, if a disruption between Rai and Dmnz occurs without crossovers at Rai, trains can be rescheduled at Asdz, either by returning them or introducing shuttle service. However, during the first phase, when trains are trapped between Rai and Dmnz, the process of removing trains can be very inefficient without these crossovers. As long as trains are stuck in the middle, the VSM cannot be implemented. The crossovers at Rai are practical in these cases.

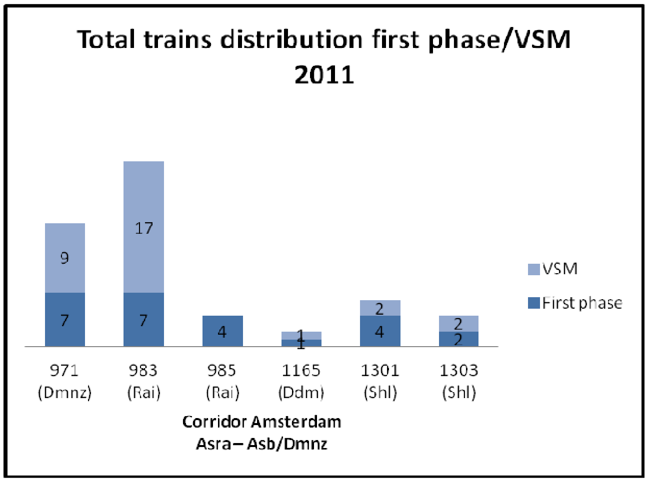


Figure 7.10 Total trains divided during first phase and VSM

7.2.4 Disturbances of Crossovers

In Figure 7.11 the disturbances of the 'potentially redundant' crossovers are shown. The data is derived from ProRail's Asset Management database. The disturbances can be split into disturbances that lead to a TAO and rescheduling (VSM) was necessary and disturbances that did not lead to a TAO. To get a more reliable overview, data from 2007 till 2011 had been collected. It can be seen that in 2007, 2008 and 2009 none of the crossovers caused a TAO. In 2010 and 2011 they did, respectively two and three times. Also in Chapter 5, it was concluded that during the years, the amount of total TAOs caused by crossovers increased. In 2010, there were a remarkably high number of disturbances that did not lead to a TAO. The three TAOs in 2011 were not severe since they were not handled with a VSM (complete or partial) i.e. there were no events where these crossovers caused disruption that led to implementation of VSM. Furthermore, there was one call in MUIS about a defect crossover 983A/B on March 1 that was not handled with a VSM but surprisingly this was not registered (no TAO) in ProRail's Asset Management database. Thus, either the ProRail Asset Management definition of a TAO or the accuracy of reporting disruptions in MUIS should be questioned.

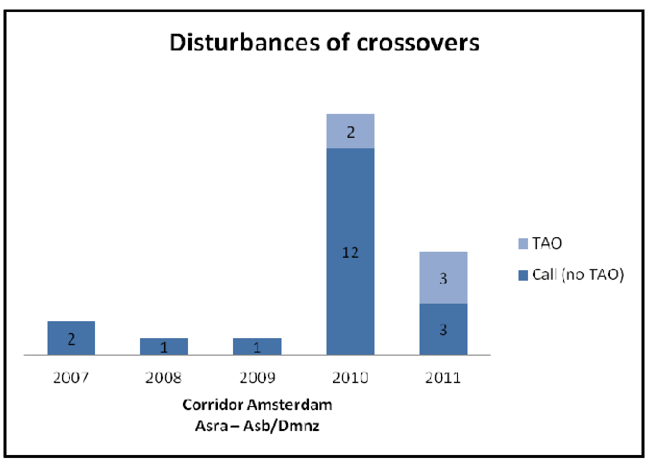


Figure 7.11 Disturbances of Crossovers

7.3 Corridor Rotterdam (Rtd – Gd)

Subparagraph 7.3.1 explains the train series and the track lay-out (crossovers). Subparagraph 7.3.2 compares the applied rescheduling and the VSM. More in-depth research about the ‘potentially redundant’ crossovers can be found in Subparagraph 7.3.3: the entire annual crossover usage and usage during VSM as well as the contribution of crossovers to the first phase and the VSM. Data of crossover disturbances is discussed in Subparagraph 7.3.4. Furthermore, in Subparagraph 7.3.5 delays and the propagation of delays are discussed.

7.3.1 Train Series and Track Lay-out

Corridor Rtd-Gd is less complicated and utilized than corridor Asra-Asb/Dmnz but it is still an important connection between Rtd and the eastern part of The Netherlands. In case of disruptions between Rtd and Gd there are no other alternatives than taking long detours through Gvc and/or Bd for through-going passengers. In that respect, passengers travelling through corridor Asra-Asb/Dmnz have the advantage of making shorter detours through Asd. Moreover, both corridors have sufficient additional public transit–metro, tram and buses–between stations. In 2011, four different train series, twice per hour were operational (Figure 7.12). There are two IC connections: the IC 2800- (Rtd-Dv) and the IC 20500- (22500-), 21700- (22700-) (Rtd-Lw) series. The latter train series are combined at Ut with the IC 500- (Gvc-Gn) and 1700- series (Gvc-Es)–each are operating once per hour (alternately). In peak hours additional train series IC 12500 and 12700 (Rtd-Lw) are operational. In between, these train series only have one stop at Rta. Finally, there are two sprinter connections: the SPR 4000- (Rtd-Utg) and SPR 9700- (Rtd-Gdg) series. The latter operates only in peak hours (06:00-09:00 and 15:00-18:00). These train series stop at all intermediate stations (Rtn, Rta, Cps, Nwk). Compared to corridor Asdz-Asb/Dmnz there are more freight trains which make rescheduling more complicated. In Annex K more information about the train series can be found.

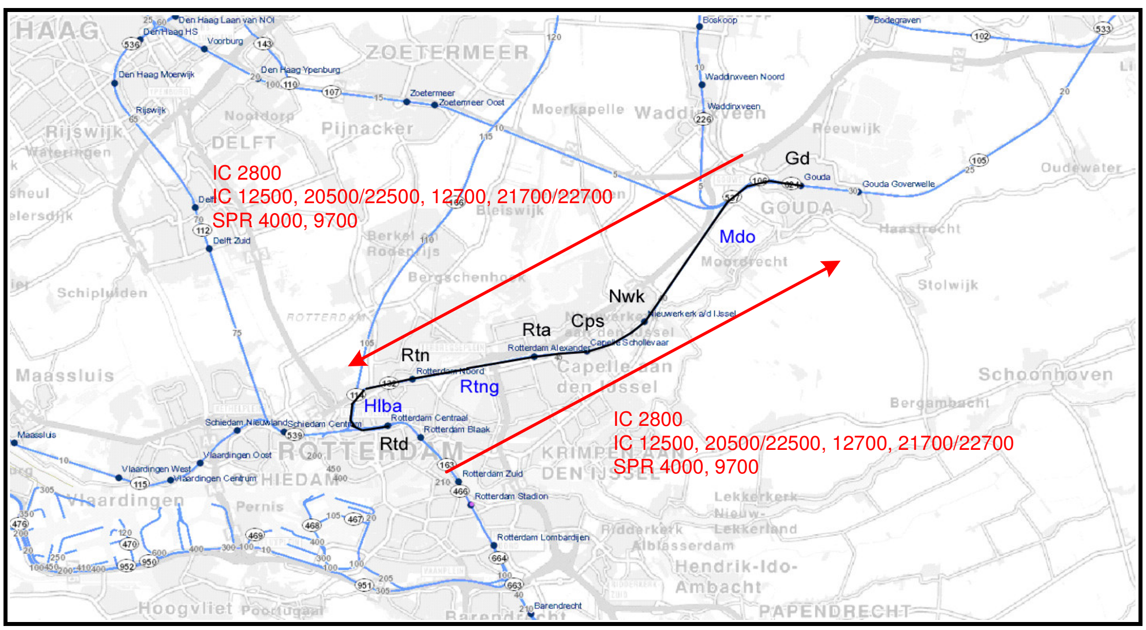


Figure 7.12 Trains through Rtd – Gd

In Figure 7.13 the track lay-out of the corridor can be seen. The red highlighted crossovers are crossovers that are ‘potentially redundant’ (from infra phase 1, ProRail). From left to right these are: 295A/B, 293A/B (Nwki), 283A/B and 281A/B (Mdo). Furthermore, there are two crossovers at Wspl (black infra) to redirect trains that enter the main station of Rotterdam, one crossover at Hlba (black infra) which enables a connection with the side track in both directions and several switches and crossovers at the side track and freight yard of Rtng. Switches and crossovers of the latter are frequently used for rescheduling as well as for both passenger and freight trains. The advantage is that traffic controllers can easily separate freight trains during disruptions by redirecting them to side tracks of Rtng thereby securing continuity of passenger train operations.

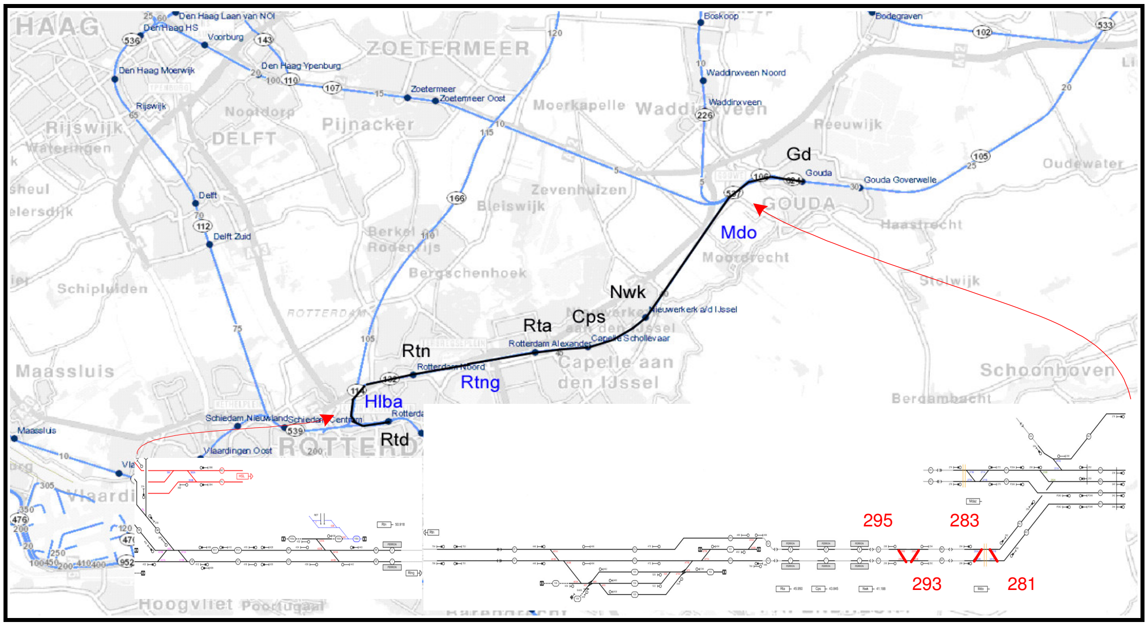


Figure 7.13 Crossovers at Rtd – Gd

7.3.2 Comparison Applied Rescheduling and VSM

In this research only partial VSM in 2011 has been investigated. As can be seen in Table 7.5 there were 10 disruptions that were handled as partial obstruction on corridor Rtd-Gd. The rescheduling (VSM no. 25) that is applicable to this corridor contains 16 different scenarios. Three out of 16 were used in 2011 which means that less than one quarter of VSM no. 25 had been used. These disruptions were handled according to VSM 25.050, 25.070 and 25.090. VSM 25.070 had the highest application– there were six disruptions between Rtng and Nwk.

Table 7.5 Partial VSM 2011

Call	Corridor	VSM	Start	End	Duration	Cause
11124231	Rtng-Hlba	25.050	27-3-2011 11:38	27-3-2011 12:15	0:37:58	Train defect
11132304	Rtng-Hlba	25.050	31-3-2011 6:48	31-3-2011 11:23	4:35:44	Train defect
11442471	Hlba-Rtng	25.050	3-11-2011 8:04	3-11-2011 8:20	0:16:55	Train defect
11015099	Nwk-Rtng	25.070	9-1-2011 21:40	10-1-2011 0:40	3:00:06	Train defect
11133955	Rtng-Nwk	25.070	2-4-2011 14:40	2-4-2011 15:50	1:10:17	Train defect
11240416	Rtng-Hlba	25.070	13-6-2011 20:50	14-6-2011 2:06	5:16:58	Catenary
11291321	Rtng-Nwk	25.070	19-7-2011 20:45	19-7-2011 21:34	0:49:39	Train defect
11460089	Rtng-Nwk	25.070	14-11-2011 4:33	14-11-2011 6:38	2:05:35	Anticipated maintenance
11485119	Rtng-Nwk	25.070	4-12-2011 21:36	4-12-2011 23:07	1:31:53	Train defect
11333234	Nwk-Mdo	25.090	19-8-2011 16:53	19-8-2011 18:07	1:14:19	Train defect

Like the previously discussed corridor, it can be concluded that the largest part of disruptions was caused by train defects (Figure 7.14). Only one disruption was caused by defect rail infrastructure but surprisingly it was no disturbance of a switch/crossover. The duration of disruptions caused by defect trains varied from 16 minutes up to 4.5 hours. But defect rail infrastructure caused the longest disruption. A broken catenary caused an obstruction of about five hours. Compared with corridor Asdz-Asb/Dmnz, rail infrastructure related disturbances also caused the longest disruptions while train defects were solved relatively quickly. Once, anticipated maintenance (maintenance according to annual planning) was delayed and resulted in rescheduled trains in the early morning. The advantage of such 'disruptions' is that traffic controllers are prepared and can implement the VSM at once entirely–there are no trapped or defect trains that have to be discharged first. Overall, it can be concluded that disruptions on corridor Rtd-Gd were longer in duration but not more complicated compared to disruptions on corridor Asdz-Asb/Dmnz.

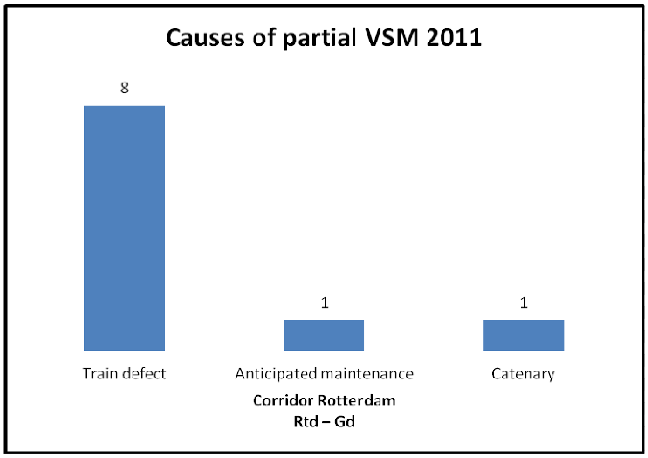


Figure 7.14 Causes of partial VSM 2011

Like corridor Amsterdam, a disruption analysis (comparison between disruption/applied VSM and TOON/reports from MUIS) was done for corridor Rotterdam. Two events of VSM 25.070 are discussed in detail in the main report. The elaboration of the other VSM can be found in Annex M while its conclusions are described in the main report. Furthermore, in Annex N the TOON analysis is elaborated. The original VSM (VSM 25.050, 25.070 and 25.090) can be found in Annex L.

VSM 25.070: one of the tracks between Rtng and Nwk is obstructed. VSM 25.070 was applied most on corridor Rtd-Gd in 2011. This measure deals with disruptions between Rtng and Nwk. The one on June 13 was the heaviest disruption which was rail infrastructure related (more than 5 hours). A defect train on January 9 caused a disruption of three hours. Table 7.6 shows the train processes of the measure.

Table 7.6 VSM 25.070

Operational	Modified	Cancelled
SPR 4000	IC 12500, 12700, 20500, 21700 (cancelled between Rtd-Gd, instead continues between Gd-Gvc)	IC 2800 (Rtd-Ut)
		SPR 9700 (Rtd-Gdg)

January 9, 21:40-00:14. Disruption was caused by a defect train 89291 at Nwk (direction Rtd => Gd). There were no trapped trains that had to be handled first. Remarkably, an international train (Asd-Shl-Rtd) was rerouted to this corridor but could continue on left track. Finally, the reoccupation phase was very short since daily timetable ended at almost one hour later. In Figure 7.15 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 2800-series were cancelled according to VSM 25.070. Almost all IC 20500 and 21700 were cancelled between Rtd and Gd, instead they continued to Gvc. Only one of them continued instead of being cancelled. The SPR 4000-series were operational as mentioned in the VSM, they were directed to the opposite track through crossovers at Nwki and at Rntg. As mentioned before the SPR 9700-series only operate in peak hours.

Differences VSM and applied rescheduling. Remarkably, one of the IC 21700-series, IC 21791 continued instead of being cancelled while it was not trapped. Traffic controllers gave no explantion for this intervention in MUIS, it was reported as rescheduling according to the VSM. Except this IC, rescheduling went according to the VSM.

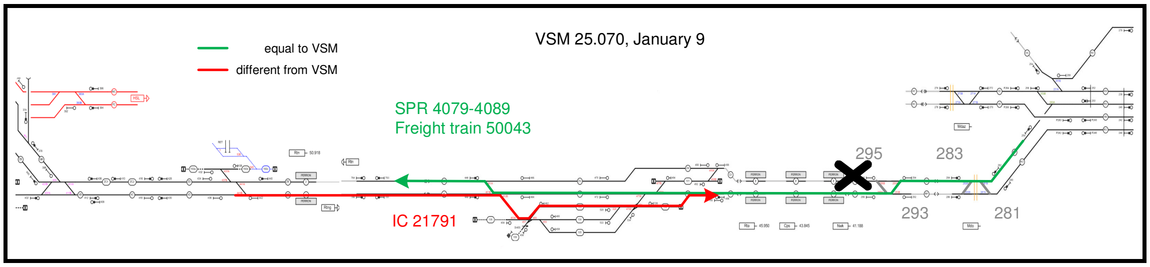


Figure 7.15 Applied rescheduling, January 9

June 13, 20:50-02:06. Because of a broken catenary on the track between Rta and Rtn partial obstruction occurred. It was the longest disruption (five hours) on corridor Rtd-Gd of 2011. One freight train that was trapped was directed on left track towards Rtd. The second arrived and trapped IC 21766 train could not continue on left track anymore since the complete power supply at Rtng had failed as well. This led to a complete obstruction and VSM 25.040 had to be implemented. Traffic controllers could not implement this VSM completely. At the same time there was anticipated maintenance at Ztmo-Mda and alternative travel advice to travel via Gvc did not hold according to reports from MUIS. Five consecutive passenger trains (IC 2800-series and SPR 4000-series) had to return at Rta or Nwk while at the opposite direction trains were cancelled at Rtd. Then power supply was available again and traffic controllers could execute the partial VSM 25.070. After seven trains that were directed to left track, repair was finished at the end of the passenger train operations (01:46). In Figure 7.16 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 2800-series were cancelled (as mentioned in the VSM: oustide peak hours it can also be cancelled between Ut and Amf) and the SPR 4000-series were operational during the disruption and were directed on left track through crossovers at Nwki and at Rtng. In first instance, during the complete obstructions these sprinter trains were cancelled too, in fact they had to return at Rta.

Differences VSM and applied rescheduling. The trapped trains IC 21768 , SPR 4075 and IC 2870 were directed left track in order to remove them from the bottleneck. During the complete obstrucion SPR 4079 and 4081 had to return at Rta and SPR 4077 and 4079 were combined and returned as well. The partial VSM had to be adapted since there was no train traffic possible between Ztmo and Mda. Therefore, the IC 20500- and 21700-series could not continue to Gvc but instead they had to return at Gd. Travelers in Amf were advised to travel via Shl to Gvc/Rtd. The FYRA had no supplement on the tickets during this period. Besides, there was alternative public transit offered by RET for travellers in the region Rotterdam.

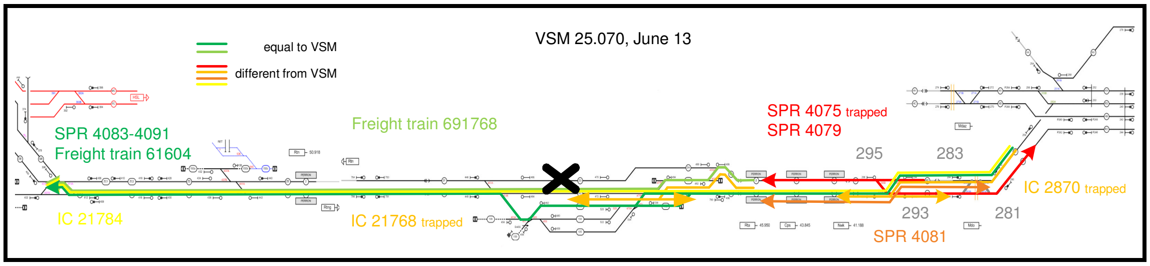


Figure 7.16 Applied rescheduling, June 13

Conclusions VSM 25.070. Disruptions between Rtng and Nwk were treated in most events according to the VSM. Only June 13 was different from VSM 25.070 but it was also more complicated. Initially there was a partial obstruction caused by a broken catenary but because of power supply failure both tracks were unreachable and it became a complete obstruction. Furthermore, there was anticipated maintenance between Ztmo and Mda so there was no possibility to travel from Rtd to Ut via Gvc or vice versa. Trapped trains were handled differently compared to the VSM. However, on January 9 one of the IC 21700-series continued instead of being cancelled while it was not trapped. In Table 7.7 the similarities and differences between VSM 25.070 and the applied rescheduling are shown.

Table 7.7 Comparison VSM 25.070 and applied rescheduling

	VSM 25.070	**January 9**	**June 13**
Operational	SPR 4000	SPR 21700 SPR 4000	IC 2800, 20500, 21700 SPR 4000
Modified	IC 20500, 21700	IC 20500, 21700	IC 20500, 21700
Cancelled	IC 2800 SPR 9700	IC 2800	IC 2800, 21700 SPR 4000
Not expected	n/a	SPR 9700	SPR 9700

The importance of crossovers in the first phase and the VSM can be seen in Table 7.8. Several times the side track at Rtng is used which indicated that this is an important option.

Table 7.8 Crossover usage VSM 25.070 (total)

Crossover	**January 9**	**June 13**
First phase		
281A/B (Mdo)	-	-
283A/B (Mdo)	-	-
293A/B (Nwki)	2	-
295A/B (Nwki)	-	-
407A/B (Wspl)	-	-
411A/B (Wspl)	-	1
441A/B (Hlba)	-	-
451A/B (Rtng)	2	-
453A/B (Rtng)	-	-
457 (Rtng)	-	-
475A/B (Rtng)	-	-
477A/B (Rtng)	-	2
493A/B (Rtng)	-	2
541 (Rtng)	-	-
VSM		
281A/B (Mdo)	-	-
283A/B (Mdo)	-	-
293A/B (Nwki)	6	8

Crossover	January 9	June 13
295A/B (Nwki)	-	2
407A/B (Wspl)	-	-
411A/B (Wspl)	-	8
441A/B (Hlba)	-	-
451A/B (Rtng)	6	-
453A/B (Rtng)	1	6
457 (Rtng)	1	6
475A/B (Rtng)	-	5
477A/B (Rtng)	-	-
493A/B (Rtng)	-	-
541 (Rtng)	1	1

Conclusions of the other VSM. All three events went according to VSM 25.050. But March 27 is a clear example of the arbitrary manner of reporting the rescheduling proces and the eventually executed rescheduling process which was analysed with TOON. Sometimes reported actions were not taken in reality. Moreover, it happened frequently that crossovers were used to couple and abduct 'defect' trains to stations/yards and not only for processing other affected trains during the disruption: first phase and VSM. It can be concluded that these kind of side tracks play an important role in rescheduling as well.

The other four disruptions of VSM 25.070 between Rtng and Nwk were mainly treated according to the VSM. On April 2 one of the IC 21700-series continued and one SPR 4000-series was cancelled as opposed to continue. These trains were not trapped but traffic controllers gave no explantion for these interventions in MUIS. Furthermore, crossovers are useful in case of delayed anticipated maintenance on one track which was the case on November 14.

With respect to VSM 25.090, the event on August 19 went according to the VSM. Only one trapped SPR 9700-series continued instead of being cancelled. But it was trapped and there was the opportunity to redirect it to left track. An advantage of a disruption between Nwk and Mdo is the availability of two crossovers at a relatively small distance of each other. Therefore rescheduling is not complicated and train operations can continue on left track without long delays. That might be a reason to process trains in such a way while in the VSM these trains must be cancelled.

7.3.3 Occupancy of Crossovers

To get some insight into the usage of the 'potentially redundant' crossovers in 2011 for corridor Rotterdam, Figure 7.17 shows the total trains that used the crossover (in curved direction). Annex O gives more details. As was the case for corridor Amsterdam, also for corridor Rotterdam the ratio curved/straight direction of the crossovers is 1%/99%. These crossovers are mostly used in straight direction and only used in curved direction during rescheduling or rust riding. From the figure it can be seen that the crossovers located near Mdo have the highest usage. This is remarkable since in the examined events of 2011, the crossovers of Mdo were only used in one event. Probably, the crossovers at Mdo are used in the regular timetable as well.

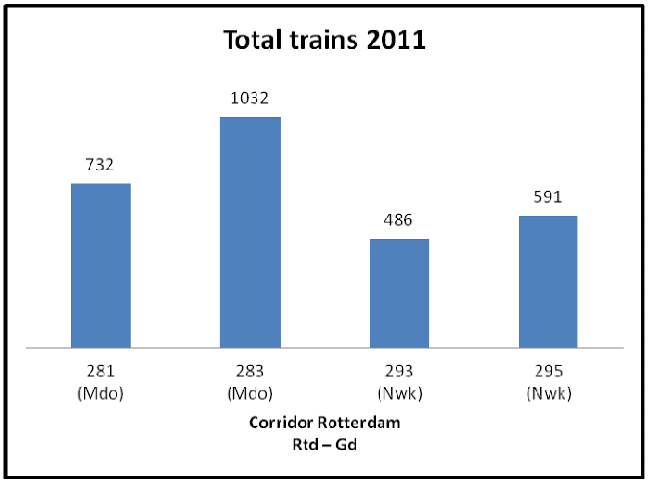


Figure 7.17 Total trains using crossover (curved)

The ones at Nwki were more used (Figure 7.18). There were more disruptions between Rta and Nwk than between Nwk and Mdo. Besides, it is understandable that traffic controllers choose these crossovers as preference in case of a disruption between Rta and Nwk since the distance operating left track is shorter, despite the fact that the crossovers at Mdo allow a higher speed (80 km/h instead of 40 km/h). Also for this case study the usage of crossovers during rescheduling is much lower compared to the total usage. This can be explained by rust riding.

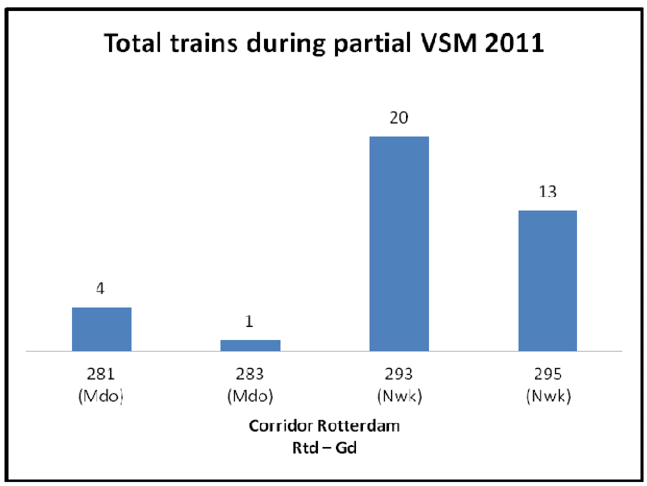


Figure 7.18 Total trains during partial VSM using crossovers (curved)

In Figure 7.19 the distribution of the 'potentially redundant' crossover usage during rescheduling can be seen. It can be concluded that during the first phase, crossovers are used less compared with case study Amsterdam–the usage of crossovers during the VSM is relatively higher. This can be explained by two things. In November there was delayed anticipated maintenance and the VSM could directly be implemented since it was at the start of daily operations. The event in June was severe and therefore the VSM lasted for a long period (five hours). If one of the crossovers, either at Nwki or Mdo is removed, train operations in both directions are still possible in case of a disruption between Rta and Nwk. If both crossovers are removed, trains have to be rerouted to Gvc. The switches and crossovers at Rtng are very important during the first phase for removing trapped trains as was observed during the TOON analysis.

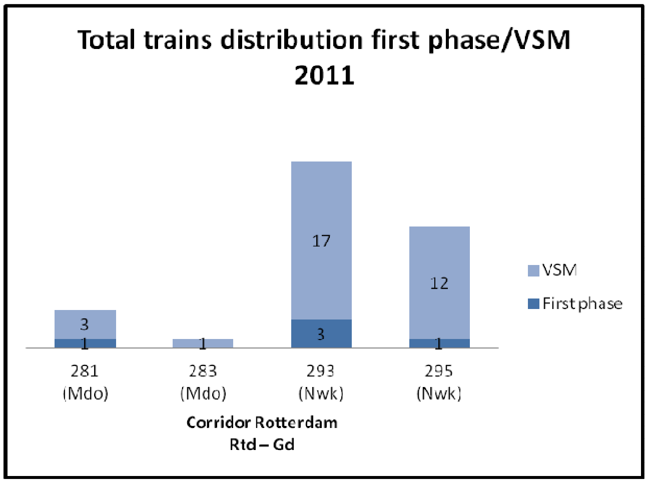


Figure 7.19 Total trains divided during first phase and VSM

7.3.4 Disturbances of Crossovers

In Figure 7.20 the disturbances of the 'potentially redundant' crossovers are shown. The data is derived from ProRail's Asset Management database. The disturbances can be split into disturbances that led to a TAO and rescheduling (VSM) was necessary and disturbances that did not lead to a TAO. For a reliable overview data from 2007 till 2011 had been collected. It can be seen that in 2007 there were no disruptions caused by one of the crossovers at Nwki and Mdo. In the consecutive years there were both disturbances that led to a TAO and disturbances that did not lead to a TAO. The amount of TAOs in 2008, 2009, 2010 and 2011 is relatively low but constant: each year, there were two TAOs caused by these crossovers. But these TAOs were not severe since they were not handled with a VSM (complete or partial) i.e. there were no events where these crossovers caused disruption. Therefore, some questions should be placed by the definition of a TAO by ProRail Asset Management.

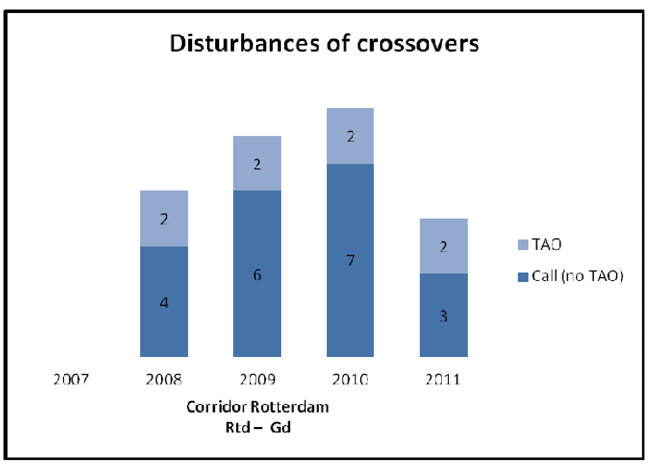


Figure 7.20 Disturbances of Crossovers

7.3.5 Delays and Propagation

Two of the events which were handled with VSM 25.070 are further analyzed concerning delays and the propagation. VSM 25.070 handles partial obstructions between Rtng and Nwk and thus makes use of crossovers: 281A/B, 283A/B (Mdo) and 293A/B, 295A/B (Nwki). Trains in the area of Rotterdam and Utrecht have been analyzed using data from the Monitoringsystem. As mentioned in Chapter 6, the Monitoringsystem stores only the explained train delays which are trains that have a delay and an increasing delay of at least three minutes.

