Communication and Sensemaking in the Dutch Railway System: Explaining coordination failure between teams using a mixed methods approach

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Early in 2014, the Dutch railway system spiralled out of control after traffic management was confronted with the decision to take four double switches and two rail tracks out of service. A lack of coordination between the responsible teams resulted in the decision to stop all traffic in one of the busiest parts of the network during the rush hour. In this study we aim to understand why the teams in the Dutch railway system were not able to adopt a coordinated approach to reschedule rail services. To answer this question, we used a mixed-method approach by combining dynamic network analysis (DNA) with sensemaking. Our analyses show that a diverging framing of the situation accumulated over time, leading to inconsistent actions, incorrect assumptions and a lack of effective communication. Informal and indirect communication spurred uncertainty and promoted negative emotions, which eventually resulted in a conflict between the actors. We discuss the difficulties of managing ambiguous events in multi-team systems.

Keywords: Coordination; sensemaking; communication; railway; Dynamic Network Analysis; complex system disruptions

1. Introduction

Early in 2014 the Dutch railway system spiralled out of control after the rail infrastructure manager decided to take four double switches and two rail tracks out of service. This decision was taken early in the afternoon by the responsible track team who thought that the equipment no longer met the authority's safety standards. These switches and tracks are located at three of the busiest train stations in the Netherlands in two different rail traffic control areas (from here on: areas A and B). Since their decision would have a huge impact on the train service, the track team decided to give the other teams several hours of preparation time. Regardless, what should have been a coordinated procedure, resulted in a loss of control. While the train dispatchers in area B managed the process adequately, train dispatchers in area A decided to stop the entire service during peak hours. Many passengers were stranded, which drew negative attention from the media and politicians. We aim to answer the following research questions: Why were the actors in the railway system unable to adopt a coordinated approach in order to adjust operations, and what explains the difference in response between the traffic control centres of areas A and B?

Like many other critical infrastructures (CIs) in Europe, the Dutch railway system has undergone major changes over the past decades under the influence of EU policies. The Dutch railway system has changed from a mostly large-scale integrated monopoly into a networked system consisting of multiple private and public organizations with diverging goals and specialized tasks, which may be conflicting (De Bruijne & Van Eeten, 2007; Schulman, Roe, Eeten, & Bruijne, 2004). Providing reliable services therefore requires multiple teams, who are separated by organizational and geographical boundaries, to continuously negotiate and renegotiate issues related to reliability (De Bruijne, 2006). However, this network of teams poses additional challenges in terms of coordination and communication. For example, studies have found that geographically dispersed teams have difficulties in distributing information evenly, accurately, and in time (Hinds & McGrath, 2006). We are therefore interested in how actors in such networks communicate. To study the flows of information, we used social network analysis tools, more specifically Dynamic Network Analysis (DNA).

The premise for this research is that coordination problems aren't just the result of deficiencies in the quantity of information flows. Given the contextual differences in which people are working and their differences with regard to knowledge, goals and expertise, there is a considerable chance that information will be interpreted differently (Vlaar, van Fenema, & Tiwari, 2008). This could lead to different understandings of specific situations and therefore to potential conflicts regarding the course of actions to be followed. Successful coordination stems from a congruent framing of a situation (Cornelissen, Mantere, & Vaara, 2014). Consequently, the structural dimensions of communication need to be studied in conjunction with the attribution of meaning in order to understand coordination in a network of diverse teams. In this study we therefore combined DNA with theories of sensemaking to understand how information is processed within and among actors in order to understand how their actions made sense to them at that time (Dekker, 2006; Muhren, Eede, & Van de Walle, 2008).

This research contributes to the literature in three areas. First, we extend coordination beyond individual actors or collocated groups and look at coordination on the level of the whole network of geographically and organizationally separated teams, something which has received little attention (Gittell & Weiss, 2004; Zaccaro, Marks, & DeChurch, 2012). Second, we use a mixed-method approach by combining Dynamic Network Analysis with an analysis of sensemaking. Third, we answer the call for the integration of time dynamics into network studies using DNA, to see how the structure of the inter-organizational network changes over time and how the relative importance of actors within the network changes (Abbasi & Kapucu, 2012; Wolbers, Groenewegen, Mollee, & Bím, 2013).

The remainder of the paper is structured as follows. We will discuss the dynamics of communication and sensemaking in network coordination in section 2. The mixed methodology is explained in Section 3, followed by an introduction to the case in Section 4. We will identify key moments and actors by looking at communication patterns in Section 5. The case is analyzed in Section 6. The discussion and conclusions are presented in sections 7 and 8.

2. Coordination and sensemaking between teams

Coordination can be achieved through pre-defined plans and procedures, but these formal modes of coordination are not always able to deal with the dynamics and uncertainty of specific situations and may severely limit the flexibility of organizations (Bigley & Roberts, 2001; Johansson & Hollnagel, 2007). Adjusting to uncertain situations requires actors to mutually adapt and collectively improvise (Cornelissen et al., 2014). Communication plays a crucial role in the coordination of actions. Especially rich informal communication has been identified as one of the most important sources of resilient system performance (Roe & Schulman, 2008). Regular information updates to other team members help to create and maintain a shared understanding of problems and the actions needed to tackle them (Kontogiannis & Malakis, 2013). Thus, accurate information updates should be provided regularly and on time (Gittell & Weiss, 2004).

While previous researchers emphasized the importance of effective communication for successful coordination, they also found that geographically distributed teams face greater obstacles in sharing information effectively. Since communication between distributed teams is often technology-mediated, the information flows in these processes are restricted (e.g. number of communication lines) and the updating of information suffers from delays (Salas, Burke, & Samman, 2001). As Hinds & McGrath (2008) describe, distributed work settings lead to less informal and spontaneous communication in comparison to teams that are collocated. People working at different locations will also have different information assumptions, preferences and constraints (Vlaar et al., 2008). Consequently, information is often distributed unevenly and communication patterns can be quite unpredictable (Powell, Piccoli, & Ives, 2004). Moreover, since information flows and format are mediated by technology, important visual and social cues associated with traditional face-to-face interaction methods that help to interpret communication and team members' actions are absent (Fiore, Salas, Cuevas, & Bowers, 2003). In short, challenges of understanding and communication are more salient in a network of diverse teams, which could result in the development of a different framing of situations.

It is therefore important that the communicating parties can reach at least a congruent or compatible shared understanding during non-routine situations, (Fiore et al., 2003). Following Wolbers & Boersma (2013), we see this act of creating a sufficiently shared understanding as a *process of sensemaking*. Sensemaking means that actors try to understand events that are novel, ambiguous or contrary to expectations. They deal with this ambiguity or uncertainty by creating plausible interpretations of reality through the extraction of cues from their environment to create an initial sense of the situation (Maitlis, 2005; Maitlis & Christianson, 2014; Sandberg & Tsoukas, 2014; Weick, Sutcliffe, & Obstfeld, 2005). Cues trigger sensemaking as they indicate a discrepancy in the ongoing flow of events, which creates uncertainty about how to act. Actors then try to interpret and explain these surprising events by placing these cues in a mental model or frames of roles, rules, procedures and authority relations (Weick, 1993). These frames thus play an important role in terms of coordination as they trigger specific activities and expectations regarding the behaviour of others (Cornelissen et al., 2014). Finally, the sense made of the situation has to be put into action, to see whether it restores the interrupted event or if it is necessary to revise the interpretation. Sensemaking is therefore essentially an *episodic* process that occurs from the moment organizational activities are interrupted until they are restored or permanently interrupted and contains three recurrent steps: noticing and bracketing cues from the environment, creating interpretations and action taking (Maitlis & Christianson, 2014; Sandberg & Tsoukas, 2014).

