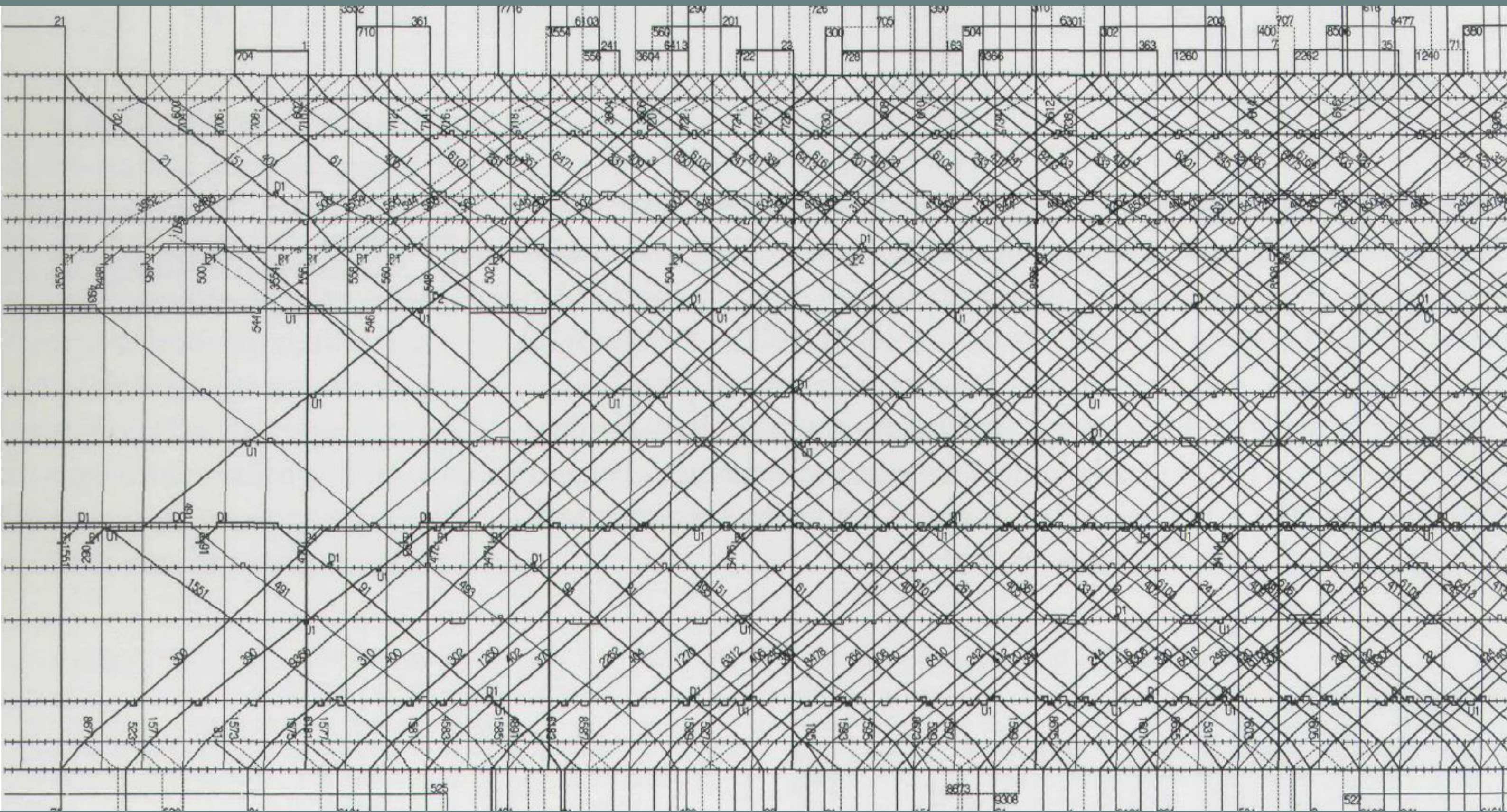
Lasse Gerrits - Danny Schipper



International comparison of rail disruption management

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About the authors

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Impressum

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Summary

Research motive and question

Effective disruption management is crucial to secure the reliability of railway systems. European railway infrastructure managers (RIMs) and train operating companies (TOCs) have invested significantly in technology to help operators solve disruptions. Despite the automation tasks, development of decision-making tools, and increasingly sophisticated information systems, railway traffic control remains a labour-intensive process that relies on the expertise of hundreds or even thousands of operators in so-called multiteams, the members of which are separated by geographical and organizational boundaries. The interdependencies between all parties become all the more visible during disruptions when operators in the different control centres have to solve a complex puzzle of rescheduling timetables, train crews and rolling stock in a coordinated manner. Both formal and informal coordination mechanisms are essential and trade-offs have to be made that limit the adaptive performance of these complex systems, i.e. their ability to move between flexibility and predictability. There is no single best way to solve the coordination, there are always trade-offs to be made.

Although disruption management is a major issue of concern for all rail systems, we found that thus far there has never been a structured comparison of railway disruption management practices between various European countries. This report investigates the following question: *"How do various European RIMs and TOCs deal with those trade-offs when organizing rail disruption management, and what can be learnt from the different practices in each country?"* The following organizations and countries are covered in this report: ÖBB Infrastruktur (Austria), InfraBel (Belgium), Banedanmark and DSB (Denmark), DB Netze and DB Regio (Germany), ProRail and NS (the Netherlands), Infraestructuras de Portugal (Portugal), and Trafikverket (Sweden). Data were collected during site visits to national and regional control centres between September 2015 and January 2018. Understanding that disruption management in practice is often different from the formalized and documented theory and that it is in practice that coordination takes concrete form, we chose to focus on the *actual activities* of the operators by observing and talking to them during their work in the control rooms. The research findings have been returned to the contact persons in each country for a member check to correct incomplete or incorrect data.

The comparison is structured around two trade-off: a) centralization versus decentralization, and b) anticipation versus resilience. The items belonging to these trade-offs are listed in the following table S1.

Table S1 List of items, their descriptions and scores used in order to categorize the various countries

Trade-off *A*: Centralization versus decentralization

Item	*Description*	*Centralized 0 – 0.33* *Decentralized 0.66 – 1*
Distribution of control centres	This concerns the number of control centres and their distribution across the country.	Low number and limited distribution: 0; high number and distribution: 1
Allocation of decision rights during disruption	This concerns whether decisions on alternative service plans are made by regional or national control centres	Centralized decision-making: 0; decentralized decision-making: 1
Autonomy of local control	This concerns the extent to which regional control centres can make autonomous decisions on the rescheduling of rail traffic	Little autonomy: 0; considerable autonomy: 1
Communication and nodes of communication	This concerns the information flows between both levels of control and the operators that process the information	Radial information flows: 0; distributed flows: 1
Co-location of RIMs and TOCs	This pertains to whether RIMs and TOCs share the same offices and desks	Co-location: 0; full separation: 1

Trade-off *B*: Anticipation versus resilience

Item	*Description*	*Anticipation 0 – 0.33* *Resilience 0.66 – 1*
Role of contingency plans	This concerns the number of contingency plans and how these plans are put into practice.	Reliance on pre-defined plans: 0; reliance on improvisation: 1
Automation of control	This concerns the availability and use of automated control that can override or replace local operations	Automation: 0; manual control: 1
Institutionalization of shared sensemaking	This concerns the extent to which shared sensemaking is organized and institutionalized	Organized: 0; not organized: 1
Use of dispatching rules	This concerns the availability and use of dispatching rules	Strict application of rules: 0; no dispatching rules: 1

Results

The results of the comparison are shown in figure S1. Three 'clusters' can be discerned. First of all, Austria and the Netherlands are both moderately centralized and of the seven countries, they rely the most heavily on a formalized approach to dealing with disruptions. Formalization reduces the coordination burden and produces more predictable outcomes, but may also reduce a system's ability to adapt to unanticipated events. The second 'cluster' consists of Belgium and Denmark as they combine a centralized structure with an emphasis on resilience. Operators in these countries seem to enjoy more flexibility when managing. The third 'cluster' contains Sweden and Portugal, primarily because they have a higher degree of decentralization than the other countries. Germany appears to be somewhat of an outlier. It is much more decentralized than the other countries. This is a reflection of the size and complexity of its railway network and the numerous TOCs, both of which limiting the possibilities for centralized control. In other words, Germany's unique characteristics are clearly reflected in the way disruption management is structured.

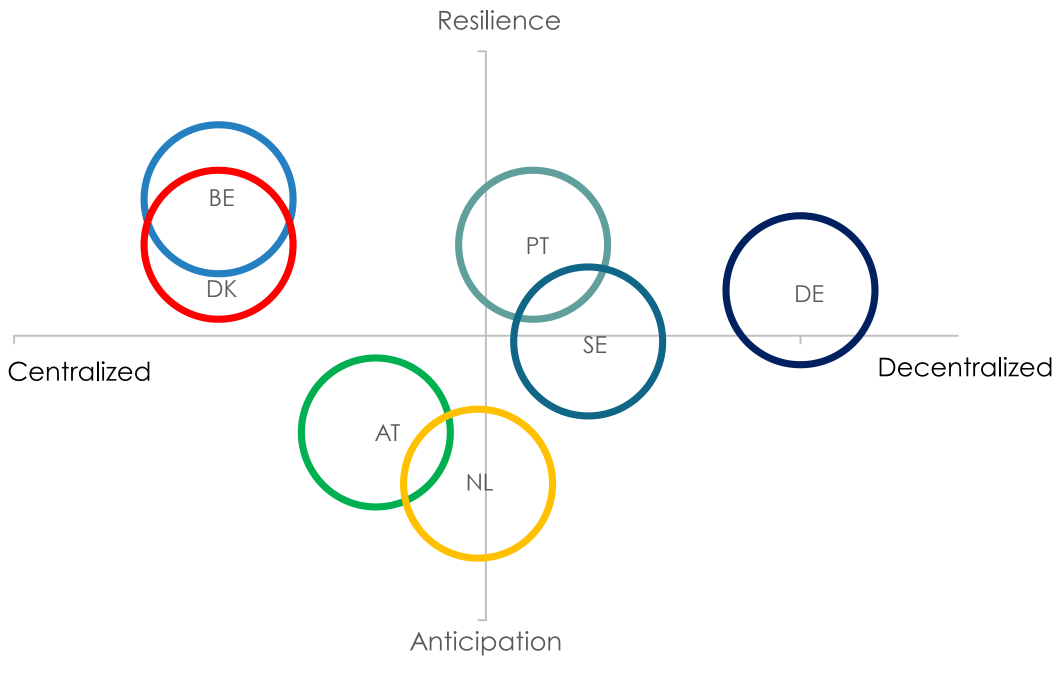

Figure S1 *The countries' average scores on each trade-off visualized*

The results show that there are several ways to achieve an overall similar type of system, as is illustrated by the three 'clusters'. Although rail systems are essentially quite similar in what they do (transferring passengers and goods) and how they do it, there are important differences between the countries studied. This study therefore shows that there is not one best way of structuring rail disruption management. It is only by comparing practices that the range of possibilities becomes apparent.

Lessons learned

Although there are major differences between the different countries, there are some general lessons that can be learned from the comparison.

1. *The relationship between central and regional or local control centres*

One reoccurring theme during the site visits was the ambiguity concerning the division of roles and responsibilities between the central and regional or decentral control centres. Although national control centres can be envisaged as being situated 'on top' of the many regional control centres, it remains very difficult for operators in the national control centres to assert direct control over the regional centres' activities. Although it is important to define roles and responsibilities, we have found that this is not enough. It is also important that operators and teams are aware of each other's tasks, roles and information needs. This can be achieved by joint training sessions. Unfortunately, these joint training sessions are often disregarded due to a lack of time and resources. This research has found that investments in joint training are crucial to improve the joint performance of teams during the management of disruptions.

2. *Information sharing during disruptions*

Swift and complete dispersion of information among teams is crucial to their ability to respond to a disruption in a quick, coordinated manner. Major improvements in the information systems are made to support operations and decision-making. While these information systems are important, they can't fully replace the more detailed telephone communication, especially during large-scale, complex disruptions when the operational picture is often unclear and a lot of communication (sense-demanding and sense-giving) is needed to create a shared understanding. It was found that it is not only important to structure the flows of information between teams and to regularly integrate the available information by supporting collective sensemaking between teams.

3. *The role of contingency plans*

Contingency plans can be a very effective way to coordinate the rescheduling activities of the different control centres and to provide passengers with reliable travel information. Moreover, when agreed upon by the TOCs they can provide non-discriminatory solutions. There are also disadvantages to adhering strictly to predefined plans, as this may lead to rigidity and the oversimplification of operational conditions. This study has shown that contingency plans can be effectively used as a template for developing a solution that fits the unique circumstances of each disruption. This proved to be a highly efficient way of integrating predictability with flexibility.

4. The relationship between TOCs and RIM

The separation of the RIM and incumbent TOC, along with the entry of non-incumbent TOCs to the rail market, has created important new coordination challenges during disruption management. Important differences were found regarding the extent to which each country has opened up its market and how countries deal with the issue of coordination. Germany and Sweden can be regarded as pioneers and much can be learned from these countries. In this study we have found that effective decision-making powers for the RIM and the provision of up-to-date information as provided to all TOCs becomes very important to effectively manage disruptions.

5. Automation and centralization of rail traffic control

All of the countries in the sample are working on further automation and centralization of rail traffic control. This transition is important to safely accommodate the increase in rail traffic on the often already congested rail lines. Naturally, automation and centralization also have their benefits from a cost perspective. Automation and centralization of rail traffic control also creates new challenges. The new and modern regional control centres are located in a limited number of large cities. This means that operators either have to move to the new location, which is difficult because of high house prices, or accept long commuting times. In addition, it was found that older operators experience in adopting and trusting new technologies, while less experienced operators may lack the essential knowledge and skills required for resuming manual control when necessary and be unable to oversee the impact of their decisions. To tackle the latter issue, it was found that it is very important to actively familiarize new train dispatchers with the rail system or to let them work at train stations for a couple of months to learn about the world beyond the control centres.

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Chapter 1: Introduction

1.1 Disruption management in a complex multiteam system

European railway infrastructure managers (RIMs) and train operating companies (TOCs) have invested significantly in technology to help operators solve disruptions. Despite the automation of certain tasks, the development of decision-making tools, and increasingly sophisticated information systems, railway traffic control remains a labour-intensive process that relies on the expertise of hundreds or even thousands of operators working in multiple control centres. Over the last decades these operators have experienced fundamental changes to the environment in which they operate. The introduction of market mechanisms (e.g. Council Directive 91/440/EEC), followed by regulations on a single railway market (e.g. Directive 2012/34/EU) have eroded national railway monopolies. The most important change has been the separation between RIMs and TOCs, and the entry of many private and semi-private or corporatized TOCs into a rail transportation market that was previously dominated by an incumbent TOC. It is therefore justified to speak of a networked or multiteam system in which multiple teams, separated by geographical and organizational boundaries, have to work together to provide reliable services.

These multiteam systems are not only unique due to their high interdependencies in reaching collective goals, but also because of the complex and dynamic environment in which they operate. With regard to the latter, disruptions are rarely static. Conditions can change fast and information often only becomes available gradually. Furthermore, disruptions can easily cascade throughout the network. These so-called knock-on effects can severely disrupt train crew and rolling stock schedules, causing the situation to escalate. What starts as a catenary failure may quickly develop into a shortage of rolling stock and staff elsewhere in the network as trains can't pass through a certain area. It is therefore important to make effective and coordinated decisions on the rescheduling of rail traffic. Good communication during disruptions is obviously essential. The more ambiguous and dynamic the situation, the more operators will be forced to interact in order to understand the situation and develop practical solutions. However, the time table often doesn't leave much time to consider and discuss all alternatives. In view of all this, it is fair to say that disruption management is a complex and dynamic task conducted within a complex system.

In such complex systems, effective disruption management requires more than sound technical equipment and infrastructure. The operators of the RIM and the many TOCs must work together closely. The interdependencies between all parties become all the more visible during disruptions when operators in the different control centres have to solve a complex puzzle of rescheduling timetables, train crews and rolling stock in a coordinated manner. Coordination between control centres can be achieved through formal coordination modes e.g. pre-defined plans and procedures, along with tight structuring and centralized decision making. However, ad-hoc and flexible decision-making and flexible structures are also often necessary due to the dynamic and uncertain conditions under which operators work. As such, both formal and informal coordination mechanisms are essential and trade-offs have to be made that limit the adaptive performance of these complex systems, i.e. their ability to move between flexibility and predictability.

1.2 Research aim

How do various European RIMs and TOCs deal with these trade-offs when organizing rail disruption management, and what can be learnt from the different practices in each country? The Dutch RIM ProRail had noticed the many differences and similarities between countries, but had no structural understanding of what was going on in other countries. This realization led to the commissioning of the current research. We subsequently discovered that this was also an issue for the operators and managers in each of the participating countries. Furthermore, there is little academic research on this topic. This report is thus the first to present a structured overview. We will compare seven European countries with regard to the ways in which they deal with the trade-offs. Understanding that disruption management in practice is often different from the formalized and documented and that it is in practice that coordination takes concrete form, we chose to focus on the *actual activities* of the operators by observing and talking to them during their work in the control rooms.

1.3 Method and sample

The following countries and organizations were willing to cooperate in our research project: ÖBB Infrastruktur (Austria), InfraBel (Belgium), Banedanmark and DSB (Denmark), DB Netze and DB Regio (Germany), ProRail and NS (the Netherlands), Infraestruturas de Portugal (Portugal), and Trafikverket (Sweden). Data were collected during site visits to national and regional control centres between September 2015 and January 2018. Given our focus on how disruption management works in practice, we conducted in-situ observations and interviews with operators. Site visits commonly lasted 2 to 3 full days, most of which would be spent on observation time in the control rooms. In all cases we were granted unrestricted access to all operations and all operators. We observed daily operations to see how operators interacted, and whether and how certain protocols, procedures etc. were followed. This included emergency meetings whenever disruptions took place. Observations in each country were carried out by two and sometimes three researchers, each taking detailed notes. These reports were compared to prevent misinterpretations and the omission of important details.

We also interviewed both operators and managers on location where daily operations allowed. The duration of these interviews varied greatly, from 15 minutes to two hours. Due to their confidential nature we were unable to make audio recordings, but the researchers took detailed notes during each interview. The resulting reports were then compared for the reasons mentioned earlier. Sixty-nine respondents were interviewed, as listed in Appendix 1. The Netherlands appears underrepresented in the sample, but data for this country had been collected through numerous hours of observations and interviews by the authors during earlier research for the research project[1]. We also obtained detailed presentations and written documentation on the standard operating procedures and organizational structure of each railway system. These materials supplemented our own observation and interview reports. The research findings have been returned to the contact persons in each country for a member check to correct incomplete or incorrect data. This so-called member check led to no major changes; in other words, the participating countries agreed with our findings.

1.4 What the report shows

The research will give a detailed account of how disruption management is organized and implemented in the participating countries. It is important to describe the context in which disruption management occurs because organizational legacy and path-dependency go a long way towards explaining why the systems are organized as they are. The decoupling of RIMs and TOCs mandated by the European Commission has led to a wide diversity of organizational forms in the various countries. Furthermore, the characteristics of the railway network vary greatly between countries. Consider, for example, the fairly radial nature of the Swedish network as opposed to the heavily decentralized German network. We will show that there are different ways of organizing disruption management (within the given contexts) and that, therefore, there is no single correct way of organizing it.

1.5 What the report can't show

Although it is tempting to relate our findings to the overall performance of individual rail systems, we will not do so for the following reasons. Firstly, the different contexts inhibit a straightforward comparison between countries with regard to performance. Some railway networks are more complex to manage than others, so we need to do justice to such differences. Secondly, performance is not determined by disruption management

[1] Schipper et al., 2015; Schipper, 2017

alone. Random events, such as the weather, impact performance and are beyond human control. Thirdly, it is difficult to measure performance precisely as each country has its own way of assessing and reporting on performance. Furthermore, there are still unresolved discussions as to what constitutes performance (e.g. the time until infrastructure is available again, the time until normal services are resumed, etc.). Our overall impression is that the countries do rather well *given the environmental constraints* that impact their work.