January 9, 21:40-00:14, train defect. Table 7.9 gives an overview of reported increasing train delays on the affected corridor. It shows that a train is directly affected by a certain cause (reported by the traffic controller) or that it is affected by an indirect coupled train (this is either done automatically or manually by the traffic controller). Nine trains were affected by defect train 89291. SPR 4078 was directly affected by disruption and had a 10 minutes delay (cause: applied VSM). IC 21772 should depart at 21:17 but had a knock-on delay of 14 minutes caused by IC 1772 at Ut. This was because IC 21772 had to continue to Gvc instead of Rtd according to the VSM. SPR 4078 had a knock-on delay caused by IC 1783 at Gdg. The train was delayed because of opposite trains that were directed to left track. According to the Monitoringsystem no trains on other corridors in the area of Rotterdam and Utrecht were affected by trains on the disrupted corridor. Hence, the propagation of disruption was small but within the disrupted area several trains had experienced long delays.

Table 7.9 Delays of trains on the affected corridor

Train	**Type**	**Post**	**Location**	**Time**	**Delay**	**Increasing delay**	**Indirect coupling train**	**Cause**
21772	IC	UT	Ut	21:17	14	14	1772	
21791	IC	RTD	Rtd	0:05	11	11		No crew available
		RTD	Rtngo		16	4		
4078	SPR	RTD	Rtngw	22:01	10	7		Applied VSM
		UT	Gdg	22:22	12	4	1783	
4080	SPR	RTD	Rtngw	22:31	5	5		Disturbance train
4086	SPR	RTD	Rtngw	0:01	3	3		Disturbance train
4079	SPR	UT	Nwki	21:47	6	5		Applied VSM
4081	SPR	UT	Gd	22:12	6	6		Applied VSM
4087	SPR	UT	Nwki	23:47	3	3		Applied VSM
89251	LM	RTD	Rtd	22:00	19	19		Disturbance train
		RTD	Rtngo	22:07	22	3		
		RTD	Rta	22:09	25	3		
89291	LM	RTD	Nwki	21:32	179	181		Disturbance train

June 13, 20:50-02:06, catenary. This event was quite severe and lasted for more than five hours. In Table 7.10 an overview of reported increasing train delays on the affected corridor can be seen: 15 trains were affected. IC 2879 had a knock-on delay of 20 minutes caused by IC 21779. However, TOON analysis shows that this train was directed left track and returned at Nwk to Ut which caused the delay.

Table 7.10 Delays of trains on the affected corridor

Train	**Type**	**Post**	**Location**	**Time**	**Delay**	**Increasing delay**	**Indirect coupling train**	**Cause**
302879	IC	UT	Nwki	21:02	18	18		Disturbance track
2879	IC	UT	Gd	21:09	20	20	21779	
		UT	Gdg	21:11	27	7		
		UT	Utwaw	21:25	34	7	709881	
21787	IC	UT	Gdg	23:26	5	4		Disturbance track
4074	SPR	RTD	Rta	21:04	10	10		Disturbance track
		UT	Gd	21:19	15	3		Disturbance track
		UT	Gdg	21:22	18	3		Disturbance track
4078	SPR	RTD	Rta	22:04	21	21		Disturbance track
		UT	Nwki	22:11	24	3		Disturbance track

Train	Type	Post	Location	Time	Delay	Increasing delay	Indirect coupling train	Cause
4082	SPR	UT	Gdg	23:22	7	4		Disturbance track
4086	SPR	RTD	Rta	0:04	4	4		Disturbance track
4088	SPR	RTD	Rtngo	0:33	4	3		Disturbance track
4090	SPR	RTD	Rtd	0:55	4	4		Disturbance track
		RTD	Rtngo	1:03	7	3		Disturbance track
4075	SPR	UT	Gd	20:42	3	3		Disturbance track
4077	SPR	UT	Gd	21:12	3	3		Disturbance track
		UT	Nwki	21:17	8	3		Disturbance track
4083	SPR	RTD	Rtngw	22:56	9	7		Disturbance track
4085	SPR	UT	Gd	23:12	3	3		Disturbance track
		RTD	Rtngw	23:26	9	3		Disturbance track
4087	SPR	RTD	Rtngw	23:56	7	5		Disturbance track
		RTD	Rtd	0:05	11	4		Disturbance track
4089	SPR	UT	Nwki	0:17	6	4		Disturbance track
		RTD	Rtngw	0:26	13	4	61604	Disturbance track
4091	SPR	UT	Gd	0:42	4	3	21784	Disturbance track

Fourteen trains on other corridors in the area of Rotterdam and Utrecht were affected by trains on the disrupted corridor (Table 7.11). But only one train had a knock-on delay caused by another train from the disrupted corridor. SPR 709881 had a 5 minutes knock-on delay caused by SPR 4074. The other 12 trains were affected but it was not clear which trains on the disrupted corridor caused these knock-on delays. Only the cause of delay was mentioned in the system (last column of the table). So either the traffic controller mentioned the wrong cause or the Monitoringsystem did not make the indirect couple between trains. This indicates that the Monitoringsystem is not reliable for analyzing delays and its propagation.

Table 7.11 Delays of trains on other corridors

Train	Type	Post	Location	Time	Delay	Increasing delay	Indirect coupling train	Cause
574	IC	UT	Ut	21:39	6	3		Applied VSM
29761	IC	UT	Gdg	21:36	6	5		Disturbance track
		UT	Wd	21:46	11	7		Rescheduling rolling stock
	IC	UT	Ut	21:57	12	3		Applied VSM
300577	IC	UT	Gdg	21:29	5	3		
		UT	Wd	21:35	9	3		Rescheduling rolling stock
691768	IC	RTD	Rtngo	20:43	4	3		Disturbance track
691775	IC	UT	Ut	21:18	7	9		Applied VSM
709872	SPR	UT	Utt	21:09	3	3	691775	
709881	SPR	UT	Gdg	21:31	5	5	4074	Disturbance track
709893	SPR	UT	Ut	0:55	10	10		
810787	LM	UT	Utoa	1:35	6	4		
		UT	Ut	1:37	11	5		
810884	LM	UT	Ut	0:54	34	33		
811986	LM	GVC	Dt	0:57	5	5	5184	

Train	Type	Post	Location	Time	Delay	Increasing delay	Indirect coupling train	Cause
		GVC	Gv	1:04	9	4	5184	
819895	LM	UT	Ut	1:17	32	32		
61604	GO	UT	Gd	23:45	26	13		Disturbance track
		RTD	Rtngw	0:03	32	5		Disturbance track

Conclusions. From the two events that were analysed it can be concluded that on January 9 the propagation of disruption was small i.e. no other trains on the corridor in the area of Rotterdam and Utrecht were affected but within the disrupted area several trains had experienced long delays. June 13 was more severe because 13 trains on other corridors in the area of Rotterdam and Utrecht were affected.

Unfortunately, data from the Monitoringsystem is not complete. Furthermore, it is not a reliable means to get total insight into delays and its propagation. Not all indirect couplings (knock-on delays) are made and frequently other causes of disruption are reported. As complement TOON could be used to see whether a knock-on delay eventually dissolves but this is difficult and very time-consuming.

7.4 Conclusions: Disruption Analysis Amsterdam and Rotterdam

Disruption analysis was done for two case studies: corridor Amsterdam and Rotterdam. From the results of both some general conclusions could be made.

Disruption calls 2011

1. Looking at the total reported disruption calls in MUIS, half of the calls resulted in no VSM, while about 35% was partial VSM and approximately 15% was complete VSM.
2. Most disruptions that needed VSM were caused by defect trains rather than infrastructure related defects.

Comparison applied rescheduling and VSM

3. The largest part of the rescheduling went according to the VSM.
4. But some disruptions were too short and therefore rescheduling was partly executed according to the VSM.
5. Sometimes it was difficult to determine the transition of the first phase to the implementation of the VSM since traffic controllers use the same measures (VSM).
6. Reporting the rescheduling process is arbitrarily done in MUIS if compared with the eventually executed rescheduling process obtained from TOON.

Occupancy of crossovers

7. Crossovers are used frequently during rescheduling.
8. Especially during the first phase–when trains are trapped–crossovers are needed to quickly remove and prevent trains to enter. This will speed up the implementation of the VSM either if partial or complete VSM is used.
9. And crossovers allow implementation of a VSM at once which is the case of delayed anticipated maintenance.
10. Crossovers are also frequently used to couple and abduct ‘defect’ trains to stations/yards.

Disturbances of crossovers

11. Crossovers do influence the performance of the railway system i.e. according to ProRail’s Asset Management database crossovers lead to a small number of TAOs.
12. But from disruption analysis (TOON and MUIS reports) there were no events where these crossovers caused disruption that led to implementation of VSM. Thus, either the ProRail Asset Management definition of a TAO or the accuracy of reporting disruptions in MUIS should be questioned.

Delays and propagation

13. Delays and its propagation depend on the severity of disruption. When disruption was shorter (< 3 hours) no other trains on other corridors within the area of Rotterdam and Utrecht were affected. When disruption took longer (> 3 hours) delays were propagated, affecting other trains on other corridors within the area.
14. But data from the Monitoringsystem is not complete and it is not a reliable means to get total insight into delays and its propagation. Not all indirect couplings (knock-on delays) are made and frequently other causes of disruption are reported.

8 Simulation Study Rotterdam

With a simulation it is possible to analyze different scenarios and its effects on the performance of rescheduling. In this chapter the corridor Rotterdam is simulated. In Paragraph 8.1 the different scenarios are described. In Paragraph 8.2 the simulation results are discussed. The passenger costs of the different scenarios are estimated in Paragraph 8.3. In Paragraph 8.4 the operator costs are estimated while in Paragraph 8.5 the costs for the infrastructure manager, the (annual) costs of crossovers are described. Finally, in Paragraph 8.6 the costs and benefits are weighed and Paragraph 8.7 ends with a short summary.

8.1 Scenarios

Three scenarios are analyzed. All scenarios deal with partial obstruction between Rta and Cps in the direction of Rtd to Gd. The disruptions take place during peak hours from 08:00 till 10:00 since the average duration of disruptions in 2011 was approximately two hours. First, the reference situation is simulated which is the situation wherein rescheduling is applied according to VSM 25.070. Second, scenario 1: crossover at Cpso is simulated whereby the crossover at Nwki is removed and replaced by a crossover between Cps and Nwk: Capelle Schollevaar overloop (Cpso). Finally, scenario 2 is analyzed wherein both crossovers (at Nwki and Mdo) are removed.

8.1.1 Reference Situation

In the reference situation rescheduling is applied according to VSM 25.070 (Annex L). There is a partial obstruction between Rta and Cps and trains are redirect to left track through crossovers at Rtng and Nwki. This can be seen in Figure 8.1. According to VSM 25.070, only SPR 4000-series are operable. Others train series (IC 2800, IC 20500/21700 and SPR 9700) are cancelled.

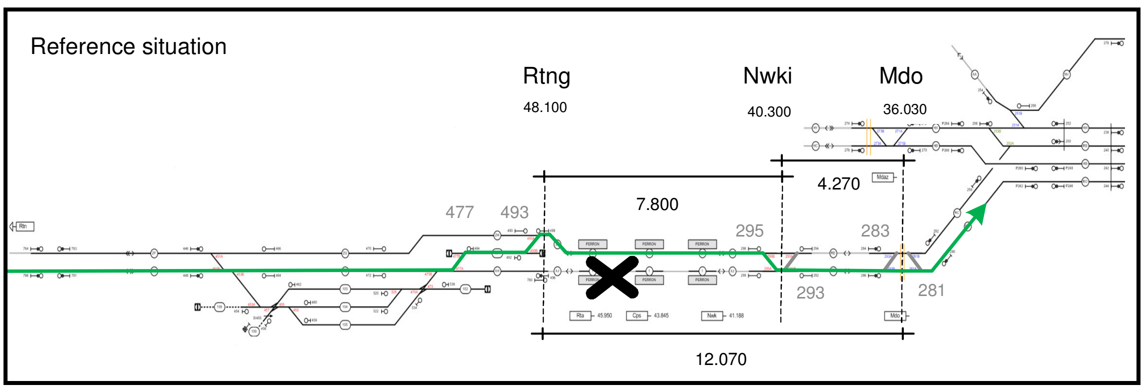


Figure 8.1 Reference situation

8.1.2 Scenario 1: Crossover at Cpso

In scenario 1 the crossover at Nwki is removed and replaced by a crossover between Cps and Nwk. As discussed in Chapter 2, Veit (2006) concluded that the optimum distance between crossovers is 7.5 kilometers in case of 6 and 4 trains/hour/track. This means that the distance between the crossovers at Nwki and Mdo is less than the optimum (4.3 kilometers) while the distance between Rtng and Nwki is above the optimum (7.8 kilometers). This can be seen in Figure 8.1. But these optimal distances are not always feasible and Veit recommended a follow-up distance of no more than 10 kilometers. With the latter statement in mind, it can be concluded that the follow-up distances of the crossovers on corridor Rotterdam are in the right order of range but not optimal.

To create a more efficient situation there is the possibility of removing the crossover at Nwki and replacing it by a crossover between Cps and Nwk (Figure 8.2). In this scenario the follow-up distances are more evenly distributed among the corridor (5.9 and 6.1 kilometers instead of 7.8 and 4.3 kilometers). Furthermore, most disruptions occur in the surroundings of stations. For example, train defects are most often notified when they are arriving or departing. Also the density of vulnerable switches is higher at stations. Moreover, Penders et al. (2011) concluded that the closer a new crossover is located to the disruption, the more the user and operator benefit. In choosing the optimal location at kilometer point 42.165, restrictions due to a slope between Rta and Cps and signal placements (minimum distance between signals and the allowed speed) have to be taken into account.

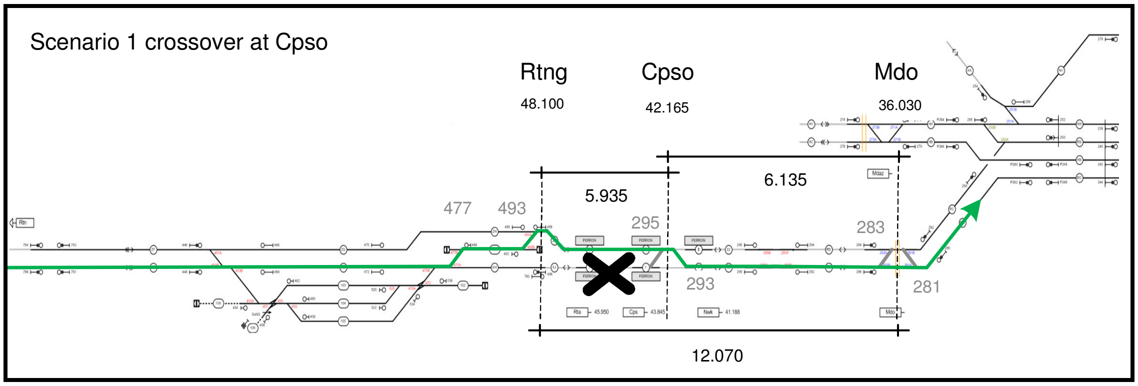


Figure 8.2 Scenario 1: crossover at Cpso

The crossover at Mdo is a 1:15 switch which means that a speed of 80 km/h is allowed in curved direction while the crossover at Nwki is a 1:9 switch and only allows a speed of 40 km/h (Annex B). For the simulation the new crossover at Cpso is also a 1:15 switch instead of 1:9. The capacity will be higher.

8.1.3 Scenario 2: Crossovers Removed at Nwki and Mdo

In the last scenario the crossovers at Nwki and Mdo are removed (Figure 8.3). In case of a partial obstruction between Rta and Cps it is possible to redirect to the left track (through switches at Rtng) but the first possibility to continue to the right track is approximately 16 kilometers further at Gd which is a long distance. Moreover, the capacity of left track is insufficient to handle four SPR trains per hour. Therefore the disruption must be handled with a complete VSM (VSM 25.060). Trains are cancelled or rerouted which affect passenger service.

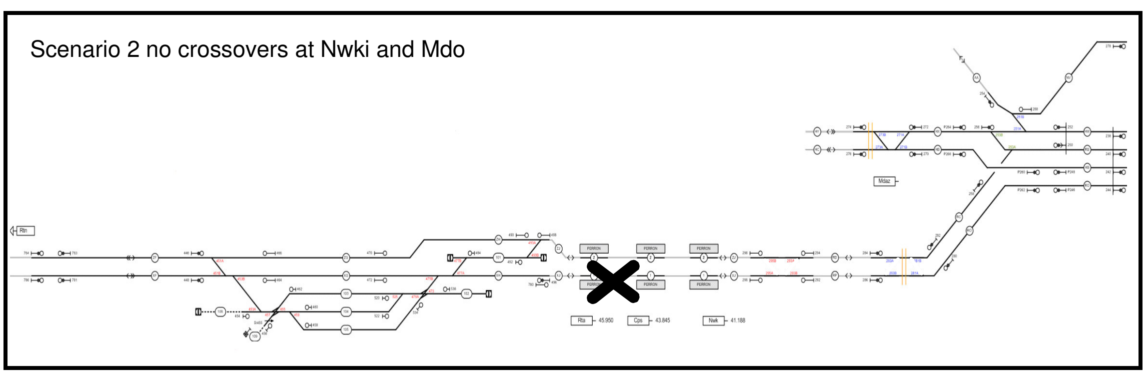


Figure 8.3 Scenario 2: crossovers removed at Nwki and Mdo

8.2 Simulation Scenarios

In this paragraph the reference situation (Subparagraph 8.2.1) and scenario 1: crossover at Cpso (Subparagraph 8.2.2) are simulated with the simulation program OpenTrack. Scenario 2: crossovers removed at Nwki and Mdo is not simulated because there are no operations possible between Rtd and Gd.

As described in the previous paragraph, a disruption in 2012 is simulated between Rta and Cps in the direction of Rtd to Gd. The disruption lasted from 08:00 till 10:00. In Annex P the BUP (Basis Uur Patroon) of corridor Rtd – Gd can be seen. In Annex Q the OpenTrack models of different scenarios can be seen. In Annex R the validation of the OpenTrack reference situation is described by means of speed-time diagrams of several trains at different times. Finally, Annex S shows the OpenTrack simulation results of the different scenarios in more detail.

8.2.1 Simulation Reference Situation

The reference situation as modeled in OpenTrack can be seen in Figure 8.4.

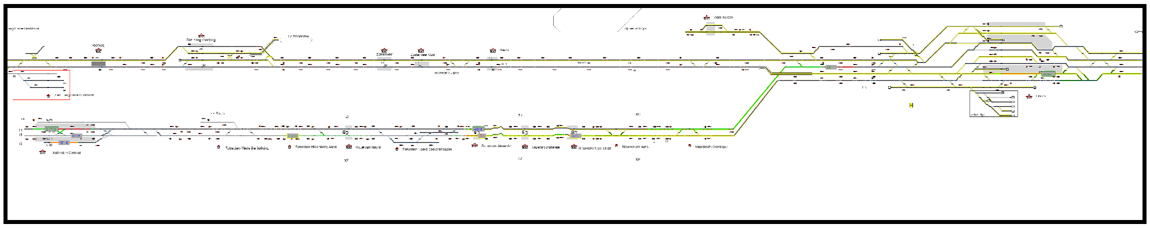


Figure 8.4 OpenTrack model reference situation

From the BUP and Figure 8.5 it can be concluded that four trains per hour on left track are feasible with the current configuration of crossovers. The dotted line is the schedule operations (BUP) and the normal line is the output of OpenTrack. The fitting of the two lines is acceptable with a 100% performance (Figure 8.5). The blue lines are SPR trains, green are IC-trains and red are freight trains. There are some delays which were the longest during the start of the VSM. The first SPR 4022 has to wait at Rtng for the opposite train and therefore has the longest delay of 7 minutes when arriving at Gd. Also the opposite train SPR 4025 has a delay of 4 minutes because it has to wait for SPR 4022 at Nwki. For consecutive trains the delay increases between Nwk and Mdo, 4 minutes at Mdo but eventually it decreases to 2 minutes at Gd.

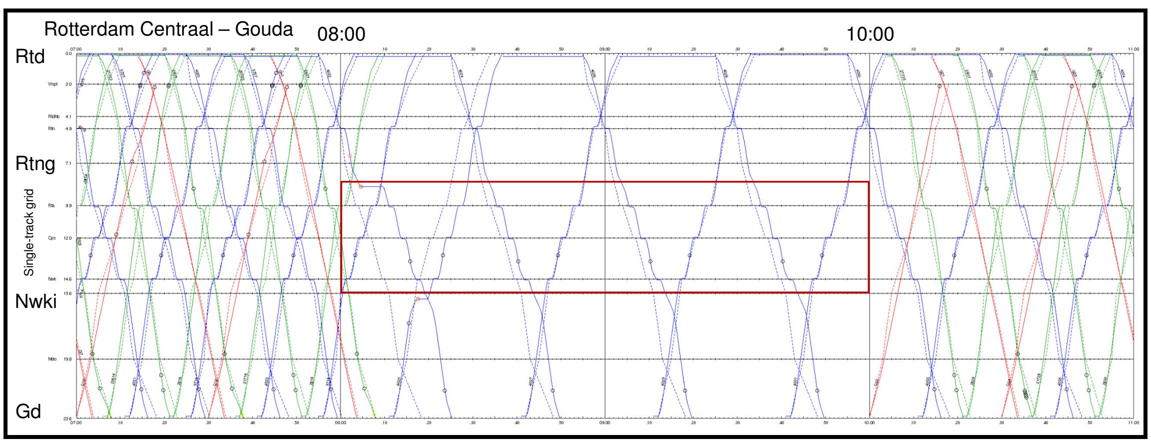


Figure 8.5 Train traffic diagram reference situation according to VSM 25.070

In Figure 8.6 an additional train series IC 2800 is added. It can be concluded that the quality of operations decreases since long delays occur. The IC 2800-series towards Gd have delays of 8 minutes at Gd. Also delays of SPR 4000-series increase. This confirms that only four trains per hour are possible for left track operations.

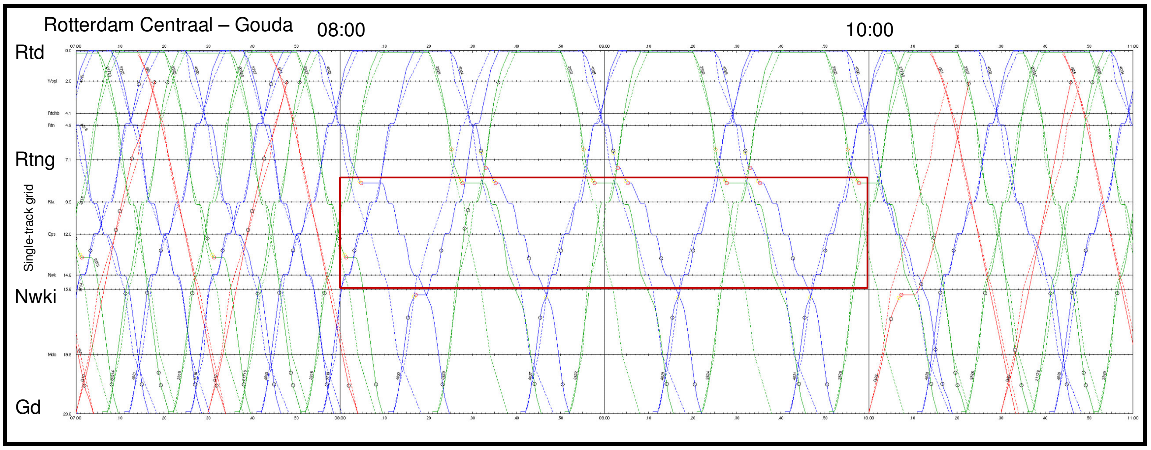


Figure 8.6 Train traffic diagram reference situation with additional IC-series

8.2.2 Simulation Scenario 1: Crossover at Cpso

The scenario can be seen in Figure 8.7.

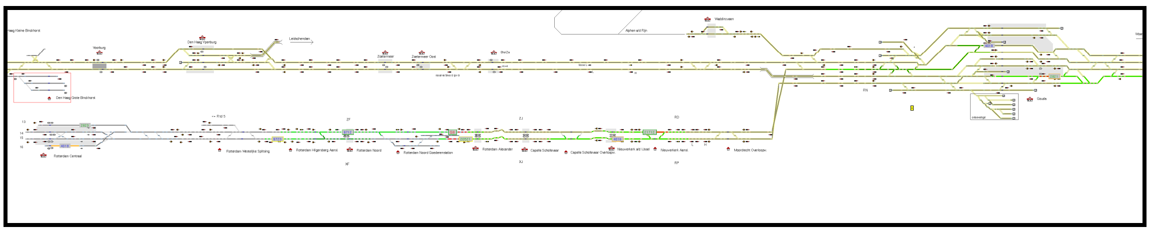


Figure 8.7 OpenTrack model scenario 1: crossover at Cpso

Simulating left track through crossover at Cpso yields shorter delays as can be seen in Figure 8.8. The maximum delay is 2.5 minutes between Rtn and Mdo but when trains arrive at Gd delays have dissolved. This is probably due to the fact that the crossover at Cpso allows a speed of 80 km/h instead of 40 km/h which was the case at Nwki.

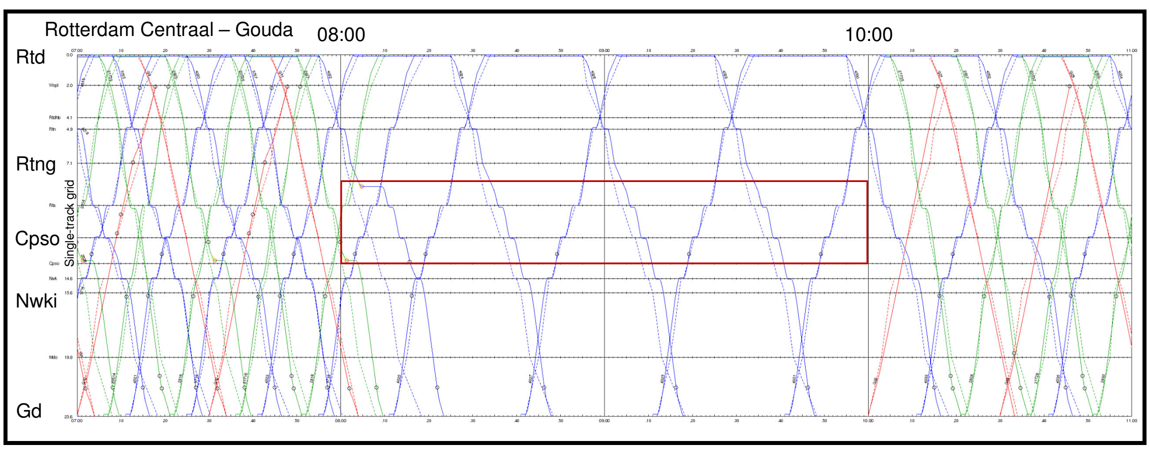


Figure 8.8 Train traffic diagram scenario 1 according to VSM 25.070

In Figure 8.9 an additional train series IC 2800 is added. It can be concluded that in this scenario the quality of operations also decreases. This means that a crossover at Cpso instead of Nwki does not increase the performance of the VSM. There is only a minor difference between this scenario and the reference situation. Therefore, it can be concluded that this scenario does not have an added value to the performance of the VSM.

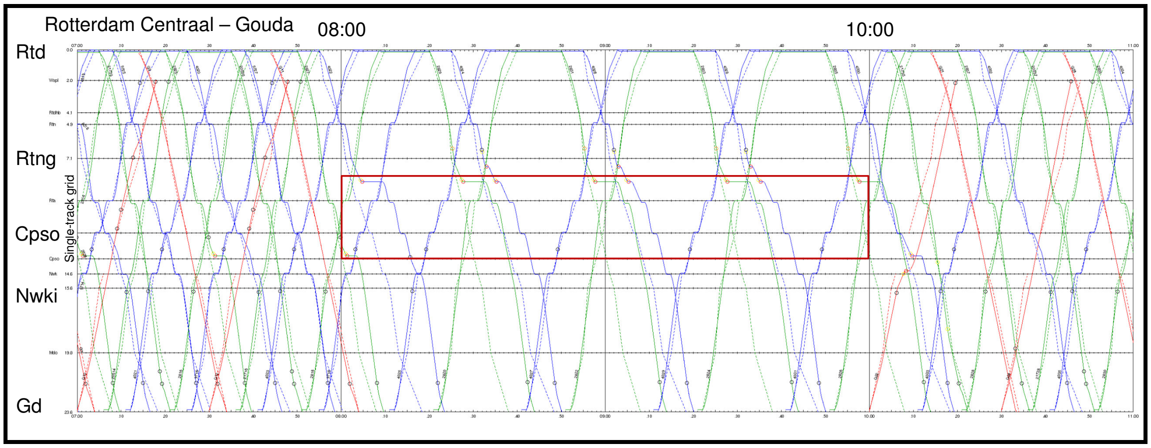


Figure 8.9 Train traffic diagram scenario 1 with additional IC-series

8.3 Passenger Costs

In this paragraph passenger costs are estimated. In case of disruption passenger benefits are negative. Data on Value of Time (VOT), train characteristics and passenger load are needed for estimates based on the conclusions from the simulation in the previous paragraph.

8.3.1 Value Of Time

To monetize the consequences of delays for passengers, it is common practise to use the VOT. The VOT defined by DVS/SEE (2011) is applied in this research. The VOT for home/work travel is €9.55 hr/passenger. For business travel this is much higher i.e. €33.07 hr/passenger. During peak hour most travel is home/work and since it is unclear what the division is among home/work travel and business travel on corridor Rotterdam, only the VOT for home/work travel is applied to estimate passenger costs. Therefore, the estimates might be lower than in reality.

8.3.2 Train Characteristics and Passenger Load

The IC 2800-series are VIRM 6 trains, the IC 20500/21700-series are ICM 7 trains and the SPR 4000- and 9700-series are SLT 6 trains. In Table 8.1 the train characteristics can be seen which are needed for the estimation of the costs (Wikipedia, 2012a). For the occupancy of the trains in peak hours, 80% is assumed. This implies 674 passengers for VIRM 6, 472 passengers for ICM 7 and 488 passengers for SLT 6 during peak hour period.

Table 8.1 Train characteristics and passenger load

	VIRM 6	ICM 7	SLT 6
1e class (seats)	129	94	56
2e class (seats)	438	346	266
Standings	276	150	288
Capacity (total)	843	590	610
Occupancy (peak hour)	80%	80%	80%
Passenger load	674	472	488

8.3.3 Estimations

Because the IC 2800-, IC 20500-/21700- and SPR 9700-series are cancelled, passengers on the corridor have to be rerouted. Through-going passengers to Gd have to be rerouted from Rtd through Gvc to Gd. This takes approximately 50 minutes while the normal travel time from Rtd to Gd is approximately 20 minutes–depending on type of train service, IC or SPR. The extra travel time for these passengers is 30 minutes. This implies extra costs of €4.775 per passenger. Part of the passengers alight at Rtn, Rta, Cps and Nwk. These passengers have to take other alternative public transit such as tram and bus. It is assumed that the extra travel time does not exceed 30 minutes. Hence, also for these passengers the extra costs are €4.775 per passenger.