Sensemaking is a social process because actors interpret their environment in and through interactions with each other, thereby constructing shared accounts that allow them to comprehend the world and act collectively (Maitlis, 2005). Actors can therefore influence the sensemaking and meaning construction of others, a process that is called *sensegiving* (Gioia & Chittipeddi, 1991). Actors can also actively demand information and clarification, which is called *sensedemanding* (Vlaar et al., 2008). As Cornelissen et al. (2014) put it, successful or failed coordination depends on how actors individually and collectively frame and reframe situations as a basis for action. These accounts don't have to be completely overlapping, but they should be equivalent enough to allow coordinated action (Maitlis & Christianson, 2014). However, the creation of a shared understanding is a difficult task that requires much effort and interaction (Bechky, 2003). The responses to violated expectations or ambiguous events depend on a variety of factors, e.g. individual, social, or organizational identity and personal and strategic goals (Maitlis & Christianson, 2014). This means that sensemaking is tied to individuals and that meaning in organizations is often contested because of the different positions, interests and backgrounds of actors (Brown, Stacey, & Nandhakumar, 2008).

To sum up, coordination in a network of diverse teams requires both effective information sharing and acts of collective sensemaking in order to create a sufficient shared understanding of the task situation. In this study we therefore combined Dynamic Network Analysis to capture the flows of information with a qualitative analysis of how this information is processed by the actors. In the next section we will explain how we gathered and analyzed the data for both the DNA and the sensemaking process and how we combined both methods.

3. Research methodology

We obtained recordings of all telephone conversations between all actors involved in the disruption. From these recordings, we selected the calls in which information on the switches and tracks was shared between actors. These recordings were transcribed (156 telephone calls in total). In addition, we carried out 9 in–depth interviews with actors involved in the case. Respondents were selected on the basis of their different roles and their geographically different locations. The interviews were used to reconstruct the events of the day from their respective locations. All interviews were transcribed. We also studied all relevant written documents, such as shift reports, e-mail conversations and logs. Finally, we attended a meeting during which actors reconstructed the day and shared their perspectives on the events. We observed this meeting and took detailed notes.

In order to reconstruct the network, it is necessary to know "who talks to whom and at what time". The telephone recordings offer rich and complete network data. Most of the files included information on the specific actors communicating and the time of communication. We transcribed the recordings and then translated them into numerical data. Using these data, we created an edge list containing the sources and targets of information flows and the time of communication. The telephone conversations don't cover the communication between actors located in the same room. The interviews and documents fill in this data-gap.

Next, we created six time slices, each lasting half an hour, following the example of Wolbers et al. (2013). Comparison of the different time slices shows how the network evolved over time. We found that a thirty-minute time interval offered us enough detail to show the general communication dynamics. We also created a two-mode network that shows which actors (mode 1) were involved during certain time periods (mode 2) of the process. The two-mode network was recorded as an incidence matrix, marking the presence (1) or absence (0) of actors in the different time periods (seen as events). The relationship between the two modes shows how many actors were actively communicating during each specific period of time. To show the relative importance of a time slice, we divided the number of actors in a time slice by the maximum number of actors (Borgatti & Halgin, 2011). This two-mode analysis required us to use time slices of fifteen

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minutes in order to obtain a more detailed picture of the network development. We used the software package ORA[1] to structure the data.

The metrics from the DNA form the backbone for the analysis of the sensemaking process. To this end, we performed a qualitative analysis of the telephone conversations. This allowed us to identify which frames emerged, persisted or disappeared throughout the day, and how that was caused by both sensegiving and sensedemanding activities. First, we coded cues or occurrences that interrupted the expectations of actors regarding normal work practices. This is where actors collect and bracket information to get an initial sense of the interrupted situation (Sandberg & Tsoukas, 2014). We then focused on how these events were categorized as interruptions to define a specific situation. Following Cornelissen et al (2014), we coded words and expressions within communication that cued or prompted a cognitive or schema of interpretation. In this step we also looked for the factors influencing sensemaking as mentioned in the literature, i.e. identity and emotions. In the final step, we identified the actions taken by actors based on the framing of the interrupted situation and how this fed into the next phase. This allowed us to detect whether and how frames are updated with the help of new information.

4. Introduction to the situation

The Dutch railway system is managed by the government-owned organization ProRail, which manages the maintenance of the railway network, assigns capacity to the train operating companies (TOC) and monitors and controls all train movements. Maintenance has been outsourced to contractors, but is monitored by ProRail's track managers and track inspectors. Railway traffic is controlled by thirteen regional traffic control centres. Regional traffic controllers optimize traffic flows within their own region and train dispatchers are responsible for safe rail traffic on the sections assigned to them. The management of the railway system is decentralized, with considerable local autonomy. Over the years, this has led to problems with local optimization and working at cross-purposes. A national control room, the Operational Control Centre Rail (OCCR), was established in 2010 to overcome such problems. In the OCCR, ProRail and Dutch Railways (by far the largest TOC in the Netherlands) monitor the railway system at the national level. We present the main actors in the Dutch railway system in Table 1[2].

Table 1.
The main actors involved in the case and a description of their role

Role	**Abbreviation**	**Role description**
Track Manager	WD 2 AM	Is responsible for the quality of the railway infrastructure in order to assure safe usage
Track Inspector	-	Supports the track manager by monitoring deviations and consulting him on corrective measures

Regional Traffic Controller	Traffic Control	Is responsible for the optimization of rail traffic flows in specific geographical areas.
Train Dispatcher	-	Is responsible for the safe allocation of railway tracks to trains, primarily by using signalling and controlling switches
National Asset Manager Coordinator	RIIB	Monitors incidents, malfunctions and maintenance work and their impact on railway traffic at national level in the OCCR
National Traffic Coordinator	RLVL	Manages railway traffic at national level in the OCCR
National Traffic Controller	LVL	Monitors the railway traffic on the main corridors of the railway system in the OCCR
Power switching and monitoring centre	SMC	Takes calls on malfunctioning infrastructure and reports them to the contractors
National Train Operating Coordinator	LBC	Manages the train operations for Dutch Railways at national level in the OCCR.
Team Leader	TL	Team leader of the regional traffic control centres
Node Coordinator	NC	Manages the shunting of trains at the large stations

We began our study when a regular inspection was conducted by the contractor in area A on February 19th, 2014. The contractor noticed that two rail tracks did not meet the safety standards defined by ProRail. This did not mean that there was an immediately unsafe situation, but action was required to assess the situation. The contractor informed the track inspector about these deviations at 8:30. At the same moment the track inspector was reading his monthly reports on four double switches (2 in area A and 2 in area B), which had been showing deviations from safety standards for some time. These switches were being monitored on a monthly basis. Large-scale renewal of switches had been scheduled for some years, but they had been postponed due to a lack of funds. Subsequently, the track team started to deviate from their own safety rules and had to increasingly rely on their own expert judgments. Audits conducted by the Human Environment and Transport Inspectorate, in which they rebuked the maintenance team for not following their own rules, served as a wake-up call. This made the team aware of their own behaviour and changed their perspective on how to apply safety standards. Consequently, the track inspector and track manager decided that the switches and tracks should immediately be taken out of service and that large-scale renewal was the only viable option left.