Another limitation in this report is that we describe disruption management as it was organized at the time of our research. However, all the countries in the sample were and still are reorganizing parts of their systems. There is a universal push to merge or remove signal boxes in favour of further centralization and automation of rail traffic control. RIMs, such as DB

1.6 Reading guide

In Chapter 2 we will present an overview of the main characteristics of the railway network in each participating country in terms of (1) historical development, (2) how unbundling was structured, (3) how competition was organized, (4) the network's complexity in terms of structure and utilization, and (5) how rail traffic control has been organized in terms of roles and responsibilities. In Chapter 3, we will discuss disruption management in each country by exploring two major trade-offs; centralization vs. decentralization and anticipation vs. resilience. Key items were derived from scientific research on disruption management to describe rail disruption management for each trade-off[2]. The trade-offs and key items are discussed in greater detail in Chapter 3. We will categorize the different countries on the basis of these two trade-offs and the related items in Chapter 4, followed by a presentation of the conclusions and some overall lessons learned.

1.7 Acknowledgements

We would like thank all rail infrastructure managers and train operating companies for their courteous hospitality and unrestricted access to all operations. We appreciate that our observations and interviews could have hindered their workflow and are grateful that we were nonetheless left free to conduct our research. We would also like to thank our contact persons for delivering feedback on earlier versions of our report. In addition, we would like to thank Emanuel Wenzel for translation duties during the site visits in Austria

[2] A list of references to the scientific research has been included at the end of the report for the interested reader.

and Germany, Sebastian Hemesath for translating the report into German, and Joop Koppenjan for his critical reflections on our findings.

Chapter 2: Country descriptions

2.1 Introduction

This chapter provides an overview of the key characteristics of the different railway systems and the way in which rail traffic control has been organized in each country. This description also sketches the context within which rail disruptions are managed in each country. As has been mentioned in the previous chapter, this context is very important to gaining an understanding of how disruption management has been organized and is being implemented. For example, an operator has different options and degrees of freedom if rerouting traffic in a distributed network with numerous nodes and various competing TOCs, rather than a more centralized network with a single TOC.

The data for this chapter has been collected from three main sources: the interviews we conducted during site visits, the presentations we received, and extensive desk research. We have made diagrams showing how rail traffic control has been organized in each country to give readers a quick overview of the main structure and some of the rail networks in order to highlight the various network typologies (figures 2.1 to 2.12). These typologies give an impression of the different degrees of complexity of traffic control per country by showing, for example, the extent to which networks are centralized or decentralized. Data for these typologies were obtained from the 2010 Eurostat database on rail transportation. Unfortunately, we were unable to find any more up-to-date and coherent data sets. There are no diagrams of countries for which we couldn't obtain quality data. The Eurostat data set shows the number of train movements between two stations or particular points on the rail network. We adapted the data in order to generate (simplified) network diagrams. In these diagrams, the width of the lines between the nodes indicates the intensity of rail traffic, while the nodes are sized according to the number of trains arriving or departing at this particular station or point. Please note that these typologies are for illustrative purposes only. They are not geographically correct and do not provide a complete overview of all rail lines.

2.2 Austria

A. Institutional reforms and competition in the rail market

In 1992, as part of Austria's accession to the EU and as an incentive to improve the company's overall performance, the state-owned rail company ÖBB was transformed into an independent company, although still fully owned by the State. In 2004, ÖBB-Holding AG was formed to split up railway operations and infrastructure management in accordance with the provisions of the Federal Railways Structure Act

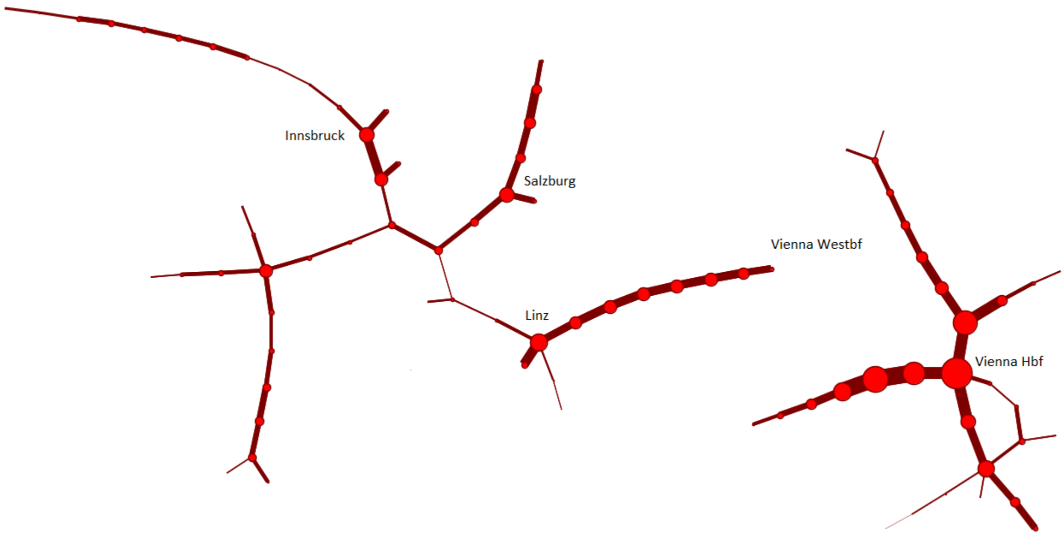
(Bundesbahnstrukturgesetz 2003). The former Federal Austrian Railways was replaced by a group structure, consisting of nine independent subsidiaries under the parent company ÖBB-Holding AG. One of the main tasks of this holding is the strategic alignment of the subsidiaries within the group. It has three direct autonomous subsidiaries to implement daily train operations: ÖBB-personenverkehr (local and long-distance passenger services), Rail Cargo Austria (freight services), and ÖBB-Infrastruktur (infrastructure management). The Austrian railway network measures almost 5,000 km in length and is managed by ÖBB-Infrastruktur. Access to the Austrian rail market is legally open.

An independent regulatory body, Schienen-Control GmBH was established in 1999. In 2011, the private company, Westbahn, started running train services on the line between Salzburg and Vienna, the country's busiest route. Westbahn was founded in 2008 by Austrian investors and the French SNC. Complaints were filed regarding the problems encountered at the start of operations, including complaints about allegedly discriminatory access (Finger et al., 2016). So far Westbahn is ÖBB's only on-track competitor in passenger services and has acquired a market share of more than 20 percent on the Vienna-Salzburg route (CMA, 2015). Other passenger services offered by non-incumbent operators focus mostly on cross-border connections, such as the Meridian train service between München and Salzburg/Kufstein operated by Bayerische Oberlandbahn GmbH. Overall, the ÖBB group still provides around 95 percent of all passenger train kilometres.

B. The Austrian rail network

Austria's rail network is 5,611 kilometres in length and is managed by multiple RIMs (Schienen-control, 2017). The railway network managed by ÖBB-Infrastruktur AG measures 4,922 km in length. In total there are 9,688 kilometres of track, 8,087 of which are electrified. Around 3,462 kilometres consists of single track, with 2,149 kilometres being double track. A significant chunk of the infrastructure is concentrated in and around the capital of Vienna and this is also where the most rail traffic and busiest stations in Austria are to be found (see figure 2.1). Long-distance (high speed) lines connect the capital to other major cities in Austria, as well as to other European cities. Austria's central location in Europe means that there are many cross-border connections to the Czech Republic, Slovakia, Hungary, Slovenia, Italy, Germany and Switzerland. Much of the freight traffic between Germany and Italy passes through the Tirol region. There are 13,677 switches and 24,786 signals on the rail network and 1,069 train stations and stops.

Fig. 2.1 Typology of Austrian railway network



Simplified network diagram of the Austrian network. The network is relatively straightforward with some main lines and a few branch lines. The main lines, especially those connecting to Vienna Hbf and Vienna Westbahnhof, see heavy traffic.

C. Usage of the rail network

In 2016, a total of 146.1 million train kilometres were operated on the ÖBB rail network (ÖBB, 2017). That is thus 29,683 kilometres per kilometre of rail line. On the total Austrian rail network TOCs made 112.1 million passenger kilometres. More than 288.8 million passengers were transported in 2016, accounting for a total of 12.6 billion passenger kilometres. Freight operators transported 114.9 million tons of goods (Schienen control, 2017). In 2016 the punctuality rate of passenger services provided by the ÖBB group was 95.9 percent overall. Long-distance passenger traffic had a punctuality rate of 87.7 percent and local passenger traffic a rate of 96.4 percent on the basis of a five-minute threshold. Freight traffic had a punctuality rate of 70.9 percent on the basis of a fifteen-minute threshold (ÖBB, 2017).

D. Railway traffic management

Railway traffic on the main rail lines is monitored from five regional traffic control centres (Betriebsführungszentralen, BFZ*)*, but in 2016 there were still 677 signal boxes. Traffic management is carried out by a regional traffic controller or Zuglenker. Rail traffic operations in the control centres are mainly automated using the ARAMIS traffic management system, which allows operators to track train positions and potential conflicts in real-time. In such cases, the system generates operational solutions. Moreover, routes (switches and signals) are set automatically and passenger information is automatically adjusted. However, not all rail lines can be fully controlled from the BFZ and are managed from signal boxes located at stations. Hence, while signallers (Fahrdienstleiter-Stellbereich*)* in the BFZ are solely tasked with monitoring the safe allocation of rail capacity, signallers at the stations still operate switches and signals on the orders of the Zuglenker. ÖBB-Infrastruktur is also tasked with shunting operations. Consequently, signallers spend a lot of time monitoring these operations.

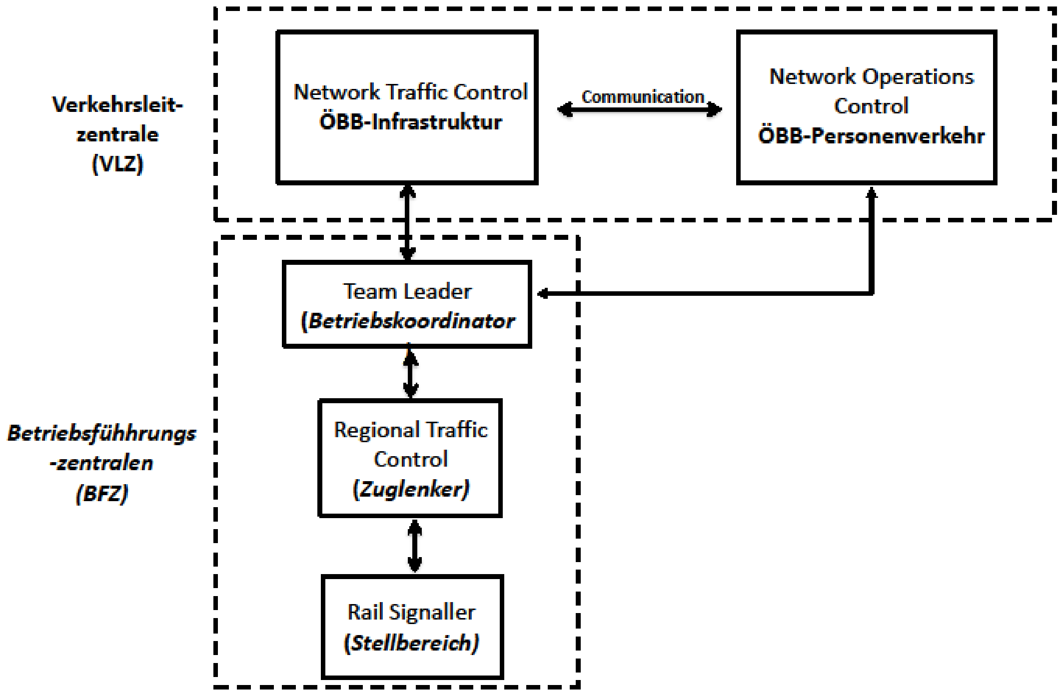


FIG. 2.2 Organizational structure and lines of communication in Austria

Each BFZ has an operations coordinator (Betriebskoordinator, Beko*)*, who is the central operational actor. He or she communicates with the TOCs, neighbouring regional traffic control centres at home and abroad, and the national traffic control centre in Vienna. During a local disruption, Beko will decide on a contingency plan and monitor the workload of all employees. An emergency coordinator (Notfallkoordinator or Noko*)* communicates with the emergency services and manages all emergencies in a specific system (REM*)*, which can be accessed by all parties in the rail system. The central control room in Vienna (Verkehrsleitzentrale Wien or VLZ*)* was established in 2006. Both ÖBB-Infrastruktur and Personenverkehr are located in the VLZ. Two operators from ÖBB-Infrastruktur work in the VLZ, monitoring the rail traffic on Austria's north-south and east-west corridors. There is also an operator responsible for the management of all information during a crisis and a network coordinator who communicates with TOCs, both at home and abroad, and informs management. A team of operators from ÖBB-Infrastruktur and Personenverkehr jointly manage both rolling stock and train crew for the whole of ÖBB-personenverkehr. Operators from ÖBB-Personenverkehr monitor the connections between trains and update passenger information on the website.

2.3 Belgium

A. Institutional reforms and competition in the rail market

On 1 January, 2005, the Belgian state railway company NMBS (or SNCB in French) was split up into an infrastructure manager, Infrabel, and a railway undertaking, NMBS. This decision was made in response to EU directives and the full liberalization of the rail freight market. Both Infrabel and the TOC NMBS became part of the NMBS holding, which was responsible for staff management, buildings, and coordination between the IM and TOC. All three companies belonged to the NMBS-Groupe, which was disbanded in January 2014. Infrabel became an autonomous, state-owned company responsible for rail infrastructure and communication with the TOC. NMBS holding and the TOC merged to form NMBS, whose sole focus was providing rail services (including train stations) and direct communication with passengers. Infrabel and NMBS nonetheless have a shared subsidiary – HR-Rail – which is the official employer of all personnel of both companies. Although there is open access for freight operators and international passenger services (Thalys, ICE and Eurostar operate international passenger services and there are eleven freight operators), NMBS still holds a monopoly on domestic rail passenger services. All domestic passenger services are covered by a PSO contract between NMBS and the federal government. In 2008, the federal government directly awarded NMBS a public service contract for domestic services and compensated NMBS for the provision of these services. That contract expired in 2012 and no new contract has yet been implemented, although negotiations have been underway for several years. A bonus/malus mechanism provides for the imposition of a fine upon either the railway operators (passenger or freight) or the infrastructure manager if operations are inadequate (CER, 2017).

B. The Belgian rail network

The Belgian network measures 3631 km in length. In total there are 6,514 kilometres of track. Most of the network is electrified and around two-thirds features double tracks. The network is particularly dense in the Flemish part of the country, especially around the cities of Brussels, Antwerp, Ghent and Leuven. Brussels forms an important but fragile node in the north-south and east-west corridors and its North, South and Central stations are the busiest in Belgium. Three high-speed lines connect Brussels with France, Germany, and the Netherlands. There are 10,176 signals on the rail network and a total of 4,180 switches (Infrabel, 2017).

C. Usage of the rail network

In 2016, NMBS operated a total of 72.4 million domestic passenger train kilometres. In 2011 all rail traffic accounted for 94.5 million train kilometres (Eurostat, 2017). That is almost 26,026 passenger kilometres per kilometre of rail line. NMBS transported 227.1 million passengers, who travelled a total of 9,840.50 million passenger kilometres. In 2017, the total punctuality rate of passenger services was 88.3 percent on the basis of a six-minute threshold (NMBS, 2017).

D. Railway traffic management

Belgium has around 86 signal boxes. This number has been reduced significantly over the years with the introduction of new traffic control systems, intended to initially centralize control to 31 regional control centres, which will eventually be reduced to 10. Operators in the signal boxes monitor rail traffic at three different control levels. At the lowest level, signallers (operatoren*)* operate switches and signals and set train routes. The next rung in the hierarchy is occupied by the traffic controllers (toezichtbedienden*)* who monitor the work of the signallers and are responsible for the safe allocation of rail capacity. At the highest level, there is one operator (regelaar*),* who is in charge of the entire team and operations in the area monitored by the local control centre. The specific task of the local control centres is the safe allocation of rail capacity.

Rail traffic management is conducted by operators in the national control centre (Railway Operations Center or ROC*)*. They decide on the rescheduling of trains in the event of delays, disturbances or disruptions. The local control centres have to implement these decisions. In the ROC Infrabel and NMBS work very closely together. The country has been divided into four regions, each of which has been assigned a team composed of operators from Infrabel and NMBS who manage rail traffic. As Belgium has a language divide between the Dutch and the French speaking regions, the ROC has been divided into French and Dutch speaking teams, even though operators are supposed to speak both languages. The high-speed lines to France, Germany and the Netherlands are managed by a separate team. The regions themselves are also subdivided into two or three sections containing several rail lines. Regional traffic controllers from Infrabel (Lijnregelaars*)* monitor the rail traffic on one or more rail lines. To do so, they must maintain close contact with the local control centres. Interestingly, the Lijnregelaars can also communicate directly with train drivers and even make emergency calls. This allows them to intervene immediately in rail traffic if necessary. In addition to the regional traffic controllers, each team has two NMBS operators who monitor their own passenger trains.

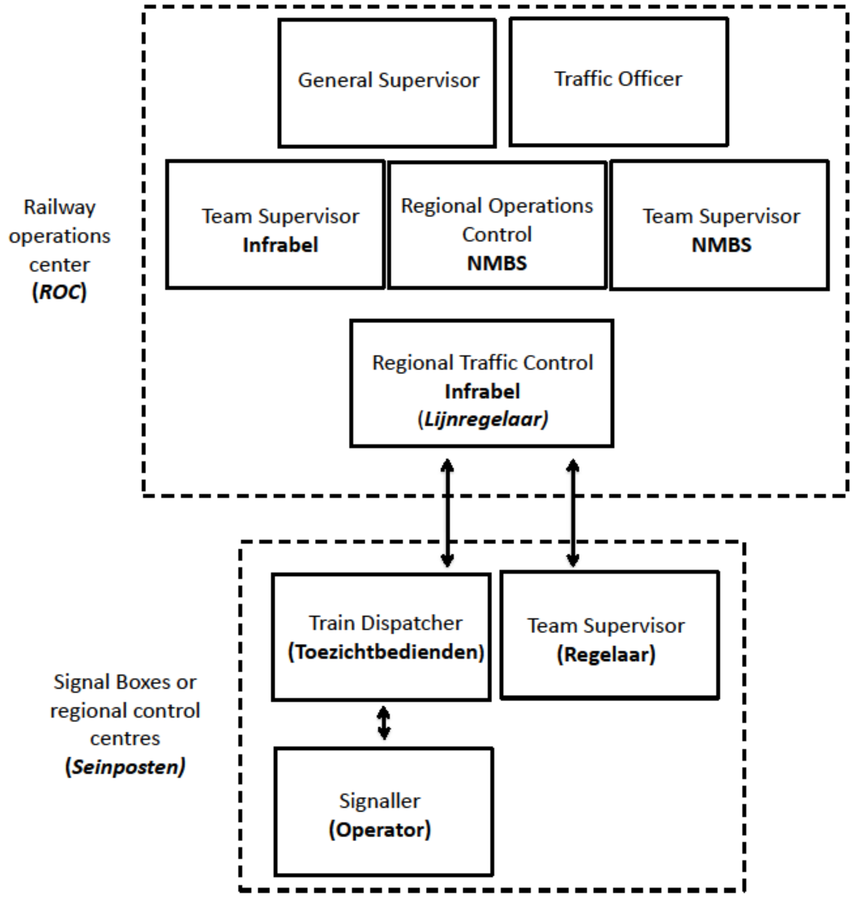


FIG. 2.3 Organizational structure and lines of communication in Belgium

2.4 Denmark

A. Institutional reforms and competition in the rail market

The state-owned railway company DSB (Danske Statsbaner) was split up in 1997, not only to comply with EU directives but also in response to calls to privatize the rail system. The state-owned IM Railnet Denmark –later renamed Banedanmark –was formed and this subsequently became a government agency under the Ministry of Transport. The TOC DSB became an independent public company, working on a for profit-basis and fully owned by the Danish Ministry of Transport, Building and Housing. With the sale of its freight division to Raillion, DSB started to focus exclusively on rail passenger services. In 1999 the rail freight market was fully liberalized. The Danish passenger rail market was opened up for competition in 2000, regardless of the distance, type and economic nature of the state-owned network (CER, 2017). The Danish railway network measures 2667 km, 2132 of which are managed by RIM Banedanmark. This means that more than 500 kilometres of rail lines are owned and operated by various 'private companies', which are, however, generally owned by regional traffic authorities (CER, 2017).