However, in case of partial obstruction (reference situation and scenario 1: crossover at Cpso) part of the passengers do not take a detour but make use of one of the nine SPR 4000-series that are still operable during the two hour disruption. This implies that the occupancy of these trains (SLT 6) increases from 80 to 100%. This is 1,098 (20% => 122 x 9 trains) passengers who otherwise would have used one of the other train series. It is assumed that these passengers have no delay. Furthermore, there were two trains (IC 2818 and SPR 9718) that were trapped because trains on the opposite direction (Rtd to Gd) were directed on left track. These trapped trains had to wait for several minutes before continuing to Rtd.

In case of complete obstruction, passengers have to take a detour, use alternative public transit or make use of bus replacement service offered by the train operator. Furthermore, the two trapped trains are able to continue to Rtd. It is assumed that traffic controllers would not return these trains to Gd because the obstruction is at the opposite track.

Finally, one must realize that this disruption is just one of events that could occur. There are also disruptions that lead to more trapped trains and consequently higher passenger costs. It depends on the location of disruption and on the applied rescheduling. Therefore, the passenger costs differ per event. In the tables below the results of every scenario are shown.

Reference situation. In the reference situation a total of 23 trains are cancelled during the two hour disruption between Rta and Cps. The total costs are €54,770 as can be seen in Table 8.2.

Table 8.2 Reference situation

	VIRM 6	**ICM 7**	**SLT 6**
Cancelled trains	8	9	6
Total affected passengers	5,392	4,248	2,928
Total affected passengers detour	5,026	3,882	2,562
VOT per passenger (30 minutes)	€4.775	€4.775	€4.775
Total costs	€23,999	€18,537	€12,234
Total costs references situation	€54,770		

Scenario 1: crossover at Cpso. The previous paragraph concluded that scenario 1 does not increase the performance of rescheduling. Adding another train series causes delays. This means that still only the SPR 4000-series are able to operate on the left track. Therefore, the costs for passengers are the same as the reference situation (Table 8.3).

Table 8.3 Scenario 1: crossover at Cpso

	VIRM 6	**ICM 7**	**SLT 6**
Cancelled trains	8	9	6
Total affected passengers	5,392	4,248	2,928
Total affected passengers detour	5,026	3,882	2,562
VOT per passenger (30 minutes)	€4.775	€4.775	€4.775
Total costs	€23,999	€18,537	€12,234
Total costs scenario 1	€54,770		

Scenario 2: crossovers removed at Nwki and Mdo. Finally, in case of removal of the crossovers, a complete obstruction occurs. Consequently all trains are cancelled including the nine SPR 4000-series, which were still operable in the reference situation. This scenario is the most adverse scenario for passengers since the total costs are €80,984, an increase in costs of €26,214 (Table 8.4).

Table 8.4 Scenario 2: crossovers removed at Nwki and Mdo

	VIRM 6	ICM 7	SLT 6
Cancelled trains	8	9	15
Total affected passengers	5,392	4,248	7,320
VOT per passenger (30 minutes)	€4.775	€4.775	€4.775
Total costs	€25,747	€20,284	€34,953
Total costs scenario 2	€80,984		

8.4 Operator Costs

In addition to passenger costs, also train operators have costs in case of disruptions. NS has reserved funding to compensate passengers that experience delays of more than 0.5 hour. This means that if passengers have a delay between 0.5 and 1 hour, NS will reimburse half the price of their ticket. If passengers have a delay of more than 1 hour, the full ticket is reimbursed (NS, 2012). Passengers that have to take a detour through Gvc will experience a delay of 30 minutes. In most cases delay is longer since passengers wait several minutes at stations to see what happens. The reimbursement is calculated for passengers from Rtd to Gd or vice versa. The ticket price is based on second class, single fare which is €4.50 per passenger. Since delays are shorter than 60 minutes the reimbursement is €2.25 per passenger. Furthermore, it is assumed that passengers to Gd would take the VIRM 6 or ICM 7 (IC-trains). A major part of the passengers that use the SLT 6 (SPR 9700-series) are alighting in Rtn, Rta, Cps and Nwk and do not experience a delay longer than 30 minutes. These passengers would take alternative transport. Table 8.5 shows the results for the reference situation.

Table 8.5 Reference situation

	VIRM 6	ICM 7
Cancelled trains	8	9
Total affected passengers detour	5,026	3,882
Compensated ticket price	€2.25	€2.25
Total costs	€11,309	€8,735
Total costs references situation	€20,044	

The same applies to scenario 1: crossover at Cpso. In Table 8.6 the results are shown. The total costs are €20,044.

Table 8.6 Scenario 1: crossover at Cpso

	VIRM 6	ICM 7
Cancelled trains	8	9
Total affected passengers detour	5,026	3,882
Compensated ticket price	€2.25	€2.25
Total costs	€11,309	€8,735
Total costs scenario 1	€20,044	

In Table 8.7 the results of scenario 2: crossover removed at Nwki and Mdo are shown. It is assumed that 50% of the passengers of the SLT 6 trains (SPR 4000- and 9700-series) are financially compensated.

In case of complete obstruction NS arranges alternative public transit by means of tram and bus replacement in cooperation with RET (VSM 25.060). There is no direct connection for passengers from Rtd to Gd or vice versa. Passenger could use a bus connection between Rtd and Nwk (no stop at Rtn) and a bus connection between Rta and Gd. Finally, RET offers a tram service between Rtd and Rtn. Part of the passengers that use bus replacement service will experience a delay of more than 30 minutes.

The travel time from Rtd to Gd with bus replacement is approximately 40 minutes, taking account of stops and transit. The capacity of a bus is approximately 80 passengers (Wikipedia, 2012b). During two hour disruption 16,960 passengers are affected. Thus, in theory 212 buses would be necessary to transport all passengers. In reality, part of the passengers takes other means of transport or stay at home. It is assumed that three buses are operable for one train. Hence, in total 72 buses are needed during the two hours disruption. Furthermore, the costs for bus replacement are €125 hr/bus (Pender et al., 2011). The operator costs in case both crossovers are removed are €47,925 as can be seen from the table below.

Table 8.7 Scenario 2: crossovers removed at Nwki and Mdo

	VIRM 6	**ICM 7**	**SLT 6**
Cancelled trains	8	9	15
Total affected passengers	5,392	4,248	7,320
Total affected passengers compensated	5,392	4,248	3,660
Compensated ticket price	€2.25	€2.25	€2.25
Total costs	€12,132	€9,558	€8,235
Hire costs per bus	€250		
Number of buses	72		
Bus replacement costs	€18,000		
Total costs scenario 2	€47,925		

Furthermore, logistic costs: crew and rolling stock are not included in the estimation since data of these costs were not available.

8.5 Infrastructure Manager Costs

Crossovers create redundancy in case of disruptions but the more crossovers the higher the costs for ProRail. In this paragraph more insight into the costs of crossovers is given. Some alternatives of removing crossovers are explained in Subparagraph 8.5.1, followed by the different costs in Subparagraph 8.5.2 and annual annuities in Subparagraph 8.5.3.

8.5.1 Removing Alternatives

Van Ree (2011) did research on costs of removing crossovers in six alternative ways. They are:

1. Maintain switch
2. Removing switch in VPT (Vervoer Per Trein)
3. Removing switch in VPT and locking tongue
4. Removing switch in VPT and removing switch counter
5. Removing switch in VPT and removing tongue and frog
6. Removing entire switch

It can be seen that the higher the number the more invasive. Alternative 2 is almost equal to alternative 1. Still all parts are functioning and therefore their performances are almost equal. The advantage of locking only the tongue (alternative 3) is that the switch can easily be operable again in the future. However, the switch is still vulnerable for disturbances, since the tongue and frog which are sensitive for wear and tear are still present. Regular checks are necessary. Alternative 4 is very similar to alternative 3. The more parts are removed, the lower the vulnerably for disturbances. Removing the tongue and frog still requires special maintenance machines because of the different sleepers for switches (interview Shevtsov, 2012). Alternative 5 is a switch that needs the most adjustments but it is still physical present while alternative 6 is the most irreversible solution namely it is entirely removed from the network.

For the estimation of costs of crossovers in case study Rotterdam, alternative 1 is applied to the reference situation. Alternatives 3, 5 and 6 are applied to scenario 2: crossovers removed at Nwki and Mdo.

8.5.2 Different Costs of Switches

Van Ree (2011) mentioned six different costs in his research which are further elaborated. The costs can be seen in Table 8.8. He assumed that a switch has a remaining life-cycle of 18 years and a section load of level 6 (average load). The first two costs are one-off, the others are annual costs.

Table 8.8 Different costs (van Ree, 2011)

	Alternative 1 Maintain switch	Alternative 3 Locking tongue	Alternative 5 Removing tongue and frog	Alternative 6 Removing entire switch
Depreciation costs	€100,000	€100,000	€100,000	€100,000
Investment costs	€0	€5,980	€25,125	€201,250
Maintenance costs	€25,000	€26,000	€2,500	€1,250
Anticipated/scheduled unavailability	€6,304	€6,460	€1,563	€782
Restoring costs of disturbances	€221	€126	€81	€63
Unscheduled unavailability	€24,083	€13,762	€8,847	€6,881

Depreciation costs. Van Ree (2011) stated that on average, switches are on half their life-cycle and therefore the residual (fixed) costs are €100,000.

Investment costs. These costs are also unique fixed amounts for the different alternatives. Removing the entire switch is most expensive since the engineering costs: removing and restoring is high.

Maintenance costs. The annual maintenance costs are the highest for the alternative 1 since this is the only option wherein the switch is operable. Removing the entire switch implies the lowest costs because only maintenance of straight track is applicable.

Anticipated/scheduled unavailability. Anticipated/scheduled unavailability is the duration of maintenance multiplied by the costs per hour of scheduled unavailability of the railway network. The duration of maintenance varies from 0.5 to 4.03 hours and the hourly tariff is fixed at €1,563 (van Ree, 2011).

Restoring costs of disturbances. The restoring costs of disturbance are the duration of the disturbance multiplied by the costs per hour of restoring. The duration of the disturbance varies from 0.42 to 1.47 hours and the hourly tariff is fixed at €150.

Unscheduled unavailability. Disturbances lead to costs of unscheduled unavailability. These are the duration of the disturbance multiplied by the costs per hour of unscheduled unavailability of the railway network. The costs per hour of unscheduled unavailability are fixed at €16,383 which is much higher than costs per hour for scheduled unavailability.

8.5.3 Annual Annuities

Van Ree (2011) estimated the annual annuities for the different alternatives which can be seen in Table 8.9. He used an interest rate of 4% and assumed a horizon of 100 years. Surprisingly, alternative 6 is not the cheapest option (€21,500), alternative 5, removing the tongue and frog is cheaper (€20,412). Maintaining the switch is the most expensive option (€41,402).

Table 8.9 Annual annuities (van Ree, 2011)

	Alternative 1 Maintain switch	Alternative 3 Locking tongue	Alternative 5 Removing tongue and frog	Alternative 6 Removing entire switch
Annual annuity switch	€41,402	€36,863	€20,412	€21,500
Annual annuity crossover	€82,804	€73,726	€40,824	€43,000

It must be said that the costs estimated by van Ree are applied to a switch. A crossover consists of two (coupled) switches. Therefore, the annual annuity is multiplied by two. Still, it is not 100% correct since not all sub costs are doubled. For example, removing a switch in VPT (interlocking) costs (investment costs) are made only one time either for a switch or a crossover.

8.6 Costs and Benefits

Passenger and operator costs described in the previous paragraphs are estimated for one disruption. The final results are described in the following subparagraph. In the second subparagraph the costs are estimated for more than one disruption.

8.6.1 Results for one Disruption per Year

Table 8.10 shows the costs and benefits of the different scenarios in case of one disruption per year. It is clear that all scenarios are negative. There are of course no benefits if disruption occurs but some scenarios have less negative benefits than others. Passenger and operator costs are higher when crossovers at Nwki and Mdo are removed (scenario 2) while for the infra manager costs are lower. Moreover, for the infra manager the most cost-effective option is removing the tongue and frog only than removing the entire crossover. This has already been concluded in the previous paragraph. From the table it can be seen that scenario 2: crossovers removed at Nwki and Mdo by removing the tongue and frog has the lowest total costs (€210,557). Removing both crossovers is more expensive (€214,909) as well as maintaining both crossovers (€240,422) or replacing the one at Nwki by a new one at Cpso (> €240,422). As concluded earlier there is no difference between the passenger and operator costs by either maintaining the current crossovers or replacing the crossover at Nwki by a crossover at Cpso. But the annual costs of scenario 1: crossover at Cpso will be higher in the first year due to additional removal costs of the crossover at Nwki. Investment costs for the crossover at Cpso are higher as well. On the other hand the restoring costs of a new crossover in case of disturbances and unscheduled unavailability may be lower.

Table 8.10 Costs and benefits (one disruption)

	Reference situation	**Scenario 1 Replace Nwki by crossover at Cpso**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**
	Maintain Crossovers Nwki and Mdo		**Locking tongue**	**Removing tongue and frog**	**Removing entire crossovers**
Passenger costs	€54,770	€54,770	€80,984	€80,984	€80,984
Operator costs	€20,044	€20,044	€47,925	€47,925	€47,925
Sum both costs	€74,814	€74,814	€128,090	€128,090	€128,090
Infra manager costs (annual annuity both crossovers)	€165,608	> €165,608	€147,452	€81,648	€86,000
Total costs	€240,422	> €240,422	€276,361	€210,557	€214,909

8.6.2 Results for more Disruptions per Year

From Table 8.11 it can be concluded that in case of two disruptions maintaining the crossovers at Nwki and Mdo has the lowest total costs (€315,236), despite the cost of passenger and operator are lower than the costs of the infra manager. However, if these crossovers are removed the passenger and operator costs exceed the infra manager savings. Hence, the total costs will be higher.

Table 8.11 Costs and benefits (two disruptions)

	Reference situation	**Scenario 1 Replace Nwki by crossover at Cpso**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**
	Maintain Crossovers Nwki and Mdo		**Locking tongue**	**Removing tongue and frog**	**Removing entire crossovers**
Passenger costs	€109,540	€109,540	€161,968	€161,968	€161,968
Operator costs	€40,088	€40,088	€95,850	€95,850	€95,850
Sum both costs	€149,628	€149,628	€257,818	€257,818	€257,818
Infra manager costs (annual annuity both crossovers)	€165,608	> €165,608	€147,452	€81,648	€86,000
Total costs	€315,236	> €315,236	€405,270	€339,466	€343,818

In reality even more disruptions per year occur. In 2011, there were 14 disruptions that were handled with a VSM on corridor Rotterdam. Ten of them were partial obstructions and six of them were handled with VSM 25.070. In Table 8.12 the costs and benefits are shown for six disruptions. As can be seen the sum of costs for passengers and operators are far exceeding the costs of maintaining the specific crossovers. Furthermore, the differences between the total costs of the scenarios are much higher. Therefore, it can be concluded that with regard to corridor Rotterdam maintaining the crossovers at Nwki and Mdo (reference situation) is the most cost-effective.

Table 8.12 Costs and benefits (six disruptions)

	Reference situation	**Scenario 1 Replace Nwki by crossover at Cpso**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**	**Scenario 2 Remove crossover at Nwki and Mdo**
	Maintain Crossovers Nwki and Mdo		**Locking tongue**	**Removing tongue and frog**	**Removing entire crossovers**
Passenger costs	€328,620	€328,620	€485,904	€485,904	€485,904
Operator costs	€120,264	€120,264	€287,550	€287,550	€287,550
Sum both costs	€448,884	€448,884	€773,454	€773,454	€773,454
Infra manager costs (annual annuity both crossovers)	€165,608	> €165,608	€147,452	€81,648	€86,000
Total costs	€614,492	> €614,492	€920,906	€855,102	€859,454

8.7 Conclusions: Simulation Study Rotterdam

Three scenarios of corridor Rotterdam were analyzed with OpenTrack. All scenarios deal with partial obstruction between Rta and Cps in the direction of Rtd to Gd. Simulating the reference situation (applied VSM 25.070) confirms that only four trains per hour (SPR 4000-series) are possible for left track operations. Second, in scenario 1 a crossover at Cpso instead of Nwki is simulated. In this scenario the follow-up distances are more evenly distributed among the corridor. But the simulation shows that scenario 1 does not improve the performance of rescheduling. Finally, scenario 2 is analyzed wherein both crossovers (at Nwki and Mdo) are removed. Because all trains are cancelled the costs for passengers and operator are the highest. The costs of crossovers (infra manager) are lower but it depends on the removing method: locking tongue, removing tongue and frog, or removing the entire crossover.

Furthermore, the costs and benefits of the different scenarios are estimated. Obviously, all three scenarios are negative. If one disruption per year occurs, scenario 2: removing the crossovers by removing the tongue and frog has the lowest total costs (€210,557). Removing both crossovers is more expensive (€214,909) as well as maintaining the crossovers at Nwki and Mdo (€240,422) or replacing the one at Nwki by a new one at Cpso (> €240,422). If two of more disruptions per year occur the total costs of maintaining the crossovers is lower than removing them. In 2011, six disruptions at corridor Rotterdam were handled with VSM 25.070. This means that maintaining the crossovers (reference situation) is the most cost-effective solution.

9 Conclusions and Recommendations

Chapter 9 consists of Paragraph 9.1 wherein the conclusions of the research are described and Paragraph 9.2 addresses the recommendations.

9.1 Conclusions

ProRail–in particular the department of Traffic Control–would like to have examined what the performance of crossovers for rescheduling is in case of partial obstructions. Several literature studies were found about performance of crossovers. However, these are foreign studies and thus apply to foreign railway networks i.e. Austria, Germany and Australia. The need for quantitative information about the performance of crossovers in The Netherlands has grown. Currently, proponents and opponents of crossovers base their judgments on 'good feelings' and qualitative data. The research is intended to fill this knowledge gap by investigating the performance of crossovers in The Netherlands in a quantitative manner for two typical corridors. Therefore, the main research question is stated as follows:

What is the performance of crossovers with respect to reliability (benefits) and life-cycle costs when rescheduling takes place?

The focus in this research is on IVO switches (crossovers in between stations) that are only used for rescheduling. The research question has been explored on two typical corridors in the Dutch railway network: corridor Amsterdam: Amsterdam Riekerpolder aansluiting (Asra) – Amsterdam Bijlmer ArenA (Asb)/Diemen Zuid (Dmnz) and corridor Rotterdam: Rotterdam Centraal (Rtd) – Gouda (Gd). Conclusions are drawn from the executed disruption analysis for both corridors (Subparagraph 9.1.1). Furthermore, conclusions are drawn from the simulation study that has been performed for corridor Rotterdam (Subparagraph 9.1.2).

9.1.1 Disruption Analysis Amsterdam and Rotterdam

Disruption calls of both corridors in 2011 were collected from database MUIS. Two conclusions could be drawn. First, looking at the total reported disruption calls, half of the calls resulted in no VSM (VerSperringsMaatregel), while about 35% was partial VSM and approximately 15% was complete VSM. Furthermore, it can be concluded that most disruptions that needed VSM were caused by defect trains rather than infrastructure related defects. Regarding corridor Amsterdam, 49% was caused by train defects while 31% was due to infrastructure failure. With regard to corridor Rotterdam 57% was caused by train defects while 20% was due to infrastructure failure.

From all disruption calls, partial VSM was further analyzed. With regard to corridor Amsterdam there were nine disruptions that were handled with partial VSM. Six of them were caused by defect trains while two of them were caused by failure of switches/crossovers. Corridor Rotterdam had ten disruptions that were handled with partial VSM. The largest part was also caused by defect trains (x8). The other two were caused by delayed anticipated maintenance and catenary failure.

With the TOON application and reports from MUIS, the applied rescheduling has been compared with the VSM. Some conclusions can be drawn. The largest part of the rescheduling went according to the VSM. Although, some disruptions were too short and therefore rescheduling was partly executed according to the VSM. Furthermore, sometimes it was difficult to determine the transition of the first phase to the implementation of the VSM since traffic controllers use the same measures (VSM). Finally, it can be concluded that reporting the rescheduling process is arbitrarily done in MUIS if compared with the eventually executed rescheduling process obtained from TOON.

Furthermore, the occupancy of crossovers has been investigated. In both case studies crossovers were frequently used during rescheduling. Especially during the first phase–when trains are trapped–crossovers are needed to quickly remove and prevent trains to enter. This will speed up the implementation of the VSM either if partial or complete VSM is used. Another advantage of crossovers is that they allow implementation of a VSM at once which is the case of delayed anticipated maintenance. Crossovers were also frequently used to couple and abduct 'defect' trains to stations/yards. Furthermore, side tracks at Rotterdam Noord Goederen (Rtng) were also frequently used to separate freight trains during disruption thereby securing continuity of passenger trains operations. It can be concluded that these kind of side tracks play an important role in rescheduling as well.

With regard to disturbance of crossovers, crossovers do influence the performance of the railway system i.e. according to ProRail's Asset Management database crossovers lead to a small number of TAOs. Corridor Amsterdam had three TAOs while corridor Rotterdam had two TAOs. However, from disruption analysis (TOON and MUIS reports) there were no events where these crossovers caused disruption that led to implementation of VSM. Thus, either the ProRail Asset Management definition of a TAO or the accuracy of reporting disruptions in MUIS should be questioned.

Finally, delay and propagations were investigated for corridor Rotterdam. Data of the monitoringsystem has been used. It can be concluded that delays and its propagation depend on the severity of disruption. When disruption was shorter (< 3 hours) no other trains on other corridors within the area of Rotterdam and Utrecht were affected. When disruption took longer (> 3 hours) delays were propagated, affecting other trains on other corridors within the area. However, data from the Monitoringsystem was not complete and therefore not a reliable means to get total insight into delays and its propagation. Not all indirect couplings (knock-on delays) are made and frequently other causes of disruption are reported. As complement TOON could be used to see whether a knock-on delay eventually dissolves but this is difficult and very time-consuming.

9.1.2 Simulation Study Rotterdam

With OpenTrack it can be analyzed whether the existing crossovers are needed and effective to handle more trains during the VSM. Furthermore, the effects of alternative VSM for train routing can be estimated. Three scenarios of corridor Rotterdam were analyzed with OpenTrack. All scenarios dealt with partial obstruction between Rotterdam Alexander (Rta) and Capelle Schollevaar (Cps) in the direction of Rtd to Gd. Simulating the reference situation (applied VSM 25.070) confirmed that only four trains per hour (SPR 4000-series) were possible for left track operations. The quality of operations decreased when adding an additional IC 2800-series because it resulted in long delays.

In scenario 1 a crossover at Capelle Schollevaar overloopwissels (Cpso) instead of Nieuwerkerk IVO wissels (Nwki) was simulated. In this scenario the follow-up distances were more evenly distributed among the corridor, since in the old situation crossovers at Nwki and Moordrecht overloopwissels (Mdo) were very close to each other. Simulating left track through crossover at Cpso yielded shorter delays: the maximum delay was 2.5 minutes between Rotterdam Noord (Rtn) and Mdo but when trains arrived at Gd delays had dissolved. However, the simulation showed that adding an additional IC 2800-series did not improve the performance of rescheduling in scenario 1 either.

Finally, scenario 2 was analyzed wherein both crossovers (at Nwki and Mdo) were removed. In this case the capacity of left track was insufficient to handle the SPR 4000-series since the distance on left track was too long. Therefore, the disruption had to be handled with a complete VSM (VSM 25.060). Because all trains were cancelled the costs for passengers and operator are the highest. The costs of crossovers (infra manager) are lower but it depends on the removing method. There are three ways to remove a crossover by locking the tongue, removing tongue and frog, or removing the entire crossover.

Furthermore, the costs and benefits of the different scenarios were estimated. Obviously, all three scenarios are negative. If one disruption per year occurs, scenario 2: removing the crossovers by removing the tongue and frog has the lowest total costs (€210,557). Removing both crossovers is more expensive (€214,909) as well as maintaining the crossovers at Nwki and Mdo (€240,422) or replacing the one at Nwki by a new one at Cpso (> €240,422). If two of more disruptions per year occur the total costs of maintaining the crossovers is lower than removing them. In 2011, six disruptions at corridor Rotterdam were handled with VSM 25.070. Passenger and operator costs are much higher than the saving for the infra manager. When choosing to remove the crossovers by removing the tongue and frog the increase in the total costs for passengers and operator are €324,570 while the savings for the infra manager are €83,960. Therefore, it can be concluded that with regard to corridor Rotterdam maintaining the crossovers at Nwki and Mdo (reference situation) is the most cost-effective.

9.2 Recommendations

The critical and unpredictable aspects of disruptions and the different stakeholders who are involved make the rescheduling process very complex. It is even more complex if decisions are only based on ‘good feelings’ and qualitative data. In this research different quantitative methods were used in combination in order to get more insight into the performance of crossovers. With help of tools: MUIS, TOON, Monitoringsystem, simulation program OpenTrack and a Cost Benefit Analysis this insight is obtained for two case studies. It is impossible to extrapolate these results to a national level since every corridor is different. But the combined methods can be used for any crossover on any corridor. The advantage is that quantitative information can be obtained and could be used as evidence for policy wherein different stakeholders with conflicting interests are involved. From this point of view some recommendations are given (Subparagraph 9.2.1). Furthermore, some recommendations with respect to the tools used are given in the last subparagraph.

9.2.1 Further Research

With regard to furhter research four recommendations are being made as follows:

1. Disadvantage of study on two cases
Executing a disruption analysis gave insight into the performance of crossovers (historical data). This has been done for two case studies Amsterdam and Rotterdam. However, as mentioned before, it is not possible to extrapolate these results to the whole Dutch railway network. Corridors in the Randstad–on which these case studies are based–are much more occupied than corridors elsewhere in The Netherlands. Furthermore, rail lay-out including locations of crossovers is also different. To get reliable data about performances that are applicable to the whole railway network more case studies should be done.

2. Usefulness of simulation in decision making
To analyze whether existing crossovers are needed and effective to handle more trains during the VSM, and the effects of alternative VSM for train routing, a simulation study is a very efficient method to get an answer to these questions. Different scenarios could be simulated without irreversible consequences and it supports the decision making. However, only one disruption (partial obstruction handled with VSM 25.070) has been simulated in this research. More different disruptions should be simulated in order to get a network-wide insight into the performance of crossovers.

3. Network-wide analysis of costs and benefits
The costs of crossovers in this research were estimated based on average values and assumptions from van Ree (2011). To get more reliable results of specific situations, for example, the life-cycle costs of a specific crossover have to be taken into account which has not been done in this research. Furthermore, the Cost and Benefit Analysis has been done based on estimations for only one kind of disruption. A network-wide analysis of costs and benefits of crossovers used in partial obstructions needs to be done in order to get reliable results for decision making. Finally, failure probability of infra and rolling stock should be incorporated to the estimation of costs and benefits.

4. Future rescheduling process and opportunities for decision support systems
It is questionable whether the new rescheduling philosophy is still sufficient in the long term. In the short term it has advantages above the current disruption strategy. However, in future utilization of the railway network will further increase and the new disruption management process might become unsuitable i.e. it needs to be adapted continuously. Introduction of new technologies (automation) in the railway system such as decision support systems in controlling and executing disruption management might be very helpful. Systems that give optimal rescheduling based on real-time delays are more flexible than the current VSM procedures. Of course these kinds of systems require large investments for the future and perhaps this could be explored in advance.

9.2.2 Integration of Tools

With regard to the tools used four recommendations are being made as follows:

1. Possibilities of integrating tools TOON and MUIS
Reporting the rescheduling process is arbitrarily done in MUIS if compared with the eventually executed rescheduling process obtained from TOON. This is because different stakeholders are allowed to fill in different fields–traffic controllers from different traffic posts but also train operators. This makes it difficult to analyze disruptions since it is hard to identify if either a partial or complete VSM was applied or not. TOON is a very reliable and additional source to analyze individual events. It is necessary to use both tools to get insight into the rescheduling process. Therefore, it might be useful to integrate these two systems.

2. Possibilities of integrating TAO reports Asset Management and MUIS
There are some questions raised about reporting disturbances of crossovers that lead to rescheduling (TAO). Data of ProRail Asset Management database did not always match with data of TOON and MUIS reports. Thus, either the ProRail Asset Management definition of a TAO or the accuracy of reporting disruptions in MUIS should be reconsidered. Furthermore, it could be beneficial if these two databases are coupled in the future.

3. TNV-Conflict instead of Monitoringsystem for analyzing delays
The Monitoringsystem has been used to analyse delays and its propagation. However, there are some disadvantages of the Monitoringsystem that have been discussed in this research earlier. TNV-Conflict, a comparable system, has been developed by TU Delft and has very accurate data (to the nearest second) about delays and its propagation. It was chosen to use data from the Monitoringsystem because it is already widely used and accepted within ProRail and easier to obtain given the limited research time. But eventually, because of its incomplete data it was not a reliable means to get total insight into delays and its propagation. For a follow-up study TNV-Conflict would be recommended.

4. Convertor for Infra Atlas to OpenTrack
With respect to the simulation study, still part of the infrastructure and entire left track signaling of corridor Rotterdam (Rtd-Gd) had to be implemented in OpenTrack. The author had chosen to do this by hand which is time-consuming. However, there is a promising (still prototype) tool that automatically imports the Infra Atlas into OpenTrack (RailML-format) (Tax, 2011). Because the converter is in the process of being developed, there are still some disadvantages. With the help of such a user-friendly application, simulation studies become less time-consuming and therefore more accessible.