The formal procedures prescribe that train dispatchers should be notified immediately in the event that rail infrastructure is no longer safe to be used. This allows them to immediately take the required safety measures to prevent trains from running over the designated switches and tracks. The SMC should provide the train dispatchers with a specific reference number (RVO number), which is also used by the contractor. In view of the huge impact of their decision on the train service, the track inspector and track manager decided that the switches and tracks could be used until 18:00 to give themselves and others some preparation time. Hence, they decided to issue an early warning to the OCCR, to let them coordinate the whole process. As the track inspector explained: "In my opinion when you call the OCCR, which is our big institute, the coordination centre, they will manage things. They will make sure that the loop is closed and the train dispatchers are informed."

However, the train dispatchers were not officially informed about the switches and tracks until just half an hour before the 18:00 deadline. Minutes before the deadline, the train dispatcher in area A deemed it necessary to suspend all rail traffic in the middle of rush hour. We will analyze the events leading up to this decision.

5. Identifying key moments and actors in the process

We start our analysis by making a reconstruction of the flows of information between the different teams and organizations leading up to the decision. The quantitative network analysis acts as a first stage in our research to identify key moments and actors in the process, which serve as important starting points for a more in-depth qualitative analysis of how the information was processed. We identified a total of 156 instances of information sharing among 40 actors. To grasp the dynamics in the spreading of information we created six time slices of half an hour each (from 15:15 until 18:15). Each time slice shows all the information exchanges between actors or nodes in that period. Network graphs of each time slice, showing the development of the communication network over time, are presented in Figures 4 through 9. In the figures each node represents an individual performing a specific role in the process. The round nodes are actors of traffic management, the square nodes are asset management, triangular nodes are Dutch Railways and the diamond-shaped nodes are contractors. The arrows show who provided whom with information during that specific time period.

We then used several network metrics to quantitatively assess the development of the network over time. As Figure 1 shows, the number of actors involved and interactions fluctuated throughout the process, with a peak in the number of interactions at time slice 6 (17:45-18:14). The spike in the number of actors involved and information exchange between time slices 2 and 3 (15:45-16:44), as well as the sudden drop at T4 (16:45-17:14), are especially remarkable and need further investigation.

Figure 1: Number of actors and interactions throughout the process.

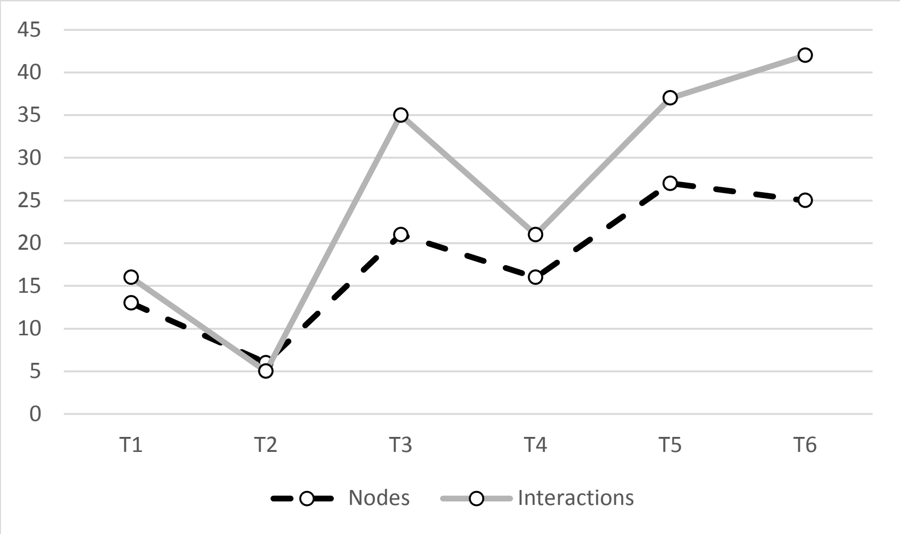
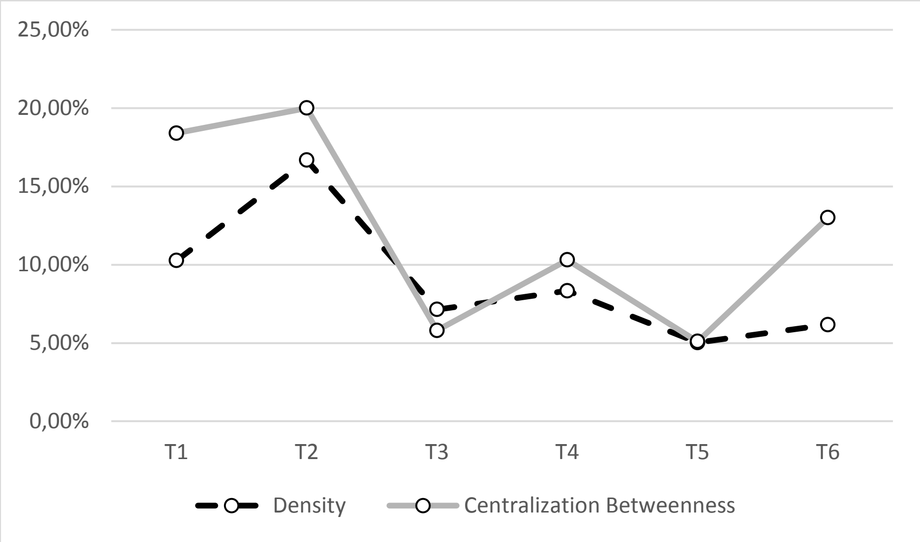


Figure 2 shows the density and betweenness centralization scores of the networks. Density describes the number of links between nodes as opposed to the maximum number of linkages possible. A dense communication structure enables a free flow of information between actors and can therefore facilitate coordination. Furthermore, a dense network also gives actors more opportunities to engage in sensemaking dialogue with others. As Figure 2 shows, density increased slightly during T1 – T2, but then fell to five percent at T5. Overall, the density is very low, which shows that many actors were not directly communicating with each other, i.e. the network was rather sparse, resulting in long communication lines. Betweenness centrality measures the extent to which a particular node lies in-between the other nodes in the network. The more central an actor is, the more control he or she has over information flows through the network and the more able to coordinate group processes (Hossain, Wu, & Chung, 2006). Networks with a high betweenness centralization thus have one node or a small group of nodes that have more potential to control the flows of information. Figure 2 shows that the network features high centralization at T1 and T2, before becoming more decentralized in the following time periods. The overall low percentages as opposed to the theoretical maximum indicate that there was little potential for a single actor or a small group to control the information flows. This was confirmed by one of the actors.

National Coordinator Rail: *"It is true that everyone had received some information, but they were just bits and pieces of information. We all knew that something was going on, but there was no one in control of the process."*

Figure 2: Density and betweenness centralization of the network over time.