The Danish government's objective was to provide affordable rail services throughout the country. In order to achieve this in Denmark's many low-density areas it is necessary to subsidize passenger rail transport. The Ministry of Transport started opening up the rail market by putting 15 percent of the total train kilometres out to tender (Holvad, 2017). This tender was won in 2002 by Arriva, which continues to operate a large part of the rail network in the west of the country (Mid and West Jutland) up to the present day. Nevertheless, DSB remains by far the largest train operating company. No operators have made use of the possibilities offered by open access to the rail market. This has partly to do with the fact that PSO services have priority over commercial services in the event of capacity restraints (CER, 2017). DSB has negotiated a public service contract until 2024 for their long-distance, regional, local (S-train) and cross-border passenger services.

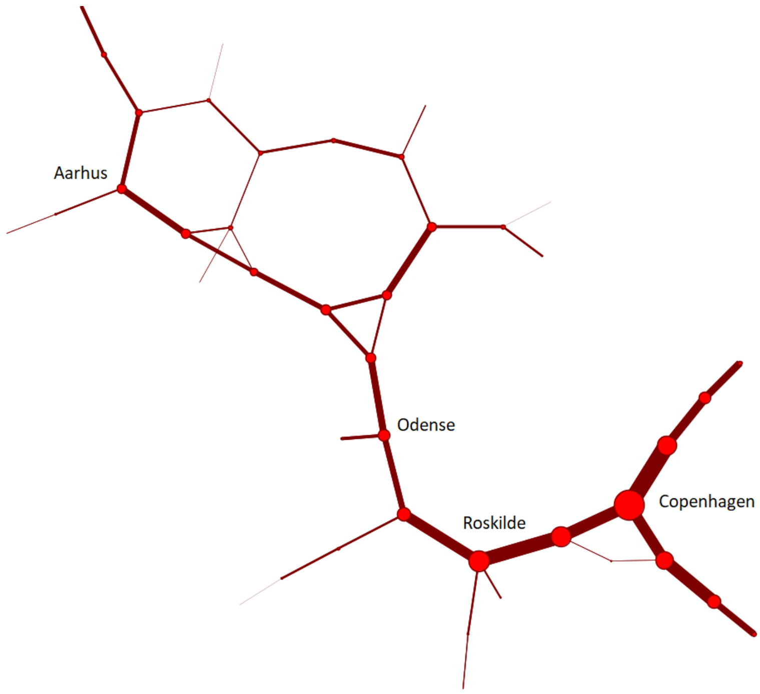
B. The Danish rail network

The Danish rail network measures 2,667 kilometres in length, with a total of 3,476 kilometres of rail track. The railway network is moderately centralized with most traffic converging around the metropolitan area of Copenhagen (see figure 2.4). Only the main line to Sweden and Germany and Copenhagen's S-train network are electrified. The main rail line is quite congested and forms a fragile backbone of the Danish railway system. There are four cross-border connections to neighbouring countries, one of which is by train ferry. The network is relatively simple outside the Copenhagen region, with mostly non-electrified, single tracks through sparsely populated areas. To replace Denmark's diverse and often aging signalling systems it was decided to adopt a nation-wide roll-out of ERTMS level 2. The roll-out is, however, facing serious delays by many years and is now not expected to be finished until 2030.

C. Usage of the rail network

Around 3,000 trains run on a daily basis on the Danish rail network. In 2016, there was a total of 65.2 million domestic passenger and 3.64 million freight train kilometres. This means that there were 24,440 passenger train kilometres per kilometre of rail line and only 1,364 freight train kilometres. This illustrates the limited role of rail freight transport in Denmark, which is around 8.5 million tons per year. The TOCs transported 199 million passengers, who travelled a total of 6.1 billon kilometres (Statbank, 2018). In 2017, DSB had an operator punctuality rate of 94.4 percent for long-distance and regional trains, while the punctuality rate of the S-trains was 98.6 percent (DSB, 2018). Operator punctuality is calculated from the total punctuality minus any delays for which DSB is not responsible. The threshold has been set at three minutes.

Fig. 2.4 Typology of the Danish railway network



Simplified network diagram of the Danish railway network. The busiest part of the network converges around Copenhagen main station, with a main line extending to Aarhus. There are limited options to reroute trains.

D. Railway traffic management

The main lines and regional network are monitored by Banedanmark train dispatchers working in four regional control centres (Regional FjernstyringsCentral, RFC). Train dispatchers are tasked with both monitoring the safe allocation of tracks and optimizing traffic flows in specific areas. Train dispatchers usually use computers to operate signals and switches, but switches are still occasionally operated using control panels. Each regional control centre has a duty officer who is in charge of operations and oversees the work of the train dispatchers. The duty officer also communicates with the national control centre (Drift Center Danmark, DCDK*)* during disruptions. The DCDK was established in 2006 and both Banedanmark and DSB are located here.

DCDK's main task is to monitor long-distance traffic and to assume a supervisory role if disruptions occur that could potentially impact the network's overall performance. Banedanmark has four traffic controllers who monitor long-distance rail passenger services in the west and east of Denmark, the Coast Line, the international services to

Sweden and Germany, and freight traffic. DCDK's traffic controllers use the same traffic management system as train dispatchers in the RFC. This provides them with highly detailed information on the local situation and allows them to swiftly assess the impact of a disruption. Train dispatchers have to explain every delay lasting longer than three minutes and record it in the traffic management system. Operators in the DCDK can then simply click on a train to see why it is delayed and assess whether it is necessary to intervene. In addition to this, a communication system allows Banedanmark operators to provide each other with more details on a disruption using short text messages.

On the other side of the control room, separated only by monitors and facing the Banedanmark team, a team from DSB monitors their operations. Two operators monitor the rail traffic and time-table deviations. A further eight operators reschedule rolling stock and train crew when needed. Both the Banedanmark and DSB teams in the DCDK have a duty officer who is in charge of the team and oversees the work of the operators. Most communication is assigned to these duty officers in order to structure the flows of information. Communication with the emergency services has also been centralized in the DCDK to avoid miscommunications.

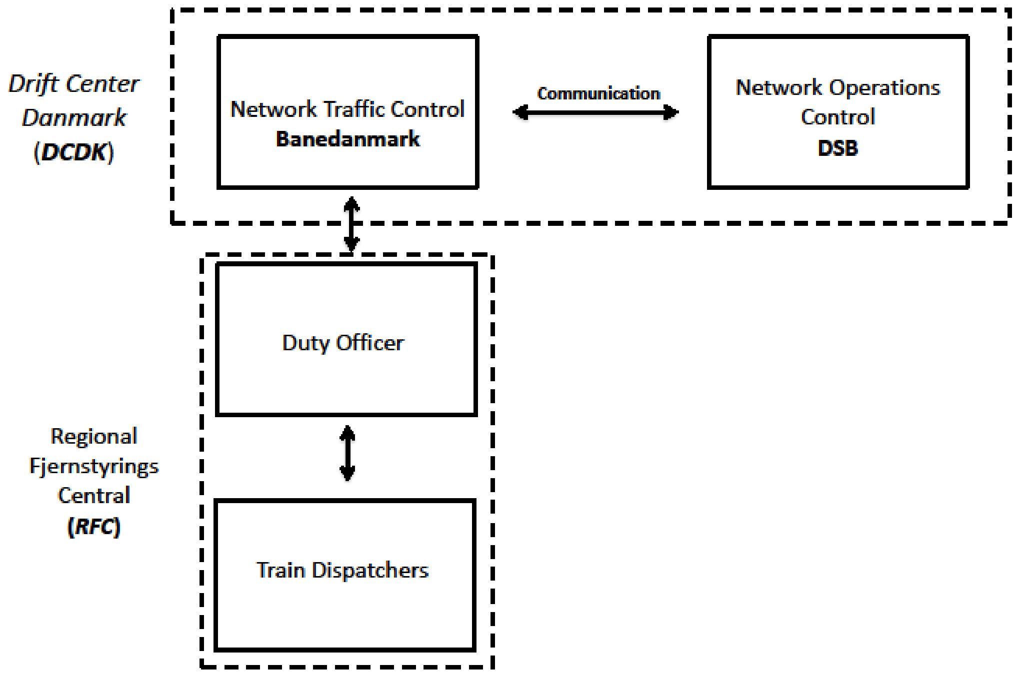


Fig. 2.5 Organizational structure and lines of communication in Denmark

2.5 Germany

A. Institutional reforms and competition in the rail market

After the reunification of Germany, Deutsche Bahn AG (DB AG) was formed in 1994 to operate the railways of both West and East Germany as a private-law commercial enterprise. Rail reform was initiated in 1994 to comply with the EU directive on railway reform, deal with the former railway companies' massive debts and excess personnel, and grasp the opportunities offered by reunification. This reform took several years and resulted in the unbundling of DB into five subsidiaries: DB Regio AG (regional traffic); DB Reise & Touristik AG (long-distance traffic); DB Cargo AG (freight services); DB Netz AG (infrastructure manager) and DB Station & Service AG (operating the stations). These subsidiaries were placed under the umbrella of a holding company, Deutsche Bahn AG. In addition, the rail networks of all public railway companies in Germany were opened to third parties. Although this was not an explicit goal, it enabled on-track competition between railway companies and the market share of non-incumbent companies in regional passenger services has steadily increased over the years (Link, 2004; 2012).

The rail reforms also meant that responsibilities for contracting passenger services subject to PSO were decentralized, shifting from the federal government to the States (Bundesländer) in 1996 (Finger & Rosa, 2012). The German federal government provides the funds (8.2 billion euros in 2016) to a regional fund (Regionalisierungsmittel), which is then divided between the States on the basis of the number of inhabitants and train kilometres. The States or other public authorities procuring regional passenger services have a great deal of freedom regarding the procedure they choose to award contracts (direct awarding, open or closed tendering) and there are marked differences between States with regard to the market share of non-incumbent companies (Finger & Rosa, 2012). Nonetheless, open tendering has gradually become the norm (CER, 2017). It must also be mentioned that regional rail services are awarded on a non-exclusive basis and thus networks remain open for competition from commercial services (Finger & Rosa, 2012).

Of all the passenger kilometres provided by TOCs in 2016, 58 percent were covered by PSO contracts and the rest was provided without subsidies (mostly long-distance traffic). Although DB Regio is still the largest operator on the PSO market, it has seen its market share decline steadily to around 67 percent (CER, 2017). Although the long-distance market is open for competition and not tied to any concession contracts, this market is still almost completely dominated by DB Fernverkehr (99 percent). The arrival of new entries to the commercial long-distance service market is limited by the high access and station charges, limited network access and upcoming, and often inexpensive, bus services (Van de Velde & Röntgen, 2017). Overall, there are almost 400 TOCs operating on the German rail network, 360 of which are not part of the DB holding.

DB Netz AG is tasked with both the management and exploitation of the rail network. Germany's track access charges are based on a full cost recovery regime. This results in quite high access charges in comparison to other European countries and makes up around half of the operational subsidies paid to TOCs (Link, 2016). Both Deutsche Bahn and the federal government provide the funds for upgrading existing and building new rail infrastructure.

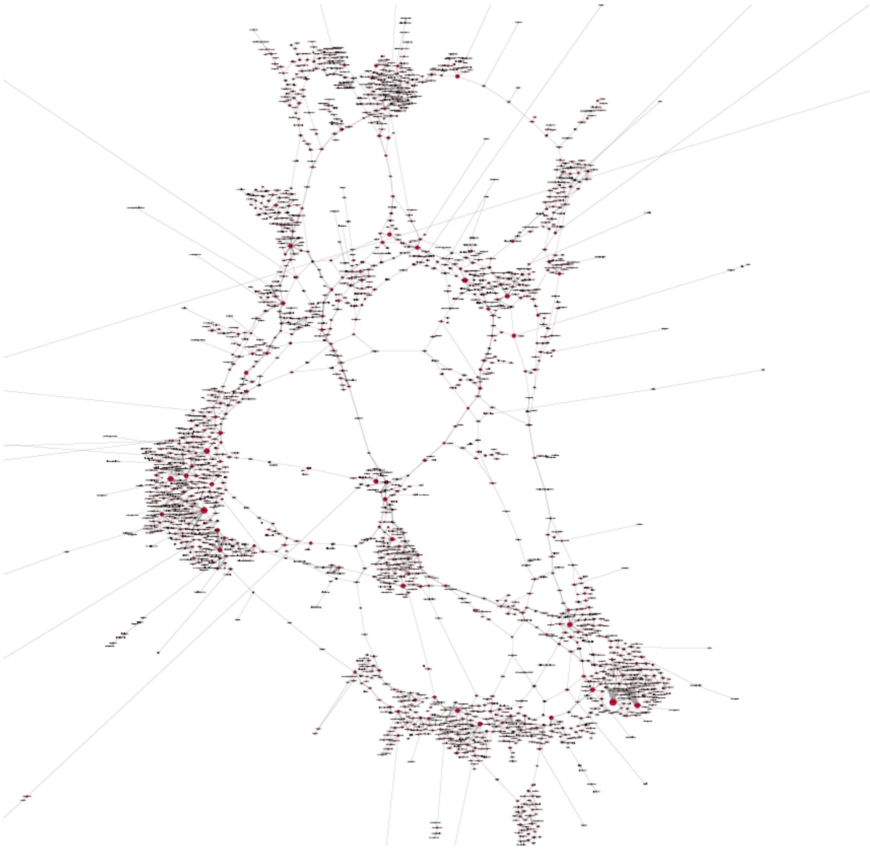
B. The German rail network

The total length of the German rail network is 38,466 kilometres (Eurostat, 2018). Deutsche Bahn (DB) Netz AG, the largest RIM, manages 33,241 kilometres of rail lines, 20,095 kilometres of which are electrified. Due to Germany's central position in Europe, six out of nine European freight corridors run through this country. Rail freight transport volumes are consequently quite high. The busiest sections are the corridors between the North Sea ports (Rotterdam/Antwerp) and the Alpine countries (Swiss, Austria, and Italy), Frankfurt – Hamburg, and the Ruhr area to Berlin and beyond. The German rail passenger network can be characterized as being decentralized. The local train lines (S-bahn system) serve the metropolitan regions and these metropolitan regions are connected by high-speed ICE trains. As such, the network has multiple high-density clusters, connected by long lines crossing the country (see fig. 2.6). The entire network consists of 60,780 kilometres of rail track, which makes it the largest rail network in Europe. The large scale makes it easier to reroute trains in the event of a disruption. There are 66,935 switches and crossings and a total of 3,226 train stations on the network.

C. Usage of the rail network

DB Netz monitors about 45,000 train journeys, consisting of approximately 39,000 passenger trains and almost 5,500 freight trains, on a daily basis. In 2016 a total of 2,685 million passengers travelled on the German rail network, covering a distance of 95,465 billion passenger kilometres (Eurostat, 2018). Freight operators transported 367,314 million tons of goods in 2015. Passenger and freight operators together operated 1,068 million train kilometres in 2016 on DB Netz AG's network (DB, 2017). This makes 32,129 train kilometres per kilometre of rail line. In 2016, the total punctuality rate for passenger rail services was 93.9 percent. The punctuality rate for Deutsche Bahn's local passenger services was 94.8 percent, while the rate for long-distance services was only 78.9 percent at a six-minute threshold (DB, 2017).

Fig. 2.6 Typology of German railway network



Simplified network diagram of Germany's railway network. The German network stands out in this report due to its highly decentralized and complex nature. It has many sub-clusters, e.g. in the Ruhr area and around Munich. Frequencies range from very high (e.g. the S-bahn networks in and around major cities) to very low (e.g. branch lines in less populated areas. There are many possibilities for rerouting traffic. On the other hand, this system can be very vulnerable to cascading disruptions.

D. Railway traffic management

Railway traffic is managed from seven regional control centres (Betriebszentrale, BZ*)*. However, only a relatively small number of the more than 12,000 signallers nationwide work in the BZs and use computers for setting switches and signals. There are still over 3,400 operational signal boxes from which switches and signals are set: some even use manually operated mechanical levers. On average, a BZ has ten train dispatchers (Zugdisponent*)*, who monitor the traffic flows on specific line sections and nodes. They manage conflicts between trains with the help of predefined dispatching rules. During a disruption, they take the first measures to isolate the disrupted area with the help of their traffic management system LeiDis-NK. They also take note of the reasons behind delays and disruptions in the traffic management system.

In addition, there are two or three regional traffic controllers (Bereichsdisponent*)* who oversee the work of the Zugdisponenten from a different control room. Bereichsdisponent manage requests and complaints from TOCs regarding matters such as connecting services. They also manage disruptions in consultation with the TOCs. The Netzkoordinator supervises all BZ activities. During large-scale disruptions, the coordinator communicates with the TOCs and neighbouring control centres. They also have the final say if there is a conflict of interests, or if TOC resources are required to solve the disruption. An emergency manager (Notfallmanager) manages incidents and communicates with the emergency services.

In 1997, a national control room (Netleitzentrale or NLZ*)* was established in Frankfurt am Main. Here, three to four operators (Bereichskoordinator*)* monitor long-distance and international rail traffic along the main corridors. Each Bereichskoordinator is responsible for two or more BZs. Together they monitor around 800 passenger trains and 1,200 freight trains per day. In addition, they coordinate with traffic control in neighbouring countries. The NLZ also has a coordinator (Netzkoordinator*)*, who mainly fulfils a supervisory role during extreme disruptions and severe weather conditions. The coordinator in the NLZ has the final say in the event of a disagreement between actors on a national level. During normal operations the Netzkoordinator is mainly occupied with monitoring the entire rail network and writing daily reports for senior management.