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Abbreviations

ATB-EG	Automatische Trein Beinvloeding-Eerste Generatie (Automatic Train Protection-First Generation)
BUP	Basis Uur Patroon (Basic Hour Pattern)
CBA	Kosten Baten Analyse (Cost Benefit Analysis)
DVL	Decentrale Verkeersleiding (Decentralized Traffic Control)
ERTMS	European Railway Traffic Management System (European Railway Traffic Management System)
ETCS	European Train Control System (European Train Control System)
FHT	Functie Herstel Tijd (Recovery Time)
IC-DP	Intercity Ontkoppelpunt (Intercity Decoupling Point)
IC-train	Intercity (Intercity train)
IFB	InFrastructuurBeperking (Rail Infrastructure Restriction)
ISVL5	Informatie Systeem VerkeersLeiding (Information System Traffic Control)
IVO switch	InfraVoorziening voor Onderhoud (Infrastructure Provision for Maintenance)
LVL	Landelijke Verkeersleiding (Centralized Traffic Control)
NO	Noordoost (Northeast)
OBE	Overzicht Baan en Emplacement (Rail Map/Track Lay-out)
OCCR	Operationele Controle Centrum Rail (Operational Control Center Rail)
RN	Randstad Noord (Randstad North)
RZ	Randstad Zuid (Randstad South)
SLT-train	Sprinter (Sprinter/regional train)
Sprinter DP	Sprinter Ontkoppelpunt (Sprinter Decoupling Point)
TA	Trein Afwijking (Train Deviation)
TAD	TreindienstAfhandelingsDocument (Train Handling Document)
TAO	Treindienst Aantastende Onregelmatigheid (Disruption Affect Train Operations)
TOC	Train Operating Company (Train Operating Company)
TSR	Tijdelijke SnelheidsRestrictie (Temporary Speed Restriction)
TVTA	Te Verklaren Trein Afwijking (Explained Train Deviation)
VKL	VerKeersLeidingsysteem (Traffic Control System)
VOT	Reistijdwaardering (Value of Time)
VPT	Vervoer Per Trein (Train Operations)
VSM	VerSperringsMaatregel (Rescheduling Measure)
Z	Zuid (South)

Abbreviations of Stations

Alm	Almere Centrum
Almo	Almere Oostvaarders
Amf	Amersfoort
Asb	Amsterdam Bijlmer ArenA
Asdl	Amsterdam Lelylaan
Asdz	Amsterdam Zuid
Asra	Amsterdam Riekerpolder aansluiting
Bd	Breda
Cps	Capelle Schollevaar
[Cpso]	[Capelle Schollevaar overloopwissels]
Ddm	De Diemen
Dmnz	Diemen Zuid
Dvd	Duivendrecht
Es	Enschede
Gd	Gouda
Gn	Groningen
Gvc	Den Haag Centraal
Hfd	Hoofddorp
Hfdo	Hoofddorp opstel
Hlba	Hillegersberg aansluiting
Ledn	Leiden Centraal
Lls	Lelystad Centrum
Lw	Leeuwarden
Mda	Moordrecht aansluiting
Mdo	Moordrecht overloopwissels
Mt	Maastricht
Nm	Nijmegen
Nwk	Nieuwerkerk a/d IJssel
Nwki	Nieuwerkerk IVO wissels
Rai	Amsterdam Rai
Rta	Rotterdam Alexander
Rtd	Rotterdam Centraal
Rtn	Rotterdam Noord
Rtng	Rotterdam Noord Goederen
Shl	Schiphol
Ut	Utrecht Centraal

Wgm	Watergraafsmeer
Wp	Weesp
Wspl	Rotterdam Westelijke Splitsing
Ztmo	Zoetermeer Oost

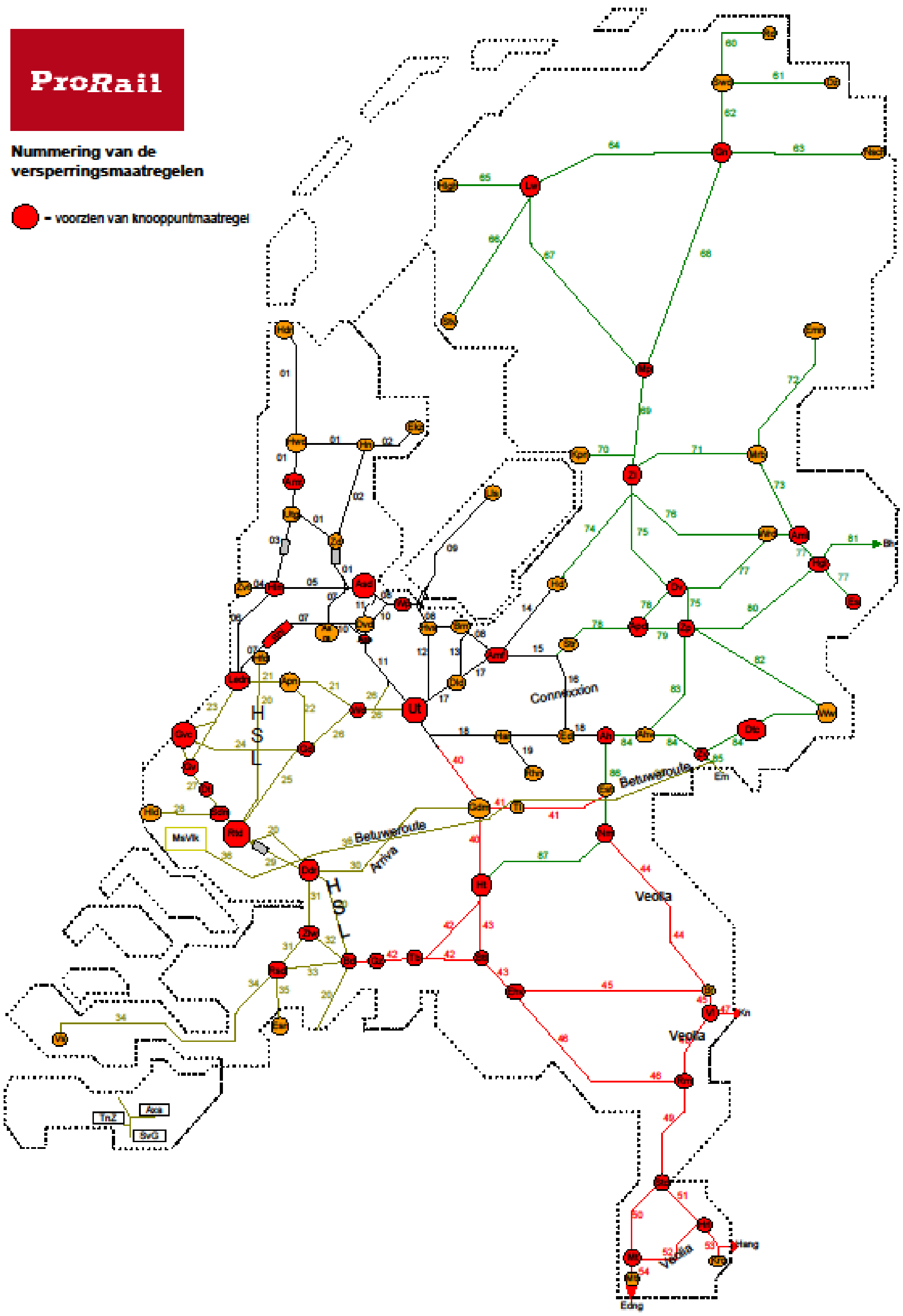
Interviews

During the research several interviews were conducted with staff from ProRail and NS. These interviews gave insight into the rescheduling process and the use of crossovers.

February 16, March 15, 2012	Reinier Klein Schiphorst	Traffic Control
May 23, June 14, 2012	Jarie Potuijt	Prestatie Analyse Bureau
May 23, 2012	Ivan Shevtsov	Asset Management
May 31, 2012	Theo Kruse	Asset Management
June 1, 2012	Anton Lamper	Asset Management
June 19, 2012	Jeroen Wesdorp	Capacity Allocation
June 21, 2012	Wim Willemars	Traffic Control
June 22, 2012	Michiel Vromans	Capacity Allocation
June 26, 2012	Ton van Diepen	Traffic Control (post Amsterdam)
July 2, 2012	Henk de Groot	NS Transportbesturing
July 30, 2012	Paul Bruning	Presatie Analyse Bureau
August 9, 2012	Rolf Deken	Traffic Control (post Rotterdam)
August 9, 2012	Peter Nagtegaal	Traffic Control (post Rotterdam)

Annex A Numbering of VSM

Every corridor has a typical VSM-series. An overview of the numbering can be seen in the figure. With respect to the case studies: corridor Amsterdam has VSM no. 10 and corridor Rotterdam has VSM no. 25.



Annex B Characteristics of Crossovers

Below, an overview of the maximum velocity for different types and different angles of switches is given (ProRail, 2011b).

Switch type	vmax deviated [km/h]	vmax straight forward [km/h]		
		0 ≤ v ≤ 80	80 < v ≤ 160	160 < v ≤ 200
GW R195 1:9	40	✓	✓	
GW R260 1:9	40	✓	✓	
GW R465 1:12	60	✓	✓	
GW R725 1:15	80	✓	✓	
GW R725 1:15 NG	80	✓	✓	✓
GW R2300 1:34.7 BP	140	✓	✓	✓

Switch type	vmax deviated [km/h]	vmax straight forward [km/h]		
		0 ≤ v ≤ 80	80 < v ≤ 160	160 < v ≤ 200
KRWL 1:9	40	✓		

Double slip switches are not allowed on sections that allow a speed of more than 60 km/h.

Switch type	vmax deviated [km/h]	vmax straight forward [km/h]		
		0 ≤ v ≤ 80	80 < v ≤ 160	160 < v ≤ 200
EW R204 1:9	40	✓		
EW R400 1:12	50	✓	✓	

Double slip switches are not allowed on sections that allow a speed of more than 80 km/h.

Annex C Crossovers (IVO switches)

The table below shows the ‘potentially redundant’ crossovers (IVO switches) that are acquired from infra phase 1 (Kern Infra Manager). The case studies have been selected according to this list.

Region	Post	Station/place	Crossover
NO	Ah	Velperbroek aansl.	231
NO	Ah	Velperbroek aansl.	239
NO	Ah	Velperbroek aansl.	283
NO	Ah	Velperbroek aansl.	285
NO	Zl	Dedemsvaart	231
NO	Zl	Dedemsvaart	233
NO	Zl	Deventer	193
NO	Zl	Koekange	301
NO	Zl	Koekange	303
RN	Amf	Nijkerk	351
RN	Amf	Nijkerk	353
RN	Amf	Putten	401
RN	Amf	Putten	435
RN	Amf	Stroe	37
RN	Amf	Stroe	57
RN	Amr	Halfweg	1
RN	Amr	Halfweg	7
RN	Amr	Lisse	305
RN	Amr	Lisse	327
RN	Amr	Purmerend Overwhere	161
RN	Amr	Purmerend Overwhere	163
RN	Amr	Purmerend Overwhere	169
RN	Amr	Purmerend Overwhere	171
RN	Amr	Wormerveer	205
RN	Amr	Wormerveer	231
RN	Amr	Zaandam Kogerveld	181
RN	Amr	Zaandam Kogerveld	183
RN	Asd	Almere Centrum	203
RN	Asd	Almere Centrum	205
RN	Asd	Amsterdam Riekerpolder aansl.	1301
RN	Asd	Amsterdam Riekerpolder aansl.	1303
RN	Asd	Amsterdam Erasmusgracht	933
RN	Asd	Amsterdam Erasmusgracht	935
RN	Asd	Amsterdam Lelylaan	955
RN	Asd	Amsterdam Lelylaan	957
RN	Asd	Amsterdam RAI	983
RN	Asd	Amsterdam RAI	985
RN	Asd	De Diem	1163
RN	Asd	De Diem	1165
RN	Asd	Diemen Z	971
RN	Asd	Lelystad Z	289
RN	Asd	Lelystad Z	291
RN	Asd	Weesp	117
RN	Asd	Weesp	119
RN	Asd	Weesp	141

Region	Post	Station/place	Crossover
RN	Asd	Weesp	143
RN	Ut	Culemborg	5
RN	Ut	De Haar aansl.	155
RN	Ut	De Haar aansl.	157
RN	Ut	Harmelen aansl.	1021
RN	Ut	Harmelen aansl.	1025
RN	Ut	Hedel	251
RN	Ut	Hedel	255
RN	Ut	Lekbrug aansl.	1
RN	Ut	Maarn goed. empl.	131
RN	Ut	Maarn goed. empl.	145
RN	Ut	Oudewater	91
RN	Ut	Oudewater	93
RN	Ut	Utrecht Overvecht	1105
RN	Ut	Utrecht Overvecht	1107
RN	Ut	Veenendaal Centrum	231
RN	Ut	Veenendaal Centrum	233
RN	Ut	Woerden	1201
RN	Ut	Woerden	1211
RZ	Gvc	Delft	465
RZ	Gvc	Delft	467
RZ	Gvc	Zoetermeer Oost	133
RZ	Gvc	Zoetermeer Oost	135
RZ	Rsd	Nieuwe Veerbrug	521
RZ	Rsd	Nieuwe Veerbrug	523
RZ	Rsd	Rilland=Bath	349
RZ	Rsd	Rilland=Bath	351
RZ	Rsd	's Heer Arendskerke	435
RZ	Rsd	Willemsdorp	121
RZ	Rsd	Willemsdorp	123
RZ	Rtd	Nieuwerkerk	293
RZ	Rtd	Nieuwerkerk	295
RZ	Ut	Moordrecht aansl.	251
RZ	Ut	Moordrecht aansl.	253
RZ	Ut	Moordrecht aansl.	271
RZ	Ut	Moordrecht aansl.	273
RZ	Ut	Moordrecht aansl.	281
RZ	Ut	Moordrecht aansl.	283
Z	Ehv	Best	1301
Z	Ehv	Best	1303
Z	Ehv	Best	1305
Z	Ehv	Best	1307
Z	Ehv	Best	1309
Z	Ehv	Best	1315
Z	Ehv	Griendtsveen	399
Z	Ehv	Liempde	1271
Z	Ehv	Liempde	1275
Z	Mt	Maarheeze	81
Z	Mt	Maarheeze	83

Annex D Causes of Rescheduling

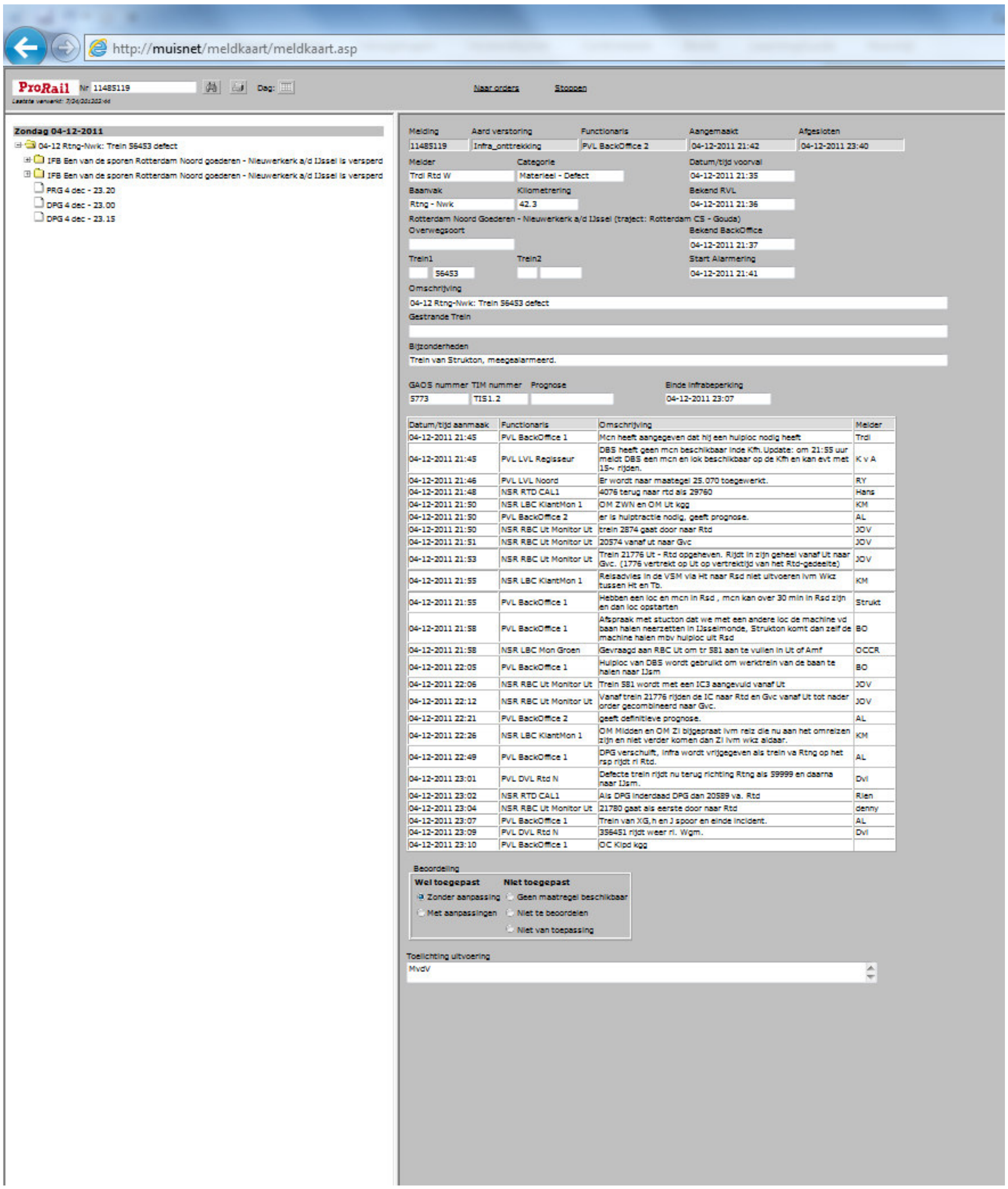
The causes of rescheduling in 2009 are depicted in the table below.

	Partial obstruction			Complete obstruction			Total		
	Number	Total duration (min)	Average duration (min)	Number	Total duration (min)	Average duration (min)	Number	Total duration (min)	Average duration (min)
ProRail (rail infra)									
Anticipated maintenance	17	2851	168	11	2805	255	28	5656	202
Catenary	47	17166	365	23	15554	676	70	32720	467
Operations	4	512	128	20	29111	16	24	29623	1234
Power supply	6	1372	229	24	2840	118	30	4212	140
Railroad crossing	13	3251	250	8	2434	304	21	5685	271
Railway defect	26	13105	504	26	4099	158	52	17204	331
Safety system	3	380	127	24	3376	141	27	3756	139
Section	55	10713	195	26	2770	107	81	13483	166
Switch/crossover	124	24829	200	26	7998	308	150	32827	219
Track direction	12	2291	191	5	1009	202	17	3300	194
Unscheduled maintenance	6	2920	487	2	919	460	8	3839	480
Total Infrastructure	*313*	*79390*	*254*	*195*	*72915*	*374*	*508*	*152305*	*300*
External									
Bomb threat	0			2	131	66	2	131	66
Collision animal	0			3	102	34	3	102	34
Collision buffer stop	1	167	167	0			1	167	167
Collision heavy traffic	1	637	637	4	3621	905	5	4258	852
Collision object	7	1326	189	5	510	102	12	1836	153
Collision person death	7	1249	178	164	23572	144	171	24821	145
Collision person injured	7	687	98	25	2026	81	32	2713	85
Collision small traffic	3	2394	798	19	6802	358	22	9196	418
Collision train	0			2	10994	1177	2	10994	5497
Collision viaduct/bridge	1	53	53	5	194	39	6	247	41
Extreme weather	10	2969	297	18	9095	505	28	12064	431

	Partial obstruction			Complete obstruction			Total		
	Number	Total duration (min)	Average duration (min)	Number	Total duration (min)	Average duration (min)	Number	Total duration (min)	Average duration (min)
Fire general	1	70	70	3	134	45	4	204	51
Fire railside	5	587	117	5	526	105	10	1113	111
Fire train	4	663	166	7	675	96	11	1338	122
Fire tunnel	0			4	417	104	4	417	104
Hazardous substances	0			2	139	70	2	139	70
OHD suspended train service	6	3185	531	26	6718	258	32	9903	309
Passenger behavior	3	111	37	2	90	45	5	201	40
Train defect	276	18304	66	17	2625	154	293	20929	71
Train derailment	7	49554	1319	3	26171	84	10	75725	7573
Vandalism	1	48	48	6	752	125	7	800	114
Total External	*340*	*82004*	*241*	*322*	*95294*	*296*	*662*	*177298*	*268*
Unknown	34	4799	141	24	45145	1881	58	49944	861
Total	*687*	*166193*	*242*	*541*	*213354*	*394*	*1228*	*379547*	*309*

Annex E Report in MUIS

Data of disruptions from database MUIS. MUIS contains data from the ISVL5 system (Informatie Systeem VerkeersLeiding) and includes all disruptions on the railway network that were reported by Traffic Control. It consists of calls that were handled with no VSM (light dispatching only), partial VSM or complete VSM. An example of a report in MUIS is depicted below.



http://muisnet/meldkaart/meldkaart.asp

ProRail Nr 11485119 Dag: Naar orders Stoppen

Zondag 04-12-2011

04-12 Rtng-Nwk: Trein 56453 defect

IFB Een van de sporen Rotterdam Noord goederen - Nieuwerkerk a/d IJssel is versperd

IFB Een van de sporen Rotterdam Noord goederen - Nieuwerkerk a/d IJssel is versperd

PRG 4 dec - 23.20

DPG 4 dec - 23.00

DPG 4 dec - 23.15

Melding: 11485119 | Aard verstoring: Infra_onttrekking | Functionaris: PVL BackOffice 2 | Aangemaakt: 04-12-2011 21:42 | Afgesloten: 04-12-2011 23:40

Melder: Trdl Rtd W | Categorie: Materieel - Defect | Datum/tijd voorval: 04-12-2011 21:35

Baanvak: Rtng - Nwk | Kilometrering: 42.3 | Bekend RVL: 04-12-2011 21:36

Rotterdam Noord Goederen - Nieuwerkerk a/d IJssel (traject: Rotterdam CS - Gouda)

Overwegsoort: | Bekend BackOffice: 04-12-2011 21:37

Trein1: 56453 | Trein2: | Start Alarmering: 04-12-2011 21:41

Omschrijving: 04-12 Rtng-Nwk: Trein 56453 defect

Gestrande Trein:

Bijzonderheden: Trein van Strukton, meegealarmeerd.

GAOS nummer: 5773 | TIM nummer: TIS1.2 | Prognose: | Einde infrabeperking: 04-12-2011 23:07

Datum/tijd aanmaak	Functionaris	Omschrijving	Melder
04-12-2011 21:45	PVL BackOffice 1	Mcn heeft aangegeven dat hij een hulploc nodig heeft	Trdl
04-12-2011 21:45	PVL LVL Regisseur	DBS heeft geen mcn beschikbaar inde Kfh.Update: om 21:55 uur meldt DBS een mcn en lok beschikbaar op de Kfh en kan evt met 15~ rijden.	K v A
04-12-2011 21:46	PVL LVL Noord	Er wordt naar maategel 25.070 toegewerkt.	RY
04-12-2011 21:48	NSR RTD CAL1	4076 terug naar rtd als 29760	Hans
04-12-2011 21:50	NSR LBC KlantMon 1	OM ZWN en OM Ut kgg	KM
04-12-2011 21:50	PVL BackOffice 2	er is hulptractie nodig, geeft prognose.	AL
04-12-2011 21:50	NSR RBC Ut Monitor Ut	trein 2874 gaat door naar Rtd	JOV
04-12-2011 21:51	NSR RBC Ut Monitor Ut	20574 vanaf ut naar Gvc	JOV
04-12-2011 21:53	NSR RBC Ut Monitor Ut	Trein 21776 Ut - Rtd opgeheven. Rijdt in zijn geheel vanaf Ut naar Gvc. (1776 vertrekt op Ut op vertrektijd van het Rtd-gedeelte)	JOV
04-12-2011 21:55	NSR LBC KlantMon 1	Reisadvies in de VSM via Ht naar Rsd niet uitvoeren ivm Wkz tussen Ht en Tb.	KM
04-12-2011 21:55	PVL BackOffice 1	Hebben een loc en mcn in Rsd , mcn kan over 30 min in Rsd zijn en dan loc opstarten	Strukt
04-12-2011 21:58	PVL BackOffice 1	Afspraak met stucton dat we met een andere loc de machine vd baan halen neerzetten in IJsselmonde, Strukton komt dan zelf de machine halen mbv hulploc uit Rsd	BO
04-12-2011 21:58	NSR LBC Mon Groen	Gevraagd aan RBC Ut om tr 581 aan te vullen in Ut of Amf	OCCR
04-12-2011 22:05	PVL BackOffice 1	Hulploc van DBS wordt gebruikt om werktrein van de baan te halen naar IJsm	BO
04-12-2011 22:06	NSR RBC Ut Monitor Ut	Trein 581 wordt met een IC3 aangevuld vanaf Ut	JOV
04-12-2011 22:12	NSR RBC Ut Monitor Ut	Vanaf trein 21776 rijden de IC naar Rtd en Gvc vanaf Ut tot nader order gecombineerd naar Gvc.	JOV
04-12-2011 22:21	PVL BackOffice 2	geeft definitieve prognose.	AL
04-12-2011 22:26	NSR LBC KlantMon 1	OM Midden en OM ZI bijgepraat ivm reiz die nu aan het omreizen zijn en niet verder komen dan ZI ivm wkz aldaar.	KM
04-12-2011 22:49	PVL BackOffice 1	DPG verschuift, infra wordt vrijgegeven als trein va Rtng op het rsp rijdt rl Rtd.	AL
04-12-2011 23:01	PVL DVL Rtd N	Defecte trein rijdt nu terug richting Rtng als 59999 en daarna naar IJsm.	Dvl
04-12-2011 23:02	NSR RTD CAL1	Als DPG inderdaad DPG dan 20589 va. Rtd	Rien
04-12-2011 23:04	NSR RBC Ut Monitor Ut	21780 gaat als eerste door naar Rtd	denny
04-12-2011 23:07	PVL BackOffice 1	Trein van XG,h en J spoor en einde incident.	AL
04-12-2011 23:09	PVL DVL Rtd N	356451 rijdt weer rl. Wgm.	Dvl
04-12-2011 23:10	PVL BackOffice 1	OC Klpd kgg	

Beoordeling

Wel toegepast	Niet toegepast
Zonder aanpassing	Geen maatregel beschikbaar
Met aanpassingen	Niet te beoordelen
	Niet van toepassing

Toelichting uitvoering: MvdV

Annex F Passenger Train Operations Corridor Amsterdam

In the table below train operations on corridor Amsterdam can be seen (ProRail, 2012c).

Train no.	**Type**	**Route**	**Stops within corridor**	**Trains/hour/ direction**	**Remark**
140/240	IC NS/DB	Shl – Berlin	Asdz, Dvd	5 a day	
700	IC	Shl - Gn	Asdz, Dvd	1	
1600	IC	Shl - Es	Asdz, Dvd	2	Is cancelled in case of train 140/240
3100	IC	Shl – Nm	Asdz, Asb	2	No evening
3500	IC	Shl – Ehv/(Mt)	Asdz, Asb	2	
3700	IC	(Gvc) Shl - Lls	Asdz, Dvd	2	
4300	SPR	Gvc – Almo (Lls)	Asdz, Rai, Dvd, Dmnz	2	
5700	SPR	(Ledn) Hfd – Ut	Asdz, Rai, Dvd, Dmnz	2	

Annex G VSM no. 10 Corridor Amsterdam

Extract of the original VSM (VSM 10.041, 10.060, 10.101 and 10.120).

VSM 10.041

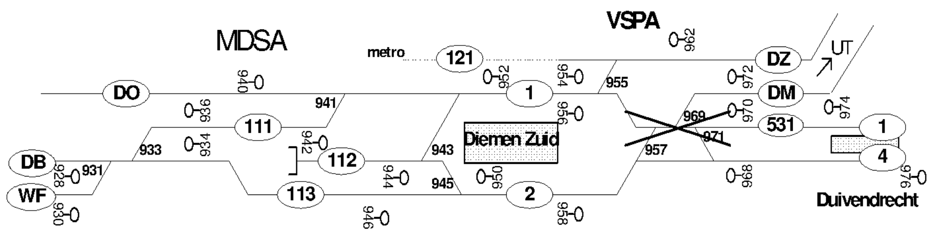
ProRail ***Maatregel 10.041***

Traject: **Gaasperdammerweg aansluiting - Amsterdam Riekerpolder**
Geldig vanaf: 12 dec 2010

Baanvak: **Diemen Zuid - Duivendrecht**
Geldig tot:

Situatie

Situatie: **Het rechterspoor tussen Duivendrecht - Diemen Zuid is versperd.**



Reizigerstreinen

Serie	*richting*	*bijzonderheden*	*werkverdeling*
Blijft rijden			
4300	-	Mat keert in Dmnz! Zie bijz. RVL.	-
74300			-
Inleggen			
29700	Lelystad centrum - Almere Oostvaarders v.v.	Na verzoek NSR. Zie bijz RVL.	Keuze LVL-DVL
Opheffen			
140	Amersfoort - Schiphol v.v.		Keuze LVL-DVL
240	Amersfoort - Schiphol v.v.		Keuze LVL-DVL
700	Amersfoort - Schiphol v.v.		Keuze LVL-DVL
1600	Amersfoort - Schiphol v.v.		Keuze LVL-DVL
3700	Lelystad centrum - Schiphol v.v.		Keuze LVL-DVL
5700	Weesp - Amsterdam-Zuid v.v.		Keuze LVL-DVL
70700	-		Keuze LVL/DVL
71600	-		Keuze LVL/DVL
73700	Hoofddorp Midden - Schiphol v.v.		Keuze LVL-DVL
Wijzigen			
70140	Amersfoort - Watergraafsmeer v.v.		Keuze LVL/DVL
70240	Amersfoort - Watergraafsmeer v.v.		Keuze LVL/DVL

Goederentreinen

Goederentreinen rijden in overleg tussen Prorail LVL en de Transportcontroller DBS of de wachtdienst van de betreffende vervoerder.

Afgedrukt op: 31-1-2011 13:04 *22 van 54* ***Maatregel 10.041***

Treinkeringen

Serie	A.tijd	A.spoor	keert op	V.tijd	V.spoor	oorspr.	bijzonderheden
Almere Oostvaarders							
29700	-.17	3	29700	-.22	3		
29700	-.47	3	29700	-.52	3		
Amersfoort							
700	-.52	7	700	-.08	2		doorwisselen via spoor 28
1600	-.22	7	1600	-.37	1		doorwisselen via spoor 28
Amsterdam-Zuid							
5700	-.18	3	5700	-.42	3		
5700	-.48	3	5700	-.12	3		
Hoofddorp Midden							
73900	-.05	233	73900	-.26	233		
73900	-.35	233	73900	-.56	233		
Lelystad centrum							
3900	-.11	1	3900	-.16	1		
3900	-.41	1	3900	-.46	1		
29700	-.02	2	29700	-.07	2		
29700	-.32	2	29700	-.37	2		
Weesp							
5700	-.16	5	5700	-.42	2		doorwisselen
5700	-.46	5	5700	-.12	2		doorwisselen

Spoorwijzigingen

Serie	A.tijd	A.spoor	V.tijd	V.spoor	oorspr.	bijzonderheden

Bijzonderheden Railverkeersleiding

Serie 4300 van en naar Wp op spoor 1 en 4300 van en naar Shl spoor 2 in Dmnz binnennemen en zowel reizigers als treinpersoneel over laten stappen op elkaars treinen.
Drgl 29700

Lls v. -.07/-.37 Almo v. -.22/-.52
Almo a. -.17/-.47 Lls a. -.32/-.02

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Alléén omroepen na overleg Operationeel Manager(NSR) en Teamleider(Verkeersleiding).

In de spits metro - Asdz - Dmnz v.v.

Reisadvies

Richting	reisadvies	reistijdverlenging

Bijzonderheden materieelkering

Voor serie 29700 Lls - Almo v.v. zijn twee composities nodig. (van serie 3700)

Bijzonderheden personeelsovergang

Personeel van de 29700 wordt geregeld door standplaats Lls.
Standplaats Lls geeft door aan MON RBC wanneer zij kunnen pendelen tussen Lls en Almo.
Machinisten die 700/1600 naar Shl zouden rijden, wisselen te Amf het materieel door.

Bijzonderheden uitvoering maatregel

Mat 700/1600 te Amf. wisselt door van sp 7 via sp 28 naar sp 1/2 om de overstap voor de reizigers op hetzelfde perron te garanderen.