It is also important to identify the most central nodes or actors in each time slice. Table 2 shows the three most central actors based on their degree and betweenness centralities. Although there are differences in the rankings between the time slices, some actors show a high level of consistency in terms of centrality. These are the National Asset Manager Coordinator (RIIB 2), National Traffic Controller (LVL 1), and the National Traffic Coordinator (RLVL) in the OCCR and the Regional Traffic Controller of area A. Their consistency can be seen as an indication of their ability to digest and distribute information in different time periods (Wolbers et al., 2013). As such their central position in the network makes them important in terms of sensedemanding and sensegiving and we should therefore follow up on the role of these actors in the sensemaking process.

Table 2.
The most central actors per time slice in terms of degree and betweenness centrality

Time Slice	Degree	Betweenness
T1 **(15:15-15:44)**	1. RIIB 2 2. RLVL 3. WD 2 AM	1. RIIB 2 2. RLVL 3. LBC
T2 **(15:45-16:14)**	1. RIIB 2 2. 3.	1. RIIB 2 2. 3.
T3 **(16:15-16:44)**	1. Traffic Control A 2. RLVL 3. LVL 1	1. Traffic Control A 2. LVL 1 3. RIIB 2
T4 **(16:45-17:14)**	1. RIIB 2 2. Traffic Control A	1. Traffic Control A 2. LVL 1

	3. LVL 1	3. RLVL
T5 **(17:15-17:44)**	1. WD RBI VL 2. RIIB 2 3. RLVL	1. WD RBI VL 2. RLVL 3. RIIB 2
T6 **(17:45-18:14)**	1. RLVL 2. LVL 1 3. RIIB 2	1. RLVL 2. Train Dispatcher A1 3. RIIB 2

Finally, we created a two-mode network on the basis of time slices of fifteen minutes to identify the critical moments of coordination in more detail. Critical periods are the ones when many actors are connected together and information can be shared to create a common understanding. Figure 3 shows the time slices ordered according to their normalized degree and betweenness centrality. Degree centrality shows the number of direct ties that a node has. In this case nodes are the time slices and direct ties indicate the number of actors sharing information during that time period. For betweenness centrality calculations, we follow Wolbers et al., (2013), by understanding time slices with a high betweenness centrality as critical periods in which actors could relay information to others since they were only linked to each other at that time period.

Figure 3: Time slices degree and betweenness centrality in a two-mode network

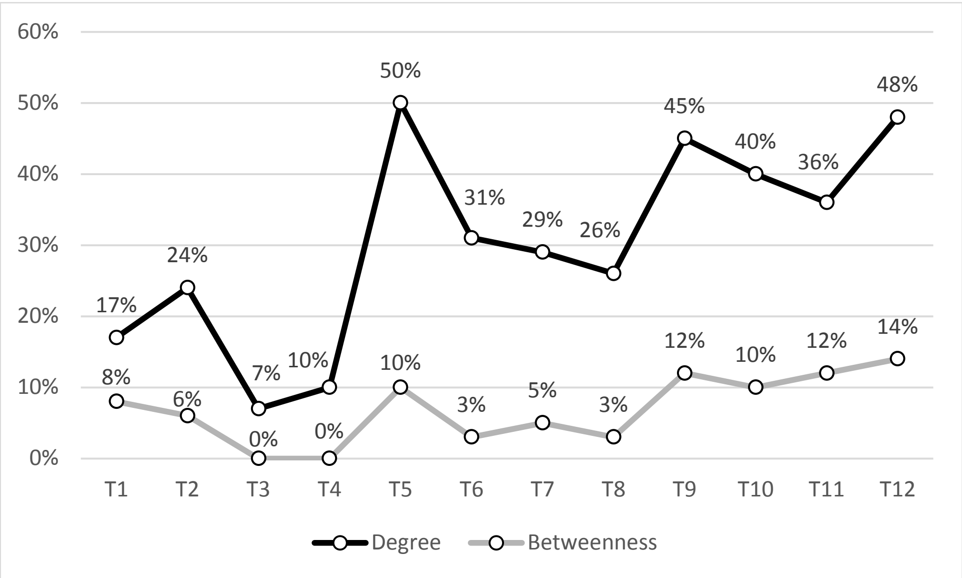


Figure 3 shows that time slice 5 (16:15-16:29) features the highest degree centrality, with half of the actors involved during this time period. This means that the spike in the number of actors communicating occurred quite early on in the process. The large gap between the degree centrality of T4 and T5, represents a sudden increase in the number of actors involved during T5, as could also be seen in Figure 1. During time slices T6 and T8 (16:30-17:14) there is a drop in the number of actors communicating, with the time slices T9-T12 (17:15-18:14) showing once again a large number of actors present in these time periods. The betweenness scores show that time slices 5 and 9-12 were critical periods of information sharing and collective sensemaking. We

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used these critical periods to divide the whole process into specific episodes of collective sensemaking to study how actors make sense of a situation, the actions they subsequently undertake, and the revisions that may be made to these interpretations.

Figure 4: Time Slice 1 (15:15-15:44)

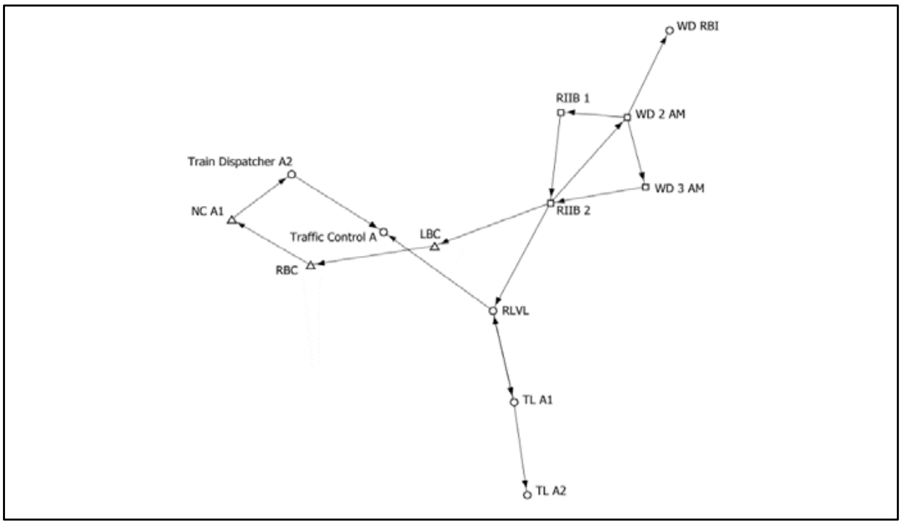


Figure 5: Time Slice 2 (15:45-16:14)

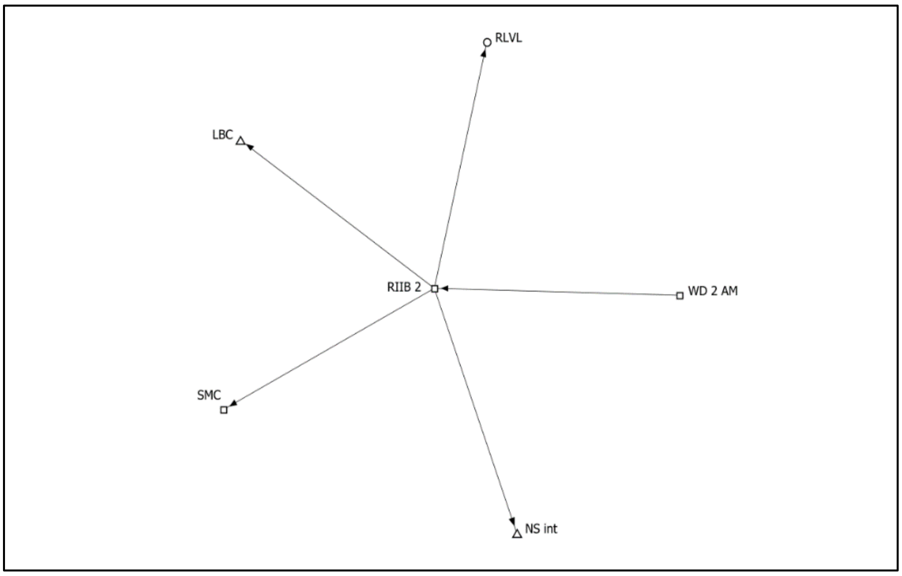


Figure 6: Time Slice 3 (16:15-16:44)