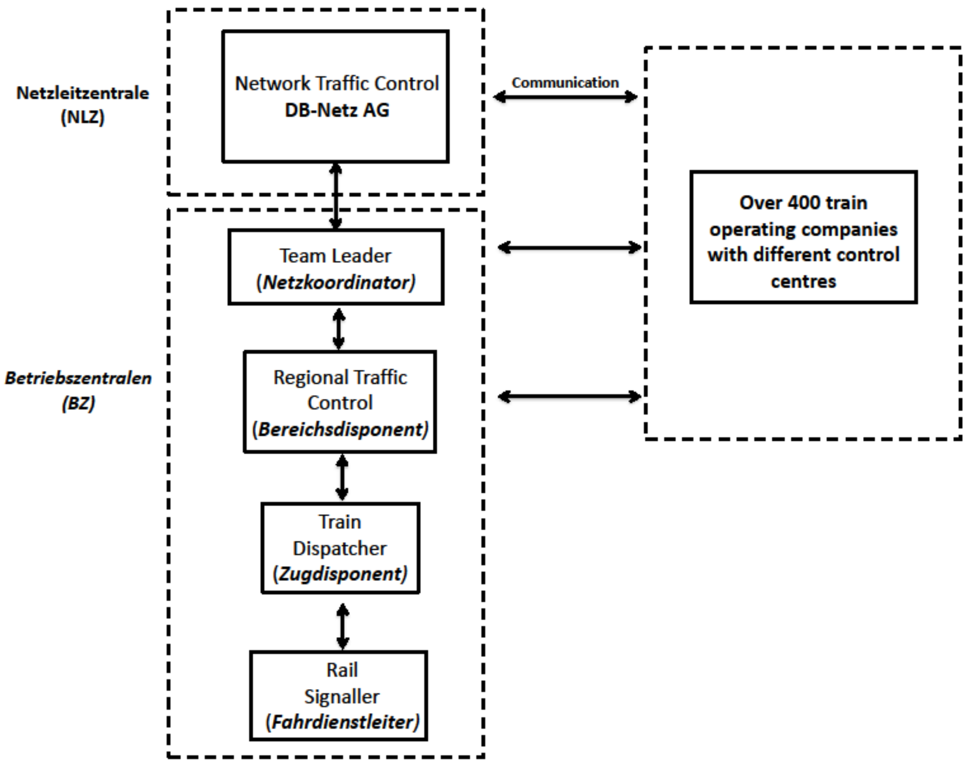


Fig. 2.7 Organizational structure and lines of communication in Germany

2.6 The Netherlands

A. Institutional reforms and competition in the rail market

In 1992, a special committee was appointed by the Ministry of Transport to examine what the Dutch railway system needed to do to comply with EU legislation and to reassess the relationship between the Dutch State and the incumbent train operating company Dutch Railways (Nederlandse Spoorwegen, NS). The committee not only issued recommendations on unbundling NS, but also on the relationship between the State and the railway company. They recommended that rail passenger transport should become a non-subsidized and deregulated activity, which would give NS more freedom to make its own commercial decisions (Van de Velde, 2011). In 1995 NS was split up, whereby commercial activities (those related to passenger and freight transport) and non-commercial activities (management of the rail network) were separated. Three separate organizations were formed, tasked with the management of the rail network: Railverkeersleiding (traffic control), Railned (capacity management), and Railinfrabeheer (construction and maintenance of the rail network). These three task organizations worked under the direct supervision of the Ministry of Transport, which covered the costs they incurred. Both commercial and non-commercial activities officially remained part of NS Holding, the shares of which were wholly owned by the Ministry of Transport.

Rail passenger services had to be provided on a commercial and profitable basis, but not all rail lines were economically profitable. It was therefore decided that the rail network should be divided into a core network of profitable lines, and a peripheral network of loss-making lines (around seven percent of the total number of passenger kilometres). NS maintained its monopoly on the core network via a ten-year concession contract directly awarded by the Dutch State. NS pays 80 million euros a year for the exclusive rights granted by this contract, which is effective until 2025. The Dutch government has always opposed exposing its core network to open access competition as it is believed that a single operator is better able to optimize the services on the heavily used Dutch rail network (Van de Velde, Jacobs & Stefanski, 2009). Regional transport authorities were made responsible for the peripheral rail lines and began to experiment with open tendering for public service contracts granting the exclusive right to offer passenger services on single lines or a set of lines. There is therefore no open-access competition, either de jure or de facto. The regional transport authorities are funded by the national government. Over the years TOCs such as Transdev, Connexxion, Arriva, and Keolis have won several tenders and often offer integrated train and bus services in the regions in which they operate.

The rail freight market was opened up in 1996 and in 2000 the freight division of NS merged with DB Cargo to acquire a larger market share. Since then NS has focussed exclusively on domestic and international rail passenger services. For international high-speed services NS works together with Thalys, Deutsche Bahn, Eurostar and NMBS (this last high speed train service only ran for 40 days due to technical issues with V250 rolling stock, (cf. Gerrits, Marks & Böhme, 2015). In 2002, rail infrastructure management and rail service provision were officially separated. The former task organizations Railned, Railinfrabeheer, and Railverkeersleiding were merged and a new RIM was formed and given the name ProRail. All of the TOCs pay infrastructure charges to ProRail, but these payments cover only a minor part of the total infrastructure maintenance costs. The remaining costs are covered by the Dutch government (Van de Velde, 2013).

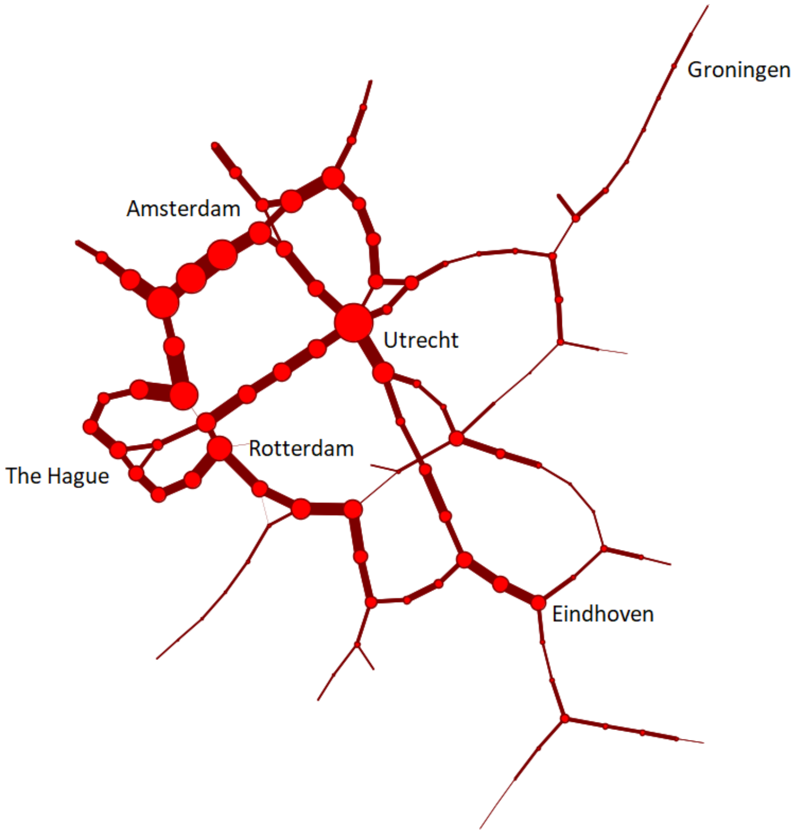
B. The Dutch rail network

The Dutch railway network measures 3,055 kilometres in length. More than 70 percent consists of double or multiple tracks. The entire network has 7,219 kilometres of rail track. 2,310 kilometres (more than three-quarters of the total network) is electrified. There are 7,006 switches, 12,093 signals and 404 train stations (ProRail, 2017). The railway network is particularly dense in and between the four largest cities (Amsterdam, Rotterdam, The Hague, Utrecht), with Utrecht being the most important node in the railway network, connecting all the lines that cross the entire country (see figure 2.8). On the rail lines a mix of both slow sprinter services (a kind of commuter train that calls at every station) and faster intercity services (covering medium and long distances) can be found connecting the cities and smaller towns. Trains also run very frequently on the busiest routes. For example, six intercity and six sprinter trains run every hour in both directions between the cities of Amsterdam, Utrecht and Eindhoven. Thanks to the relatively small size of the Netherlands and the density of its network, passengers can usually find alternative routes to reach their destination during a disruption.

C. Usage of the rail network

The Dutch rail network is one of the busiest rail networks in Europe, with almost 5,500 passenger train runs per day and a total of 16.9 billion passenger kilometres annually (CBS, 2017). In 2016, trains travelled a total of 159 million kilometres on this relatively small network (ProRail, 2017). That is more than 52,000 train kilometres per kilometre of rail line. There is also a considerable amount of freight traffic between Germany, Belgium and the ports of Rotterdam and Amsterdam. In 2015, a total of 42 million tons of goods were transported by train. However, compared to the other countries in this study and given the fact that Rotterdam is the largest port in Europe, rail freight traffic is relatively small in size. This can be explained by the fact that a lot of freight in the Netherlands is transported by inland waterways. Rail passenger transport had a punctuality rate of 89.4 percent at a three-minute threshold in 2016. That of freight traffic was 73.7 percent.

Fig. 2.8 Typology of the Dutch railway network



Simplified network diagram of the Dutch railway network. The network has a very busy sub-cluster between Amsterdam, Utrecht, Rotterdam and The Hague, where trains run every few minutes. This part of the network has reached its maximum capacity and there is little room for deviation from the time table. Main lines extend north and south. The possibilities for rerouting traffic are somewhat limited.

D. Railway traffic management

Rail traffic is managed from 13 regional traffic control centres (Verkeersleidingspost*)*. Each centre has one or two regional traffic controllers (Decentale verkeersleider, DVL*)* who optimize the traffic flows in their control area and process orders from the TOCs. There are also several train dispatchers (Treindienstleiders, TDL*)*, whose main responsibility is the safe allocation of rail capacity on the specific sections (nodes) assigned to them. All switches and signals are operated using computer-based control. In addition, train dispatchers reschedule the rail traffic in their own control areas (mostly around large stations). A team leader monitors the crew's workload. NS also has five regional control centres (Regionale Bijsturingscentra*)* to manage its train crew and rolling stock. These control centres more or less mirror those of ProRail. This means that there are two operators (who communicate with the DVL), to monitor traffic flows, node coordinators (who communicate with the train dispatcher) to arrange the shunting of trains and manage train crew at major train stations and a shift leader (who communicates with the team leader). There are also several operators tasked with the management of rolling stock and train crew.

The central Operational Control Centre Rail (OCCR) was established in 2010. The OCCR houses all the parties involved in rail operations under one roof in order to improve collaboration and communication and a wide range of specialized teams can consequently be found there, including ICT, asset management, maintenance contractors, and a freight operator. Although all of the TOCs were invited to take up workstations, NS is the only passenger TOC active in the OCCR. Back-office functions have also been centralized. Back-office employees collect all information on disruptions and malfunctions in a specific system, notify emergency services and contractors and provide updates on disruption management. Each team in the OCCR is represented by a director *(regisseur)*. These directors meet at the beginning and end of every shift in meetings chaired by a coordinator (Landelijk Coordinator Rail*)*. Directors will often meet to provide each other with updates and make joint decisions during a major disruption.

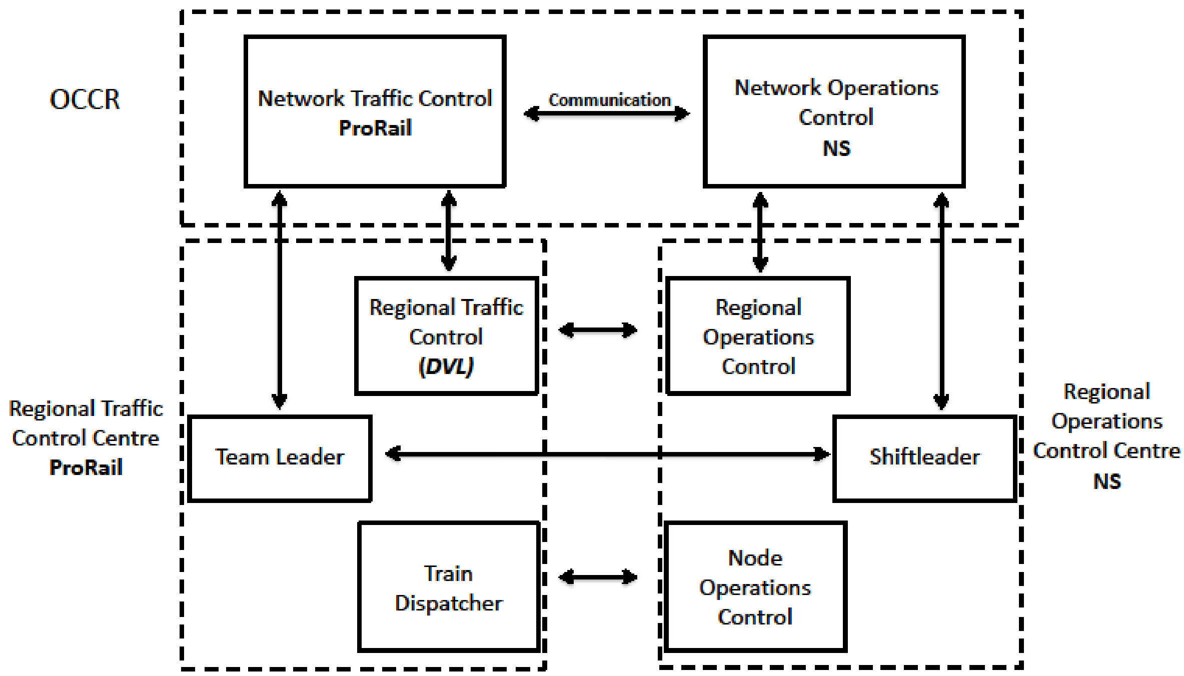


Fig. 2.9 Organizational structure and lines of communication in the Netherlands

From the OCCR, operators of ProRail's traffic management and NS's operations management monitor rail traffic on a national level and coordinate the activities of the regional control centres. Two operators from ProRail monitor rail traffic on the main corridors and communicate with the regional traffic controllers (*DVL)*. The director of the national traffic control communicates directly with the team leaders of the regional control centres. Their NS counterparts monitor the traffic and rolling stock on a national level to optimize punctuality and the distribution of rolling stock over the regions.

2.7 Portugal

A. Institutional reforms and competition on the rail market

When the incumbent TOC, Comboios de Portugal (CP), was split up in 1997, the state-owned company, REFER, became responsible for managing rail infrastructure. In 1999 CP lost its monopoly when *Fertagus*, a private operator, won the competitive tender for the PSO contract to provide commuter rail services to suburbs on the Setubal Peninsula, located south of Lisbon on the other side of the river Tagus. This is 54 kilometre-long suburban line is extremely busy, with 2.2 million train kilometres per annum (Arriva, 2013). It is also the only rail line in Portugal to have been tendered. With a market share of 79 percent of all train kilometres, CP is still the main rail passenger operator (IP, 2017). The concession allowing CP to operate trains on the rest of the rail network was granted by law (CER, 2017). As this law obliges CP to provide a minimum level of service there is no open access in the domestic passenger service market. The market for international passenger services was opened up in 2010. Nevertheless, the number of cross-border connections is very limited and all are provided by CP in partnership with the Spanish incumbent Renfe. In 2015 REFER merged with the Portuguese road infrastructure manager to create a new company, *Infraestruturas de Portugal* (IP).

B. The Portuguese rail network

The Portuguese rail network is 2,544 kilometres long. 1,639 kilometres of the network (64 percent) is electrified and around three-quarters consists of single track lines. Signalling on the network is a mix of electronic signalling (1740 km) and mechanical signalling (806 km). In the last few decades the rail passenger sector has faced increasingly fierce competition from both public and private road transportation. This, in combination with scant investment in the rail infrastructure, has resulted in the closure of many narrow gauge railway lines (Sarmento, 2002). Currently, around 1,075 kilometres of the rail network are closed.

C. Usage of the rail network

Portuguese railway traffic is heavily concentrated in the metropolitan areas of Porto and Lisbon. Suburban railway traffic makes up two-thirds of the 2,200 passenger trains operated daily, while intercity services and the high-speed Alfa Pendular service (which connects Portugal's major cities) only account for five percent of all train runs. In 2015 more than 130 million passengers were transported by rail. Altogether, these passengers travelled 3,957 million kilometres. In the same year 11.1 million tons of goods were transported by rail (Eurostat, 2018). In 2016, the passenger trains of TOCs travelled 30.1 million kilometres, while freight trains travelled 5.8 million kilometres. A total of 37 million train kilometres were driven in 2016 (IP, 2017). That is 14,544 train kilometres per kilometre of rail line. The overall punctuality rate was 94 percent for passenger trains and 80 percent for freight trains at a five-minute threshold for passenger trains and a 30-minute threshold for freight trains. Long-distance passenger trains recorded a punctuality rate of 76.3 percent, while local passenger services had a punctuality rate of 96 percent (ibid.).

D. Railway traffic management

Railway traffic is managed by three regional control centres (CCO) in Porto, Lisbon, and Setubal. There is quite some variation in the number of trains being monitored by each CCO. While Lisbon's CCO monitors 1650 trains (70 percent of all trains), Porto's CCO monitors 650 trains (23 percent), and Setubal's 150 trains (7 percent) on a daily basis. In the CCO train dispatchers (*Operação Regulação*) control rail traffic from their workstations through electronic interlocking and supervise rail traffic on the sections with mechanical interlocking. Since there is no train detection on the mechanical sections, manual input from local signallers on the position of trains is integrated into the rail traffic systems of the train dispatchers using a software tool that simulates the position of the trains. The work of the train dispatchers is coordinated and optimized by Traffic Supervisors (*Supervisão*). Lisbon's CCO has four supervisors, each monitoring the work of around four train dispatchers. The Traffic Supervisors are in direct contact with the TOCs.

Several supportive functions have been integrated within the CCO to reduce the burden of communication and coordination between teams. For instance, there are operators tasked with monitoring the status and repair of the rail infrastructure, catenary power supply, travel information, and video surveillance of trains. One supervisor (*Chefe CCO)* is in charge of overseeing the work of all operators in the CCO and has the final say during major disturbances or if there is a potential conflict with a TOC. In contrast to the other countries in this study (with the exception of Sweden), Portugal does not have a real national control centre, but there is a Central Command Centre where two coordinators collect information from the three CCOs and coordinate their activities. The Central Command Centre is not involved in routine daily operations, but comes into action during large-scale and infrequent events, such as wildfires. There are no operators from the TOCs in the CCO. They have their own service centres from which they manage train crew and rolling stock. In anticipation of new entrants to the rail passenger market it was decided not to locate the incumbent CP workstations in the CCO, but there is a crisis room in the CCO where IP can meet the TOCs to discuss events and make decisions.

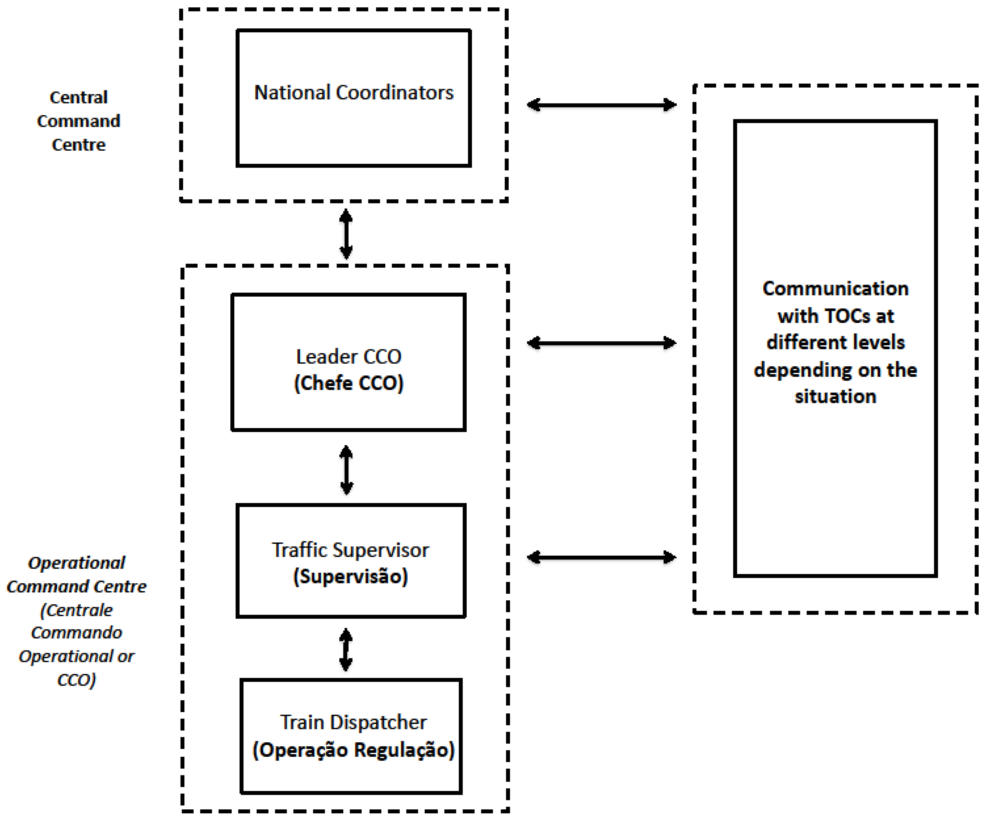


Fig. 2.10 Organizational structure and lines of communication in Portugal

2.8 Sweden

A. Institutional reforms and competition on the rail market

Sweden has been one of the forerunners in Europe with regard to railway reform. Many of its reforms are rooted in the Transport Policy Act of 1998. This act not only initiated the splitting up of the incumbent rail operator Statens Järnvägar (SJ) into the infrastructure manager, Banverket, and the train operating company SJ, but also heralded the decentralization of responsibilities and resources for the provision of generally unprofitable regional train services to the regional authorities. This reform was initiated in order to manage the deficits of the state-owned railway company and to control finances, as SJ was increasingly struggling to cover the costs of its train services and to make the necessary infrastructure investments (Alexandersson & Hultén, 2007). Moreover, the reforms were intended to create a level playing field across transport modes. Note that Sweden initiated these reforms without much external pressure as it only joined the EU in 1995 (Finger & Rosa, 2012).