Bijzonderheden busregeling

ProRail

Maatregel 10.060

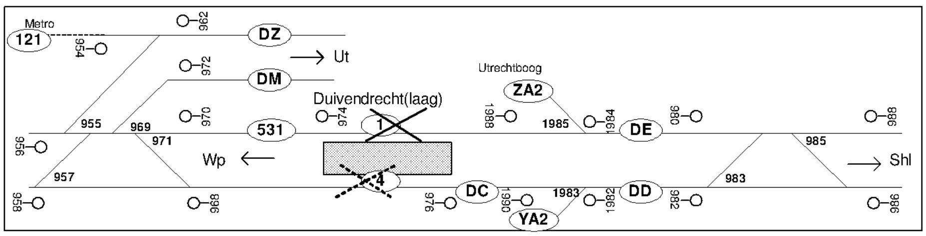
Traject: **Gaasperdammerweg aansluiting - Amsterdam Riekerpolder**

Baanvak: **Duivendrecht - Duivendrecht**

Geldig vanaf: 12 dec 2010
Geldig tot:

Situatie

Situatie: **Spoor 1 of 4 in Duivendrecht is versperd.**



Reizigerstreinen

Serie	richting	bijzonderheden	werkverdeling
Blijft rijden			
140	-		-
240	-		-
700	-		-
1600	-		-
4300	-		-
70700	-		-
71600	-		-
Inleggen			
29700	Lelystad centrum - Almere Oostvaarders v.v.	Na verzoek NSR. Zie bijz RVL.	Keuze LVL-DVL
Opheffen			
3700	Lelystad centrum - Schiphol v.v.		Keuze LVL-DVL
5700	Weesp - Amsterdam-Zuid v.v.		Keuze LVL/DVL
73700	Hoofddorp Midden - Schiphol v.v.		Keuze LVL-DVL

Goederentreinen

Goederentreinen rijden in overleg tussen Prorail LVL en de Transportcontroller DBS of de wachtdienst van de betreffende vervoerder.

Treinkeringen

Serie	A.tijd	A.spoor	keert op	V.tijd	V.spoor	oorspr.	bijzonderheden
Almere Oostvaarders							
29700	-.17	3	29700	-.22	3		
29700	-.47	3	29700	-.52	3		

Amsterdam-Zuid

5700	-.18	3	5700	-.42	3	4	
5700	-.48	3	5700	-.12	3	4	

Hoofddorp Midden

73900	-.05	233	73900	-.26	233		
73900	-.35	233	73900	-.56	233		

Lelystad centrum

3900	-.11	1	3900	-.16	1		
3900	-.41	1	3900	-.46	1		
29700	-.02	2	29700	-.07	2		
29700	-.32	2	29700	-.37	2		

Weesp

5700	-.16	5	5700	-.42	2		doorwisselen
5700	-.46	5	5700	-.12	2		doorwisselen

Spoorwijzigingen

Serie	*A.tijd*	*A.spoor*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*

Bijzonderheden Railverkeersleiding

Drgl 29700

Lls v. -.07/-.37 Almo v. -.22/-.52
Almo a. -.17/-.47 Lls a. -.32/-.02

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Reisadvies

Richting	*reisadvies*	*reistijdverlenging*

Bijzonderheden materieelkering

Voor serie 29700 Lls - Almo v.v. zijn twee composities nodig. (van serie 3700)

Bijzonderheden personeelsovergang

Personeel van de 29700 wordt geregeld door standplaats Lls.
Standplaats Lls geeft door aan MON RBC wanneer zij kunnen pendelen tussen Lls en Almo.

Bijzonderheden uitvoering maatregel

ProRail

Maatregel 10.101

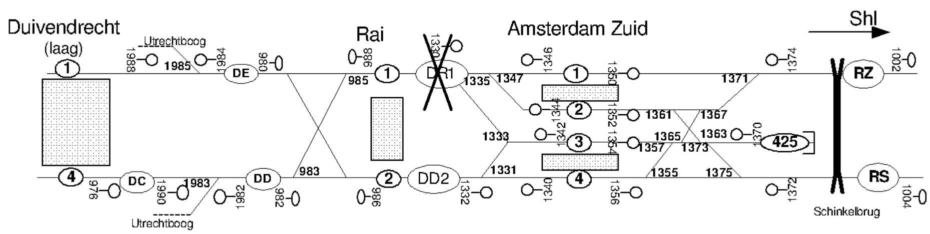
Traject: **Gaasperdammerweg aansluiting - Amsterdam Riekerpolder**

Baanvak: **Amsterdam RAI - Amsterdam-Zuid**

Geldig vanaf: 7 feb 2011
Geldig tot:

Situatie

Situatie: **Het rechterspoor spoor tussen Amsterdam Zuid - Amsterdam Rai is versperd.**



Reizigerstreinen

Serie	*richting*	*bijzonderheden*	*werkverdeling*
Blijft rijden			
140			-
240			-
700			-
1600			-
3500			-
3700			-
4300	-		-
5700	-		-
70700	-		-
71600	-		-
Opheffen			
3100	Schiphol - Utrecht CS		Keuze LVL-DVL
73100	Hoofddorp opstel - Schiphol		Keuze LVL-DVL

Goederentreinen

Goederentreinen rijden in overleg tussen Prorail LVL en de Transportcontroller DBS of de wachtdienst van de betreffende vervoerder.

Treinkeringen

Serie	*A.tijd*	*A.spoor*	*keert op*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*
Utrecht CS							
3100	-.23	4	3100	-.37	4		
3100	-.53	4	3100	-.07	4		

ProRail

Maatregel 10.120

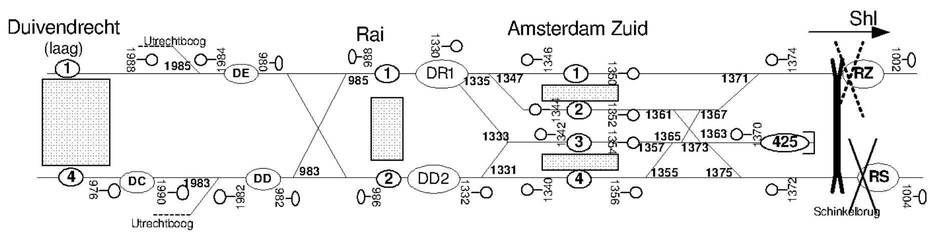
Traject: **Gaasperdammerweg aansluiting - Amsterdam Riekerpolder**

Baanvak: **Amsterdam-Zuid - Amsterdam Riekerpolder**

Geldig vanaf: 7 feb 2011
Geldig tot:

Situatie

Situatie: **1 spoor tussen Amsterdam Zuid - Amsterdam Riekerpolder is versperd.**



Reizigerstreinen

Serie	richting	bijzonderheden	werkverdeling
Blijft rijden			
140			-
240			-
700			-
1600			-
3500	-		-
5700	-	Let op spoorgebruik Shl.	-
70700	-		-
71600	-		-
73500	-		-
Inleggen			
29700	Lelystad centrum - Almere Oostvaarders v.v.	Na verzoek NSR. Zie bijz RVL.	Keuze LVL-DVL
Opheffen			
3100	Utrecht CS - Schiphol v.v.		Keuze LVL-DVL
3700	Lelystad centrum - Schiphol v.v.		Keuze LVL-DVL
4300	Amsterdam-Zuid - Hoofddorp		Keuze LVL/DVL
73100	Schiphol - Hoofddorp opstel v.v.		Keuze LVL-DVL
73700	Hoofddorp Midden - Schiphol v.v.		Keuze LVL-DVL
74300	Hoofddorp - Hoofddorp opstel v.v.		Keuze LVL/DVL

Goederentreinen

Treinkeringen

Serie	A.tijd	A.spoor	keert op	V.tijd	V.spoor	oorspr.	bijzonderheden
Almere Oostvaarders							
29700	-.17	3	29700	-.22	3		
29700	-.47	3	29700	-.52	3		
Hoofddorp Midden							
73900	-.05	233	73900	-.26	233		
73900	-.35	233	73900	-.56	233		
Lelystad centrum							
3900	-.11	1	3900	-.16	1		
3900	-.41	1	3900	-.46	1		
29700	-.02	2	29700	-.07	2		
29700	-.32	2	29700	-.37	2		
Utrecht CS							
3100	-.23	4	3100	-.37	4	14	
3100	-.53	4	3100	-.07	4	14	

Spoorwijzigingen

Serie	A.tijd	A.spoor	V.tijd	V.spoor	oorspr.	bijzonderheden

Bijzonderheden Railverkeersleiding

Let op indien het rechterspoor Asra - Asdz (RZ) versperd is! Treinen ri Asdz in Shl van sp 2 ipv sp 1.
Drgl 29700

Lls v. -.07/-.37 Almo v. -.22/-.52
Almo a. -.17/-.47 Lls a. -.32/-.02

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Reisadvies

Richting	reisadvies	reistijdverlenging

Bijzonderheden materieelkering

Voor serie 29700 Lls - Almo v.v. zijn twee composities nodig. (van serie 3700)

Bijzonderheden personeelsovergang

Personeel van de 29700 wordt geregeld door standplaats Lls.
Standplaats Lls geeft door aan MON RBC wanneer zij kunnen pendelen tussen Lls en Almo.

Bijzonderheden uitvoering maatregel

Bijzonderheden busregeling

Annex H Comparison Applied Rescheduling and VSM Corridor Amsterdam

VSM 10.041 is elaborated in the main report while the other VSM: 10.060, 10.101 and 10.120 are discussed in this Annex.

VSM 10.060: track 1 or 4 at Dvd is obstructed. In 2011, VSM 10.060 was selected three times. The measure dealt with partial obstruction between Dvd and Dmnz. Disruption occurred in all three events at the same location. The one on February 9 was caused by a defect switch–1985 LL. Consequently, partial train operations were possible between Rai and Dmnz. The following day–February 10–the same problem occurred. Therefore the same rescheduling measure was executed. The last one occurred on April 26 caused by a defect train. VSM 10.060 is almost the same measure as VSM 10.041–the only differences are that the IC 140-, 240-, 700- and 1600-series are operational and that there is no shuttle service of SPR 4300-series. In fact all these trains are directed to left track. Table H1 shows the train processes of the measure.

Table H1VSM 10.060

Operational	Inserted	Cancelled
IC 140, 240, 700, 1600	29700 (Lls-Almo)	IC 3700 (Lls-Shl)
SPR 4300		SPR 5700 (Wp-Asdz)
70700, 71600		73700 (Hfd-Shl)

February 9, 13:50-15:36. At 13:50, traffic controllers reported that they could not control switch 1985 LL. Hence, there was no train traffic possible between Rai and Dmnz. IC 3100- and 3500-series between Rai and Asb were still operational since switch 1985 RL was still usable. The trapped IC 1649 and SPR 5747 were directed on left track (crossovers 983A/B and 971A/B). The other trapped IC 3749 returned on left track through crossover 985A/B to Asdz where it was terminated (according to the VSM). In the reoccupation phase normal schedule was set in step-by-step. The IC 1600-series restarted at Shl once every two hours in combination with the IC140/240. In Figure H1 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 3700-series were cancelled according to the measure. Because of logistic problems the IC 3700-series were cancelled for the whole day. Instead, the shuttle service 29700 between Lls and Almo was introduced as is mentoined in the VSM. The SPR 4300-series continued according to VSM 10.060 and were directed left track through crossover 983A/B and on right track through crossover 971A/B. In total three SPR 4300-series were directed left track (SPR 4349-4353). Finally, the SPR 5700-series ended at Asdz and returned to Ledn. At the opposite direction the SPR 5700-series returned from Wp. In total four SPR 5700-series returned at Asdz (SPR 5749-5755).

Differences VSM and applied rescheduling. Traffic controllers cancelled the IC 700- and 1600-series from Shl. Only IC 751 continued towards Dmnz on left track. It can be concluded that the overall rescheduling went according to the VSM and as was mentioned in MUIS.

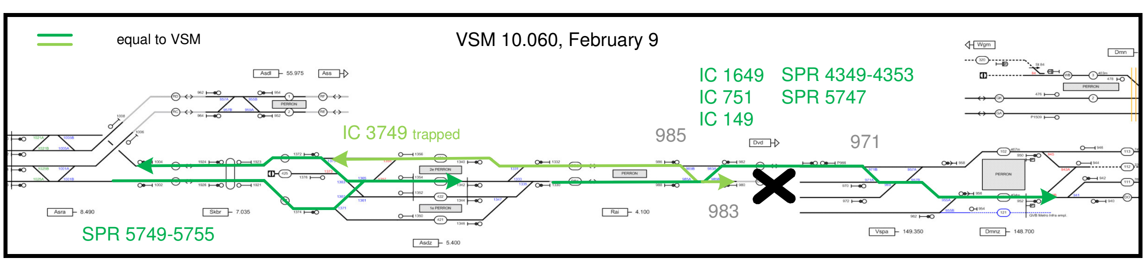


Figure H1 VSM 10.060 and applied rescheduling, February 9

February 10, 13:00-14:10. The next day at almost the same time, again switch 1985 LL was not controllable. With the event of the previous day in mind, one could think that the excecution of the measure could be done more efficiently. The disturbance of the switch lasted one hour shorter– engineers were able to repair it provisionally. Hence, the rescheduling operations were less extensive than the previous day. However, still a sensor of switch 1985 had to be replaced but then the switch had to be taken out of service. This meant that the IC 3100- and 3500-series had to be rescheduled as well (VSM 10.081). This is more complicated and therefore the traffic controllers decided to postphone maintenance till night hours. They rerouted the first affected train, IC 147 through switch 1985 RL to Ut (passengers remained in the train) instead of returning and redirecting it left track to Dmnz. This because it was a 'pulled' train (separate loc) and it was already trapped. In Figure H2 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. IC 747 and 1649 continued and the IC 3700-series were cancelled according to the measure. The SPR 4300-series continued according to the measure and were directed left track through crossover 983A/B and back on right track through crossover 971A/B. In total two SPR 4300-series were directed left track (SPR 4345 and 4347). The SPR 5700-series ended at Asdz and returned towards Ledn. At the opposite direction the SPR 5700-series returned from Wp. In total two SPR 5700-series returned at Asdz (SPR 5745 and 5747).

Differences VSM and applied rescheduling. IC 147 was rerouted but this train was already trapped and had to return first before it could be directed to the opposite track. Furthermore, shuttle service 29700 between Lls and Almo was not possible because of insufficient crew and rolling stock. But this deviation from the VSM was mentioned in MUIS.

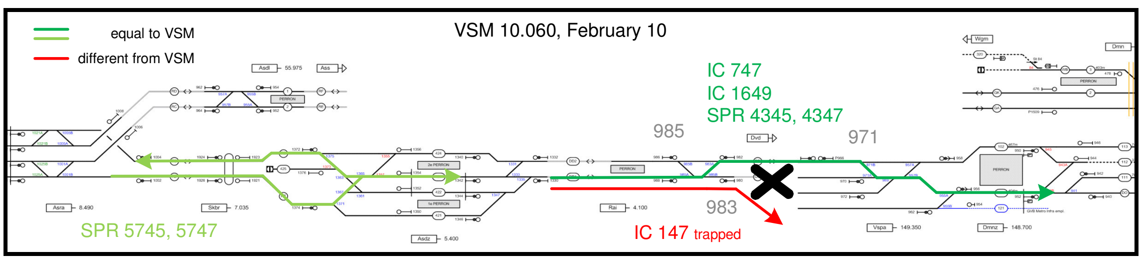


Figure H2 VSM 10.060 and applied rescheduling, February 10

April 26, 13:42-14:21. April 26 had the shortest disruption of the three events. It was caused by a defect train (SPR 4347) instead of disturbances on the rail infrastructure. At first instance–at 13:00–the train had stopped before switch 1985 consequently blocking both directions: towards Dmnz and Asb. This situation would require another measure–it also affected the IC 3100- and 3500-series. However, at 13:58 the train was able to move several meters forward. Eventually, the train was able to continue at 14:20 by itself. The total duration of the disruption was 39 minutes. Therefore, the initially planned VSM (as was mentioned in MUIS) was not executed–it was solved by some dispatching (which was also mentioned in MUIS). The IC 3749 was directed left track (through crossover 983A/B) and back on right track (through crossover 971A/B) because it was trapped (Figure H3). The SPR 5747 and SPR 4349 were waiting at Asdz and continued after the defect was solved.

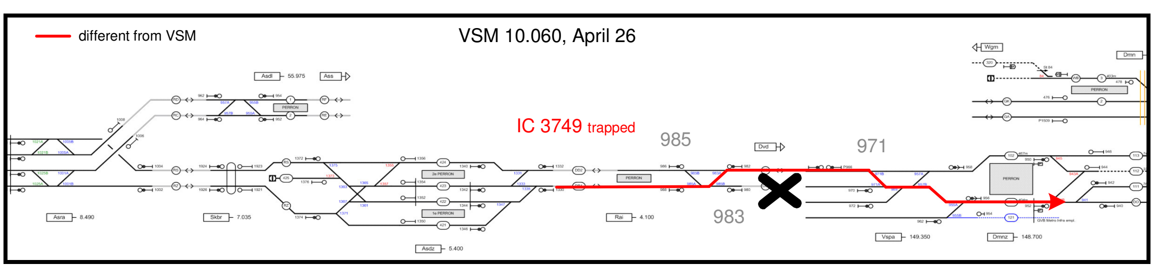


Figure H3 VSM 10.060 and applied rescheduling, April 26

Conclusions VSM 10.060. Table H2 summarized the similarities and differences between VSM 10.060 and the applied rescheduling. An advantage in case of disruptions on these corridors is that rerouting through Asd is a possible option. In 2010, the VSM prescribed rerouting for the IC 140-, 240-, 700- and 1600-series but in 2011 it was decided to keep these train operational. However, on February 9 traffic controllers cancelled the IC 700- and 1600-series and on February 10, they rerouted IC 140. The SPR 4300-series continued and the SPR 5700-series returned at Asdz to Ledn and at Wp according to the VSM. The inserted 29700 between Lls and Almo was not applied on February 10. In the last event the problem was solved quickly. Apart from some dispatching for the IC 3749 that was trapped, no VSM was executed.

Table H2 Comparison VSM 10.060 and applied rescheduling

	VSM 10.060	February 9	February 10	April 26
Operational	IC 140, 240, 700, 1600 SPR 4300	IC 700 SPR 4300	IC 700, 1600 SPR 4300	IC 3700
Inserted	29700	29700	-	-
Cancelled	IC 3700 SPR 5700	IC 700, 1600, 3700 SPR 5700	IC 3700 SPR 5700	-
Rerouted	-	-	IC 140	-
Not expected	n/a	IC 140, 240	IC 240	IC 140, 240, 700, 1600 SPR 4300, 5700

In Table H3 an overview is given of the crossovers that were used during disruption and measure/dispatching. In case of February 9, the crossovers were used three times to remove trapped trains which is a large part of the total usage that day.

Table H3 Crossover usage VSM 10.060 (total)

Crossover	February 9	February 10	April 26
First phase			
957A/B (Dmnz)	-	-	-
971A/B (Dmnz)	3	1	1
983A/B (Rai)	3	1	1
985A/B (Rai)	1	-	-
1165A/B (Ddm)	-	-	-
VSM			
957A/B (Dmnz)	1	-	n/a
971A/B (Dmnz)	4	3	n/a
983A/B (Rai)	4	3	n/a
985A/B (Rai)	-	-	n/a
1165A/B (Ddm)	-	-	n/a

VSM 10.101: right track between Asdz and Rai is obstructed. In 2011, VSM 10.101 was selected once. The measure dealt with partial obstruction between Asdz and Rai. Table H4 shows the train processes of the measure.

Table H4 VSM 10.101

Operational	Cancelled
IC 140, 240, 700, 1600, 3500, 3700	IC 3100 (Shl-Ut)
SPR 4300, 5700	73100 (Hfd-Shl)
70700, 71600	

February 1, 22:40-23:10. A defect SPR 4383 caused a partial obstruction between Asdz and Rai. In contrast to the previous events–VSM 10.041 and 10.060–this situation affected all trains on the corridor Asdz and Rai–including the IC 3100- and 3500-series to Asb. Fortunately, the problem was solved quickly by coupling the next SPR 4385 to SPR 4383. Therefore only the trapped IC 3585 and SPR 5783 were directed left track (through a crossover at Asdz) and back on right track (through crossover 985A/B) (Figure H4). The crossovers at Asdz are important for trains to continue in case of disruption between Asdz and Rai.

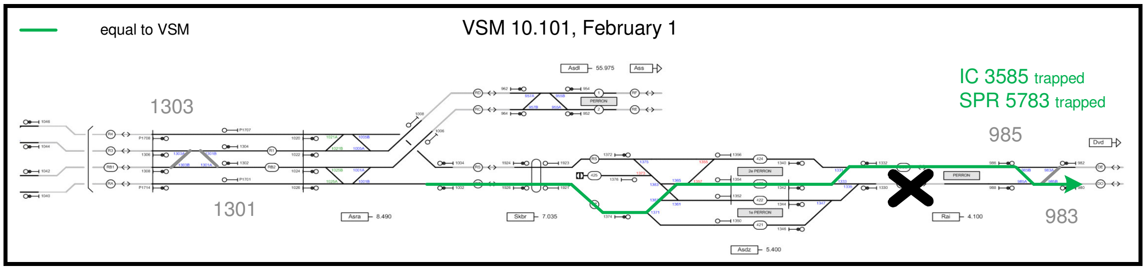


Figure H4 VSM 10.101 and applied rescheduling, February 1

Conclusions VSM 10.101. It can be concluded that no VSM was needed. In MUIS, traffic controllers reported VSM 10.101 but eventually the problem could be solved by some dispatching which was similar to the measures in VSM 10.101. In Table H5 an overview is given of the crossovers that were used during disruption and measure/dispatching.

Table H5 Crossover usage VSM 10.101 (total)

Crossover	**February 1**
First phase	
957A/B (Dmnz)	-
971A/B (Dmnz)	-
983A/B (Rai)	-
985A/B (Rai)	2
1165A/B (Ddm)	-

VSM 10.120: one of the tracks between Asdz and Asra is obstructed. In 2011, VSM 10.120 was selected three times. The measure dealt with partial obstruction between Asra and Asdz. Disruptions in all three events were caused by a defect train. On June 17 and July 1 the direction Asdz-Asra was disrupted. In September 8 the opposite direction was disturbed. The defects were solved relatively quickly: from 20 minutes to 55 minutes. Table H6 shows the train processes of the measure.

Table H6 VSM 10.120

Operational	**Inserted**	**Cancelled**
IC 140, 240, 700, 1600, 3500	29700 (Lls-Almo)	IC 3100 (Ut-Shl)
SPR 5700		IC 3700 (Lls-Shl)
70700, 71600, 73500		SPR 4300 (Asdz-Hfd)
		73700 (Hfd-Shl), 74300 (Hfdo)

June 17, 14:05-14:42. In the afternoon IC 1642 had broken down at section 923 A CT, near the connection with Asdl. In the first phase, the consecutive IC 3544, SPR 5744, IC 3144 and IC 744 were directed to left track (through a crossover at Asdz) and back on right track (through crossovers 1025A/B and 1301A/B). After 39 minutes IC 1642 was able to continue to Shl. The VSM was only partly executed. In the reoccupation phase the IC 700- and 1600-series were operational once every two hours. In Figure H5 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. IC 744 was directed to the opposite track and the IC 3500- and SPR 5700-series continued according to VSM 10.120. The IC 3100-series were cancelled between Ut and Shl, only the first IC 3144 was directed to left track. But afterwards, the IC 3100-series were cancelled for the rest of the day. There was too little capacity at Hfdo according to the log files in MUIS. SPR 4344 ended at Asdz and returned to Dmnz according to the VSM.

Differences VSM and applied rescheduling. The IC 3700-series had to be cancelled as well but it was decided to let IC 3744 return to Lls through track 425 at Asdz (first phase). In the reoccupation phase, the first IC 3746 also returned to Lls at Asdz. SPR 4346 was terminated instead of returned to Dmnz. In MUIS it was reported as rescheduling according to the VSM which was not the case.

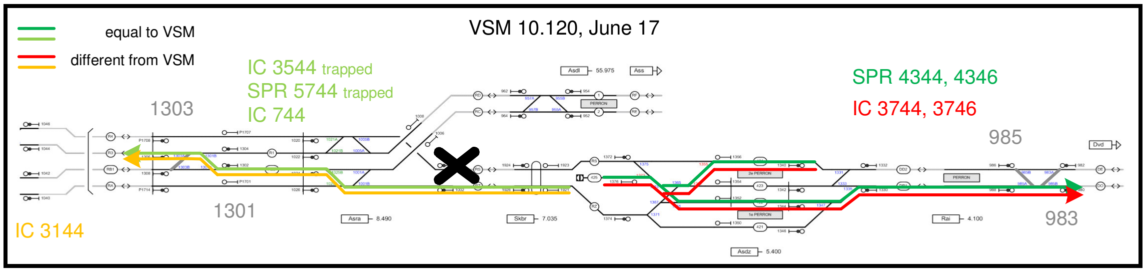


Figure H5 VSM 10.120 and applied rescheduling, June 17

July 1, 07:49-08:10. At 07:49, IC 3718 broke down at section 923 D ET towards Shl. Traffic controllers waited to execute the VSM. Instead, some dispatching was done. IC 3118 and IC 1618 were directed to left track (through a crossover at Asdz) and back on right track (through crossovers 1025A/B and 1301A/B) (Figure H6). At 08:10 the train defect was solved. SPR 4318 ended at Asdz and returned as SPR 304325 to Alm. At Ut, the IC 3120 was already cancelled–as prescribed by the VSM. After 21 minutes IC 3718 was able to continue to Shl. At 08:25 queuing dissolved around Shl. It can be concluded that no VSM was needed. In MUIS, traffic controllers reported initially, VSM 10.120 but eventually the problem could be solved by some minor dispatching.

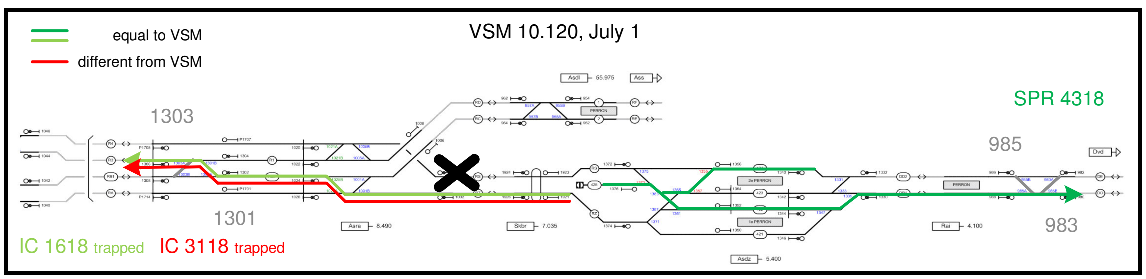


Figure H6 VSM 10.120 and applied rescheduling, July 1

September 8, 07:40-08:35. At 07:40, IC 3125 broke down at section 926 A CT towards Asdz. In the first phase, IC 3725 was rerouted through Asdl and Asd. The consecutive IC 1625, SPR 4325, SPR 5725 and IC 727 were directed to left track (through crossovers 1303A/B and 1021A/B) and back on right track (through a crossover at Asdz). The IC 3525 was coupled to IC 3125 and continued as IC 3129 to Nm at 08:35. In the reoccupation phase, the IC 3129 started at Ut while the IC 3124 was cancelled. Besides, IC 3131 and IC 3731 started at Hfd. In Figure H7 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 3127 and IC 3729 were cancelled at Shl. The SPR 4300-series returned from Asdz to Alm according to the VSM. Only the trapped SPR 4325 was different from the VSM and was directed to left track instead of being cancelled. The IC 727, 1625 and SPR 5725 were sent to the opposite direction towards Asdz.

Differences VSM and applied rescheduling. The trapped IC 3725 and 3727 were rerouted instead of cancelled according to the VSM. Finally, the trapped SPR 5723 was rerouted through Asdl instead of continuing to Asdz. The consecutive trains were handled according to the VSM and as reported in MUIS.

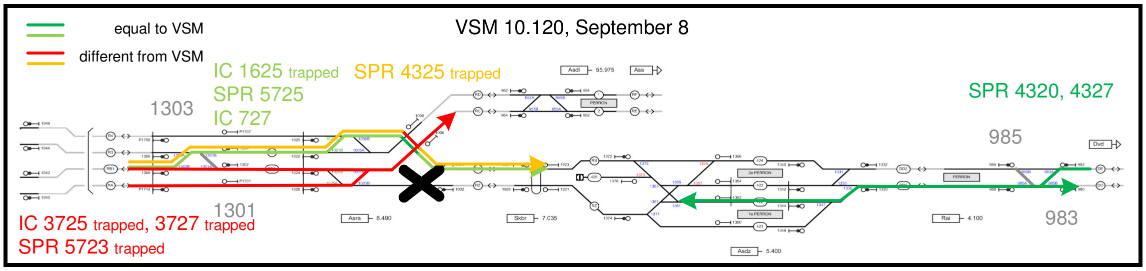


Figure H7 VSM 10.120 and applied rescheduling, September 8

Conclusions VSM 10.120. Table H7 summarized the similarities and differences between VSM 10.120 and the applied rescheduling. All three disruptions were too short and therefore no rescheduling was completely executed according to the VSM. In the first phase, trapped trains had to be removed or had to wait until the trains were repaired. Eventually, only some dispatching/partly VSM was executed.

Table H7 Comparison VSM 10.120 and applied rescheduling

	VSM 10.120	**June 17**	**July 1**	**September 8**
Operational	IC 140, 240, 700, 1600, 3500 SPR 5700	IC 700, 3100, 3500, 3700 SPR 5700	IC 1600, 3100 SPR 4300	IC 700, 1600 SPR 4300, 5700
Inserted	29700	-	-	-
Cancelled	IC 3100, 3700 SPR 4300	IC 3100 SPR 4300	IC 3100	SPR 4300
Rerouted	-	-	-	IC 3700 SPR 5700
Not expected	n/a	IC 140, 240, 1600	IC 140, 240, 700, 3500, 3700 SPR 5700	IC 140, 240, 3100, 3500

In Table H8 an overview is given of the crossovers that were used during disruption and measure/dispatching. As can be seen from the table, in June 17 and September 8, the share of crossovers during the VSM is the same as the share of crossovers during the first phase.

Table H8 Crossover usage VSM 10.120 (total)

Crossover	**June 17**	**July 1**	**September 8**
First phase			
983A/B (Rai)	-	-	-
1021A/B (Asra)	-	-	2
1025A/B (Asra)	2	2	-
1301A/B (Asra)	2	2	-
1303A/B (Asra)	-	-	2
VSM			
983A/B (Rai)	-	n/a	1
1021A/B (Asra)	-	n/a	2
1025A/B (Asra)	2	n/a	-
1301A/B (Asra)	2	n/a	-
1303A/B (Asra)	-	n/a	2

Annex I TOON Analysis Corridor Amsterdam

TOON has been used to analyze disrupted train operations which are based on TROTS log-files, exact information from signals and sections. The tables below give a detailed analysis.