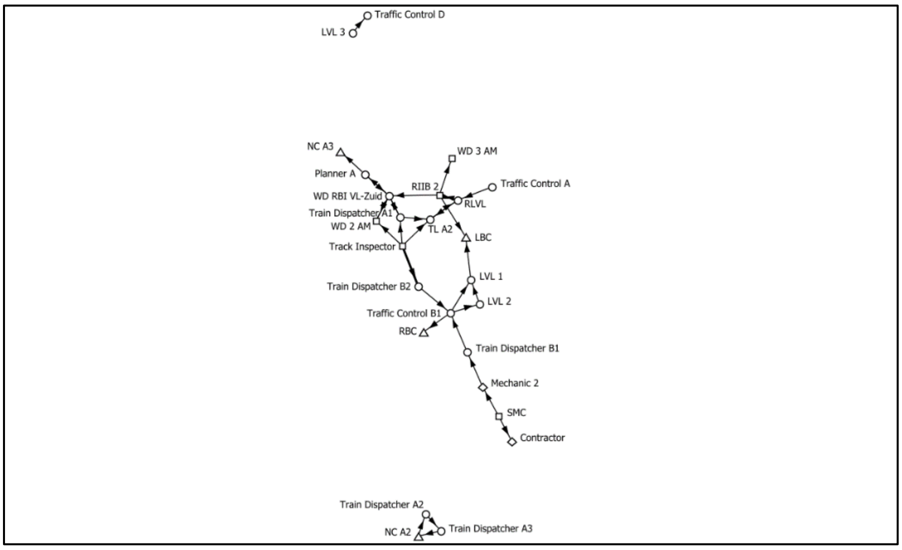


Figure 7: Time Slice 4 (16:45-17:14)

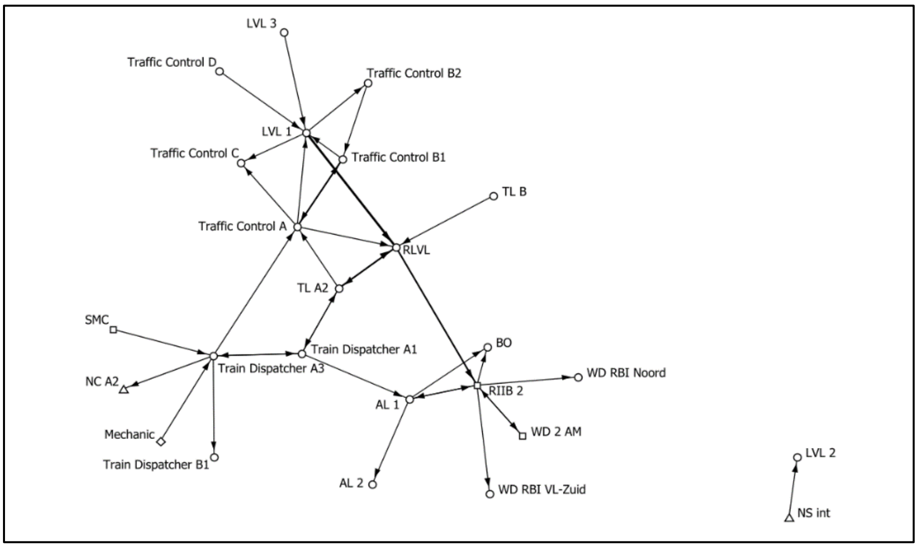


Figure 8: Time Slice 5 (17:15-17:44)

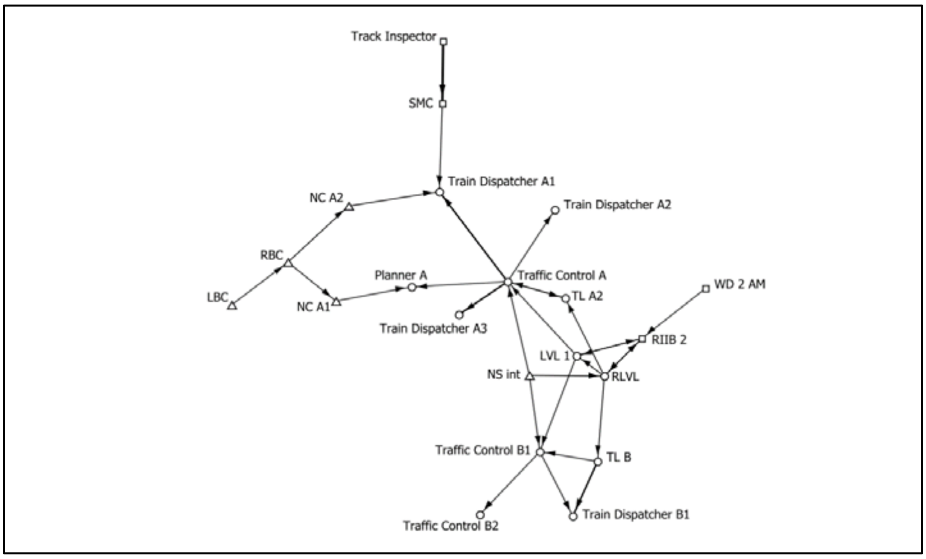
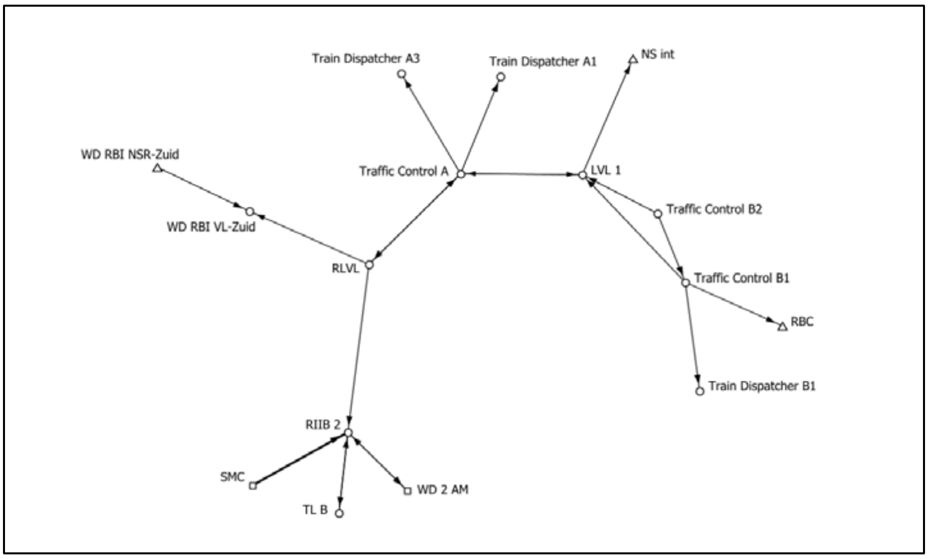


