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Challenges to Critical Infrastructure Resilience in an Institutionally Fragmented Setting

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Abstract

Under the influence of neo-liberal ideals such as New Public Management, the ownership, operation, and maintenance of many Critical Infrastructures have been divided among an increasing number of public as well as private actors. Limited research has investigated the role of this institutional fragmentation for shaping resilience of Critical Infrastructures, especially in relation to recovery after infrastructure failures. The aim of this paper is to empirically explore inter-organisational challenges to response and recovery operations in the increasingly multi-actor setting characterising many contemporary Critical Infrastructures. Using the Swedish railway system as a case, the paper explores response and recovery operations following two frequent types of events. The findings show that once disruptions occur, response and recovery operations are often complicated and time-consuming. Multiple actors with diverse roles and mandates are involved in the operations, which prompts a need for communication and coordination. The case study also illustrates the important role of contractual arrangements for shaping resilience of deregulated Critical Infrastructures. The contracts incentivise actors to certain behaviours, but they also give rise to unintended side-effects. While individual actors typically make adaptations and goal trade-offs with regards to their individual tasks and actions in a way that is both locally rational and efficient, interconnections and interdependencies among the different actors give rise to cross-scale challenges to stimulating resilient operations of the infrastructure system as a whole.

Keywords: Critical Infrastructure; Resilience, Recovery, Institutional Fragmentation, Deregulation, Contracts

1. INTRODUCTION

Critical Infrastructures, including transportation systems, water supply, telecommunications, power supply, and banking and finance, provide essential functions and services to our modern society (Amin, 2001; Little, 2004). Their criticality means it is of utmost importance that these systems are resilient to accidental as well as intentional disturbances in the sense that they have an ability to resist failures and/or quickly resume their functionality when such events occur (McDaniels et al, 2008).

Under the influence of New Public Management (NPM), the ownership, operation, and maintenance of many Critical Infrastructures have been divided among an increasing number of public as well as private actors during the last decades (de Bruijne, 2006). While the effects from this organisational restructuring on the reliability of Critical Infrastructures have received some attention in the research community (see e.g. Schulman et al., 2004; Roe & Schulman 2008; 2016), less attention has been paid to studying response and recovery operations once these institutionally

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fragmented Critical Infrastructures actually suffer from incidents and disturbances (Antonssen et al., 2010).

Moreover, most studies of response and recovery following failures affecting Critical Infrastructures centre around catastrophic events such as the World Trade Centre terror attacks and Hurricane Katrina (e.g. Leavitt & Kiefer, 2006; Mendonça, 2007, Zorn & Shamseldin, 2015), while fewer studies have explored small-scale but frequent failures that accumulated over time give rise to major costs and inconvenience to society. This paper presents a case study, and discusses the implications, of response and recovery operations following Critical Infrastructure disturbances in the multi-organisational setting characterising contemporary deregulated infrastructures. This issue is explored with a case study of incidents in the Swedish railway system as a point of departure.

2. THE TURN TOWARDS DEREGULATION OF CRITICAL INFRASTRUCTURES

2.1 Reliability in the face of institutional fragmentation

Influenced by neo-liberal programmes, such as New Public Management (NPM), many Critical Infrastructures have faced substantial reorganisations during the last decades (Almklov & Antonsen, 2010; Clifton et al., 2011; Almklov et al., 2012). NPM entails the transformation of the public sector towards enterprise-like forms of management practice with focus on cutting costs and "doing more with less" through processes of outsourcing and "lean production" (see e.g. Hood, 1991). Following these principles, many Critical Infrastructures that used to be organised as state-owned monopolies have been deregulated and privatised with the aim of obtaining a more efficient public sector (Egan, 2010). In such ways, responsibility for operation and maintenance of the services provided by these systems have been divided across a multitude of public as well as private actors.

Previous research on the effects from deregulated Critical Infrastructures has indicated that these systems operate with a remarkably high level of reliability, despite significant shifts in institutional arrangement. For example, de Bruijne and van Eeten (2007) found no significant change in the level of service provision following institutional restructuring, which contradicts the predictions of Normal Accident Theory (Perrow, 1984) as well as High Reliability Theory (see e.g. Weick, Sutcliffe, and Obstfeld, 1999). Normal Accident Theory (NAT), on the one hand, predicts that decentralisation of systems characterised by high interactive complexity and tight couplings would lead to inevitable ("normal") failures. High Reliability Theory (HRT), on the other hand, would predict that streamlined production advocated by neo-liberal ideals would result in a reduction of the kind of positive redundancy (duplications and overlaps) that HRO theorists emphasise as essential for sustaining highly reliable organisations.