VSM 10.041

June 14, 05:30-13:27

	Train	Arrival time (Asdz)			Used crossovers (no black infra)
Incoming call	05:30, section disturbance switch 971A/B (Rai => Dmnz)				
First phase	SPR 5715	05:30		Continued through section	
	IC 1617	05:57		Continued through section	
	SPR 4317	06:03	06:28 defect (Dvd), 06:44 repaired and continued	Continued through section	
	SPR 5717	06:19		Continued through section	
	IC 719	06:26		Opposite (because trapped behind SPR 4317)	Left: 983A/B Right: 1165 A/B
	IC 721-727 and 1619-1633 rerouted through Asd				
	IC 3131	09:08			
	SPR 5729	09:10		Continued through section	
	IC 3731	09:16		Continued through section	
	IC 3531	09:23			
	SPR 4331	09:35		Continued through section	
	IC 3133	09:39			
	SPR 5731	09:49		Continued through section	
	09:49, maintenance started				
VSM	SPR 4333	10:05	10:23 as SPR 304328 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3135	10:10			
	SPR 5733	10:18	10:44 as SPR 305730 (Asdz)	Returned to Ledn	
	IC 3535	10:25			
	SPR 4335	10:32	10:53 as SPR 29673 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3137	10:37			
	SPR 5735	10:48	11:13 as SPR 305732 (Asdz)	Returned to Ledn	
	IC 3537	10:54			
	SPR 4337	11:03	11:24 as SPR 304332 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3139	11:12			
	SPR 5737	11:17	11:43 as SPR 305734 (Asdz)	Returned to Ledn	
	IC 3539	11:21			
	SPR 4339	11:33	11:48 as SPR 304334 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3141	11:37			
	SPR 5739	11:48	12:12 as SPR 305736 (Asdz)	Returned to Ledn	
	IC 3541	11:53			
	SPR 4341	12:02	12:18 as SPR 304336	Opposite and	Left: 983A/B

	Train	Arrival time (Asdz)			Used crossovers (no black infra)
			(Dmnz)	returned to Gvc	
	IC 3143	12:08			
	SPR 5741	12:17	12:40 as SPR 305738 (Asdz)	Returned to Ledn	
	IC 3543	12:20			
	SPR 4343	12:32	12:54 as SPR 304338 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3145	12:36			
	SPR 5743	12:50	13:12 as SPR 305740 (Asdz)	Returned to Ledn	
	IC 3545	12:52			
	IC 147	12:57			Left: 983A/B Right: 1165A/B
	SPR 4345	13:01	13:18 as SPR 304340 (Dmnz)	Opposite and returned to Gvc	Left: 983A/B
	IC 3147	13:06			
	IC 3547	13:21			
	SPR 5745	13:22	13:42 as SPR 305742 (Asdz)	Returned to Ledn	
End of call	13:27, maintenance finished				
Reoccupation phase	SPR 4347	13:33	13:57 as SPR 304342 (Dmnz)	Opposite and returned to Gvc	Left: 957A/B (instead of 983A/B)
	IC 3149	13:37			
	SPR 5747	13:51	14:13 as SPR 305744 (Asdz)	Returned to Ledn	
	SPR 4349	14:04		Continued	
	IC 1649	14:10		Continued	
	IC 3751	14:17		Continued	
	SPR 5749	14:19		Continued	
	IC 751	14:28		Continued	

	IC 149	14:59		Continued	

	IC 3755	15:16		Continued	

	IC 755	15:26		Continued	

	IC 3757	14:48		Continued	

	IC 1657	15:56		Continued	

	IC 759	16:26		Continued	

	IC 3761	16:46		Continued	

	IC 241	16:57		Continued	

	IC 1665	17:55		Continued	

November 11, 07:12-08:31

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	07:12, defect IC 141 at Dvd (Dvd => Dmnz)				
First phase	IC 141	07:03			
	SPR 4321	07:05		Returned and continued	Left: 985A/B Right: 971A/B
	IC 3123	07:08			
	IC 3723	07:15			Left: 983 A/B Right: 971A/B
VSM	SPR 5721	07:18	07:45 as SPR 305718 (Asdz)	Returned to Ledn	
	IC 3523	07:22			
	IC 723	07:32	07:57 as 89116	Cancelled	
	IC 716	07:40	Dvd <= Dmnz	Opposite (because of SPR 4321)	Left: 983A/B
	SPR 4323	07:44			Left: crossover at Asdz Right: 971A/B
	IC 3125	07:49			
	SPR 5723	07:55	08:16 as SPR 305720	Returned to Ledn	
	IC 3525	08:03			
	SPR 4325	08:05			Left: crossover at Asdz Right: 971A/B
	IC 3127	08:09			
	89120	Passed 08:14	Freight train		
	SPR 5725	08:22	08:43 as SPR 305722	Returned to Ledn	
	IC 3527	08:25			
	IC 141	08:29 repaired		Continued	
End of call	08:31				
Reoccupation phase	SPR 4327	08:35		Continued	
	IC 3129	08:42			
	SPR 5727	08:48		Continued	
	IC 3731	09:15		Continued	
	IC 143	09:40		Continued	
	IC 1633	09:56		Continued	

VSM 10.060

February 9, 13:50-15:36

	Train	Arrival time (Asdz)			Used crossovers (no black infra)
Incoming call	13:50, switch 1985 LL not in control (Rai => Dmnz)				
First phase	IC 3549	13:50			
	IC 1649	13:56		Opposite (because trapped)	Left: 983A/B Right: 971A/B
	SPR 5747	13:59		Opposite (because trapped)	Left: 983A/B Right: 971A/B
	IC 3749	14:04		Opposite (because trapped) and returned to Shl	Right: 985A/B
VSM	SPR 4349	14:06		Opposite	Left: 983A/B Right: 971A/B
	IC 3151	14:17			
	SPR 5749	14:21	14:46 as SPR 305746	Returned to Ledn	
	IC 751	14:28		Opposite	Left: 983A/B Right: 971A/B
	IC 3153	14:38			
	SPR 4351	14:46		Opposite	Left: 983A/B Right: 971A/B
	IC 3551	14:49			
	SPR 5751	14:52	15:12 as SPR 305748	Returned to Ledn	
	IC 149	15:03		Opposite	Left: 983A/B Right: 971A/B
	IC 3553	15:05			
	IC 3155	15:10			
	SPR 4353	15:12		Opposite	Left: 983A/B Right: 971A/B
	SPR 5753	15:22	15:46 as SPR 305750	Returned to Ledn	
	350063	Passed 15:23	Freight train		Left: 957A/B
	IC 3555	15:24			
	IC 3157	15:35			
End of call	15:36				
Reoccupation phase	IC 755	15:30		Continued	
	SPR 4355	15:40 (Dvd)		Continued	
	SPR 5755	15:50	15:10 as SPR 305752	Returned to Ledn	
	IC 1657	16:00		Continued	

	IC 759	16:27		Continued	
	IC 241	16:29		Continued	

	IC 763	17:27		Continued	

	IC 767	18:27		Continued	

	IC 243	18:58		Continued	

	IC 771	19:27		Continued	

	IC 1673	19:57		Continued	

February 10, 13:00-14:10

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	13:00, switch 1985 LL not in control (Rai => Dmnz)				
First phase					
	IC 147	12:55		Rerouted to Asb (because trapped)	
	SPR 4345	13:02		Opposite	Left: 983A/B Right: 971A/B
	IC 3147	13:05			
VSM	SPR 5745	13:18	13:44 as SPR 305742	Returned to Ledn	
	IC 3547	13:20			
	IC 747	13:33		Opposite	Left: 983A/B Right: 971A/B
	SPR 4347	13:37		Opposite	Left: 983A/B Right: 971A/B
	IC 3149	13:43			
	SPR 5747	13:52	14:15 as SPR 305744	Returned to Ledn	
	IC 3549	13:55			
	IC 1649	14:00		Opposite	Left: 983A/B Right: 971A/B
	SPR 4349	14:06			
End of call	14:10				
Reoccupation phase	IC 3151	14:30			

April 26, 13:42-14:21

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	13:42, defect SPR 4347 (Rai => Dmnz)				
First phase	IC 3149	13:36			
	53064	13:40	Freight train to Asb		
	SPR 3749	13:44		Opposite	Left: 983A/B Right: 971A/B
	SPR 5747	13:46		Queue	
	IC 3549	13:55			
	SPR 4349	14:07		Queue	
	IC 3153	14:10			
End of call	14:21, SPR 4347 repaired and continued				
	IC 751	14:29			
	IC 3153	14:36			
	IC 3551	14:26			
	SPR 4351	14:31			

VSM 10.101

February 1, 22:40-23:10

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	22:40, defect SPR 4383 (Asdz => Rai)				
First phase	IC 3585	22:51		Opposite	Left: crossover at Asdz Right: 985A/B
	SPR 4385	22:03	Coupled to SPR 4383 and dep 23:11	Continued	
	SPR 5783	22:47		Opposite	Left: crossover at Asdz Right: 985A/B
End of call	23:13, SPR 4383 repaired and continued				
	IC 3587	23:19		Continued	
	SPR 5785	23:17		Continued	

VSM 10.120

June 17, 14:05-14:42

	Train	Arrival time (Asdz)			Used crossovers (no black infra)
Incoming call	14:05, defect IC 1642 (Asra <= Asdz)				
First phase	IC 3544	14:07		Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
	SPR 5744	14:10		Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
	IC 3744	14:23	14:46 as IC 303753	Returned	Return track 425 at Asdz
VSM					
	SPR 4344	14:26	14:52 as SPR 4351	Returned	Return track 425 at Asdz
	IC 3144	14:30		Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
	IC 744	14:37		Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
	IC 3546	14:41		Continued	
	IC 1642	14:40 repaired		Continued	
End of call	14:42				
Reoccupation phase	SPR 5746	14:44		Continued	
	IC 3746	14:45	15:16 as IC 3755	Returned to Wp	
	SPR 4346	14:54	14:59 as SPR 304346	Cancelled and returned to Hfd	
	IC 148	15:01		Continued	
	IC 3548	15:06		Continued	
	SPR 5748	15:09		Continued	
	SPR 4348	15:24		Continued	
	IC 748	15:30		Continued	
	IC 3550	15:37		Continued	
	IC 5750	15:40		Continued	
	SPR 4350	15:55		Continued	
	IC 1650	16:00		Continued	

	IC 752	16:32		Continued	

	IC 146	16:58		Continued	

	IC 1658	17:59		Continued	

	IC 760	18:30		Continued	

July 1, 07:49-08:10

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	07:49, defect IC 3718 (Asra <= Asdz)				
First phase	IC 3118	07:50		Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
	SPR 4318	07:54	08:10 as SPR 304325 (Asdz)	Returned	
	IC 1618	08:01	Renamed in 80108 (Shl)	Opposite	Left: crossover at Asdz Right: 1025A/B, 1301A/B
End of call	08:10, IC 3718 repaired and continued				
	IC 3520	08:13		Continued	
	SPR 5720	08:15		Continued	

September 8, 07:40-08:35

	Train	**Arrival time (Asdz)**			**Used crossovers (no black infra)**
Incoming call	07:40, defect IC 3125 (Asra => Asdz)				
First phase	IC 3725	07:34 (Shl)		Rerouted to Asdl, Asd and Wp	
	IC 3525	07:51 (Shl)		Coupled to IC 3125 and renamed in IC 3125	
	IC 1625	07:53		Opposite	Left: 1303A/B, 1021A/B Right: crossover at Asdz
	SPR 4325	07:57		Opposite	Left: 1303A/B, 1021A/B Right: crossover at Asdz
	SPR 5723	07:59		Rerouted to Asdl, Asd and Asb	
	IC 3727	08:05		Rerouted to Asdl, Asd and Wp	
VSM	SPR 5725	08:16		Opposite	Left: 1303A/B, 1021A/B Right: crossover at Asdz
	IC 727	08:21		Opposite	Left: 1303A/B, 1021A/B Right: crossover at Asdz
	SPR 4320	08:22	(Asra <= Asdz) 08:43 as SPR 4327	Returned to Alm	Left: 983A/B (because of SPR 5725 on left track)
	IC 3125	08:29 repaired		Continued	
	IC 3527	08:32		Continued	
End of call	08:35				
Reoccupation phase	SPR 5727	08:46		Continued	
	IC 3529	08:48		Continued	

Annex J Crossover Usage Corridor Amsterdam

The table below shows the usage of the 'potentially redundant' crossovers in 2011 for corridor Amsterdam.

Crossover	Place	Turnover	Contra Curved Total Trains	Contra Straight Total Trains	Pliant Curved Total Trains	Pliant Straight Total Train	Total Curved	Total Straight	Share Curved	Share Straight	Total Trains	Total Passenger Trains	Total Freight Trains	Total Other Trains	Track Load	Signal Load
985A	Rai	916	317	413	62	70739	379	71152	1%	99%	71531	71260	21	250	C	II
985B	Rai	910	62	138	317	69519	379	69657	1%	99%	70036	69815	6	215	C	II
983A	Rai	890	260	69520	98	137	358	69657	1%	99%	70015	69787	5	223	B	II
983B	Rai	904	98	70681	260	470	358	71151	1%	99%	71509	71238	21	250	B	II
971A	Dmnz	1478	369	442	205	48736	574	49178	1%	99%	49752	49589	20	143	C	II
971B	Dmnz	1458	205	64	369	47867	574	47931	1%	99%	48505	48363	3	139	C	II
1303A	Shl	1236	60457	613	1529	108	61986	721	99%	1%	62707	62541	32	134	A	II
1303B	Shl	1274	61944	108	1036	613	62980	721	99%	1%	63701	63566	41	94	A	II
1301A	Shl	1392	164	1036	660	61941	824	62977	1%	99%	63801	63630	41	130	C	II
1301B	Shl	1394	660	977	164	60906	824	61883	1%	99%	62707	62542	31	134	C	II
1165A	Ddm	1434	226	241	290	48644	516	48885	1%	99%	49401	47470	1346	585	C	II
1165B	Ddm	1383	290	338	226	49025	516	49363	1%	99%	49879	48226	983	670	C	II

Annex K Passenger Train Operations Corridor Rotterdam

In the table below train operations on corridor Rotterdam can be seen (ProRail, 2012c).

Train no.	Type	Route	Stops within corridor	Trains/hour/ direction	Remark
2800	IC	Rtd – Dv	Rta, Gd	2	
4000	SPR	Rtd – Utg	Rtn, Rta, Cps, Nwk, Gd	2	
9700	SPR	Rtd – Gdg	Rtn, Rta, Cps, Nwk, Gd	2	Only in the peak hours and early morning (06:00-09:00 and 15:00-18:00)
12500	IC	Rtd – Lw	Gd	1*	Extra in the peak hours
12700	IC	Rtd – Lw	Gd	1*	Extra in the peak hours
20500/22500	IC	Rtd – Ut	Rta, Gd	1*	Wing train of IC 500 (Ut)
21700/22700	IC	Rtd – Ut	Rta, Gd	1*	Wing train of IC 1700 (Ut)

Annex L VSM no. 25 Corridor Rotterdam

Extract of the original VSM (VSM 25.050, 25.070 and 25.090).

VSM 25.050

ProRail ***Maatregel 25.050***

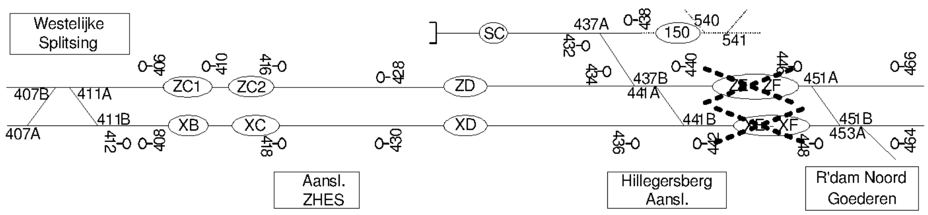
Traject: **Rotterdam CS - Gouda**

Baanvak: **Hillegersberg-aansluiting - Rotterdam Noord Goederen**

Geldig vanaf: 7 feb 2011
Geldig tot:

Situatie

Situatie: **Een van de sporen Hillegersberg aansluiting - Rotterdam Noord Goederen is versperd.**



Reizigerstreinen

Serie	*richting*	*bijzonderheden*	*werkverdeling*
Blijft rijden			
4000			-
12500			-
12700			-
20500			-
21700			-
Opheffen			
2800	Rotterdam CS - Utrecht CS v.v.		Keuze LVL-DVL
9700	Rotterdam CS - Gouda Goverwelle v.v.		Keuze LVL-DVL

Goederentreinen

Goederentreinen in overleg met Prorail LVL en Transportcontroller DBS en de andere vervoerders via de destbetreffende wachtdienst.

Treinkeringen

Serie	*A.tijd*	*A.spoor*	*keert op*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*
Utrecht CS							
2800	-.28	9	2800	-.32	9		
2800	-.58	9	2800	-.02	9		

Spoorwijzigingen

Serie	*A.tijd*	*A.spoor*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*

Afgedrukt op: 1-2-2011 11:59 *14 van 35* ***Maatregel 25.050***

Bijzonderheden Railverkeersleiding

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Reisadvies

Richting	*reisadvies*	*reistijdverlenging*
Roosendaal - Utrecht CS v.v.	via 's-Hertogenbosch	0.30

Bijzonderheden materieelkering

Bijzonderheden personeelsovergang

Bijzonderheden uitvoering maatregel

Als buiten de spits de serie 2800 niet rijdt tussen Dv en Amf, kan deze eventueel opgeheven worden over het gehele traject.

Bijzonderheden busregeling

ProRail

Maatregel 25.070

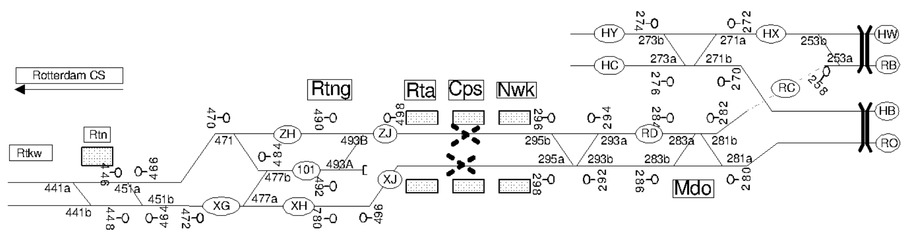
Traject: **Rotterdam CS - Gouda**

Baanvak: **Rotterdam Noord Goederen - Nieuwerkerk a/d IJssel**

Geldig vanaf: 7 feb 2011
Geldig tot:

Situatie

Situatie: **Een van de sporen Rotterdam Noord goederen - Nieuwerkerk a/d IJssel is versperd**



Reizigerstreinen

Serie	*richting*	*bijzonderheden*	*werkverdeling*
Blijft rijden			
4000			-
Opheffen			
2800	Rotterdam CS - Utrecht CS v.v.		Keuze LVL-DVL
9700	Rotterdam CS - Gouda Goverwelle v.v.	Spitstoevoeger	Keuze LVL-DVL
Wijzigen			
12500	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
12700	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
20500	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
21700	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL

Goederentreinen

Goederentreinen in overleg met Prorail LVL en Transportcontroller DBS en de andere vervoerders via de destbetreffende wachtdienst.

Treinkeringen

Serie	*A.tijd*	*A.spoor*	*keert op*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*
Den Haag CS							
12500	-.25	2	12500	-.35	2		Spits IC Gvc-Lw
12700	-.55	3	12700	-.05	3		Spits IC Gvc-Lw
20500	-.25	2	20500	-.35	2		IC Gvc-Gn/Lw
21700	-.55	3	21700	-.05	3		IC Gvc-Es
Utrecht CS							
2800	-.28	9	2800	-.32	9		
2800	-.58	9	2800	-.02	9		

Spoorwijzigingen

Serie	*A.tijd*	*A.spoor*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*

Bijzonderheden Railverkeersleiding

Treinen van de serie 12500,/20500 en 21700/12700 rijden door van/naar Gvc in de volgende dienstregeling en stoppen niet op tussenliggende stations:
Gd v -.07 / -.37
Gvca -.25 / -.55
Gvcv -. 35 / -.05
Gd a -.53 / -.23 v.o.

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Reisadvies

Richting	*reisadvies*	*reistijdverlenging*
Rotterdam CS - Amersfoort v.v.	via Den Haag CS	0.30
Rotterdam CS - Utrecht CS v.v.	via Den Haag CS	0.30
Utrecht CS - Roosendaal v.v.	via 's-Hertogenbosch	0.30

Bijzonderheden materieelkering

Bijzonderheden personeelsovergang

RC bekijkt per trein van serie 12500/12700 of deze kering heeft of keert op serie 20500/21700

Bijzonderheden uitvoering maatregel

Als buiten de spits de serie 2800 niet rijdt tussen Dv en Amf, kan deze eventueel opgeheven worden over het gehele traject.

Bijzonderheden busregeling

ProRail

Maatregel 25.090

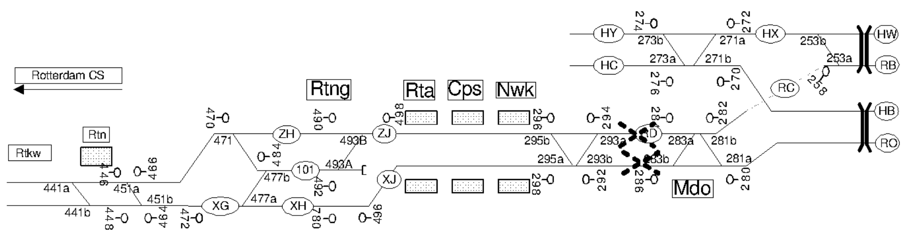
Traject: **Rotterdam CS - Gouda**

Baanvak: **Nieuwerkerk a/d IJssel - Moordrecht-overloop wissels**

Geldig vanaf: 7 feb 2011
Geldig tot:

Situatie

Situatie: **Een van de sporen Nieuwerkerk a/d IJssel - Moordrecht Overloop is versperd.**



Reizigerstreinen

Serie	*richting*	*bijzonderheden*	*werkverdeling*
Blijft rijden			
2800	-		-
4000			-
Opheffen			
9700	Rotterdam CS - Gouda Goverwelle v.v.	Spitstoevoegers	Keuze LVL-DVL
Wijzigen			
12500	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
12700	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
20500	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL
21700	Rotterdam CS - Gouda v.v.	Opheffen Rtd - Gd v.v. Doorleggen Gd - Gvc v.v.	Keuze LVL-DVL

Goederentreinen

Goederentreinen in overleg met Prorail LVL en Transportcontroller DBS en de andere vervoerders via de destbetreffende wachtdienst.

Treinkeringen

Serie	*A.tijd*	*A.spoor*	*keert op*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*
Den Haag CS							
12500	-.25	2	12500	-.35	2		Spits IC Gvc-Lw
12700	-.55	3	12700	-.05	3		Spits IC Gvc-Lw
20500	-.25	2	20500	-.35	2		IC Gvc-Gn/Lw
21700	-.55	3	21700	-.05	3		IC Gvc-Es

Spoorwijzigingen

Serie	*A.tijd*	*A.spoor*	*V.tijd*	*V.spoor*	*oorspr.*	*bijzonderheden*

Bijzonderheden Railverkeersleiding

Treinen van de serie 12500/20500 en 12700/21700 rijden door van/naar Gvc in de volgende dienstregeling en stoppen niet op tussenliggende stations:
Gd v -.07 / -.37
Gvca -.25 / -.55
Gvcv -. 35 / -.05
Gd a -.53 / -.23 v.o.

Omroepberichten

Instelling CTA-bakken

Vervangend vervoer

Reisadvies

Richting	*reisadvies*	*reistijdverlenging*
Rotterdam CS - Amersfoort v.v.	via Den Haag CS	0.30
Rotterdam CS - Utrecht CS v.v.	via Den Haag CS	0.30
Utrecht CS - Roosendaal v.v.	via 's-Hertogenbosch	0.30

Bijzonderheden materieelkering

Bijzonderheden personeelsovergang

RC bekijkt per trein van serie 12500/12700 of deze kering heeft of keert op serie 20500/21700

Bijzonderheden uitvoering maatregel

Als buiten de spits de serie 2800 niet rijdt tussen Dv en Amf, kan deze eventueel opgeheven worden over het gehele traject.

Bijzonderheden busregeling

Annex M Comparison Applied Rescheduling and VSM Corridor Rotterdam

Two events of VSM 25.070 are elaborated in the main report while the other VSM: 25.050, remainder of 25.070 and 25.090 are discussed in this Annex.

VSM 25.050: one of the tracks between Hlba and Rtng is obstructed. In 2011, VSM 25.050 was selected three times. The measure dealt with partial obstruction between Hlba and Rtng. In all events disruption was caused by a defect train. March 31 was the heaviest event where disruption lasted 4.5 hours. In the other two events disruption was solved quickly and therefore the VSM could be ended very soon. Table M1 shows the train processes of the measure.

Table M1 VSM 25.050

Operational	Cancelled
IC 12500, 12700, 20500, 21700	IC 2800 (Rtd-Ut)
SPR 4000	SPR 9700 (Rtd-Gdg)

March 27, 11:38-12:15. On March 27, at 11:38 SPR 704037 broke down at Rtn (direction to Rtd). Consecutive trains IC 21732 and SPR 704039 were both trapped and were directed on left track through crossovers and the side track switches of Rtng (Figure M1). According to the VSM, the IC 2800-series (IC 2836 and 2840) were cancelled during disruption. Because the defect lasted 38 minutes, only eight trains in both directions were affected and the impact was minimal as can be seen in TOON. In MUIS traffic controllers reported that the VSM was executed with adaptations; it was reported that IC 21732 had been cancelled but according to TOON, IC 21732 actually continued on left track.

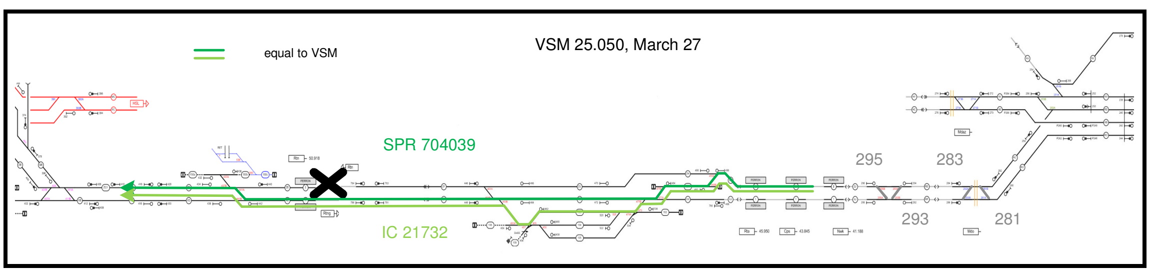


Figure M1 Applied rescheduling, March 27

March 31, 06:48-11:23. SPR 9712 was defect at the same location of the previous event. The consequences of this defect were more severe and rescheduling during 4.5 hours was necessary. Repair of SPR 9712 was delayed and more upstream on the opposite track, IC 21731 had an emergency brake near Wspl that caused a complete obstruction. The latter problem was solved quickly and eventually the VSM was ended: IC 2843 departed again from Rtd and IC 2836 continued from Ut to Rtd. In Figure M2 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 21700-, 20500- and SPR 4000-series continued on left track, through crossovers at Rtng according to the VSM. The IC 2800- and SPR 9700-series were cancelled between Rtd and Ut.

Differences VSM and applied rescheduling. In the first phase, IC 2814 and SPR 9714 were trapped and therefore not cancelled (returned) according to the VSM but directed on left track through crossovers at Rtng towards Rtd.

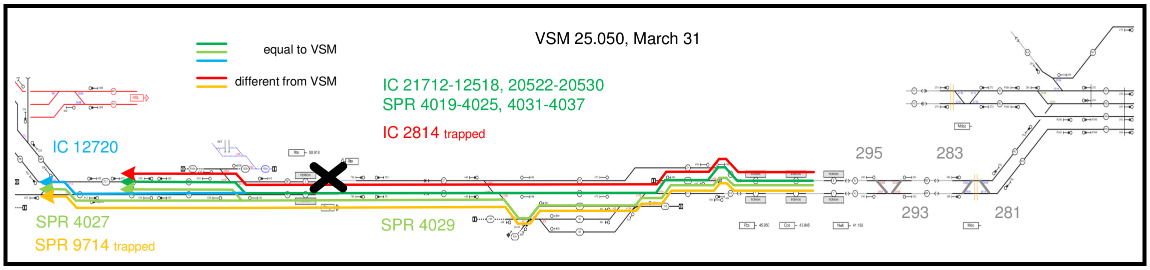


Figure M2 Applied rescheduling, March 31

November 3, 08:04-08:20. The last disruption between Hlba and Rtng occurred on the opposite direction to Rtd. Because of the defect SPR 4022, IC 21727 was redirected on left track (through crossovers at Hlba) and back on right track (through crossovers at Rtng), to continue towards Ut (Figure M3). Traffic controllers executed the VSM and IC 2829, SPR 9729 and 9730 were cancelled. Eventually, the disruption was solved after 16 minutes, no more trains were affected and the VSM was terminated. It can be concluded that the overall rescheduling went according to the VSM and as was mentioned in MUIS.

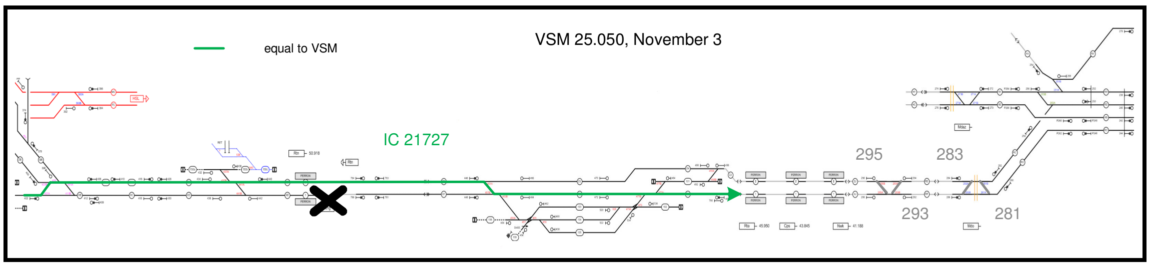


Figure M3 Applied rescheduling, November 3

Conclusions VSM 25.050. All events went according to VSM 25.050. Only March 31 was slightly adapted but this deviation was in the first phase where trains were trapped. It was impossible to process them according to the VSM. In Table M2 the similarities and differences between VSM 25.050 and the applied rescheduling are shown. The event on March 27 is a clear example of the arbitrary manner of reporting the rescheduling process and the eventually executed rescheduling process which was analysed with TOON. Sometimes reported actions were not taken in reality.

Table M2 Comparison VSM 25.050 and applied rescheduling

	VSM 25.050	**March 27**	**March 31**	**November 3**
Operational	IC 12500, 12700, 20500, 21700 SPR 4000	IC 12500, 12700, 20500, 21700 SPR 4000	IC 12500, 12700, 20500, 21700, 2800 SPR 4000, 9700	IC 12500, 12700, 20500, 21700 SPR 4000
Cancelled	IC 2800 SPR 9700	IC 2800	IC 2800 SPR 9700	IC 2800 SPR 9700
Not expected	n/a	SPR 9700	-	-

In Table M3 an overview is given of the crossovers that were used during the disruption and measure/dispatching. In these events it happened frequently that crossovers were used to couple and abduct ‘defect’ trains to stations/yards and not only for processing other affected trains during the disruption: first phase and VSM. Crossovers of Wspl, Hlba and Rtng are mostly used in case of VSM 25.050. It must be noted that crossovers from infra phase 1 at Nwki and Mdo were not used in these events. The event on March 31 had a long duration and 18 trains were directed through crossovers at Rtng which is formally a freight train side track. It can be concluded that these kind of side tracks play an important role in rescheduling as well.

Table M3 Crossover usage VSM 25.050 (total)

Crossover	March 27	March 31	November 3
First phase			
407A/B (Wspl)	n/a	1	n/a
411A/B (Wspl)	n/a	1	n/a
441A/B (Hlba)	n/a	3	n/a
451A/B (Rtng)	n/a	-	n/a
453A/B (Rtng)	n/a	1	n/a
457 (Rtng)	n/a	1	n/a
475A/B (Rtng)	n/a	1	n/a
477A/B (Rtng)	n/a	4	n/a
493A/B (Rtng)	n/a	4	n/a
541 (Rtng)	n/a	-	n/a
VSM			
407A/B (Wspl)	1	-	2
411A/B (Wspl)	-	2	-
441A/B (Hlba)	2	16	-
451A/B (Rtng)	-	-	2
453A/B (Rtng)	1	2	1
457 (Rtng)	1	2	1
475A/B (Rtng)	1	2	-
477A/B (Rtng)	2	18	-
493A/B (Rtng)	2	18	-
541 (Rtng)	-	-	-

VSM 25.070: one of the tracks between Rtng and Nwk is obstructed. The events on January 9 and June 13 are described in the main report. The other four events are discussed in this part. Delayed anticipated maintenance on November 14 caused a disruption of more than two hours. The other disruptions on April 2, July 19 and December 4 were shorter.