Figure 9: Time Slice 6 (17:45-18:14)



6. Making sense of the decision to stop the train service

Having covered the structural and quantitative features, it is now time to turn to the content of the communication, i.e. the sensemaking processes. Table 3 describes the process leading to the train dispatchers' decision to stop the train service. This table is based on the one Cornelissen et al. (2014) developed for their analysis of sensemaking in the Stockwell Shooting. Using the findings from the DNA, we divided the process into three episodes. The first episode started with the first phone call from the Track Manager to the Asset Management Coordinator (RIIB) in the OCCR

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and ended at time slice four (Figures 3, time 16:14) when the schematics with all the details were sent to the OCCR. Episode 2 started at T5 (16:15), when there was a sudden peak in the number of actors and interactions, marking the start of the official procedure. The second episode ended at T8 (17:14), when it was discovered that no one had taken responsibility to inform the train dispatchers. The third episode consists of time slice T9-12 (17:15-18:14) during which there was considerable communication. It started with the Track Inspector informing the train dispatchers and ended with the decision by the train dispatchers in area A to suspend the rail traffic during rush hour. For each episode we looked at how the key actors (as identified in Table 2) tried to make sense of the disrupting events or how they shaped the meaning construction of others (sensegiving). The last column describes the actions that followed from the initial sense made by the key actors, from which a new cycle of sensemaking commenced.

Table 3.
Overview of the episodes of sensemaking among key actors following the decision to take several rail tracks and switches out of service, and outcomes.

Time	*Event*	*Key Actor(s)*	*Sensemaking*	*Actions/ Outcome*
08:30	The Track Inspector receives the information that two rail tracks do not meet the safety standards, while reading the monthly maintenance reports on four switches which have deviated from the standard for quite some time.	Track Inspector	The Track Inspector feels that he can no longer look away and that concrete measures have to be taken, given the recent audits by the inspectorate and the worsened measurement results for the switches.	The Track Inspector decides to consult with his superior, the Track Manager.
10:30 - 13:00	The Track Inspector discusses the measurement results with the Track Manager.	Track Inspector and Track Manager	After a long debate the Track Inspector and Track Manager conclude that it is too great a risk to continue using the switches and tracks. Hence, they should be taken out of service, but not immediately given the impact this would have on the train service.	The Track Inspector and Track Manager start giving the other parties in the rail system an early warning that the switches and tracks will be taken out of service at 18:00.
Episode 1: An early warning to the OCCR				
15:19	The Track Manager (WD 2 AM) gives an early warning to the Asset Management Coordinator in the OCCR (RIIB).	Track Manager and RIIB	The RIIB was told that there was a very serious situation which would have a huge impact on the train service for which he used the term red flag often: *"While you are seated, I want to share something with you (...). We have four red flags at this moment (in area A) and it's pretty serious. There have been inspections last night, which showed major deviations from standard. In terms of responsibility we have to plant a red flag now."*	The RIIB hands this information over to his colleague working the next shift (RIIB 2).
15:27	The RIIB 2 asks for	Track	The RIIB does not hesitate to	The RIIB warns his

	more information on the situation from the Track Manager and schematics showing which switches and tracks should be taken out of service.	Manager and RIIB 2	abide by the track team's decision and wants to stay in control of the situation: *"It's just a fact that this red flag will be planted, but when we have more information we will be able to prepare our logistics."*	colleagues in the OCCR of Traffic Control and Dutch Railways (RLVL and RLBC).
15:30	The RLVL calls the Team Leader of Traffic control area A.	RLVL and Team Leader	The RLVL feels that there is still not enough information to justify alarming the train dispatchers: *"We don't know exactly what is going on and why, so we first want to gather more information. Because imagine if it (red flag - authors) isn't necessary, then we would be making a lot of fuss about nothing, and I would regret that."*	The RLVL tells the Team Leader to keep his eyes and ears open, without letting the train dispatchers know anything.
15:41	Nevertheless, the information that a red flag will be planted in the rail tracks reaches the regional control centre of Area A.	Regional Traffic Controller and RLVL	Both agree that since this is a safety issue, the train dispatcher should have been called first and that the OCCR shouldn't be the first in the line of communication. They also find it strange that trains are still running over the switches and tracks despite the apparent safety risks.	Both the Regional Traffic Controller and the RLVL still believe it to be a regular situation in which a mechanic has judged the switches and rail track as no longer safe and that the train dispatcher will be called anytime soon.
15:57	The RIIB receives schematics with details on the four switches and two tracks and discusses them with the Track Manager.	RIIB and Track Manager	The Track Manager once more warns that there are safety risks and that they actually should have acted immediately, but that they have given a deferment until 6 pm: *"You know they have been running* (over the switches and tracks) *all morning, so I expect them to hold for another couple of hours. However, if the Inspectorate saw these values, we would get a big fine."*	The RIIB appreciates the postponement of the red flags in order to keep the train service in control. He shares the latest information with his colleagues in the OCCR during the standard meeting at the beginning of their shifts.
Episode 2: The official procedure is started				
16:18-16:43	The Track Inspector calls the SMC to start the official procedure.	Track Inspector and SMC	The Track Inspector enumerates which switches and tracks should no longer be used after 6 pm and that the surrounding switches should be locked to prevent trains from passing over the switches. When the SMC asks who will inform the train dispatchers, the Track Inspector states that they have informed the OCCR and thus the train dispatchers should be aware of the situation and preparations should be ongoing to adjust the train service.	Based on advice from the SMC it is decided to follow the simpler RVO procedure, instead of the more time-consuming BUTA procedure, the latter being the normal procedure in the case of deferred maintenance work. In contrast to what the RVO procedure prescribes, the SMC believes they have no role in informing the train dispatchers about the situation.