The twenty-one County Public Transport Authorities (CPTAs) became responsible for the procurement of rail services, for which they received state subsidies and rolling stock. As these CPTAs had gained a good deal of positive experience in the procurement of bus services through competitive tendering, some started to award PSO contracts for train services in a similar fashion (Alexandersson & Rigas, 2013). It was in this way that BK Tåg became the first non-incumbent train company to provide passenger services in 1990. The CPTAs became responsible for the local and regional lines, but there were also unprofitable interregional services on the main network. The Swedish State had been procuring these interregional services on the basis of negotiated contracts with SJ. Given the positive experiences with competitive tendering on local and regional lines, competitive tendering on interregional lines was introduced in 1993 in order to reduce costs and increase efficiency. Nevertheless, there were still significant barriers for new entrants to the market and it was 1999 before a contract was won by a company other than SJ (Alexandersson & Rigas, 2013). In 1996, the rail freight market was also made open access in order to increase its modal share.

After 2000, several competitors began to enter the market for non-profitable commuter and interregional services. In 2001, in response to this influx of new operators and to provide equal access to services it was decided to unbundle SJ into several state-owned limited companies (e.g. the freight operator Green Cargo and the manager of real estate Jernhusen), while other parts were fully privatized (Alexandersson & Hultén, 2007). The newly formed train operating company SJ AB could now turn its full attention to providing rail passenger services and competing with the new entrants to the subsidised market. The next big step in the opening up of the Swedish rail market came in 2010 when the market for commercial passenger services was also opened up to competition. Nonetheless, the number of entrants to this market remained low. The biggest development came in 2015 when the Hong Kong based company, MTR Express, started to operate intercity railway services between Sweden's two largest cities, Stockholm and Göteborg, in direct on-track competition with SJ AB. In 2012 it also became possible for any operator to provide commercial services on PSO awarded lines. Interestingly, commercial long-distance services actually experienced increasing competition from services covered by PSO contracts. Some CPTAs have grouped services into larger networks to provide interregional services and to share the administrative burden (CER, 2017). However, this development towards increased cooperation between CPTAs has also meant that commercial services have had to compete with PSO awarded services and that some commercial services have even been squeezed out of the market (Van de Velde & Röntgen, 2017).

Between 1999 and 2010 the state agency Rikstrafiken was responsible for tendering non-commercial interregional services. In 2011 Banverket merged with the road and maritime transportation agencies to form Trafikverket. Since then Trafikverket has been responsible for the planning and management of all state-owned roads, railways and a large number of ferry services: hence, Trafikverket also became responsible for tendering non-commercial inter-regional services. The main objective in creating an intermodal state agency was to reap potential benefits when planning and executing infrastructure maintenance and synchronize construction and capacity use between the different modes of transport (CER, 2017). The TOCs pay Trafikverket charges for the use of the infrastructure based upon marginal maintenance costs (Alexandersson & Hultén, 2007).

B. The Swedish rail network

Sweden is the largest country in this study, but with less than 10 million inhabitants, it is also one of the least populated countries in Europe. The Swedish rail network is relatively dense in the more populated south of the country, where the western and southern main lines connect the three largest cities of Stockholm, Göteborg, and Malmö. From Malmö the Öresund line provides a direct train connection with the Danish capital, Copenhagen, and there are four border crossings with Norway (passenger and freight) and one with Finland (freight only). Rail traffic is especially heavy in and around the capital of Stockholm, with 1,700 train runs per day in the metropolitan region, 1,200 of which pass through the central station of Stockholm. The less populated north of the country is connected by long rail lines originating in the capital (see figure 2.11). Sweden's entire rail network is 10,882 kilometres long with 3,700 kilometres of double or multiple tracks and 8,184 kilometres of electrified track (Eurostat, 2018). This makes Sweden a country with one of the highest share of electrification in this study. The rail network has 4,000 bridges, 147 tunnels and 15,176 switches.

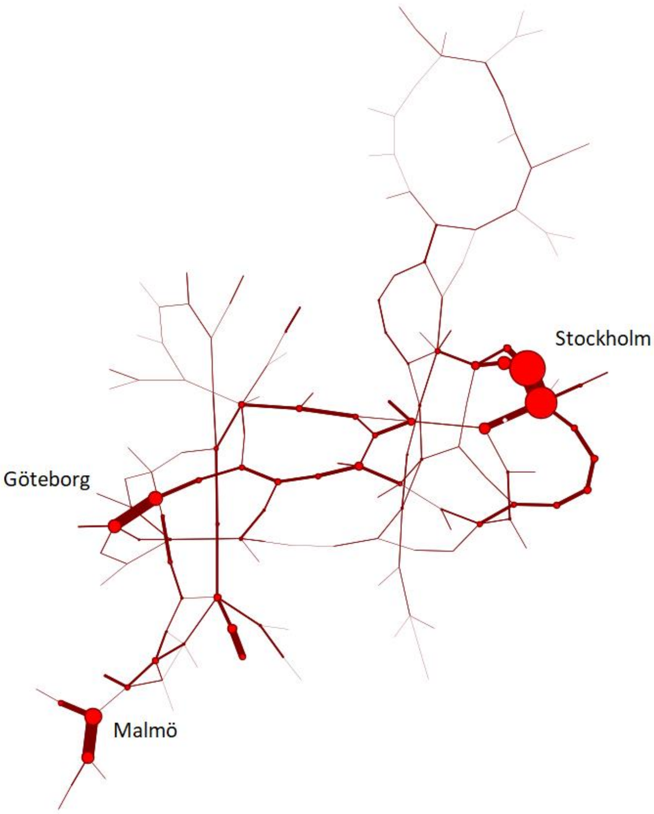
C. Usage of the rail network

The total number of train kilometres in Sweden was 158 million in 2016[3]. This is 14,519 train kilometres per kilometre of rail line. While rail passenger services have steadily increased in the last five years (17 percent in the period from 2011 to 2016), freight traffic has declined by 18 percent in the same period. The number of train journeys increased by three percent to a total of 211 million journeys, a new record for Sweden. Although the long-distance train service still accounts for more than half of the passenger kilometres, regional subsidized passenger services are growing at a faster pace and accounted for 48 percent of all passenger kilometres in 2016. In total, rail passengers travelled 12.8 billion kilometres, which is also a new record and a twelve percent increase compared to 2011. The total of goods transported in 2016 was 67.5 million tonnes. Rail freight operators travelled 21.4 billion tonne kilometres in the same year. The punctuality rate of rail passenger trains at terminating stations in Sweden was 90 percent measured using the Combined Performance Measure CPM(5)[4]. Long-distance passenger traffic noted a

[3] Data in this section is from *Trafikanalys'* (2017a,b) annual reports on rail traffic and punctuality in Sweden
[4] "CPM combines punctuality and reliability into a single performance measure. CPM is the percentage of the scheduled trains, as planned the day before departure, arriving on time. On time is compared to the

punctuality rate of only 78 percent, while regional services and local traffic had much better scores, with punctuality rates of 88 percent and 94 percent respectively.

Fig. 2.11 Typology of the Swedish railway network



Simplified network diagram of the Swedish network. The network has three busy clusters around the main cities, Stockholm, Göteborg and Malmö. Of these, Stockholm is by the far the busiest part of the network. The other lines feature a much lower frequency.

D. Railway traffic management

There are eight regional rail control centres. Although the majority of the rail traffic control has been centralized in these modern control centres, there are still some signal boxes throughout the country. Four of the regional control centres (Stockholm, Gävle, Göteborg, and Malmö) combine both rail and road traffic management. Two of them

scheduled arrival time and is presented with different time margins to enable user options. CPM(5) means that trains can have delays of up to 5 minutes and still be counted as if they were on time" (*Trafikanalys*, 2017b: 9).

also have control rooms for the power supply (Gävle and Göteborg). Rail traffic control in Sweden has been divided into three different levels.

The first –the 'operational level' –is made up of train dispatchers, travel informants, and train managers[5]. Train dispatchers in Sweden have a comparable role to those in Denmark, Portugal and the Netherlands. They are not only responsible for the safe allocation of the rail capacity, but also for the optimization of the rail traffic in their area of control. Hence, train dispatchers enjoy quite a lot of autonomy in the re-scheduling of rail traffic in the event of deviations. For the monitoring and re-scheduling of rail traffic, train dispatchers make use of digital information systems and basic pre-printed paper time-distance graphs. By drawing lines on these paper graphs the train dispatchers can follow trains and identify any potential conflicts between them.

Sitting next to every train dispatcher is an Information Officer. They manually adjust the departure times at the platforms for long-distance trains (this is automated in the case of commuter trains), update the website, and provide station announcements. The travel informants also play a role in distributing information among the various operators in the control room. They need to safeguard against ambiguous information being distributed. An important aspect of this work is the BASUN messaging system, which collects information on disruptions and can be accessed by all control centres of Trafikverket and the TOCs. Four out of the eight regional control centres have a Train Manager. Train managers oversee the work of the train dispatchers and support them during disruptions. However, they are often not located in the same control room. This means that train dispatchers must notify train managers of disruptions and request help if needed. Train managers communicate with the TOCs during a disruption and discuss which trains should be cancelled, short-turned or rerouted. During normal operations, train managers are tasked with managing ad-hoc requests for train paths. Not directly involved in rail traffic control, but also part of the first operational level, are the power supply, infrastructure, and road traffic controllers.

The second level of control is at the supra-regional level. Sweden has been divided in four regions for road and rail traffic management. Interestingly, these regions do not completely overlap. For each of these regions there is an operational management centre (OMC).[6] The OMCs coordinate the activities of the rail and road traffic control centres. At the head of the OMC is the Regional Operations Leader *(ROL)*. The ROL is responsible for all decisions made and actions taken by the operators in his area of control. During large-scale disruptions the ROL not only oversees the work of the different control centres in his own area, but also coordinate with other regions during OPL conference calls. In addition, the ROL stays in contact with the various TOCs to make

[5] We must point to the fact that the role of the train manager differs between the regional control centres. Here we follow the structure observed in Stockholm's control centre.

[6] These operational management centres are located in the regional control centres of Stockholm, Gävle, Göteborg, and Malmö.

decisions on rescheduling rail traffic. The ROL is not directly involved in rail traffic control, but within and between the OMCs it is important to maintain a general overview of the situation. Within the OMC the ROL is assisted by an information and infrastructure manager, and some OMCs train managers.

Finally, there is a national operational management centre to coordinate the activities of the four regions at national level. The national OMC is located in Stockholm's regional traffic control centre and is staffed by two National Operations Leaders *(NOL)*. The NOLs deal with disruptions that affect two or more regions and therefore affect road and rail traffic nationwide. Their role is comparable to that of the ROL, but is limited to quite rare events which happen only two to three times a month. It is important for the NOL to receive notification from the ROL in good time. They can, however, also make use of the BASUN information system.

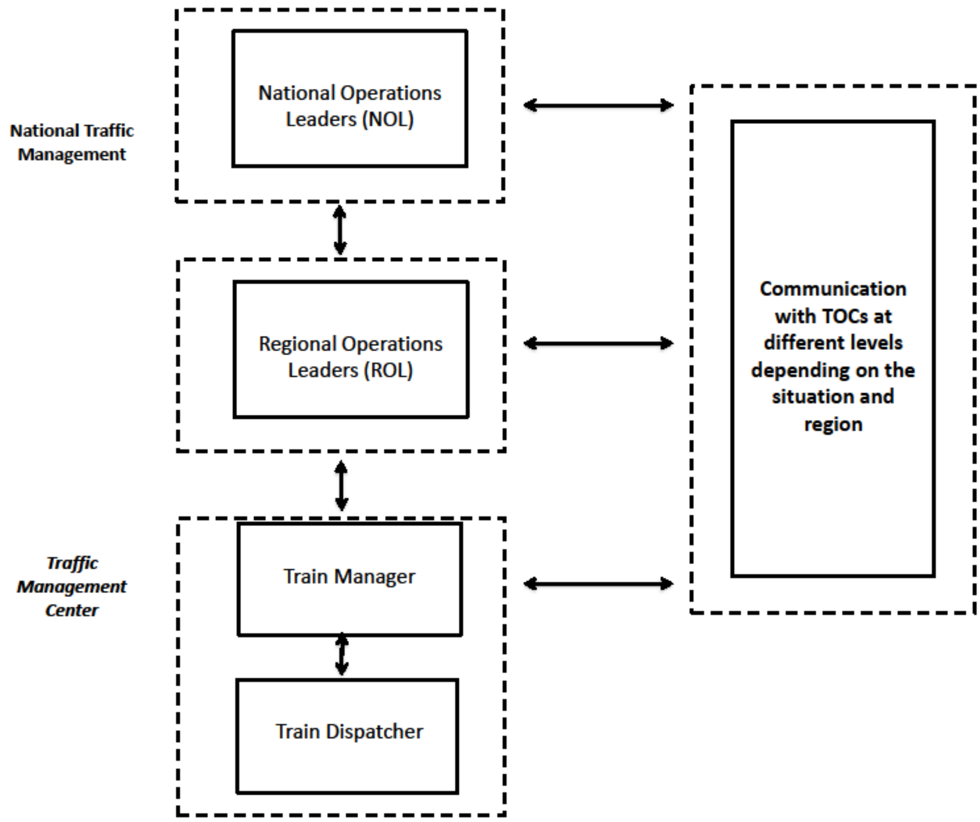


FIG. 2.12 ORGANIZATIONAL STRUCTURE AND LINES OF COMMUNICATION IN IN SWEDEN

2.9 Main characteristics of the countries in this report

Table 2.1 summarizes the main characteristics of each country in this report. While most countries have completely separated train operating services from rail infrastructure management, in both Austria and Germany the incumbent TOC and RIM are still part of the same holding. Nevertheless, both countries, along with Sweden, have been forerunners in opening up their rail market to open access on-track competition and in tendering regional lines. Germany is noteworthy because the tendering of regional lines, as well as the relative ease with which freight operators can gain access to the network have led to a very high number of TOCs operating in Germany. In any country, opening up the market has a significant impact on the role of coordination during disruptions. It makes all the difference whether one needs to coordinate with just one TOC or is required to discuss matters with multiple TOCs. This point also seems to be partially reflected in how traffic control has been organized in the different countries. In countries where the previously incumbent TOC still dominates the market, such as Austria, the Netherlands, Denmark, and especially Belgium, we can see that the TOC and RIM are co-located in the national control room. There are also major differences in the intensity of use of the rail networks. The Netherlands has by far the most intensively used network in terms of the number of train kilometres travelled relative to the size of the network. The extremely intensive use of the Dutch network means that there is little slack in the time table and disturbances will quickly cascade. Disruptions need to be isolated quickly and there are few opportunities to reroute trains. At the same time, the train kilometres per inhabitant are relatively low in the Netherlands, Belgium, and especially Portugal. In contrast, there is much more leeway in large parts of the Swedish networks, which gives operators more time to devise solutions and more room to take ad hoc measures without upsetting overall network performance.

Table 2.1 Main characteristics of countries

	GERMANY	AUSTRIA	NETHERLANDS	DENMARK	SWEDEN	PORTUGAL	BELGIUM
Relationship between RIM and incumbent TOC	Holding	Holding	Complete separation	Complete separation	Complete separation	Complete separation	Complete separation
Domestic passenger market entry rules	Open access for domestic passenger services	Open access for domestic passenger services	No open access. Direct award of core network and open tendering regional lines.	Open access, but no effective competition. New entrants via tendered PSO contracts.	Open access for domestic passenger services	No open access. Public tendering of one suburban line	Domestic market not open for competition
Length of rail network (km)	38,466	4,922	3,055	2,667	10,882	2,544	3,631
Share of network electrified (percentage)	60.5%	71.9%	75.6%	28.1%	75.2%	64.4%	84.4%
Number of TOCs (passenger and freight)	Over 350 active TOCs	45 TOCs	28 TOCs	+/- 10 TOCs	28 TOCs	5 TOCs	15 TOCs
Passenger kilometres (billions)	95.5	12.6	16.9	6.1	12.8	4.0	9.8
Train kilometres per annum (million)	1,068	146	159	69	158	37	95
Thousand train kilometres per kilometre of rail line	32.1	29.7	52.0	25.9	14.5	14.5	26.0
Passenger kilometres per inhabitant of country	1,155	1,440	993	1,065	1,293	384	863
Train kilometres per inhabitant of country	12.9	16.9	9.3	12.0	16.0	3.6	8.4

Chapter 3: Disruption management per country

3.1 Introduction

Disruption management is made particularly complex by the multiteam network (operators from different companies, geographically dispersed) on one hand, and the characteristics of the railway network and the nature of the disruptions on the other. National characteristics have been discussed in the previous chapter. This chapter will discuss disruption management in each country on the basis of two important trade-offs: anticipation vs. resilience and decentralization vs. centralization. We will first explain the role of these trade-offs in more detail before looking at a number of factors that allow us to observe how trade-offs work in practice and how they apply to the disruption management practices in each country.

3.2 Trade-offs in disruption management

There is no single best way to manage disruptions. Each RIM and TOC has to deal with the specific constraints and requirements dictated by the various developments and country-specific characteristics described in the previous chapter. What all of the countries have in common, is that the different teams involved in the management of disruptions work in a complex and dynamic environment. This specific operational environment leads to paradoxical demands in terms of coordination. On the one hand there is a need for formal coordination modes, such as plans and procedures, coupled with centralized decision-making to enable a swift, coordinated response to disruptions. At the same time, the dynamic and uncertain environment requires flexibility and on-the-spot decision making by operators. It is thus necessary for systems to be both flexible (in order to deal with changes during the disruption) and stable in applying standard operating procedures (in order to be predictable to others solving the disruption). This is not a matter of always improvising or always sticking to pre-defined rules and plans; rather, it is about finding the appropriate response to each specific disruption. RIMs and TOCs make a number of trade-offs, which may differ significantly from country to country, to achieve this. In order to structure the comparison between countries, we will examine the main trade-offs, as derived from scientific research into the coordination of complex systems, such as railways. A list of relevant sources is included in the reference list. The trade-offs can be grouped into two categories: (a) centralization versus decentralization; and (b) anticipation versus resilience. We discuss these briefly before presenting each comparison.

The occurrence of unexpected disruptions in complex systems highlights the importance of a decentralized structure because detailed knowledge of the local context and direct control over resources give local operators the flexibility required to deal with these non-routine situations. However, disruptions, especially larger ones, can severely compromise the ability of local operators to maintain an overview of, and control over, the situation. Decisions made locally don't always contribute to the overall performance of the system. To put it simply, what makes sense at a local level may be counterproductive at the system level. The main solution to this problem is to centralize control in order to facilitate rapid and decisive coordinated action. Centralized control, however, is not without its problems. Decisions made during disruptions necessitate the sharing of a considerable volume of information between the different levels of control; something that is not always possible when working under stress or if the situation is still unclear. Consequently, decisions may perpetually lag behind the actual situation locally. It is therefore necessary to tread a fine line between decentralized and centralized control.