April 2, 14:40-15:50. In this event the opposite direction was affected. SPR 4048 broke down at Rta in the afternoon. In the first phase two trapped trains had to be removed. Also, the defect train had to be removed as soon as possible but this process was quite unclear. In TOON it is difficult to see what the reason behind specific actions are and if the reports in MUIS are also not clear, one has to make assumptions. SPR 4050 continued on left track as mentioned in the VSM but SPR 4052 went behind the defect train SPR 4048. After a while the defect train continued as an empty train towards Ut while SPR 4052 went back to Rtd. Probably, this train functioned as a shuttle train that brought passengers back to Rtd but there was train traffic at the opposite direction. Another possible reason is that the train transported an engineer to the defect train. SPR 4048 was renamed back in Rtd in SPR 4054 that continued its service to Utg on the right track since disruption was solved. In the reoccupation phase trains operated according to normal timetable. In Figure M4 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The IC 2800-series were cancelled and the SPR 4000-series continued on left track trough crossovers at Rtng and 293A/B (Nwki). Only SPR 4048 was cancelled.

Differences VSM and applied rescheduling. It is logical that IC 20553 was redirected through crossovers at Rtng and Nwki because this train was trapped. The consecutive IC 21755 which departed more than one hour later from Rtd continued instead of being cancelled and SPR 4048 was cancelled. It can be concluded that there were some differences compared to the VSM.

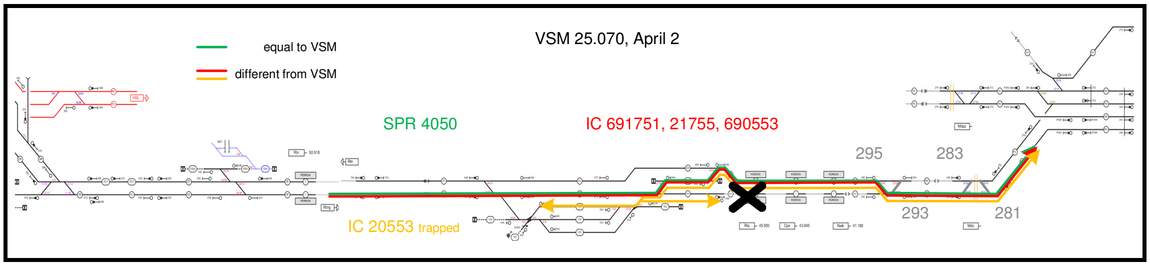


Figure M4 Applied rescheduling, April 12

July 19, 20:45-21:34. The sixth disruption of 2011 was caused by a defect IC 20577 at Rta in the direction of Gd. There were no trapped trains since the start of the operations at Rtd was very close by. The consecutive SPR 4074 departed and was directed to left track through crossovers at Rtng and Nwki (295A/B) as can be seen in Figure M5. The IC 2800-series were cancelled (IC 2870 and 2872) and the IC 20500/21700-series were cancelled, this was only one train IC 21722. Disruption was solved within 1 hour by combining the defect IC with another train and returning via a side track of Rtng to Rtd. There were no differences between the applied rescheduling and VSM. However, the VSM was only shortly executed.

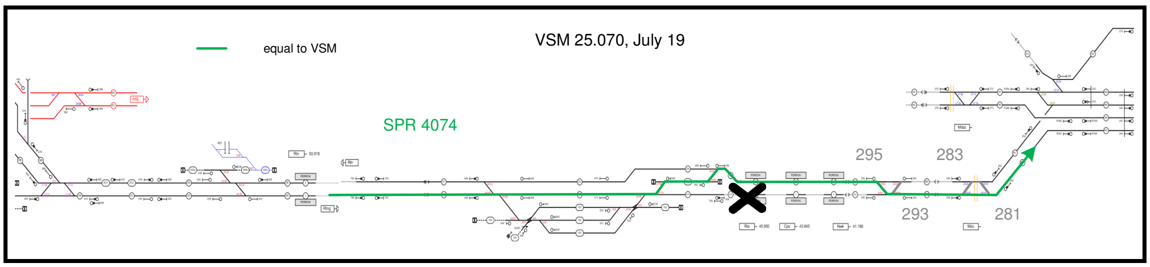


Figure M5 Applied rescheduling, July 19

November 14, 04:33-06:38. The usefulness of crossovers in case of delayed anticipated maintenance on one track is shown on November 14. In the early morning maintenance between Rtn and Rta had not finished on time. When passenger train operations started, partial VSM 25.070 was introduced. Hence, there were no trapped trains. However, the first prognosis was a delay till 06:15 the VSM was applied till 06:38. During the VSM, trains were able to depart from Rtd and to use the crossovers at Wspl and Nwki. The distance that trains had to travel on left track was quite long. There were no crossovers available in between. But these operations were before the peak hour. The IC 2800-series were cancelled and the SPR 4000-series departed from Rtd as planned in the VSM (Figure M6). There were no differences between the VSM and applied rescheduling–it was also reported in MUIS as a VSM without adjustments.

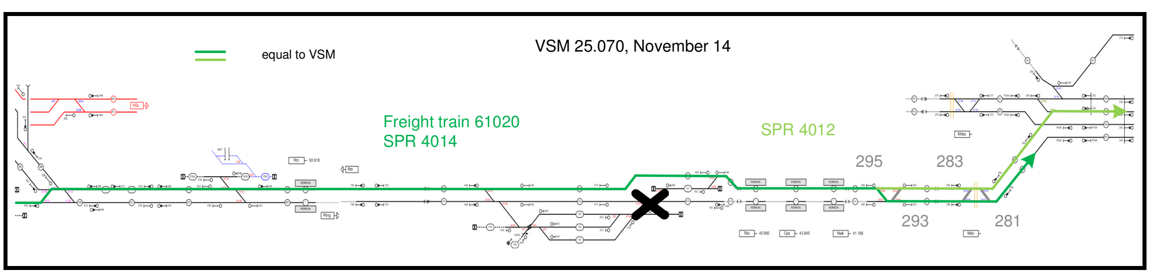


Figure M6 Applied rescheduling, November 14

December 4, 21:36-23:07. A defect freight train was the cause of this disruption in the late evening in the direction of Gd. SPR 4076 was trapped and instead of continuing on left track according to the VSM it was cancelled.

Similarities VSM and applied rescheduling. The IC 2800-series were cancelled and after disruption was solved, it was not operational anymore. The IC 20500/21700-series were modified: the IC-trains continued from Ut to Gvc instead of Rtd (IC 20574-20578). Apart from SPR 4076 all SPR 4000-series continued on left track according to the VSM.

Differences VSM and applied rescheduling. Only the trapped IC 4076 was cancelled as can be seen in Figure M7.

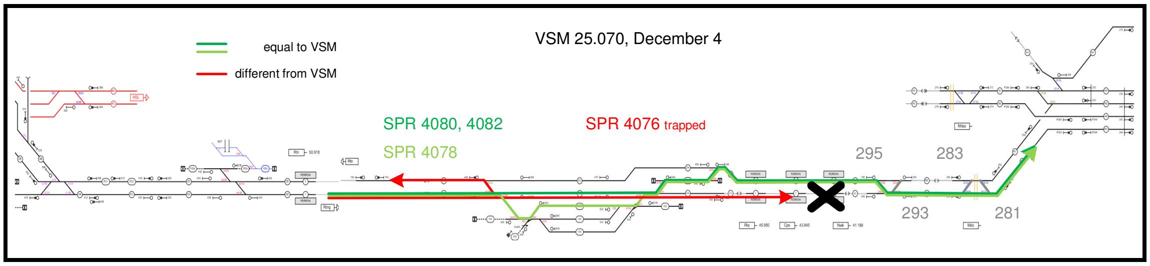


Figure M7 Applied rescheduling, December 4

Conclusions VSM 25.070. Disruptions between Rtng and Nwk were treated in most events according to the VSM. On April 2 one of the IC 21700-series continued and one SPR 4000-series was cancelled as opposed to continue. These trains were not trapped but traffic controllers gave no explantion for these interventions in MUIS. In all events the IC 2800-series were cancelled, the majority of the IC 20500/21700-series were modified and the SPR 4000-series continued according to the VSM. In Table M4 the similarities and differences between VSM 25.070 and the applied rescheduling are shown.

Table M4 Comparison VSM 25.070 and applied rescheduling

	VSM 25.070	**April 2**	**July 19**	**November 14**	**December 4**
Operational	SPR 4000	IC 20500, 21700 SPR 4000	SPR 4000	SPR 4000	SPR 4000
Modified	IC 20500, 21700	IC 20500, 21700	IC 20500, 21700	IC 20500, 21700	IC 20500, 21700
Cancelled	IC 2800 SPR 9700	IC 2800 SPR 4000	IC 2800	IC 2800	IC 2800 SPR 4000
Not expected	n/a	SPR 9700	SPR 9700	SPR 9700	SPR 9700

The importance of crossovers in the first phase and the VSM can be seen in Table M5. Several times the side track at Rtng is used which indicated that this is an important option.

Table M5 Crossover usage VSM 25.070 (total)

Crossover	**April 2**	**July 19**	**November 14**	**December 4**
First phase				
281A/B (Mdo)	-	n/a	n/a	-
283A/B (Mdo)	-	n/a	n/a	-
293A/B (Nwki)	-	n/a	n/a	-
295A/B (Nwki)	1	n/a	n/a	-
407A/B (Wspl)	-	n/a	n/a	-
411A/B (Wspl)	-	n/a	n/a	-
441A/B (Hlba)	-	n/a	n/a	-
451A/B (Rtng)	-	n/a	n/a	1
453A/B (Rtng)	-	n/a	n/a	-
457 (Rtng)	-	n/a	n/a	-
475A/B (Rtng)	-	n/a	n/a	-
477A/B (Rtng)	1	n/a	n/a	-
493A/B (Rtng)	1	n/a	n/a	-

Crossover	April 2	July 19	November 14	December 4
541 (Rtng)	1	n/a	n/a	-
VSM				
281A/B (Mdo)	-	-	-	-
283A/B (Mdo)	-	-	-	1
293A/B (Nwki)	-	-	-	-
295A/B (Nwki)	4	1	2	3
407A/B (Wspl)	-	-	3	-
411A/B (Wspl)	-	-	-	-
441A/B (Hlba)	-	-	-	-
451A/B (Rtng)	-	1	-	1
453A/B (Rtng)	-	1	-	1
457 (Rtng)	-	1	-	1
475A/B (Rtng)	1	-	-	1
477A/B (Rtng)	4	1	-	3
493A/B (Rtng)	4	1	-	3
541 (Rtng)	-	1	-	-

VSM 25.090: one of the tracks between Nwk and Mdo is obstructed. In 2011, there was only one partial obstruction between Nwk and Mdo where VSM 25.090 was applied. Table M6 shows the train processes of the measure.

Table M6 VSM 25.090

Operational	Modified	Cancelled
IC 2800	IC 12500, 12700, 20500, 21700 (cancelled between Rtd-Gd, instead continues between Gd-Gvc)	SPR 9700 (Rtd-Gdg)
SPR 4000		

August 19, 16:53-18:07. In the afternoon IC 20561 broke down at Mdo before the crossovers 283A/B and 281A/B. Because the disruption occurred in between Nwk and Mdo the crossovers of both were used. The disruption lasted one hour and 14 minutes. In Figure M8 similarities and differences between the VSM and the applied rescheduling are shown.

Similarities VSM and applied rescheduling. The train series IC 2800 and SPR 4000 continued accorrding to the VSM. The IC 20500- and 22700-series were cancelled between Rtd and Gd and continued to Gvc instead. The SPR 9700-series were cancelled too.

Differences VSM and applied rescheduling. Because SPR 9763 was trapped it had to be redirected left track while according to the VSM it had to be cancelled between Rtd and Gd.

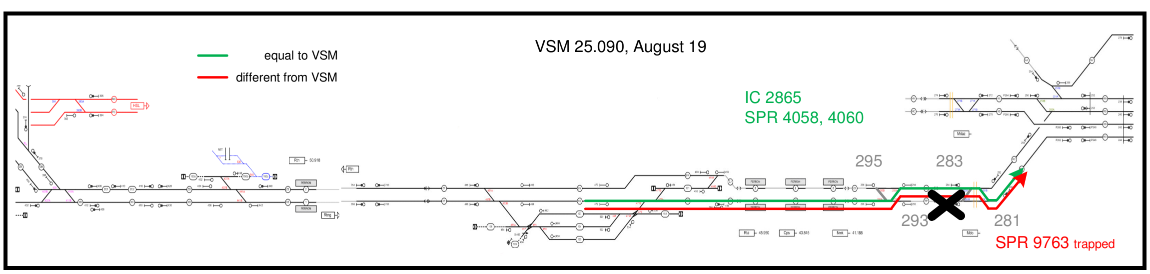


Figure M8 Applied rescheduling, August 19

Conclusions VSM 25.090. Rescheduling went according to the VSM. Only one trapped SPR 9700-series continued instead of being cancelled. But it was trapped and there was the opportunity to redirect it to left track. Finally, in Table M7 the crossover usage can be seen. An advantage of a disruption between Nwk and Mdo is the availability of two crossovers at a relatively small distance of each other. Therefore rescheduling is not complicated and train operations can continue on left track without long delays. That might be a reason to process trains in such a way while in the VSM these trains must be cancelled.

Table M7 Crossover usage VSM 25.090 (total)

Crossover	**August 19**
First phase	
281A/B (Mdo)	1
283A/B (Mdo)	-
293A/B (Nwki)	1
295A/B (Nwki)	-
453A/B (Rtng)	-
457 (Rtng)	-
541 (Rtng)	-
VSM	
281A/B (Mdo)	3
283A/B (Mdo)	-
293A/B (Nwki)	3
295A/B (Nwki)	-
453A/B (Rtng)	1
457 (Rtng)	1
541 (Rtng)	1

Annex N TOON Analysis Corridor Rotterdam

TOON has been used to analyze disrupted train operations which are based on TROTS log-files, exact information from signals and sections. The tables below give a detailed analysis.

VSM 25.050

March 27, 11:38-12:15

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	11:38, defect SPR 704037 at Rtn (Rtd <= Gd)				
VSM	IC 21732	11:56		Opposite. Has to wait for SPR 704038	Left: 493A/B, 477A/B, 475A/B, 457, 453A/B Right: 441A/B
	SPR 704039	12:02		Opposite. Has to wait for SPR 704038	Left: 493A/B, 477A/B Right: 441A/B
	SPR 704038	12:04	Rtd => Gd		
	21743	12:18	Rtd => Gd	Queue. Has to wait for IC 21732 and SPR 70439	
	IC 2836			*Cancelled*	
	IC 2838			*Returned at Ut*	
	IC 2843		*Rtd => Gd*	*Cancelled*	
	IC 2845		*Rtd => Gd*	*Started at Ut*	
End of call	12:15				
Reoccupation phase	SPR 704037	12:17 repaired		Renamed in 89278 and continued	Left: 407A/B
	IC 20534	12:16		Continued	
	SPR 704041	12:24		Continued	
	IC 21736	12:45		Continued	
	704043	12:53		Continued	
	IC 2847	12:59	Rtd => Gd	Continued	
	IC 20538	13:15		Continued	
	SPR 704045	13:24		Continued	
	IC 2840	13:32		Continued	

March 31, 06:48-11:23

	Train	**Arrival time (Rtd)**			**Used crossovers (no black infra)**
Incoming call	06:48, defect SPR 9712 at Rtn (Rtd <= Gd)				
First phase	IC 21712	07:05		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 2833		Rtd => Gd	Queue. Has to wait for IC 21712	
	SPR 4018		Rtd => Gd	Queue. Has to wait for IC 21712	
	SPR 4019	07:16		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 2814	07:19		Opposite	Left: 493A/B, 477A/B

	Train	Arrival time (Rtd)			Used crossovers (no black infra)
					Right: 441A/B
	IC 21723		Rtd => Gd	Queue. Has to wait for SPR 4019 and IC 2814	
	89250	07:21	Rtd => Gd	Coupled to 9712 and renamed in 89251	Left: 407A/B
	SPR 9714	07:28		Queue. Has to wait on side track for IC 21723	Left: 493A/B, 477A/B, 475A/B, 457, 453A/B Right: 411A/B
VSM	IC 12514	07:30		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4021	07:37		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4020		Rtd => Gd	Queue. Has to wait for SPR 4021	
	IC 12716	07:57		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4023	08:10		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 21727		Rtd => Gd		
	SPR 4022		Rtd => Gd		
	IC 12518	08:31		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4025	08:38		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4024		Rtd => Gd		
	IC 20529		Rtd => Gd		
	IC 12720	09:01		Opposite	Left: 493A/B, 477A/B Right: 411A/B
	SPR 4026		Rtd => Gd		
	SPR 4027	09:13	Renamed in SPR 4030 for Rtd => Gd (SPR 4028 was cancelled)	Opposite Has to wait on side track for SPR 4026	Left: 493A/B, 477A/B, 475A/B, 457, 453A/B Right: 411A/B
	IC 21731	09:14	Rtd => Gd	Emergency brake at Wspl	
	IC 20522	09:33		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 21731		Rtd => Gd	Queue. Has to wait for SPR 4027 and IC 20522	
	89251	09:32		Returned to Rtd	
	SPR 4029	10:10		Opposite. Has to wait on side track for 21731and 51103	Left: 493A/B, 477A/B, 475A/B, 457, 453A/B Right: 441A/B
	52033		Rtd => Gd	Queue. Has to wait for SPR 4029	

	Train	Arrival time (Rtd)			Used crossovers (no black infra)
	IC 12724	10:05		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4031	10:12		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 21735		Rtd => Gd		
	SPR 4030		Rtd => Gd		
	IC 12526	10:28		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4033	10:44		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4032		Rtd => Gd	Queue. Has to wait for SPR 4033	
	IC 20537		Rtd => Gd	Queue. Has to wait for SPR 4033	
	IC 12728	11:00		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4035	11:08		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4034		Rtd => Gd		
	IC 21739		Rtd => Gd		
	IC 20530	11:26		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	IC 2816-2834			*Cancelled at Ut*	
	IC 2825-2841		*Rtd => Gd*	*Cancelled from Rtd to Ut*	
End of call	11:23				
Reoccupation phase	SPR 4037	11:35		Opposite	Left: 493A/B, 477A/B Right: 441A/B
	SPR 4036	11:38 (Rta)	Rtd => Gd		
	IC 12732	11:59		Continued	
	SPR 4039	12:05		Continued	
	IC 20534	12:25		Continued	
	SPR 4041	12:34		Continued	
	IC 2836	12:39	Renamed in IC 2847 for Rtd => Gd	Continued	
	IC 2843	11:57 (Rta)	Rtd => Gd	Continued	
	SPR 21736			Continued	
	IC 4043			Continued	
	IC 2838			Continued	
	IC 20538			Continued	
	SPR 4045			Continued	
	IC 2840			Continued	
	SPR 21740			Continued	

November 3, 08:04-08:20

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	08:04, defect SPR 4022 at Rtn (Rtd => Gd)				
VSM	IC 21727	08:21		Opposite. Has to wait for SPR 4023 and IC 2818	Left: 407A/B Right: 451A/B
	SPR 9718	08:20 (Rtn)	Rtd <= Gd	Queue. Has to wait for IC 21727	
	IC 2829			*Cancelled*	
	SPR 9729, 9731			*Cancelled*	
	IC 2820		*Rtd <= Gd*	*Returned at Gd*	
	IC 2822		*Rtd <= Gd*	*Returned at Ut and coupled as 302827*	
End of call	08:20				
	SPR 4022			Cancelled at Rtng and returned to Rtd	Side track: 453A/B, 457 Right: 451A/B Left: 407A/B
	SPR 4024	08:38		Continued	
	IC 20529	08:45		Continued	
	57480	Passed 08:49	Freight train	Continued	
	IC 2831	08:58		Continued	
	SPR 4026	09:08		Continued	
	IC 21731	09:12		Continued	
	SPR 9733	09:18		Continued	

VSM 25.070

January 9, 21:40-00:40

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	21:40, defect 89291 at Nwk (Rtd <= Gd)				
First phase	SPR 4079	22:02		Opposite	Left: 293A/B Right: 451A/B
	INT 9272	22:04		Opposite	Left: 293A/B Right: 451A/B
	57064	Passed 22:12	Freight train, Rtd => Gd		
	SPR 4089	22:15	Rtd => Gd		
VSM	SPR 4081	22:32		Opposite	Left: 293A/B Right: 451A/B
	89251	22:46		Coupled to 89291 and renamed in 89291	
	SPR 4080		Rtd => Gd		
	SPR 4083	22:56		Opposite	Left: 293A/B Right: 451A/B
	SPR 4082		Rtd => Gd		
	SPR 4085	23:27		Opposite	Left: 293A/B Right: 451A/B
	SPR 4084		Rtd => Gd		
	50043	Passed 23:53	Freight train	Opposite	Left: 293A/B Right: 451A/B
	SPR 4087	23:58		Opposite	Left: 293A/B Right: 451A/B
	SPR 4086		Rtd => Gd		
	SPR 4089	00:23		Opposite	Left: 293A/B Right: 451A/B
	IC 21791	00:30	Rtd => Gd	Rerouted through side track	Side track: 453A/B, 457, 541
	89291	00:31		Continued to Rtd	
	IC 2874			*Returned at Gd empty*	
	IC 21772, 20574, 21776, 20578, 21780, 20582			*Continued to Gvc instead of Rtd*	
	IC 21783		*Rtd => Gd*	*Cancelled*	
	IC 20585		*Rtd => Gd*	*Cancelled*	
End of call	00:40				
Reoccupation phase	IC 21784	00:48		Continued	
	SPR 4091	01:08		Continued (last train of the passenger train schedule)	

April 2, 14:40-15:50

	Train	**Arrival time (Gd)**			**Used crossovers (no black infra)**
Incoming call	14:40, defect SPR 4048 at Rta (Rtd => Gd)				
First phase	IC 20553*			Returned (because trapped behind SPR 4048)	Side track: 541
	691751	15:00		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	SPR 4051		Rtd <= Gd	Queue. Has to wait for 691751	
	IC 2846, 690546, 20546		Rtd <= Gd		
VSM	SPR 4050	15:39		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	IC 21755	15:45		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	690553	15:51		Opposite. Queue at Gd	Left: 477A/B, 493A/B Right: 295A/B
	IC 20553*	15:53		Opposite. Queue at Gd	Left: 475A/B, 477A/B, 493A/B Right: 295A/B
	89238 (SPR 4052)	15:37		Shuttle. Coupled with SPR 4048	
	SPR 4048	15:42	Renamed in 89237	Cancelled and continued as empty train to Ut	
	89238	15:46	Rtd <= Gd	Returned as 89239, at Rta renamed in SPR 4054 (Rta => Gd)	Side track: 541, 457, 453A/B Right: 451A/B
	SPR 4052			*Cancelled*	
	IC 21748		*Rtd <= Gd*	*Returned at Ut*	
	IC 2848		*Rtd <= Gd*	*Returned at Gd, IC 2859*	
	IC 2850		*Rtd <= Gd*	*Returned at Ut, IC 2855*	
End of call	15:50				
Reoccupation phase	IC 21759	16:14 (Rta), 16:23 (Gd)		Continued	
	SPR 4054	16:17 (Rta), 16:30 (Gd)		Continued	

	SPR 4056			Continued	

	691759			Continued	
	IC 20561			Continued	
	IC 2863			Continued	
	SPR 4058			Continued	
	690561			Continued	
	IC 21763			Continued	

June 13, 20:50-02:06

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	20:50, broken catenary between Rta and Rtd, track ZG (Rtd <= Gd)				
First phase	691768	Passed 20:43	Freight train	Opposite	Left: 493A/B, 477A/B Right: 411A/B
	IC 21768	20:48	21:24 as IC 29761, 21:35 (Gd)	Opposite and returned at Rtng	Left: 493A/B, 477A/B
VSM complete	SPR 4075	20:57	21:50 as SPR 4074, 21:30 (Gd)	Returned at Rta	Right: 295A/B
	IC 2870	21:03 opposite (Nwk)	21:20 as IC 32870, 21:27 (Gd) continued as IC 2879 to Ut	Opposite and returned at Nwk	Left: 293A/B
	SPR 4077	21:33	Renamed as SPR 4076	Coupled and returned	
	21:40 engineers at the place of disruption				
	SPR 4079	21:52 (Cps)	Coupled with SPR 4076 and 22:26 as SPR 4078, 22:43 (Gd)	Coupled and returned at Rta	Right: 295A/B
	SPR 4081	22:28 opposite	22:36 as 4080, 22:51 (Gd)	Opposite and returned at Rta	Left: 293A/B
VSM partial	SPR 4083	22:54 opposite		Opposite Has to wait on side track for SPR 4082	Left: 293A/B Side track: 475A/B, 457, 453A/B Right: 411A/B
	SPR 4082	23:07, 23:21 (Gd)	Rtd => Gd		
	SPR 4085	23:29 opposite		Opposite. Has to wait on side track for SPR 4084	Left: 293A/B Side track: 475A/B, 457, 453A/B Right: 411A/B
	SPR 4084	23:37, 23:48 (Gd)	Rtd => Gd		
	SPR 4087	23:56 opposite		Opposite. Has to wait on side track for SPR 4086	Left: 293A/B Side track: 475A/B, 457, 453A/B Right: 411A/B
	SPR 4086	00:05, 00:19 (Gd)	Rtd => Gd		
	61604	Passed 00:27 opposite	Freight train	Opposite. Has to wait on side track for SPR 4088	Left: 293A/B Side track: 475A/B, 457, 453A/B Right: 411A/B
	SPR 4089	00:31 opposite		Opposite. Has to wait on side track for SPR 4088	Left: 293A/B Side track: 541, 457, 453A/B Right: 411A/B
	SPR 4088	00:39, 00:51 (Gd)	Rtd => Gd		
	IC 21784	00:55 opposite			Left: 293A/B Right: 411A/B
	SPR 4091	01:04		Opposite. Has to wait on side track for SPR 4090	Left: 293A/B Side track: 475A/B, 457, 453A/B Right: 411A/B
	SPR 4090	01:11, 01:22 (Gd)	Rtd => Gd		
	IC 2872			*Stayed at Ut*	
	IC 2874			*Stayed at Amf*	
	IC 20570-20582			*Returned at Gd (for example: IC 21776*	

	Train	Arrival time (Rta)			Used crossovers (no black infra)
				returned in IC 20585	
	91887			*Rerouted trough Ut-Ht-Ddr*	
	01:46, repair finished				
End of call	02:06				
Reoccupation phase	IC 2402 (empty)	Passed 02:07 opposite			Left: 293A/B Right: 411A/B
				No passenger train traffic anymore	

July 19, 20:45-21:34

	Train	Arrival time (Rta)			Used crossovers (no black infra)
Incoming call	20:45, defect IC 20577 at Rta (Rtd => Gd)				
VSM	SPR 4074	21:07, 12:24 (Gd)		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	89195	21:09	Renamed as 89196	Coupled to IC 20577	
	89196	21:22		Returned to Rtd	Side track: 541 Right: 457, 453A/B, 451A/B
	SPR 4077	21:27	Rtd <= Gd	Queue. Has to wait for 89196	
	61072	Passed 21:27, passed 21:39 (Gd)	Freight train	Continued	
	IC 2879			*Cancelled, used as 89195 for IC 20577*	
	IC 2870		*Rtd <= Gd*	*Returned at Gd*	
	IC 2872		*Rtd <= Gd*	*Returned at Gd*	
	IC 21772		*Rtd <= Gd*	*Continued to Gvc instead of Rtd*	
End of call	21:34				
Reoccupation phase	SPR 4076	21:35		Continued	
	IC 29700 (IC 20581)	21:43		Continued	
	62070	Passed 21:49	Freight train	Continued	
	IC 21783	22:14		Continued	

November 14, 04:33-06:38

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	04:33, anticipated maintenance between Rtn and Rta on track XG and XH is delayed and not finished yet (Rtd => Gd)				
	05:05, tracks has to be operational. VSM introduced				
	05:28, situation stayes minimally till 06:15				
VSM	SPR 4012	05:40 , 05:59 (Gd)		Opposite	Left: 407A/B, crossover at Gd to track 8 Right: crossover at Gd
	61020	Passed 05:48 and passes 06:09 (Gd)	Freight train	Opposite	Left: 407A/B Right: 295A/B
	SPR 4014	06:06, 06:23 (Gd)		Opposite	Left: 407A/B Right: 295A/B
	06:15, question do we continue VSM or proceed with yellow flashing?				
	14015	06:26	Rtd <= Gd	Queue. Has to wait for SPR 4014 before crossover 293A/B	
	14017	06:30	Rtd <= Gd		
	IC 21719			*Cancelled (not from Gvc)*	
	SPR 9712			*Returned at Gd in 19812 and 19814*	
	IC 2812			*Stayed at Oz*	
	IC 2814			*Returned at Ut in IC 2819*	
End of call	06:38				
Reoccupation phase	SPR 4016	06:55, 07:11 (Gd)		Continued (yellow flashing)	
	SPR 4018	07:11, 07:26 (Gd)			
	IC 21723	07:35 (Gd)		Last IC that is rerouted through Gvc	
	SPR 9725	07:24, 07:40 (Gd)			
	IC 2825	07:33, 07:47 (Gd)	Eerste IC vanuit Rtd	Trein 2823 opgehgeven op Amf	
	SPR 4020	07:38, 07:53 (Gd)			
	IC 20525	07:45, 07:57 (Gd)			
	SPR 9727	07:51, 08:05 (Gd)			
	IC 2827	08:01, 08:11 (Gd)			
	SPR 4022	08:07, 08:22 (Gd)			
	IC 21727	08:16, 08:27 (Gd)			
	SPR 9729	08:21, 08:34 (Gd)			

	20529				

	21731				
	07:24, still TOBS (unidentified track occupation) in track XH				
	15:09, no prognosis about TOBS				

December 4, 21:36-23:07

	Train	**Arrival time (Rta)**			**Used crossovers (no black infra)**
Incoming call	21:36, defect 56453 at Nwk (Rtd => Gd)				
First phase	SPR 4076	21:38, 21:42 (Cps)	21:58 returned as 29760	Returned to Rtd renamed SPR 4080 (Rtd => Gd)	Right: 451A/B
	IC 21772	21:46	Rtd <= Gd		
	SPR 694079	21:54	Rtd <= Gd		
	IC 2874	22:02	Rtd <= Gd	Last IC 2800 serie to Rtd	
VSM	SPR 4078	22:14, 22:31 (Gd)		Opposite	Left: 453A/B, 457, 475A/B, 477A/B, 493A/B Right: 295A/B
	356451	22:28 (side track Rtng)	Freight train	Queue. Has to wait for SPR 4080 and 4082 that passed and defect train that returned to Rtd	
	SPR 4081		Rtd <= Gd	Queue. Has to wait for SPR 4078 before 293A/B	
	SPR 4080	22:37, 22:52 (Gd)		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	94910	22:44	22:59 as 59999	Coupled to 56453 and returned	Right: 451A/B
	SPR 4083	22:56	Rtd <= Gd		
	SPR 4082	23:05, 23:20 (Gd)		Opposite	Left: 477A/B, 493A/B Right: 295A/B
	356451	Passed 23:10, 23:25 (Gd)	Freight train		
	57010		Freight train Rtd <= Rtng		
	IC 20574-20578			*Continued to Gvc instead of Rtd*	
End of call	23:07				
Reoccupation phase	SPR 4084	23:34, 23:50 (Gd)			
	20589	23:45, 23:56 (Gd)			
	IC 12780	23:47		Continued to Rtd according to schedule (instead of Gvc)	
	SPR 4086	00:07, 00:20 (Gd)			
	IC 21791	00:14	00:54 as IC 21784	Returned to Rtd	Left: 283A/B, crossover at Gd to track 11
	56457	Passed 00:23 and Gd 00:33	Freight train		