16:23-16:29	Once again information on the red flags reaches the traffic control centres of areas A and B from the train operating companies. Both regional traffic control centres are surprised to receive this information indirectly and to hear that the red flag has been deferred until 6 pm.	Regional Traffic Controllers of areas A & B and the National Traffic Controller (LVL).	The National Traffic Controller assures the regional traffic controllers that the normal RVO procedure will be followed: *"We expect a phone call from you later on that the train dispatchers have been informed on what will be taken out of service at 6 pm. I just received a whole bunch of information, but said sorry let them speak with the train dispatcher."*	The RLVL and LVL feel that they have no role in the process until the train dispatchers have been informed. They therefore decide not to communicate with the regional traffic controllers until the train dispatchers have been informed and it is clear which switches should be taken out of service.
16:29	By now the train dispatchers in area A are starting to look for confirmation of the 'troubling messages' they have received about several red flags with the SMC	Train Dispatcher and SMC	The SMC can't give the train dispatcher more information and instead blames the train dispatcher for acting on rumours. He assures the train dispatcher that official procedures and lines of communication will be followed.	The train dispatchers have the feeling that, given the many rumours, other actors have more information on the switches and tracks and that they are intentionally being excluded from the process: *"I got the impression that everyone knew what was going on and we, the train dispatchers, knew nothing! Who is responsible for safety? And how is it possible that we can use the switches until 6 pm?"*
16:30	The RIIB asks the Back Office of ProRail to make a logging in the communication system with the exact numbers of the switches and tracks that have to be taken out of service, which can be read by the regional traffic controllers.	Regional Traffic Controllers, Train Dispatchers, National Traffic Controller	The regional traffic control rooms are still in doubt as to whether the information in the communication system is correct and if so, in which position the switches will be locked. The latter is of great importance in terms of rail capacity. Hence, they find it difficult to formulate a contingency plan. The train dispatchers in area A even show reluctance to seek solutions, as long as they are not informed.	Given the high amount of uncertainty it is decided to prepare firm measures in order to stay in control of the train service.
17:08	After waiting and inquiring with the regional control rooms if they have received more details on the red flags, the RLVL urges the RIIB to ask the SMC when they will inform the train dispatchers.	RIIB and SMC	Here there is a clash between the two different frames of the situation held by the SMC and the RIIB. While the RIIB believes that the SMC will inform the train dispatchers in accordance with formal procedures, the SMC is under the impression that the OCCR has already informed the train dispatchers.	Both parties believe they are not authorized to impose restrictions on the usage of the switches and tracks. They conclude that the Track Inspector or a contractor does have the authority and therefore should do the job. The RIIB calls the Track Manager to let the Track Inspector inform the train dispatchers.
Episode 3: The train service is stopped				
17:27	The Track Inspector calls a train dispatcher in area A to inform her	Train Dispatcher area A and	Since the train dispatchers have been using the switches and tracks for the last couple of hours	The train dispatchers in area A decide not to cooperate and continue to operate the

	of the situation. The Track Inspector mentions the switches and tracks that should be taken out of service at 18:00 and indicates that the RVOs will be provided shortly. He also emphasizes that there are safety issues concerning the switches and tracks.	Track Inspector	they believe that there is no immediate risk and therefore do not feel obliged to cooperate. Cooperating is also seen as an invitation to the track team to let them deviate from the procedures more often. Moreover, the Track Inspector is not seen as an expert who can tell them to take the rail infrastructure out of service: *"Only experts can tell me if there is something wrong with the infrastructure (...). We need to hear it from an expert, which is a mechanic or the SMC."*	switches and tracks. The Track Inspector is told to get in contact with the Team Leader of area A.
17:30	The Track Inspector calls a train dispatcher in area B to inform him of the situation. Once more, the Track Inspector says the switches that should be taken out of service at 18:00 and that the RVOs will be provided shortly. He also mentions that there are safety issues with the switches and that all approach switches need to be locked.	Train Dispatcher area B and Track Inspector	For the train dispatcher it is inconceivable that the red flags have been deferred until 18:00 on the basis of its impact on the train service and workload of the operators, thereby giving less priority to the role of safety. The train dispatcher feels it is too great a risk to let another train pass over one of the switches, given the information provided by the Track Inspector.	Immediately after the phone call from the Track Inspector, the train dispatcher in area B decides to take the switches out of service. In other words: 30 minutes before the deadline.
17:40	A Regional Manager (WD VL RBI) calls the Team Leader of area A, but gets put through to one of the train dispatchers (A1).	Regional Manager and Train Dispatcher	The Regional Manager asks the train dispatcher what they need to take the switches and tracks out of service at 18:00. They are, however, unable to create a shared understanding of the situation. The train dispatcher expresses a lot of negative emotions, as she feels they are being left on their own: "*The whole course of events is flawed and everyone is just actively cooperating. It* (taking the switches and tracks out of service) *should happen no matter what. This is just ridiculous!"*	The train dispatcher tells the Regional Manager to get in contact with the team leader as she refuses to cooperate
17:47	A mechanic calls a train dispatcher in area A to tell him that two switches have to be taken out of service because they don´t meet safety standards. However, the	Mechanic and Train Dispatcher in area A	The train dispatcher repeatedly asks whether he can use the switch since a train is approaching it, but the mechanic can't give any absolute certainty. Given the high amount of uncertainty the train dispatcher is no longer certain whether the	The train dispatchers see the mechanic as an expert on whose judgement they should act. However, since the mechanic also can't provide exact details, the train dispatcher decides to let the train make an emergency stop as he believes it is no

	information he received from the SMC is very sketchy and he is still unsure in what position the switches should be locked at 6 pm. At that moment a train approaches one of the switches mentioned by the mechanic.		switches in his area of control are safe to be operated.	longer safe.
17:54	The train dispatcher in area A calls the SMC to check the information he received from the mechanic.	Train Dispatchers area A and SMC	The SMC assures the train dispatcher that the message on the switches and tracks comes from an expert, the Track Inspector. Nevertheless, the train dispatchers feel that there is too much uncertainty regarding which switches are safe and which ones are not, and that they are thus unable to guarantee safe rail traffic. Train dispatcher: *"Look, a situation is safe or unsafe! How is it possible that the people responsible for safety know nothing, at least not officially?"*	The dispatchers once more reject the Track Inspector as an expert, along with his information. They decide to suspend all rail traffic around the two major train stations in their area of control until they receive the correct information from a contractor, along with the official reference numbers, according to formal procedures. Consequently, there are no services between various main cities during rush hour.

7. Discussion

As the summaries in Table 3 show, even though it was rooted in good intentions, the track team's decision to give an early warning to the OCCR created an ambiguous situation for the other actors in the system. The early warning violated expectations in several ways. Firstly, an early warning is not a regular practice in the Dutch railway sector. Secondly, although the track team designated the situation as a 'red flag', they also allowed a six-hour delay. This sent a contradictory message. Thirdly, informing the OCCR created a top-down flow of information, which deviated from the formalized bottom-up approach for maintenance work. In such situations people have to ask themselves and others: "what is going on?" As the case has shown, the term 'red flag' played a very important role in the sensemaking process. A red flag is jargon for a situation in which the safe usage of a railway track or switch can no longer be guaranteed and so trains are forbidden to run over the track or switch. By framing their actions as placing several red flags the track team thus created the impression of an immediate safety risk. As one of the managers explained: *"A red flag can be like a red rag to a bull. A red flag means an unsafe situation"*.

Labels, like the term red flag, carry their own implications for action. They focus attention and shrink the number of possibilities as to what is occurring (Weick, 2001). In this case the term red flag triggered a routine procedure in which the train dispatchers should take the lead according to formal procedures and be informed by a mechanic or the SMC. This frame was dominant among the actors in the OCCR throughout the entire process and was reinforced through their communication and actions. For instance, there was a strong commitment to restoring action to familiar practices, i.e. to make sure that the train dispatchers were officially notified by the SMC or a mechanic in order to start the official procedure. This frame was also shared with the regional traffic control centres. Even when the regional traffic control centres confronted the national traffic controllers with the absence of an official notification and the contradictory signals they had received, the national traffic controllers repeatedly reinforced the frame of a routine procedure. In fact, they decided to reduce communication with the regional control centres (as could be seen in figure 1, fourth time slice) when confusion started to increase, agitation grew among the regional operators, and communication became mainly focused on blaming instead of problem solving.