The second main trade-off concerns anticipation versus resilience. The anticipation approach is based on the prediction of potential failures or disruptions in order to plan ahead. It involves the development of pre-defined coordination mechanisms, such as contingency plans, rules and procedures which specify roles and tasks for all operators, as well as solutions in any given situation. Pre-defined coordination mechanisms reduce potential conflicts between actors, increase responsiveness and decrease the time needed to develop a solution. However, as any operator will tell you, it will always remain impossible to anticipate every situation. For instance, the type, location, and timing of an incident will influence the effectiveness of the response. This could be as specific as a train breaking down just before a certain switch instead of fifty meters beyond. Consequently, there needs to be discretionary capacity for operators to modify plans to fit a specific situation through mutual adjustment and improvisation. Real-time adaptation can be seen as a resilient approach that substitutes foresight for the reactive capacity of control room operators, focussing on their expertise and tacit knowledge. However, an improvised response still needs to be swift and coordinated when dealing with a rapidly changing environment. Anticipation and resilience are not mutually exclusive but constitute a trade-off when developing an effective response.

The two trade-offs can be observed in practice through the items summarized in table 3.1. We made a *qualitative assessment* of how each country scores on each item as compared to the other countries in the sample. We express this assessment quantitatively on a fuzzy scale (0, 0.33, 0.66, and 1). A low score (closer to 0) represents a high degree of centralization and reliance on anticipation; a high score (closer to 1) expresses a high degree of decentralization and reliance on resilience. We use this scale to rank our qualitative assessments. It allows us to characterize countries in terms of trade-offs, while preventing us from ranking them with a 'safe' middle score that expresses neither centralization or decentralization, nor anticipation or resilience. In other words, countries are always 'closer' to one side of the dimensions.

Table 3.1 List of items, their descriptions and scores used in order to categorize the various countries

Trade-off *A*: Centralization versus decentralization

Item	*Description*	*Centralized 0 – 0.33* *Decentralized 0.66 – 1*
Distribution of control centres	This concerns the number of control centres and their distribution across the country.	Low number and limited distribution: 0; high number and distribution: 1
Allocation of decision rights during disruption	This concerns whether decisions on alternative service plans are made by regional or national control centres	Centralized decision-making: 0; decentralized decision-making: 1
Autonomy of local control	This concerns the extent to which regional control centres can make autonomous decisions on the rescheduling of rail traffic	Little autonomy: 0; considerable autonomy: 1
Communication and nodes of communication	This concerns the information flows between both levels of control and the operators that process the information	Radial information flows: 0; distributed flows: 1
Co-location of RIMs and TOCs	This pertains to whether RIMs and TOCs share the same offices and desks	Co-location: 0; full separation: 1

Trade-off *B*: Anticipation versus resilience

Item	*Description*	*Anticipation 0 – 0.33* *Resilience 0.66 – 1*
Role of contingency plans	This concerns the number of contingency plans and how these plans are put into practice.	Reliance on pre-defined plans: 0; reliance on improvisation: 1
Automation of control	This concerns the availability and use of automated control that can override or replace local operations	Automation: 0; manual control: 1
Institutionalization of shared sensemaking	This concerns the extent to which shared sensemaking is organized and institutionalized	Organized: 0; not organized: 1
Use of dispatching rules	This concerns the availability and use of dispatching rules	Strict application of rules: 0; no dispatching rules: 1

Since there is no theoretical reason to prioritize a certain item, we assigned equal weight to all items in the final aggregation. Note that this quantification could give a false impression of precision. We want to stress that there is a qualitative assessment underlying these scores. Please also note that the scores express how the countries are ranked in relation to one another, but not in absolute terms. For example, no country will rely exclusively on full manual control. Nevertheless, a country can be ranked '1' if it relies more heavily on manual control than any other country in the sample, even if only part of the control in that country is automated.

3.3 Distribution of control centres

If we were to go back to the emergence of the European railway network, we would see a decentralized network controlled by numerous signal boxes, either at larger train stations or somewhere along the track. This extreme form of geographically dispersed, decentralized control has largely disappeared due to technological advances. Although differences can be observed, all countries in the sample have greatly reduced the number of signal boxes in favour of modern regional control centres. These regional control centres have made it possible to control larger areas with a reduced number of operators working in relatively fewer control rooms. A further development has been the establishment of national control centres supervising daily traffic management. Although they are not a direct result of deregulation, these national control centres certainly perform a function that relates to the organizational fragmentation in the railways. Centralizing control reduces the coordination and communication burden: however, it may also reduce the specific local knowledge needed to deal with unique events.

Austria
ÖBB is in the process of integrating rail traffic control on the main rail lines into five regional traffic control centres (Betriebsführungszentralen, BFZ). This process started in 2005 and should be complete by 2030. The transition to more centralized control is a step-by-step process in which all the separate elements of the rail network and even different parts of rail lines are being integrated into the BFZ, one at a time. This means that some parts of the network may be controlled by signallers in the BFZ, while other parts are still controlled from signal boxes at the stations. BFZ currently controls around 1600 kilometres of rail line. Several peripheral lines and shunting yards which have not been included in the transition due to limited rail traffic will continue to be controlled locally. The central control room in Vienna (Verkehrsleitzentrale Wien or VLZ) was established in 2006 and houses both operators from ÖBB infra-management and passenger services.

Belgium
Belgium has been significantly reducing the number of its signal boxes in recent years. In 2005 it had 368 signal boxes of various ages using a range of different technologies. By 2016 there were only around 86 signal boxes left in operation. With the introduction of new traffic control and information systems and the increasing centralization of control, the aim is to have 31 modern signal boxes (initially) and ten modern local control centres by 2022. The national control centre (Railway Operations Centre or ROC) was established in 2014 when Infrabel's rail traffic control and NMBS's operations control were co-located in one control room.

Denmark
Banedanmark has four regional control centres (Regional Fjernstyrings Central, RFC) from which all rail traffic is controlled. A national control centre (Drift Centre Danmark or DCDK) was established in 2006 and houses operators from both Banedanmark and DSB. If the full implementation of ERTMS goes ahead, the aim is to reduce the number of control centres to two.

Germany
Rail traffic is managed from seven regional control centres (Betriebszentrale, BZ). However, only a relatively small number of the more than 12,000 signallers nationwide work in the BZs and use computers for setting switches and signals. There are still over 3400 operational signal boxes from which switches and signals are set: some even work via mechanical levers. In 1997, a national control room (Netleitzentrale or NLZ) was established in Frankfurt am Main. Here, three to four operators (Bereichskoordinator) monitor long-distance and international rail traffic along the main corridors. Given the high number of active TOCs on the German network (over 350), it is no surprise that there are numerous control centres from which the many different TOCs manage their operations. For instance, Deutsche Bahn has control rooms for local rail traffic (Transportleitung Personenverkehrs) and long-distance traffic (Verkehrsleitung Fernverkehr). Not all of these control rooms have been integrated into DB Netz's Betriebszentrale.

The Netherlands
All rail traffic is managed from 13 regional traffic control centres (Verkeersleidingspost). Dutch Railways also has five regional control centres (Regionale Bijsturingscentra) to manage its train crew and rolling stock. These control centres more or less mirror those of ProRail. The national Operational Control Centre Rail (OCCR) was established in 2010 and houses all parties involved in rail operations under one roof to improve collaboration and communication. The Dutch railway system is the only one in the sample to have fully replaced its signal boxes with modern regional control centres equipped with computerized control systems.

Portugal
Portugal is in the process of centralizing its rail traffic control. Signal boxes along the lines are being merged into regional control centres. As of 2018, there are three such regional centres, which will at some point in the future be merged to create just two control centres (one in Lisbon and one in Porto). Consequently, the system is becoming increasingly centralized. While there is a national coordination mechanism, we were told that this only becomes operational during extreme events, such as national disasters. As

such, we don't consider it to be part of the daily traffic control and disruption management process.

Sweden

Sweden has eight regional traffic control centres from which traffic is managed and capacity is allocated. There are still some local signal boxes in operation. As mentioned before, the regional (ROL) and national (NOL) operation leaders have a passive role with regard to daily operations and only come into action during large-scale disruptions or extreme events, in a very similar way to their peers in Portugal.

Table 3.2 Distribution of control centres

Country	Distribution control centres low or high
Austria	.33
Belgium	1
Denmark	0
Germany	1
Netherlands	.33
Portugal	.33
Sweden	.33

3.4 Allocation of decision rights during disruptions

The organization of traffic control into more centralized or decentralized networks is only part of the story. Also important is the allocation of decision rights during a disruption. Centralized decision- making and planning helps to synchronize the activities of the regional control centres, monitor system goals, and steer resources between regions. Centralized decision-making can, however, also be slow and necessitates the sharing of large amounts of information. Naturally, there is a fairly large grey area between centralized and decentralized decision rights. Indeed, we observed that many operators try to reach a degree of consensus about certain solutions to avoid situations where decisions have to be enforced from one quarter. There is, nevertheless, always an ultimate decision-making authority and it is these that have been identified and used to rank the countries.

Austria

Decision rights regarding long-distance traffic in Austria have been allocated to the VLZ, while the BFZ has the authority to decide over regional traffic. With the latter accounting for the majority of traffic, it is fair to say that decision rights are primarily local – even though the VLZ can (and sometimes does) overrule local decisions if they would impact a long-distance train negatively. Although there is a lot of consultation between RIM and TOCs, the train operating companies have the final say on the alternative service plan.

Belgium
The Belgian system is set up so that signal boxes are tasked with implementing the solutions devised in the ROC. As such, they have no decision rights during disruptions. However, since there are four teams within the ROC, each responsible for a specific geographical area, there is basically no decision- making at a national level. Decisions are made within teams made up of operators from both Infrabel and NMBS.

Denmark
On any given shift, solutions for a disruption are developed within the DCDK by a team consisting of operators from both Banedanmark and DSB. They will tell the regional control centres to implement the decision, though in practice there is considerable consultation with the regional control centres on the development of a contingency plan

Germany
Decision-making in Germany, is decentralized, with the BZs making most decisions on rescheduling rail traffic. The role of the Netzleitzentrale is to coordinate the decisions made by the different Betriebszentralen with regard to long-distance traffic. As such, their involvement in the management of a disruption depends on the situation, but is usually restrained.

The Netherlands
In the Netherlands the regional traffic controller (DVL) assesses the remaining rail capacity in the event of a disruption. ProRail's national traffic controllers in the OCCR evaluate this assessment on the basis of their system-wide knowledge of the rail traffic. Dutch Railways operators in the OCCR then select a contingency plan on the basis of the boundaries set by national traffic control. There is often consultation between both parties in the OCCR.

Portugal
Decision-making takes place within the three control centres. Since these are staffed by operators of Infrastruturas de Portugal, it is they who are primarily responsible for the solution. However, operators (except the dispatcher in CCO) can communicate with their colleagues in the TOC, thus facilitating coordination. As mentioned above, the national coordination mechanism only plays a role in extreme cases.

Sweden
Train dispatchers have considerable autonomy in Sweden. They are given the freedom to take the measures necessary to solve commonplace disruptions, often in consultation with the train manager. While such commonplace disruptions are usually solved locally,

more major disruptions which may impact multiple regions require more coordination. This is achieved by holding joint conference calls, known as OPL meetings. These OPLs play an important role in day-to-day coordination. Even operators who are not directly involved in a disruption often join them in order to stay up-to-date. An OPL is initiated by the regional head, but dispatchers can ask for one to be organized. Although train dispatchers are allowed to make operational decisions, the final call is made by the regional heads.

Table 3.3 Allocation of decision rights during disruption

Country	Allocation of decision rights during disruption central or decentral
Austria	.66
Belgium	0
Denmark	0
Germany	1
Netherlands	0
Portugal	.66
Sweden	.66

3.5 Autonomy of local control centres

Disruption management consists of more than just determining the decision-making authority. Another important dimension is the extent to which local control centres are allowed to develop and implement solutions on their own: in other words, how autonomous they are. Much can be said for this as local operators are likely to have a thorough understanding of the situation and be able to respond quickly to changing circumstances. However, as mentioned above, decisions that make sense locally do not necessarily contribute to the overall performance of a system and as such, there may be a perceived or actual need to limit the autonomy of the local control centres.

Austria

Originally, the VLZ's role was less clearly defined and this sometimes led to misunderstandings and even friction between the VLZ and the BFZ. This was solved by assigning long-distance traffic to the VLZ and regional trains to the BFZ. This means that he VLZ does not interfere in the daily operations and disruption management carried out locally by the BFZ, which allows for considerable local autonomy. There is, however, one notable exception: the BFZ has to follow the VLZ's decisions and recommendations if long-distance traffic is involved. This seems to work well.

Belgium
The specific purpose of signal boxes, which are numerous in Belgium, is to guarantee the safe allocation of rail capacity. Decisions on rescheduling rail traffic are made exclusively by the operators in the ROC. This strict separation of responsibilities between the two layers of control seems to work quite well and the hierarchical structure appeared undisputed.

Denmark
Local traffic controllers are tasked with the optimization of rail traffic in their own area of control, while national operators monitor rail traffic on the main corridors. However, consultation with the national operators is mandatory if rescheduling decisions taken by the regional traffic controllers affect multiple regions. In practice, this appears to work efficiently.

Germany
The BZ in Germany have considerable autonomy within their own regions of control. The NLZ monitors their actions and only intervenes during major disruptions that affect long-distance traffic in multiple regions. In practice, we observed that intuition also plays an important role with regard to the decision to intervene in local operations and there are therefore no strict boundaries between the two layers of control.

The Netherlands
As in Denmark, local traffic controllers optimize rail traffic in their own area of control, while operators in the OCCR monitor rail traffic in the main corridors. Consultation with the national operators is mandatory if rescheduling decisions taken by the regional traffic controllers affect multiple regions. We noticed that the point at which a local issue becomes a supra-regional problem it isn't always clear to operators in the Netherlands (at both the regional and national control centre). This creates ambiguity concerning when and how national operators should intervene in local operations. In practice this seemed to happen haphazardly and depended on the individual operators working during a given shift.

Portugal
Portugal is in the process of centralizing control into three, and eventually two, regional control centres. As such, it appears that local autonomy is being reduced. The fact that the national control centre is only activated in the case of extreme events means that the three centres usually take decisions on their own.

Sweden
Regional control centres enjoy considerable autonomy in Sweden. Like Portugal, there is no national control centre from which rail traffic is constantly monitored. In order to

coordinate the activities of the regional control centres it is essential that the regional and national operational management centres are kept up-to-date. Teams in the regional traffic control centre are trained in the active sharing of information. Authority shifts to the ROL and, if necessary, the NOL during large-scale disruptions.

Table 3.4 Autonomy of local control centres

Country	Autonomy of local control low or high
Austria	.66
Belgium	0
Denmark	1
Germany	1
Netherlands	1
Portugal	1
Sweden	1

3.6 Communication and nodes of communication

Disruption management requires a considerable amount of communication between actors. This communication can be subdivided into two categories. Sensedemanding concerns all those instances of communication when actors try to figure out what is going on (e.g. "What is the situation now?"; "What are we supposed to do now?"). Sensegiving is all communication that attempts to create clarity regarding the situation (e.g. "This is what the situation is like now"; "This is what we should be doing now"). The general rule is that the more ambiguous the operational picture, the more communication (of both types) is needed to obtain an accurate picture of the operational situation and develop a solution. Any form of communication will have to travel through the network. The more operators involved in one communication stream, the longer it will take for communication to travel from sender to recipient and the greater the risk that the communication will become distorted and be misunderstood. However, it is often inevitable that multiple operators are involved in a communication stream, especially if they are geographically dispersed. The communication stream should ideally involve as few operators as possible. Having said that, we would also like to point out that a single operator can become overburdened by the many messages being conveyed. If a node becomes overburdened, the communication stream will no longer function effectively.

Austria

Austria's communication network is relatively straightforward. Each BFZ has an operations coordinator (Betriebskoordinator, Beko), who is the central operational actor. He or she communicates with the TOCs, neighbouring regional traffic control centres at home and abroad, and the national traffic control centre in Vienna. An emergency coordinator (Notfallkoordinator or Noko) communicates with the emergency services and manages all emergencies in a specific system, accessible to all parties in the rail system. The VLZ has two operators from ÖBB-Infrastruktur who monitor rail traffic on Austria's north-south and east-west corridors. There is also an operator responsible for the management of all information during a crisis and a network coordinator who communicates with the TOCs, both at home and abroad, and informs management.

Belgium

The important role of the rail operations centre (ROC) in the Belgian system means that many of the communications pass through this centre. Everything except minor disruptions is managed in the ROC, which can therefore issue orders for all signal boxes or regional centres nationwide. Conversely, anything that requires the ROC's attention must be communicated accordingly. This implies a considerable volume of sensedemanding and sensegiving communication activities. In practice, we noticed that this is indeed the case but that the co-location and centralization on the ROC's shared work floor reduces the burden in contrast to a geographically dispersed system. There is also a risk of telephone lines becoming overloaded during disruptions when the system is strongly centralized.

Denmark

Communication in Denmark passes through relatively few nodes. Within the regional control centres, the most common disruptions are solved by the train dispatchers and duty officers. The national control centre (Drift Center Danmark, DCDK) only kicks into action when disruptions threaten to cascade through the network. Communication within DCDK is decidedly horizontal (cf. Germany) in the sense that all operators are situated in the same room and that there is no strict hierarchy as to how communication should flow. Communication flows freely within DCDK thanks to the rather flat hierarchy of Banedanmark and DSB, and doesn't require the involvement of many people. However, regional operators must inform DCDK of each disruption that will cause delays of five minutes or longer.

Germany

Germany's communication network features a large number of nodes. Each traffic control centre (Betriebszentralen, BZ) has a number of train dispatchers (Zugdisponenten) who direct the work of the rail signallers (Fahrdienstleiter), some of whom are in the BZ while others are located at signal boxes along the tracks. Team leaders and regional traffic controllers have to communicate with the TOCs. Train dispatchers and signallers do not communicate directly with the TOCs. Each BZ also has an emergency operator who maintains communication with the emergency services, for example if police request that a certain section be locked-down or an ambulance is needed. The communication structure is such that a relatively high number of nodes are involved in the information stream. Communication follows a somewhat strict hierarchical order within the BZs. Inevitably, there is a considerable amount of communication between the BZs, and between the BZs and the TOCs. In theory, there is no need for continuous communication between the BZs and the NLZ, but in practice, we observed that some operators in the NLZ were more active in gathering information, mostly by phone, about certain trains than others, who would take a more reactive role.

The Netherlands

The Dutch communication network is fairly decentralized. ProRail's train dispatchers and regional traffic controllers play an important role in the lines of communication. Train dispatchers in particular collect and distribute a great deal of information during disruptions. Communication with the TOC NS also takes place at the regional level. This communication is not restricted to one role within the control room, but rather each operator can communicate freely with their counterpart at NS or ProRail. Given the many regional control centres of ProRail and NS communication can increase rapidly and telephone lines can easily become overloaded. Another issue is maintaining communication channels vertically with operators in the OCCR when the workload rises. The sheer volume of information that must be shared in order to maintain a shared understanding can become quite a problem for regional operators. The co-location of the many different parties in the OCCR does, however, provide a platform for quick information-sharing and joint sensemaking. The communication burden is further reduced by the centralization of a back office in the OCCR. This back office collects and shares information on the disruption management process with all parties.

Portugal

Communication in Portugal is a straightforward matter that doesn't involve many nodes. This is due to the fact that the network is relatively simple in comparison to the other countries in this report. The operational command centres (Centrale Commando Operational, CCO) are organized around the train dispatcher (operação regulação) and the traffic supervisor (supervisão), whereby the train supervisor makes the decisions and the train dispatcher implements them. It is also the supervisor who communicates with the TOC, although the CCO leader can also communicate with the TOC. In practice, most situations are solved by the traffic supervisor without any need for upscaling. As mentioned before, the national coordinators only take action if there is a major crisis. Given the nature of the railway network, there is little need for coordination across the CCOs and the small number of TOCs means that communication flows can remain restricted. Centralization in the CCOs means that communication is predominantly radial.