VSM 25.090

August 19, 16:53-18:07

	Train	Arrival time (Gd)			Used crossovers (no black infra)
Incoming call	16:53, defect IC 20561 at Mdo (Rtd => Gd)				
First phase	SPR 9763	17:06		Opposite	Left: 293A/B Right: 281A/B
	SPR 9754, 348526, IC 20554 and SPR 4061		Rtd <= Gd		
VSM	IC 2863	17:30 (Mdo)	Renamed in 29827	Coupled with defect train IC 20561	
	SPR 4058	17:31		Opposite	Left: 293A/B Right: 281A/B
	IC 2856		Rtd <= Gd		
	IC 2865	17:45		Opposite	Left: 293A/B Right: 281A/B
	29827	17:43		Returned to Rtd. Has to wait for SPR 4060	Right: 295A/B
	SPR 4060	17:50		Opposite	Left: 293A/B Right: 281A/B
	IC 22763-22767		*Rtd => Gd*	*Cancelled?*	
	SPR 9765-SPR 6967		*Rtd => Gd*	*Cancelled?*	
	IC 20554 - 22758		*Rtd <= Gd*	*Continued to Gvc instead of Rtd*	
	SPR 9756-9758		*Rtd <= Gd*	*Cancelled?*	
End of call	18:07				
Reoccupation phase	51361	Passed 18:05		Continued	
	29700 (empty for passengers at the side)	18:22		Continued. Has to wait on side track for 51361	Side track: 453A/B, 457, 541
	IC 2860	18:25 (Mdo)	Rtd <= Gd		
	IC 2867 (extended train, 10 parts)	18:30	Queuing at Gd	Continued	
	SPR 9760	18:31 (Mdo)	Rtd <= Gd		
	SPR 4062	18:34	Queuing at Gd	Continued	
	SPR 9769	18:38	Queuing at Gd	Continued	
	IC 2869	18:41		Continued	
	IC 22760	18:42 (Mdo)	Rtd <= Gd		
	SPR 4064	18:48		Continued	
	IC 20569	18:57		Continued	

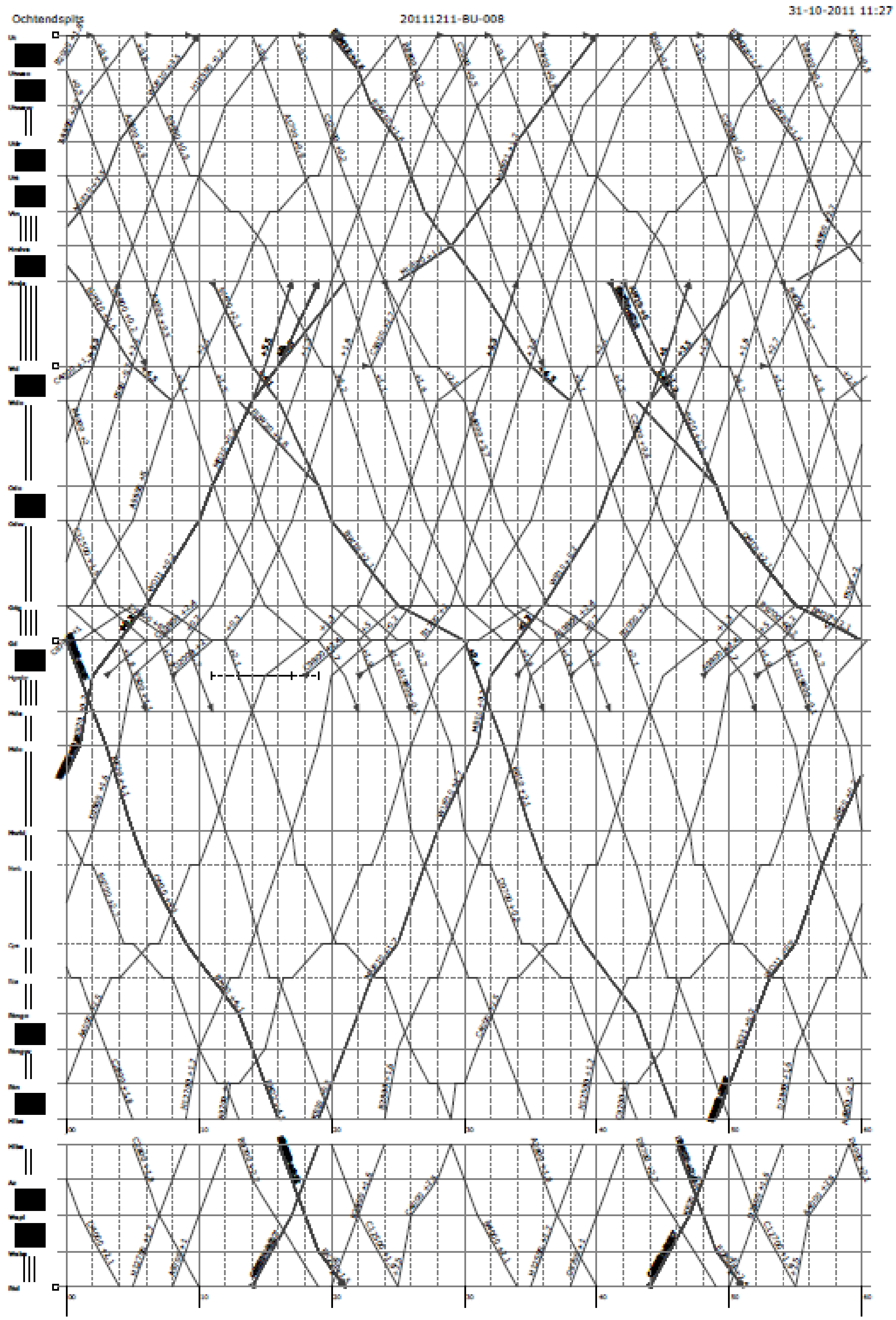
Annex O Crossover Usage Corridor Rotterdam

In the table below the usage of the ‘potentially redundant’ crossovers in 2011 for corridor Rotterdam can be seen.

Crossover	Place	Turnover	Contra Curved Total Trains	Contra Straight Total Trains	Pliant Curved Total Trains	Pliant Straight Total Train	Total Curved	Total Straight	Share Curved	Share Straight	Total Trains	Total Passenger Trains	Total Freight Trains	Total Other Trains	Track Load	Signal Load
281A	Mdo	1579	214	303	42921	429	43135	732	98%	2%	43867	40365	2249	1253	A	II
281B	Mdo	1546	761	429	44099	303	44860	732	98%	2%	45592	42079	2503	1010	A	II
283A	Mdo	2151	86	44318	946	244	1032	44562	2%	98%	45594	42081	2503	1010	B	II
283B	Mdo	2191	946	42917	86	213	1032	43130	2%	98%	44162	40673	2228	1261	B	II
293A	Nwk	1307	380	43959	106	156	486	44115	1%	99%	44601	41219	2390	992	C	III
293B	Nwk	1269	106	43889	380	325	486	44214	1%	99%	44700	41046	2289	1365	C	III
295A	Nwk	1492	484	223	107	43892	591	44115	1%	99%	44706	41046	2288	1372	C	III
295B	Nwk	1502	107	156	484	43958	591	44114	1%	99%	44705	41290	2397	1018	C	III

Annex P BUP Corridor Rotterdam

Below, the timetable of Rtd – Ut in the morning peak hour of 2012 is shown.



Annex Q Network in OpenTrack

For simulating case study Rotterdam OpenTrack has been used. A screenshot of the reference situation can be seen in Figure Q1.

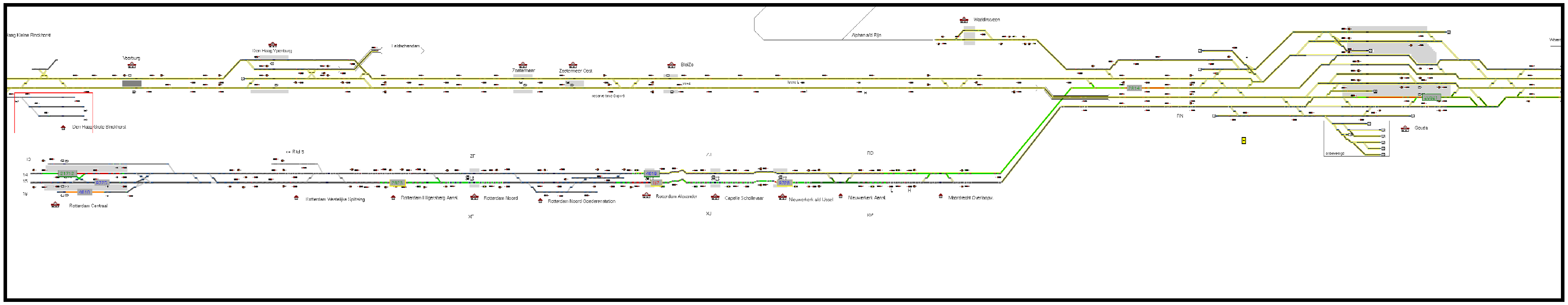


Figure Q1 Screenshot reference situation

In Figure Q2, a screenshot of scenario 1 with a crossover at Cpso instead of Nwki can be seen.

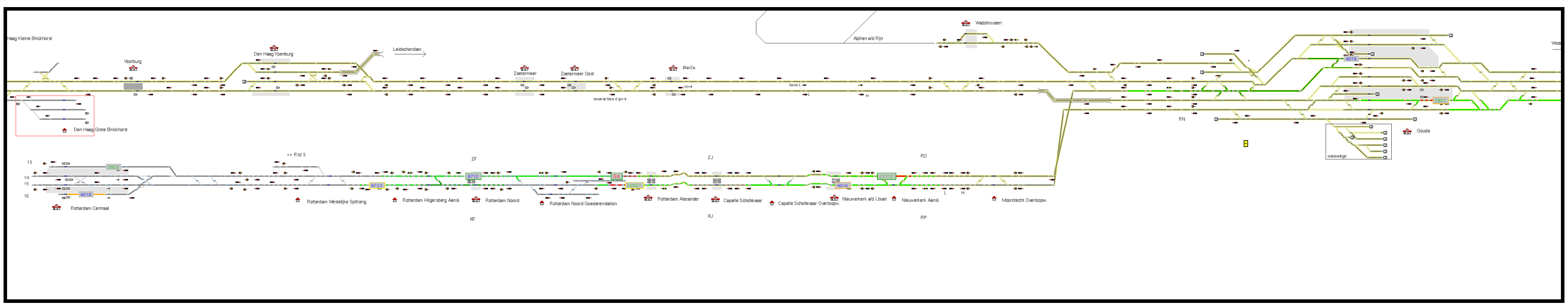
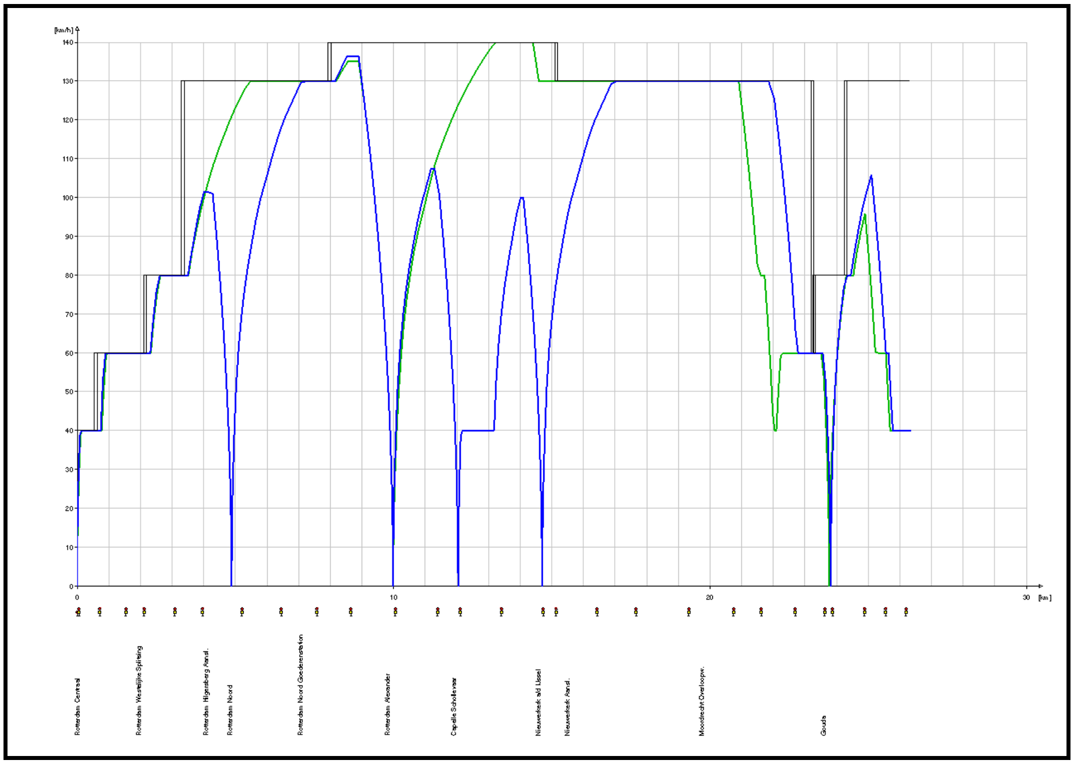


Figure Q2 Screenshot scenario 1: crossover at Cpso

Annex R Validation OpenTrack Model

The validation of the OpenTrack reference situation is described by means of speed-time diagrams of several trains at different times as can be seen on the following two pages.

Reference situation before VSM started

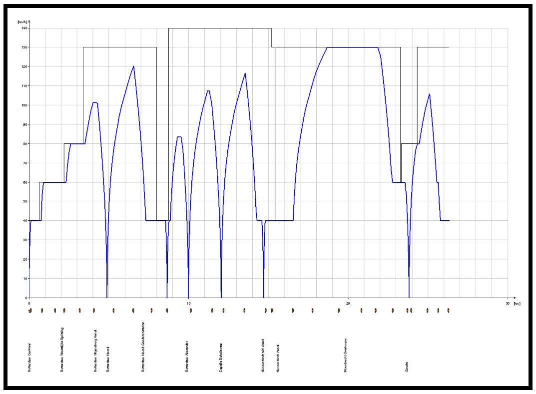


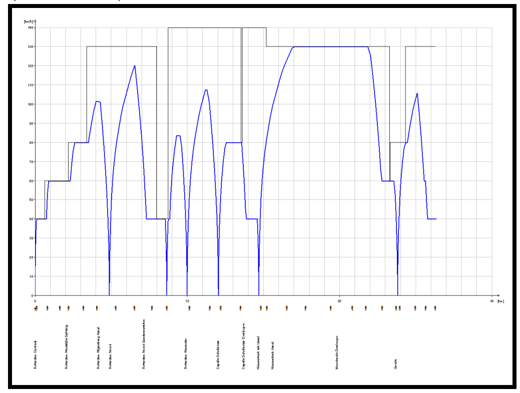
SPR 4016 (Rtd – Gd) blue line
IC 21719 (Rtd – Gd) green line

Reference situation | **Scenario 1: crossover at Cpso**

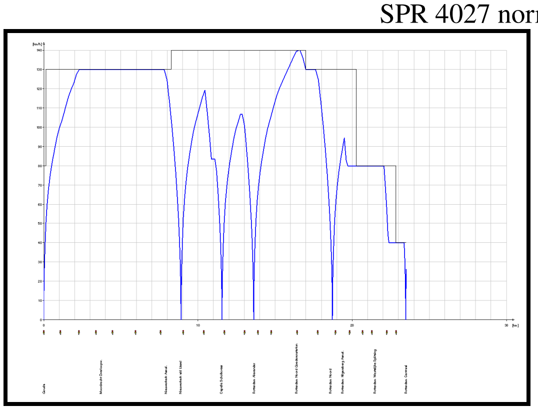
during VSM 25.070

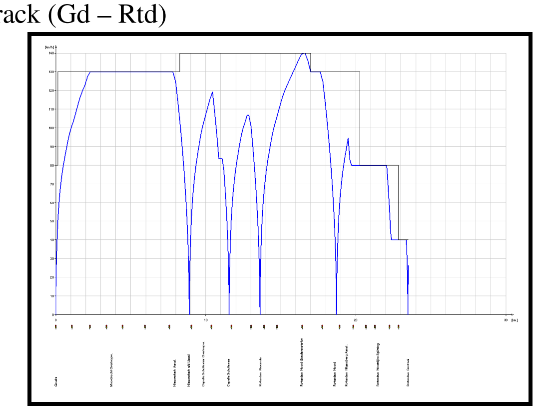
SPR 4022 left track (Rtd – Gd)



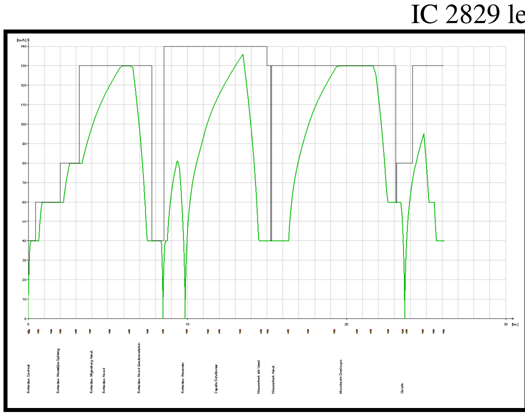


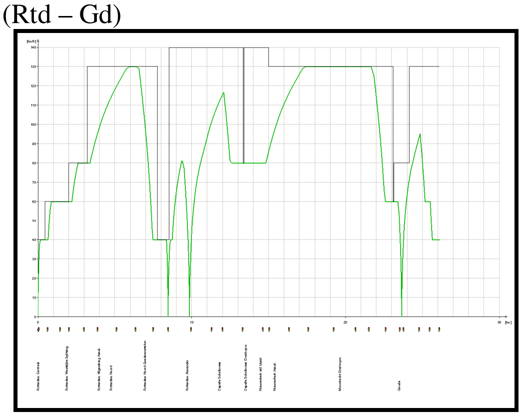
SPR 4027 normal track (Gd – Rtd)





IC 2829 left track (Rtd – Gd)





Annex S Train Traffic Diagrams

The annex shows the OpenTrack simulation results of the different scenarios. In Figure S1 the train traffic diagram of the reference situation according to VSM 25.070 can be seen.

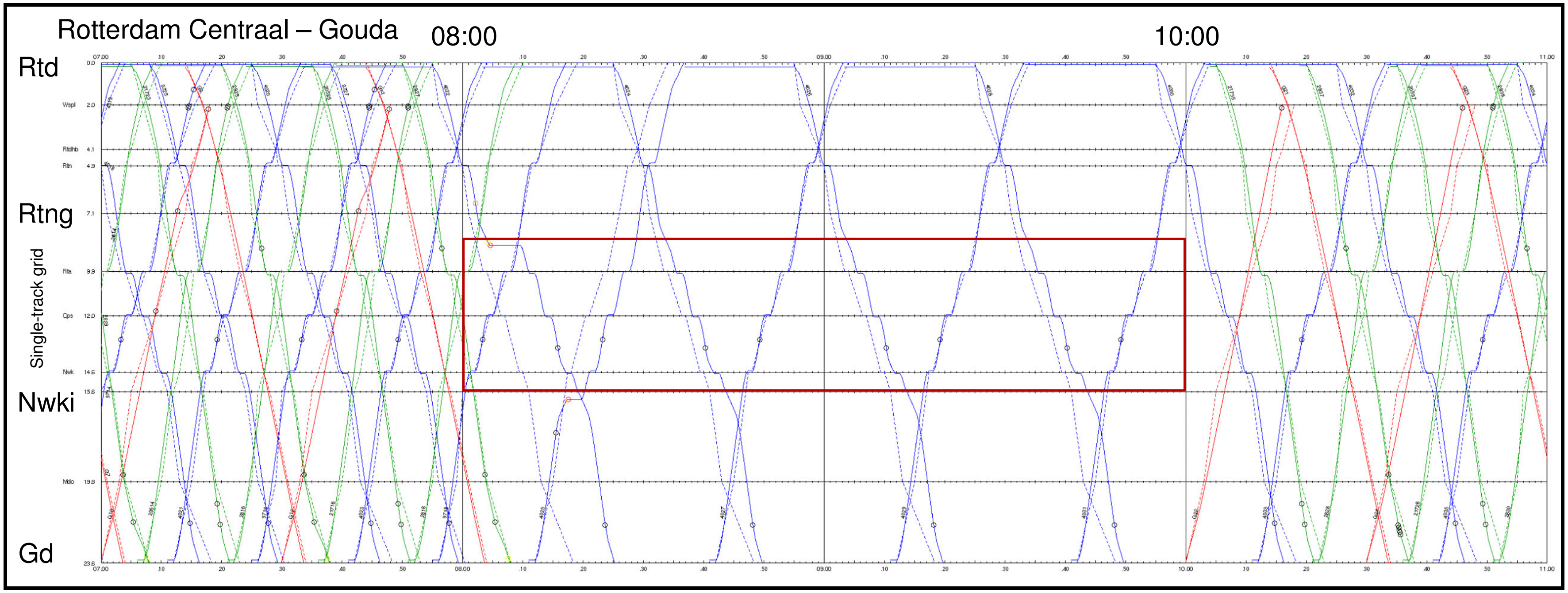


Figure S1 Train traffic diagram reference situation according to VSM 25.070

In Figure S2 the train traffic diagram of the reference situation with additional IC-series can be seen.

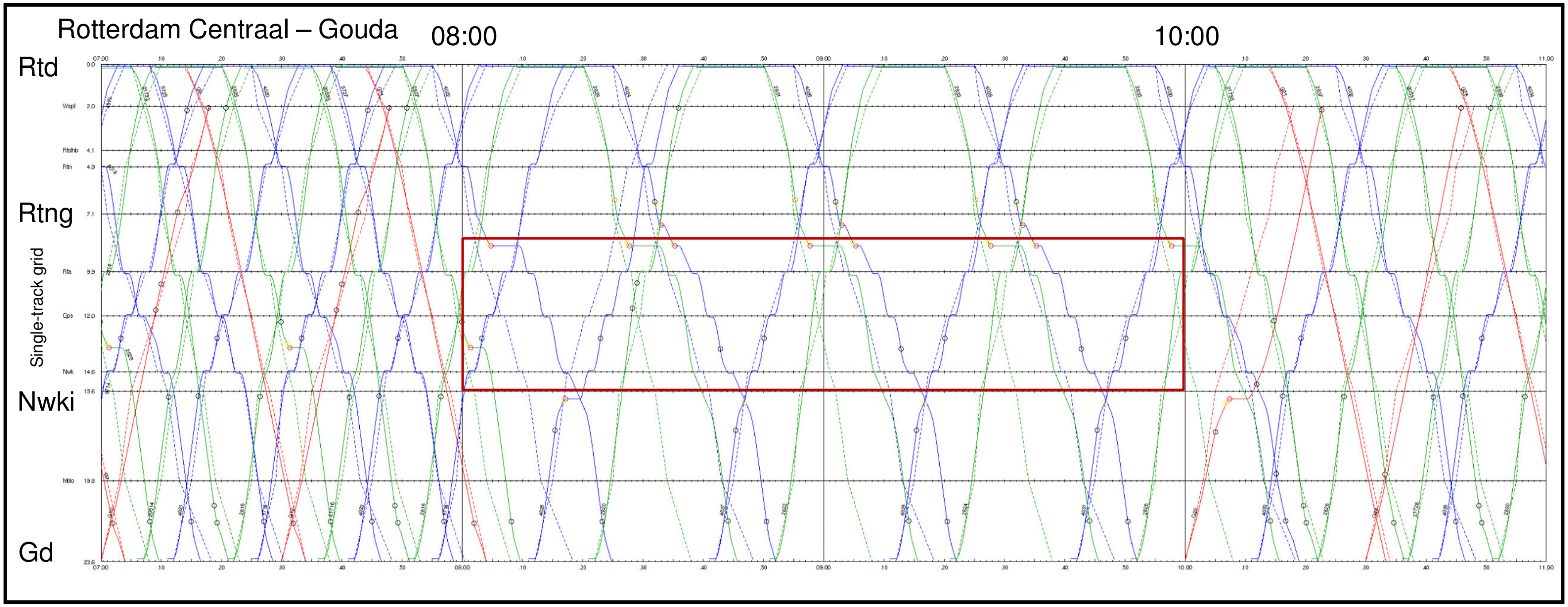


Figure S2 Train traffic diagram reference situation with additional IC-series

In Figure S3 the train traffic diagram of scenario 1 according to VSM 25.070 can be seen.

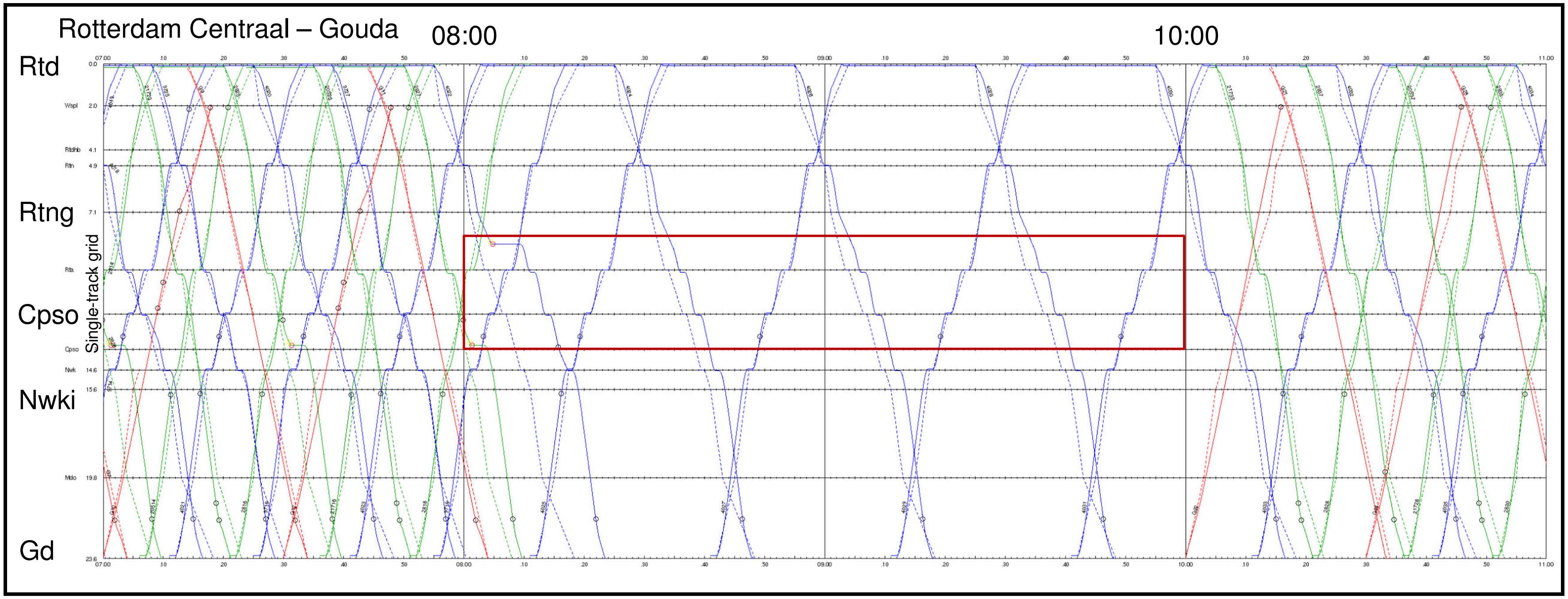


Figure S3 Train traffic diagram scenario 1 according to VSM 25.070

In Figure S4 the train traffic diagram of scenario 1 with additional IC-series can be seen.

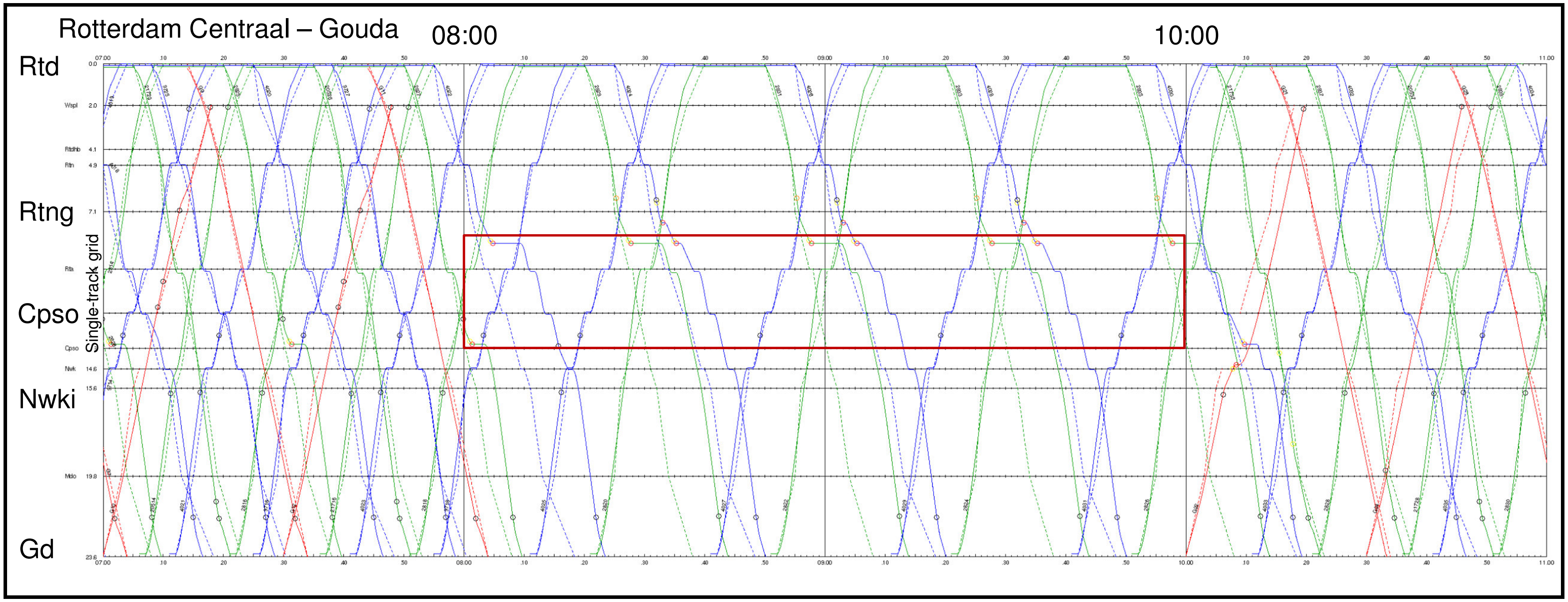


Figure S4 Train traffic diagram scenario 1 with additional IC-series