The dominance of the frame also explains why the National Asset Management Coordinator and the National Traffic Control Coordinator did not use their central position in the network (Table 2) to provide others with this crucial information, despite them having full details on the switches and tracks. They simply did not believe that it was their role, or that they had the authority to do so. Instead, communication and actions were aimed at restoring standard procedures, which conflicted with the intentions of the track team for an improvised course of action with the OCCR coordinating the process and informing the regional control centres. The latter framing of the situation was also shared with the SMC by the track inspector. As a result of these different interpretations of the situation, actors started to make wrong assumptions about what others knew and which actions they would take. Consequently, the task of informing the train dispatchers was not assigned to anyone. In addition, the strategy of waiting until the train dispatchers had been officially notified was severely undermined by the many rumours that were circulating, because other actors in the system were checking, updating and revising their sense of events. The time slices show that the train dispatchers and regional traffic controllers in areas A and B were approached several times by train operating companies seeking confirmation of the 'rumours' they had heard about the red flags (Figures 4 through 9).

However, the train dispatchers and regional traffic controllers could not officially confirm any information to the train operating companies, as they had still not been officially notified of the situation. The sensedemanding of the train operating companies caused a chain of reactions, which explains the sudden increase in the number of interactions between time slices 2 and 3 (figure 1). More and more actors became involved and information on the red flags spread through the network uncoordinatedly. With information being dispersed among people and locations, sensemaking became fragmented, i.e. diverse accounts of the situation existed among the actors in the railway system. As a result, the train dispatchers felt isolated and lost grasp of what was happening. Train dispatchers rely on a strong dichotomy between safe or unsafe, as they are held responsible for safe operation. Hence, for them it is very difficult to understand that they are running trains over a piece of infrastructure, the safety of which cannot be guaranteed. Although they knew that there were issues with the safety of some switches and tracks, they had not received any official information or a reference number, and therefore they could not fulfil their role.

What explains the difference in response between the train dispatchers in areas A and B? The telephone conversations revealed that there were considerable negative emotions among the train dispatchers in area A, and this negativity increased during the day. These emotions were fuelled by the fact that critical information was not shared with them. This was not only seen as a threat to their social identity, but also created a state of anxiety which was widely shared among the train dispatchers in the control room. The literature on sensemaking points to the importance of emotions (Maitlis & Sonenshein, 2010; Maitlis, Vogus, & Lawrence, 2013; Maitlis & Christianson, 2014). These studies show that emotions are an important factor in individual and collective sensemaking. Negative emotions, in particular, are contagious and can easily spread among group members (Bartunek, Rousseau, Rudolph, & DePalma, 2006). In this case, a collective belief that emerged among the train dispatchers of area A was that non-compliance and strictly following procedures was the best course of action. Hence, they continued to operate the switches and tracks and rejected the track inspector as an expert. Such negative emotions were less prominent in area B. An important explanatory difference is that area B had a team leader on-site, while in area A the team leader was on call. As the team leader of area B explained: *"After receiving the phone call from the RLVL I was busy tempering emotions, saying 'Guys keep on going, don't get carried away by emotion because of this uncertainty about what we can and can't do. Make sure that the trains keep running!'"*

The lack of contextual information made it difficult for the team leader of area A, who was on call, to identify the specific coordination issues and to recognize the negative emotions emerging among his train dispatchers. In area A, the regional traffic controller played an important role in the line of communication between the train dispatchers and the OCCR, as can be seen in the graphs and Table 2. The regional traffic controller, however, was very busy with his preparations to adjust the train service and showed resistance in his communication. Therefore, national traffic control did not want to antagonize him. Instead, new actors who were able to circumvent the formal lines of communication, such as the regional manager, stepped in to help create some common ground between the track team and the train dispatchers and to mediate in their conflict. However, the regional manager failed to develop a congruent understanding of the situation with the train dispatcher and actually contributed to the growing negative emotions. In the end the lack of a common ground between the track team and the train dispatchers resulted in the decision by the train dispatchers in both areas A and B not to comply (each in their own manner) with the track inspector's six o'clock deadline.

The unexpected split-second decision taken by the train dispatchers of area A to suspend the rail traffic, also cascaded into area B, where the dispatchers and regional traffic controllers were struggling to keep the traffic flowing. Large service cuts had to be made in order to cope with the reduced capacity in an orderly fashion. As a result, many passengers were stranded. Altogether, it took more than an hour for the train dispatchers in area A to receive the correct information and reference numbers so that they could gradually restart the train service. A nightly inspection of the switches by ProRail revealed that three out of the four switches could be put back into service by applying new broadened safety standards that were scheduled to enter into effect two months later.

8. Conclusion

We have demonstrated how and why the actors involved were unable to create a shared understanding on which to base coordinated action. The OCCR's framing of the situation as a normal procedure on the basis of the term 'red flag' and their desire to restore action to familiar practices was in conflict with the track team's intention to find an improvised way of managing the process. We have shown how these different understandings of the situation accumulated over time, leading to inconsistent actions, incorrect assumptions and a lack of effective communication. Our DNA results show how information spread among the actors in the system, rapidly and uncoordinatedly. Consequently, actors held different pieces of information and created fragmented accounts of the situation. We found that informal and indirect communication (sensedemanding) negatively influenced the process, as it increased uncertainty among the train dispatchers about the course of action to be followed and their role in the process. We observed two different responses to this uncertainty and the time pressure: one in which procedures were strictly followed and the track inspector was excluded as an authority, which eventually resulted in the decision to stop the train service (area A), and one in which safety concerns triggered improvisation (area B).

The findings in this research confirm earlier work on networks of teams, in that there are additional challenges for effective coordinated action between multiple teams with a variety of skills, functions, and knowledge (Shuffler, Rico, & Salas, 2014; Zaccaro et al., 2012). In order for these teams to work together effectively, it is important to develop shared mental models on expected behaviour patterns concerning task procedures, team and team member behaviours and needs, and patterns of communication (Rentsch & Staniewicz, 2012). Shared mental models thus help individuals to choose actions that are coordinated with other team members. As we show in our study, failure to develop a common set of assumptions and expectations may lead to role violations, communication failures, and even conflicts between teams. Building shared mental models in a large system with many diverse teams can, however, be a challenge. It is therefore important to ensure that common understanding is established around a congruent framing of the situation through collective sensemaking (Cornelissen et al., 2014).

However, strict adherence to a framing can also have a negative outcome. Commitment to frames reduces the number of cues that are considered and so it ties actors to a certain repertoire of actions and assumptions regarding the behaviour of others (Cornelissen et al., 2014). In our case, adherence to the initial framing of the situation by the actors in the OCCR, and their attempts to restore procedures, along with the long and indirect lines of communication, created blind spots that led people to miss the signs that they were not dealing with a routine situation. Hence, it is important to be able to update frames when dealing with ambiguous events (Maitlis & Sonenshein, 2010). This particularly applies to networks of teams. As teams are geographically separated it is often difficult to quickly identify misunderstandings and prevent escalation. Hence, it is important that actors feel free to doubt and question the information they receive from their partners and to take the time to deliberate with them on the framing, instead of blaming each other for not following procedures or diminishing communication (Weick, 1993; Weick, 2005). This is not something that is easily achieved, but in the long run it can help to improve the adaptive capacity of the system.

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Endnotes

[1] See Schipper, Gerrits & Koppenjan (2015) for more details on the use of DNA and ORA in analyzing railway disruptions.
[2] See Schipper, Gerrits & Koppenjan (2015) for more details on traffic control in the Dutch railway system