Sweden

The Swedish communication network veers towards being distributed as each region caters for itself without the pressing need for continuous cross-regional coordination. Most commonplace disruptions are solved by the train dispatcher and the train manager in the traffic management centres, whereby the latter also communicates with the TOCs if necessary. The regional operations leaders ensure that everything is coordinated across the regions, but not every disruption necessitates cross-regional coordination. Likewise the train manager and the regional operations leader, are allowed to communicate with the TOCs at various levels. The exact level depends on the circumstances and the region – we found that the traffic management centre in the busy Stockholm area did things a little differently to, for example, the management centre in the quieter Gãvle region. Given Sweden's size, its relatively autonomous regions, and the minor role of the national control centre (NOL; cf. the situation in Portugal), the communication network can be regarded as a hybrid where much communication is kept local but can easily be shifted towards a more radial structure.

Table 3.5 Communication and nodes of communication

Country	Communication and nodes of communication radial or distributed
Austria	.33
Belgium	.33
Denmark	0
Germany	1
Netherlands	1
Portugal	.33
Sweden	.66

3.7 Co-location of RIM and TOCs

The thrust towards deregulation of the European railway market means that, in principle, there is now a separation between the RIM and the historically incumbent TOC. In theory, the RIM should operate the infrastructure and the TOCs the trains, the distinctions are more blurred in reality, as we have seen in the previous chapter. Some countries still have the RIM and the former national TOC in the same holding (e.g. Germany and Austria) while other countries have separated them into two distinct companies (e.g. the Netherlands). We have, however, seen that despite this complete separation, there is often still a close relationship between the RIM and the incumbent TOC and some are even co-located in control centres. It is arguable that co-location shortens communication lines and contributes to quicker decision-making. There is a catch, however, now that the rail market is being opened up more to new entrants. In order to comply with EU regulations, co-location should extend to all TOCs operating in the network. Despite this, other than the incumbent TOC, many TOCs do not have the resources to staff the joint control rooms and therefore decide to use their own cheaper locations. As such, we see a very diverse picture in our sample when it comes to co-location.

Austria
ÖBB-Infrastruktur and ÖBB-Personenverkehr are co-located in the VLZ but not in the BFZs. The BFZs deal with multiple TOCs in addition to ÖBB-Personenverkehr, including Westbahn and several cargo operators. These TOCs work from their own control rooms.

Belgium
The Belgian situation is exceptional in the sense that the ROC is staffed by teams consisting of operators from both the RIM and NMBS. These teams are jointly responsible for certain sections of the network. As such, it is fair to say that integration is strongest in Belgium compared to the other countries in the sample. This can be seen as the logical consequence of the domestic rail market still being fully dominated by NMBS.

Denmark
While not as highly integrated as Belgium, the Danish national control centre consists of two teams from Banedanmark and DSB sharing same control room. This doesn't include Arriva, which operates a limited number of local lines in the north-east of Denmark. The situation is very similar to that prevailing in Austria.

Germany
We found that although some TOCs in Germany (mostly regional branches of DB) are co-located in the BZs, most of them by far have opted to use their own control centres. The NLZ in Frankfurt is staffed by operators from DB Netze and is not open to operators from TOCs. TOCs make use of DB Netz's traffic management system, which gives them a real-time overview of their own trains and potential delays. However, they are unable to monitor services operated by other TOCs because DB Netz wants to avoid potential discussions about unfair treatment.

The Netherlands
The traditionally strong ties between ProRail and Dutch Railways, coupled with Dutch Railways' monopoly of the core network are expressed in the co-location of operators from both organizations in the OCCR. Although they are jointly responsible for solving disruptions, they are not as integrated as the teams in the Belgian ROC. Until recently the largest freight operator, DB Cargo, also had operators in the OCCR. The TOCs operating the tendered peripheral lines have decided not to place staff in the OCCR. These TOCs are in direct contact with the regional traffic control centres and manage disruptions jointly.

Portugal
Portugal maintains a strict separation between the RIM and the TOCs in all its control rooms, which are exclusively staffed by operators from the RIM. It was decided to maintain this strict separation in anticipation of new entrants into the rail market. Communication with the TOCs takes place by phone or through a messaging system.

Sweden
Like Portugal, Sweden also maintains a strict separation between the RIM and the various TOCs and operators are not co-located in the regional traffic control centres. Interestingly, Trafikverket's railway control rooms are combined with those for the road network, but there is no actual integration in daily operations, although the potential is there.

Table 3.6 Co-location of RIM and TOCs

Country	Co-location of RIM and TOCs
Austria	.33
Belgium	0
Denmark	.33
Germany	1
Netherlands	.66
Portugal	1
Sweden	1

3.8 Role of contingency plans

Devising a solution for a disruption is a time-consuming process. Consequently, there is an incentive to reduce the time needed to make a decision by working with pre-defined contingency plans. It is possible to prepare the system for the most frequently occurring failures by developing a standard response that can be implemented swiftly because it offers a workable and familiar template. Such a response may be more efficient than having to develop a solution from scratch for each individual disruption. These standard responses also reduce the operators' workload, make the process more predictable (i.e. less reliant on specific teams), and reduce the need for consensus-building as they have been agreed upon in advance. There are, however, two drawbacks. Firstly, it can take a long time to find the correct plan. The complexity of the disruption and the management process could lead to the search time being so prolonged that the solution is obsolete by the time it has been found.

Secondly, every disruption has a degree of novelty, especially if it is large-scale. It is therefore unrealistic to expect to have a pre-defined contingency plan for every possible disruption. The skill of improvisation remains essential when dealing with unforeseen circumstances, but is only useful to a certain extent. If measures and outcomes are not recorded, there is a real risk that it will be necessary to reinvent the wheel over and over again. This would also require more resources. In other words, the use of contingency plans represents yet another trade-off.

Austria
Contingency plans have been developed for the most common disruptions. Although these contingency plans are detailed and numerous, they mainly serve as a template for the operators managing a disruption. In practice, there are often constraints set by the availability of rolling stock and train crew. Hence, on-the-spot decision-making is still dominant and the final solution depends on the specific circumstances.

Belgium
Belgium doesn't use contingency plans, even though there are templates for some regular disruptions. Operators from Infrabel and NMBS stressed the unique characteristics of each disruption and the consequent need for improvisation. During our observations we were struck by the fluidity of the teams and the amount of implicit coordination, i.e. their actions appeared to be coordinated despite relatively limited communication (see further on) and the absence of a predefined plan.

Denmark
Denmark has around 30 predefined contingency plans that are revised frequently due to constraints set by train crew and rolling stock availability. During disruptions, operators of Banedanmark and DSB gather in the emergency room in the DCDK to decide on an alternative plan on-the-spot. This makes the disruption management process in Denmark more flexible than it is, for example, in the Netherlands, but also very dependent on the team of operators in charge – as in Belgium. We also observed that most of these ad-hoc plans are not recorded for later use, so the solution is often lost once the disruption has been solved. Another issue concerns the fact that both parties have to reach a consensus in the heat of the moment. A contingency plan could be helpful in giving clear indications as to what has to happen next.

Germany
In Germany contingency plans have been developed with the TOCs for the main lines carrying long-distance traffic, but not for the entire network. These plans also mainly serve as a template. For instance, it is common practice to reroute long-distance trains during disruptions, which is possible because of the large and dense network (many stations can be reached by more than one route). These alternative routes are not part of a predefined plan, but the operators rely on their creativity and extensive knowledge of the rail network to reroute trains in consultation with the TOCs.

The Netherlands

Of all the cases in the sample, the Dutch railway system relies most heavily on predefined contingency plans (Versperringsmaatregel). ProRail and NS have developed numerous (reputedly more than 1500) alternative service plans for dealing with almost any kind of disruption on all lines. The swift implementation of a contingency plan is intended to prevent the propagation of the disruption and to facilitate coordination between the various control centres. Accordingly, with the exception of international and cargo trains, trains are not rerouted. Instead, passengers are advised to use an alternative route or alternative transport (busses). This reliance on contingency plans is not without its difficulties. In practice, defining, checking and implementing a contingency plan requires intensive communication between the different control centres. In addition, minor deviations or changes within the operational environment might render these static plans unfeasible, necessitating real-time adjustment. In contrast to Austria, there is less flexibility for developing solutions. One could therefore argue that an abundance of contingency plans may sometimes make it more difficult to get things back on track.

Portugal

Portugal doesn't have any contingency plans. Operators of Infrastruturas de Portugal are given the freedom to do whatever it takes to solve a disruption. One important reason why this is possible is that the network is used less intensively than the networks of countries like Germany and the Netherlands. With more leeway between trains, there is relatively less time pressure to fix things quickly. Therefore, the benefits of contingency plans are not immediately apparent.

Sweden

Given the considerable competition in the Swedish railway market, there is a clear need for contingency plans. They are drawn up and approved by all parties and present a transparent set of plans and decision rules. This allows Trafikverket to make clear-cut and incontestable decisions. The exact use of the contingency plans varies and changes when local conditions require operators to deviate from them. In addition, operators may not always feel the need to use a plan if they understand the situation and believe they can devise a quick solution. The time it can take to select the correct plan may influence their decision of whether or not to opt for a make-shift solution, especially under time pressure. The ROL works with colour codes to indicate the severity of the situation and the selection of the relevant contingency plan. The colour codes – ranging from green when the timetable is undisturbed to red for major crises – are assigned by the regional leaders. The assessment doesn't follow strict measures but is more like a subjective indication that depends heavily on the regional leaders' experience.

Table 3.7 Reliance on contingency plans

Country	Reliance on contingency plans or on improvisation
Austria	.33
Belgium	1
Denmark	1
Germany	1
Netherlands	0
Portugal	1
Sweden	.33

3.9 Automation of control

There is no doubt that the automation of control can contribute to the efficient solving of disruptions. Many countries are currently implementing various forms of automation. Automation can take different forms, ranging from the setting of all the switches and signals by the operator to implement a chosen solution, to computing solutions given certain parameters for the operator to implement. While full automation is often seen as the ideal situation, a lot has to happen before RIMs and TOCs can get there. Firstly, there are a vast number of parameters to take into account and current software is not able to compute everything correctly. Secondly, implementing automation often requires capital-intensive changes to the physical infrastructure. Thirdly, and importantly, we noticed that human operators do not necessarily get on very well with automation (of whatever kind). Age and experience may play a role in this. While we don't have any statistical evidence to back it up, we feel that we can confidently claim that older, more experienced operators don't want to rely on automation. This is partially a matter of pride, but also a matter of believing that human operators are capable of better and more creative solutions. Younger operators may feel more comfortable with automation. However, a case can be made that this reliance on automation comes at a price: the loss of the intuitive ability to 'feel' what does and doesn't make sense. Modern traffic management systems often feature more possibilities than human operators can comprehend. Operators may become fixated on computer screens and lose the detailed knowledge and experience of traffic management processes that is acquired through manual control, such as what is actually involved in braking and stopping a very long freight train.

Austria

Austria can arguably be seen as very advanced when it comes to automation. Rail traffic operations are mainly automated using the ARAMIS traffic management system, which makes it possible to track train positions and potential conflicts in real-time. The package also offers decision support. In such cases, the system generates operational solutions. Moreover, routes (switches and signals) are set automatically, and passenger information is automatically adjusted. Having said that, some lines are still operated from local switch boxes if there is no automation, and some sections of other lines have not yet been fully integrated. This is usually found on minor branches such as the line between Garmisch-Partenkirchen and Innsbruck. ÖBB-Infrastruktur's aim is to switch the entire network to automation in the long run but funds dictate the speed of conversion.

Belgium

Of all the countries in the sample, Belgium has the lowest degree of automation and relies heavily on manual control with the exception of the four high-speed railway lines that run on ERMTS. However, the control of these is more or less fully isolated from the operations of the regular network. Regular control is predominantly manual and partially effected through levers, switch boards and relays. New or renovated signal boxes are fitted with a new traffic management system and computer control.

Denmark

Denmark is the first European country planning to deploy ERTMS level 2 for both train track communication and the back office. The new signalling should make it possible to manage all rail traffic in Denmark from just two control centres. Implementation is still a long way off, however, and mired in politics, so many operations are still carried out manually.

Germany

Due to its history and the haphazard investments in infrastructure, German operations cover the full range from full manual control using levers on branch lines to high levels of automation on some high-speed lines. Part of the work load for operators comes from having to switch back and forth between different systems that have not yet been integrated. While some branch lines may not have a pressing need for automation due to their simple configuration, the lack of automatic train detection can be inconvenient. As in other countries in the sample, DB Netze is looking into expanding automation. To this end, it has acquired the Swiss Rail Control System, which provides conflict detection and simulates possible solutions.

The Netherlands

The Netherlands is the only country within the sample that has implemented full computer-based control and automatic route setting. This has decreased the workload significantly. However, regional traffic controllers still have to rely on their experience to detect conflicts between trains and to find solutions, i.e. the highest level of automation has not yet been implemented. As in Denmark, there is a recurring discussion about the need to switch to ERMTS level 2 but the scale of the costs associated with such a transition have prevented its roll-out over the entire network.

Portugal

Although Portugal is also in the process of implementing various forms of automation in certain sections of the network, branch lines will keep their simple form of control in the foreseeable future. The centralization from switch boxes to the five control centres is related to the transition from manual to partially automated control. Like ÖBB-Infrastruktur, Infrastruturas de Portugal has acquired ARAMIS but only the information modules and not the modules for automation. At the time of the site visit, management was busy preparing the software and hardware for implementation.

Sweden

Traffic control in Sweden has a relatively low degree of automation. Much work is still done by hand, even though the setting of switches and signals is mostly done remotely. We observed how operators would still use the pen-and-paper approach to make changes to the time-distance diagram. There are projects to introduce automation (e.g. STEG), but as the frequency of the train services is relatively low on large parts of the network there is no overall push towards full automation on the entire network.

Table 3.8 Automation of control

Country	Automation of control or manual control
Austria	.33
Belgium	1
Denmark	.66
Germany	.66
Netherlands	.33
Portugal	.66
Sweden	.66

3.10 Institutionalization of shared sensemaking

We have discussed the issues in terms of communication and the time needed to create a common operational picture on which decisions can be based. It is possible to facilitate and institutionalize shared sensemaking in the disruption management process. Examples of this include obligatory joint conference calls or the use of a crisis room in which operators from the different parties can put all the pieces of the puzzle together and discuss the status quo. While shared sensemaking seems like the obvious thing to do, it does not always occur. This is sometimes for pragmatic reasons (e.g. geographical dispersion) and sometimes because the time pressure is such that operators feel the need to act instantly and don't give themselves enough time to understand the situation fully. As with the other items discussed above, this involves a trade-off. While shared sensemaking is useful and needs to be facilitated, it may be impossible if the disruption is too ambiguous to be overseen. Decisions – even though they may not be optimal – will have to be made in the face of ambiguity at some point in order to get things going again.

Austria
Shared sensemaking is relatively well-catered for in Austria. The VLZ in Vienna has a fully-equipped crisis room. During major disruptions, all relevant parties (TOC emergency services etc.) are invited to join in order to arrive at a joint operational picture and to develop joint solutions. This facility is absent in the BLZs, but this doesn't seem to be a problem.

Belgium
The ROC in Belgium facilitates shared sensemaking: in fact, this seems to be its core operating principle. Face-to-face communication between the RIM and TOC is always guaranteed because operators cooperate in teams. Nevertheless, we observed that operators often didn't take a time-out to discuss ongoing activities and plans in a quick meeting. Most – if not all – discussions took place on the work floor in a rather improvised matter. As such, sensemaking is not institutionalized, even though the potential is there. Shared sensemaking is more difficult to achieve for operators working at switch boxes away from the ROC.

Denmark
Banedanmark has a dedicated and fully-equipped crisis room in its national control centre. It is used for almost every disruption that could threaten supra-local operations. Unlike in Austria, the crisis room is only used by operators from Banedanmark and from the TOCs, primarily DSB; the emergency services do not use it. As in the other countries, operators working elsewhere in the country can't use these facilities.

Germany
The NLZ has a crisis room that can be used in the event of major disruptions. However, this is not strictly necessary as the size of the NLZ and the relatively low numbers of operators working during a shift enable swift communication within the NLZ. A major caveat is that the crisis room of the NLZ is exclusively used by operators from DB Netze. Due to the sheer size and complexity of the German rail network, face-to-face meetings between RIM and TOCs are extremely difficult. Many TOCs work from different locations. Information exchanges have therefore become increasingly standardized and shared sensemaking has to be done by phone.

The Netherlands
The OCCR in the Netherlands has a crisis room that is available to all parties, but is only used in the event of major disruptions. We also often observed that operators of ProRail and Dutch Railways would arrange ad-hoc meetings at a coffee corner the OCCR. Outside of the OCCR, shared sensemaking is relatively difficult due to the many geographically dispersed regional control rooms.

Portugal
The control room in Lisbon has a fully-equipped crisis room overlooking operations. It is accessible for all relevant actors but is only used during major crises. The strict separation between RIM and TOC means that sensemaking across the board is not possible.

Sweden
Shared sensemaking in the Swedish case is primarily institutionalized through frequent joint teleconferences (by phone or Skype) called OPL. Any regional leader can call an OPL and they are generally joined by anyone who is involved, but also by operators who are not directly involved but who need to stay informed of developments. The OPL's primary purpose is to share all the information available in order to create a coherent operational picture from which everyone can work. OPLs are an important part of the daily routines and contribute strongly to shared sensemaking. Minor issues are discussed through an internal chat application.

Table 3.9 Shared sensemaking

Country	Shared sensemaking organized and institutionalized or not
Austria	.33
Belgium	.66
Denmark	0
Germany	.66
Netherlands	0
Portugal	.66
Sweden	0

3.11 Use of dispatching rules

An important part of disruption management is the use of dispatching rules. Dispatching rules regulate the allocation of capacity. They tell operators which trains need to go first, helping them to find a solution. This is not only important for the resumption of the disrupted service, it is also necessary in order to enforce a level playing field and fair access to the network when multiple TOCs are involved, as they often are due to the deregulated nature of the EU railway market.

Austria

As can be seen from the task distribution between the BFZs and the VLZ, long-distance trains are given priority over all other trains (apart from emergency vehicles) to ensure the conflict-free management of rail traffic by the BFZ. The BFZ may, however, deviate from these rules if doing so would benefit local traffic flows, but only in consultation with the traffic controllers in the VLZ. For instance, the third dispatching rule dictates that punctual trains (−5 to +10 min) should remain punctual. In practice, we observed that in both instances there is considerable pressure to prioritize long-distance and express trains, even if this means delaying local traffic.

Belgium

A total of fifteen dispatching rules give high-speed trains priority over slower trains; international or intercity services priority over local traffic and most passenger services priority over freight traffic. However, operators are allowed to deviate from these rules if doing so would help to restore services more quickly. During our observations, a bomb threat at Brussels North blocked all traffic in the Brussels region. We observed how international trains were the first to be dispatched, followed by regional and local trains. The order of dispatching local trains, however, seemed to be based on pragmatism.

Denmark

Banedanmark decides on the priority of trains. There are no formal dispatching rules and operators can do whatever it takes to get things running again. Consequently, experience plays an important role in the decision on the order of priority

Germany

In the event of a disruption DB Netz's dispatching guidelines prescribe a maximum usage of the remaining capacity, the need to improve joint punctuality of all trains, and the task of quickly rescheduling in order to operate according to an alternative plan. This rescheduling is done on the basis of dispatching rules that give priority to emergency vehicles, trains with express routes, and high-speed over slow-speed trains. TOCs can purchase an express (priority) status for their passenger and cargo trains to assure a swift and direct journey during disruptions. The dispatching rules are intended to ensure non-discriminatory access to the German rail network and to provide a framework for the dispatchers. However, one of the issues with the use of dispatching rules is that delayed express or high-speed trains will overtake slower but punctual trains. This sometimes causes severe disruption to local rail traffic, consequently increasing the workload for operators on those local services.

The Netherlands
In the Netherlands, train dispatchers refer to a set of dispatching rules (Trein Afhandelings Document or TAD) for the most common situations. These were developed jointly with NS. TADs tell the train dispatcher how long a train can wait for a connecting train and where to short-turn a train. They also provide resolution rules if there is a conflict between trains. However, not every conflict situation is covered in the TAD. Consequently, train dispatching still relies heavily on the skill and experience of the train dispatchers to decide on the right order. ProRail doesn't make a distinction between trains, but trains running on time are given priority over delayed trains.

Portugal
IP is tasked with restoring the time table after a disruption, and this is often done in consultation with the TOCs. There are some formal dispatching rules prioritizing certain trains over others. However, this prioritization also depends on the time of day. Intercity services normally have priority over commuter services, but this changes during rush hour when commuter services are given higher priority, reflecting the predominance of commuter services in Portugal. However, we observed that operators have the flexibility to deviate from the rules should the situation give them reason to do so.

Sweden
Like Denmark, Sweden doesn't have specific dispatching rules, other than giving trains that are running on time priority over trains that are too early or late. It is left up to the operators to do whatever it takes to resume optimal service. TOCs may, however, state their own priority list. Freight trains carrying iron ore travelling from the north of Sweden are often given priority due to the value and weight of their load. The same goes for trains transporting jet fuel to the national airport.

Table 3.10 Use of dispatching rules

Country	Use of dispatching rules or not
Austria	.33
Belgium	.33
Denmark	1
Germany	0
Netherlands	.66
Portugal	.33
Sweden	1

3.12 Wrap-up

This chapter has discussed how the various countries deal with the two groups of trade-offs: (a) centralization vs. decentralization, and (b) anticipation vs. resilience. Our qualitative assessment is based on our observations and interviews, and this is important because practices can (and often do) deviate from the way in which the system is formally designed. We will discuss the implications of our findings in the following chapter.

Chapter 4: The many paths towards effective disruption management

4.1 Introduction to the chapter

The previous chapters have shown that different countries have different ways of dealing with disruptions. Much, but not all of each country's approach is dictated by the contexts in which its RIMs and TOCs operate. For example, Germany's policies of rerouting long-distance trains across different nodes gives operators extra flexibility, but such flexibility is only made possible by its decentralized railway network. This option would be impossible in Denmark's more centralized railway network. The purpose of this chapter is to interpret the findings and derive recommendations that could be of use to ProRail – and possibly other RIMs and TOCs, too.

4.2 Aggregated results

The scores assigned to each factor can be aggregated for each country. The numerical results are shown in table 4.1.

	Distribution control centres	Allocation of decision rights	Autonomy of local control	Comm. and nodes	Co-location of RIM and TOC	**Average [a]**	Contingency plans or improvisation	Automation or manual	Shared sensemaking	Dispatching rules	**Average [b]**
Austria	.33	.66	.66	.33	.33	**.46**	.33	.33	.33	.33	**.33**
Belgium	1	0	0	.33	0	**.26**	1	1	.66	.33	**.74**
Denmark	0	0	1	0	.33	**.26**	1	.66	0	1	**.66**
Germany	1	1	1	1	1	**1**	1	.66	.66	0	**.58**
Netherlands	.33	0	1	1	.66	**.59**	0	.33	0	.66	**.24**
Portugal	.33	.66	1	.33	1	**.66**	1	.66	.66	.33	**.66**
Sweden	.33	.66	1	.66	1	**.73**	.33	.66	0	1	**.49**

Table 4.1 *The scores per country / factor and the averages per group (a) centralization vs. decentralization, (b) anticipation vs. resilience.*

Figure 4.1 shows the average scores for each trade-off (a) centralization vs. decentralization and (b) anticipation vs. resilience, per country. Note that this figure is purely illustrative and does not imply a precise measurement. Three 'clusters' can be discerned. First of all, Austria and the Netherlands are both moderately centralized and of the seven countries, they rely the most heavily on a formalized approach to dealing with disruptions. As we mentioned earlier, formalization reduces the coordination burden and produces more predictable outcomes, but may also reduce a system's ability to adapt to unanticipated events. The second 'cluster' consists of Belgium and Denmark because they combine a centralized structure with an emphasis on resilience. Operators in these countries seem to enjoy more flexibility when managing disruptions than their peers in the Netherlands. The third 'cluster' contains Sweden and Portugal, primarily because they have a higher degree of decentralization than the other countries.

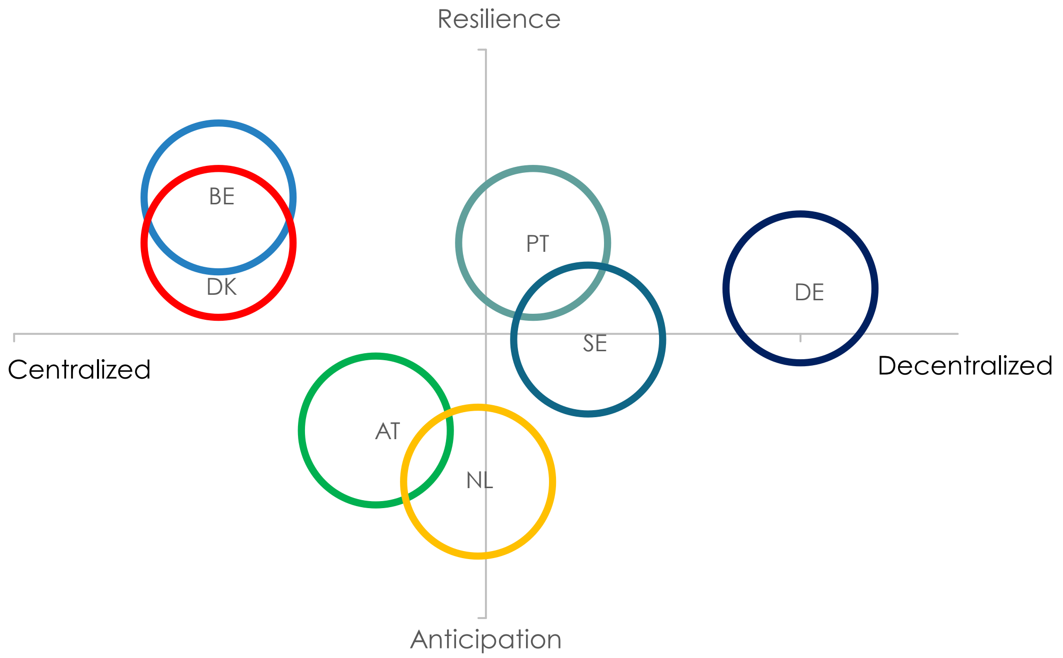


Figure 4.1 *The countries' average scores on each trade-off visualized*

Germany appears to be somewhat of an outlier. It is much more decentralized than the other countries. This is most probably a reflection of the size and complexity of its railway network (see Chapter 2) in addition to its numerous TOCs, both of which limit the possibilities for centralized control. In other words, Germany's unique characteristics are clearly reflected in the methods it uses to organize disruption management.

The most important point about this whole exercise is that the results show a degree of equifinality: i.e. there are several ways to achieve an overall similar type of system, as is illustrated by the three 'clusters'. Although rail systems are essentially quite similar in what they do (transferring passengers and goods) and how they do it, we nonetheless found several important differences between the countries studied. This study therefore shows that there is not one best way of structuring rail disruption management. It is only by comparing practices that the range of possibilities becomes apparent. As such, comparative studies help rail infrastructure managers and train operating companies to reflect on their own work routines, which have been shaped over a long period of time and are often taken for granted. It also shows that a railway network's characteristics influence the way in which disruption management is organized. But it does not determine everything. The clearest examples here are Belgium and the Netherlands. Although the railway networks in both countries have comparable features, their disruption management process is organized quite differently. This gives reason to believe that although infrastructure is important it does not necessarily restrict all opportunities to organize things differently, should that be regarded as desirable.

4.3 Lessons learned

In Chapter 1, we stressed that one should exercise caution when it comes to relating the way in which disruption management is organized and executed. The complexity of rail disruption management makes it impossible to look for a direct causal link between how disruption management is organized and the overall performance of a rail system. There are many contextual variables that have a major impact on overall performance, and these can vary from country to country. The specific characteristics and context of a system not only help to explain how disruption management has been organized; they also determine the available room for improvement and what can be learned from other countries. So while we won't state that "country x is better organized than country y", we believe that we have seen many interesting things in each country that deserve highlighting within the overall goal of the report as given by ProRail. These have been grouped under several general lessons learned.

The relationship between central and regional or local control centres

One reoccurring theme during the site visits was the ambiguity concerning the division of roles and responsibilities between the central and regional or decentral control centres. Although national control centres can be envisaged as being situated 'on top' of the many regional control centres, it remains very difficult for operators in the national control centres to assert direct control over the regional centres' activities. This is not only due to the geographical distance between teams, but also because operators in the national control centres rely on the knowledge and expertise of local operators regarding the safe allocation of rail capacity in their own area of control. Effective disruption management therefore relies on effective cooperation between both layers of control.
During the site visits, we observed that this is difficult to achieve. There are often no strict guidelines on when national operators should intervene in local matters or when regional operators should escalate situations. This ambiguity concerning roles and tasks may lead to friction between regional and national operators. In Austria and Germany we have

seen how the overlap in roles and tasks and ensuing ambiguity has been greatly reduced by making the national control centres solely responsible for long-distance traffic. The strict task distribution between BLZ and the VLZ in Vienna seems to work rather well and is generally regarded as a major improvement upon the previous situation. In Germany we also noticed that operators in the NLZ are supported in their monitoring role with specific traffic management tools that only show long-distance trains with a minimum delay of five minutes.

Although it is important to define roles and responsibilities, we have found that this is not enough. It is also important that operators and teams are aware of each other's tasks, roles and information needs. This can be achieved by joint training sessions. Unfortunately, there are often not enough resources and time to initiate such training sessions and consequently training is often given within single teams. In Sweden we saw how cross-training is used to make operators more aware of how their actions influence other teams in the network and why it is important to keep each other up-to-date. In Denmark we also saw how certain operators would divide their working hours between DCDK and a regional control centre (such as the one in Copenhagen at a stone's throw from DCDK). This taught them to appreciate what decisions from one side mean for the people working on the other side, constituting an informal but highly effective form of cross-training between centralized and decentralized layers of control.

Information sharing during disruptions

Swift and complete dispersion of information among teams is crucial to their ability to respond to a disruption in a quick, coordinated manner. We have seen major improvements in the information systems used to support operations and decision-making. While these information systems are important, they can't fully replace the more detailed telephone communication, especially during large-scale, complex disruptions when the operational picture is often unclear and a lot of communication (sensedemanding and sensegiving) is needed to create a shared understanding. One of the problems is that regional control centres can easily become overwhelmed with information requests during a disruption and that telephone lines quickly become overloaded – as witnessed in Belgium and the Netherlands. It is therefore important to find the right balance between requesting information and waiting for information to be provided by others. In Denmark, we observed that operators in DCDK trust others to deliver information when needed and therefore hold back from collecting information themselves.

In most cases, we also noticed that it is important that there is someone assigned (usually the team leader) to collect and distribute information within and across the control centres of both the RIM and TOCs. Preferably this would be someone not directly involved in managing the disruption. Prime examples are the BeKo in Austria and the ROL in Sweden.

We have already addressed the importance of collective sensemaking in order to integrate the available information and to create a common operational picture. Collective sensemaking is primarily organized in the national control centres, without the direct involvement of regional operators. The OPL meetings in Sweden show that structured and frequent (i.e. institutionalized) conference calls could be a good way of facilitating collective sensemaking with regional operators.
A final observation we would like to share is that the more information is shared, the fewer information requests there will be. It therefore seems logical to provide as much information as possible, as soon as possible, through the information systems. We noticed, however, that operators often refrain from sharing information when a situation is still uncertain or if they think it might be solved in a couple of minutes. Making this information available in the information system could result in the unnecessary activation of the network. In addition, some operators may withhold information if they believe that management will hold them accountable if the information is not perfect. In Belgium and Sweden we have seen how a simple messaging system could be used as an alternative way of sharing information quickly with a select group of operators in order to communicate informally, without having to worry about wording and the status of the information, as it is completely separate from the public, formal information.

The role of contingency plans

Contingency plans can be a very effective way to coordinate the rescheduling activities of the different control centres and to provide passengers with reliable travel information. Moreover, when agreed upon by the TOCs they can provide non-discriminatory solutions. Especially in a country like the Netherlands, with its extremely intensively used rail network, predefined plans are a good way to respond quickly to disruptions and prevent them from spreading to the rest of the network. The numerous and detailed contingency plans in the Netherlands are unique in our sample and could set an example for other countries. However, we would also like to point out that there are disadvantages to adhering strictly to predefined plans, as this may lead to rigidity and the oversimplification of operational conditions, when what is actually needed is to revise the plans. Alternatively, one can opt to have only limited contingency plans or none at all in order to maintain the flexibility required to deal with every unique disruption. This, however, means less predictability. This approach seems to work on less dense networks (e.g. Portugal) or if there are numerous possibilities to reroute trains (e.g. Germany). In Austria and Sweden we have seen how contingency plans mainly serve as a template for developing an actual solution and this seems to be a highly efficient way of integrating predictability with flexibility. Another method for providing predictability to those involved in managing disruptions and passengers is the development of standard recovery times. In Denmark this is done for the most commonplace disruptions. Even if a disruption is solved sooner, train services won't resume before the expiry of the standard recovery time. This seems to work very well in avoiding disappointment among passengers and also gives operators a clear and manageable time frame in which they can try to restore services, making them less likely to take rash decisions.

The relationship between TOCs and RIM

The separation of the RIM and incumbent TOC, along with the entry of non-incumbent TOCs to the rail market, has created important new coordination challenges during disruption management. We have seen in this study that there are significant differences regarding the extent to which each country has opened up its market and how countries deal with the issue of coordination. Countries where the incumbent TOC is still dominant (e.g. the Netherlands, Denmark, Austria, and Belgium), have opted for co-location in the national control room. Others countries, (e.g. Sweden and Portugal) have opted for full separation of their daily operations. Co-location definitely has it merits. In Belgium, the country with the tightest integration of RIM and TOC in single teams, we noticed that these teams encountered few difficulties when sharing information and making joint decisions. Naturally, these teams work under the condition that the separation between RIM and TOC is not strictly enforced.

Other countries in the sample have considerably more competition between TOCs both for passenger and freight services. Moreover, current EU policies on the opening up of the domestic rail market will make it difficult to maintain this close relationship between RIMs and the incumbent TOC. It is therefore important to study countries like Sweden and Germany. Germany is a prime example of an open market in which it is possible to coordinate decisions with over 350 TOCs during disruptions. Likewise, Sweden has ample experience in dealing with competing TOCs. In these countries we have seen that it is important that the RIM has effective decision-making powers during a disruption if it is to be able to optimize the rail traffic for all TOCs. Moreover, providing up-to-date information to TOCs on disruptions through information systems or e-mail (e.g. Basun, BZ-info), shared (restricted) traffic management tools, or, of course, by phone is very important, not only to allow TOCs to reschedule their resources quickly, but also to avoid being overwhelmed by information demands. A possible downside is the need to formalize some of the communication in order to remain transparent and accountable to all TOCs, as seen in Germany and Sweden.

Automation and centralization of rail traffic control

As we have already mentioned in this report, all of the countries in the sample are working on further automation and centralization of rail traffic control. This transition is important to safely accommodate the increase in rail traffic on the often already congested rail lines. Naturally, automation and centralization also have their benefits from a cost perspective, as they will mean fewer staff and buildings. The transition from a manually controlled, decentralized system to an automated, centralized system is long and complex, and RIMs often encounter resistance from both operators and politicians. We have also noticed that the automation and centralization of rail traffic control creates new challenges. The new and modern regional control centres are often located in a limited number of large cities. This means that operators either have to move to the new location, which is difficult because of high house prices, or accept long commuting times. In practice, older operators often reject both options and new operators have to be hired. Hiring new operators and keeping them on board is, however, difficult. Train dispatching is a relatively unknown profession, with irregular hours and stressful moments and it is not uncommon for people to move to different positions and jobs after a few years, an issue that seems to haunt most countries.

In an attempt to further professionalize traffic control we also noticed that RIMs try to hire people with higher educational qualifications. In practice, it is often difficult to retain them, not only because of the aforementioned stress and irregular hours, but also because automation (e.g. automatic route setting) has made human intervention less pressing for most of the time and shifts therefore consist of short periods of action interspersed with long periods of inactivity. The Dutch policy of making employees change control areas every two hours seems to help keep people focussed. In addition, downtime can be used for training.
Automation also has a major effect on the dispatching of operators. One reoccurring theme has been the difficulties that older operators experience in adopting and trusting new technologies, while less experienced operators may lack the essential knowledge and skills required for resuming manual control when necessary and be unable to oversee the impact of their decisions. To tackle the latter issue, we saw that some countries actively familiarize new train dispatchers with the rail system or make them work at train stations for a few months to learn about the world beyond the control centres.

4.4. Conclusions

This report is the first time that disruption management in a range of European countries has been mapped and compared. Observing the difficult circumstances and immense complexity of keeping the system running has left us with a deep admiration of the operators' dedication and the hard work they perform on a daily basis. We have observed strengths in each system and identified points that could be improved. Overall, railway disruption management is a complex task that demands a great deal of capacity. The countries we researched manage to make things work – each in their own way. This may be one of the more interesting findings: that similar pressures such as deregulation, competition and EU frameworks give rise to highly diverse systems. Path-dependence plays a major role in this situation. As such, there is no single best way to organize disruption management. Situations that have evolved over time must be taken into account, and they lead to various trade-offs being made. In one country this may lead to more centralization and standardized contingency plans, while another country will require decentralization and place a greater emphasis on improvisation. It is therefore crucial to investigate and understand the advantages and drawbacks of the various approaches and how they work out in practice.

We would like to end our overview with the comment that at the end of the day, efficient disruption management requires the propensity to work together. No matter the technology used or the complexity of the network, disruption management hinges on the willingness of operators to find joint solutions. There is a constant drive to develop and implement better technology to aid disruption management. And while we agree that disruption management can benefit from technological advances, we believe that the human in the system plays a crucial role that cannot be eliminated by technology. There is still a great deal of unchartered territory in our understanding of the interaction between human operators and technology during railway disruption management.

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Appendix - Overview of respondents per country and organization, in order of meeting

Austria	
Location	*Function*
Regional traffic control Innsbruck	Regional leader Executive leader Leader traffic and production Manager operations Regional coordinator Emergency coordinator Train dispatcher Kufstein Regional traffic controller Wörgl
Central traffic control	Leader traffic control Traffic and production manager

Belgium	
Location	*Function*
Central traffic control Brussels	Deputy operational planning Team leader operational planning Manager operational planning Developer communication system Planner General supervisor Traffic officer Team leader Antwerp Regional traffic controller
Signal house Brussels	Instructor

Denmark	
Location	*Function*
Central traffic control	Director Banedanmark Manager traffic control Punctuality manager DSB Director disruptions DSB Duty officer Monitor freight traffic Duty officer DSB
Local control centre Copenhagen	Manager Copenhagen Duty officer Train dispatcher
S-train Copenhagen	Duty officer

Germany

Location	*Function*
Central traffic control	Shift leader Traffic controller West Network coordinator Network coordinator
Local control centre Frankfurt	Coordinator Frankfurt Deputy coordinator Emergency coordinator Train dispatcher Train dispatcher Rail signaller Rail signaller Manager Frankfurt
DB Regio Frankfurt	Monitor rolling stock DB Traffic information DB Coordinator DB

Netherlands

Location	*Function*
Local control centre Utrecht	Team leader Train dispatcher Regional traffic controller Regional traffic controller

Portugal

Location	*Function*
Control centre Lisbon	Head railway operations Manager International Representation Head traffic control Production officer Training and development traffic management system

Sweden

Location	*Function*
Central traffic control	Head national coordination centre
Local control centre Stockholm	Production manager Manager Stockholm Regional leader Regional leader Train dispatcher Traffic information Production manager Train leader
Local control centre Gävle	Manager Gävle Production manager Operations manager Train dispatcher Train leader