According to de Bruijne and van Eeten (2007), maintained reliability in spite of substantial organisational reforms of Critical Infrastructures can largely be explained by the ways the organisations that manage these infrastructures work with real-time management, improvisation and informal communication and coordination. The dedication and commitment by "reliability professionals" (such as for example control room managers, dispatchers, and other middle-level operators) have been highlighted as a highly important source of sustaining reliability in this type of complex systems (Roe & Schulman, 2008; 2016).

2.2 From reliability to resilience

Notwithstanding research pointing at a sustained level of reliability of deregulated Critical Infrastructures, these systems do intermittently suffer from disturbances and service disruptions. In addition to increasing reliability by measures mainly aimed at strengthening resistance to failures, several authors have emphasised the need for increased focus on building capacity to recover from failures as quickly as possible as a crucial component towards enhancing resilient operations of Critical Infrastructures (Fritzon et al, 2007; Boin & McConnell, 2007; LaPorte, 2007).

While far from sufficient for covering the different facets of the term resilience, recovery from disturbances captures one of the most popularised (yet simplified) ideas of this concept; the ability of a system to "bounce back" from stress or disruption. Resilience is a concept that has been used in several research domains in recent decades, with Holling's (1973) use of the term in relation to ecological systems being one of the most renowned ones. In addition, the concept of resilience has flourished in several other fields of research, including for example psychology, engineering, and sociology (Birkland & Waterman, 2009; de Bruijne, Boin, & van Eeten, 2010), with somewhat different connotations (e.g. the ability to return to a normal state, or the ability of continual adjustment and adaptation, see e.g. Pendall et al., 2010). This greatly increasing popularity in the use of the concept has caused some researchers to critically remark that it seems that everything and everyone can, and should be, resilient (Boin, Comfort, & Demchak, 2010).

In safety science literature (particularly Resilience Engineering), resilience has been described as the ability of a system to effectively "adjust its functioning prior to, during, or following changes and disturbances, so that it can continue to perform as required after a disruption or a major mishap, and in the presence of continuous stresses" (Hollnagel, 2009: p. 117). The introduction of the concept of resilience has thus contributed to a shifting focus in the system safety discourse from building strength against failure to regaining functionality as quickly as possible (Hollnagel & Woods, 2006).

In the emergence of resilience as a concept widely used in the domain of safety science, inspiration has been drawn from a number of researchers and sub-disciplines (see Woods, 2003, for a brief account of some vital background publications). Interestingly, resilience has been used interchangeably as an ability of a "system", an "organisation", or a "team". These different levels of analysis have frequently been treated in more or less the same way, suggesting that resilience is not only a scalable concept, but a panacea ensuring continuous performance that can be found on several levels of analysis. Moreover, the connection between various levels has generally not been problematized (see McDonald, 2006; Mendonça, 2008; Woods, 2006, for a few exceptions).

In relation to research on resilience of Critical Infrastructures, these cross-scale interactions are particularly interesting. The goal of this type of research is to understand how to sustain and, when disturbances occur, quickly recover functionality of vital infrastructure services in the face of multiple (sometimes conflicting) objectives. However, these insights cannot be obtained without analysing the roles, behaviours, incentives and constraints of the key actors contributing to the provision of these services. As a result of the institutional fragmentation of many Critical Infrastructures during the last decades, the organisations involved in operation, maintenance and recovery of these systems, as well as their mutual dependencies, have changed. Against this background, there is an increasing need for research exploring the role of privatisations and deregulations for shaping resilience of Critical Infrastructures, especially in relation to recovery following failures (Antonsen et al., 2010). The aim of this paper is therefore to empirically explore practical inter-organisational challenges of response and recovery operations in the increasingly multi-actor setting characterising many contemporary Critical Infrastructure systems. Let us now turn to our case study on the recovery from two rather frequently occurring types of incidents in the Swedish railway system.

2.3 Swedish Railways as a case study

The Swedish railway system represents a highly relevant example of a Critical Infrastructure system that has undergone significant organisational reforms. From being a fully state-owned and state-operated monopoly, the Swedish railway system has been gradually deregulated over the last decades (Alexandersson et al., 2012; SOU 2008:92).

The first step in this process was taken in 1988 by separating responsibility for train operation from infrastructure provision. In consecutive steps, train operation has been opened up for market competition, starting with the operation of freight trains and followed by gradually increased competition also on operation of passenger trains. In 2012, the last step towards fuller market competition of freight and passenger trains was taken. In addition, responsibility for maintenance of trains and infrastructure has been subjected to deregulation and privatisation, resulting in a Critical Infrastructure characterised by multiple actors often competing on a lowest price basis (Alexandersson et al., 2012; SOU, 2015).

While the Swedish Transport Administration is the national authority responsible for long-term planning of the transport system and for building, operating and maintaining public railways and roads, performance of all maintenance and acute recovery work is outsourced and conducted by private contractors. Moreover, each private train operator bears responsibility for their trains as well as train drivers and on-board staff. In addition, in cases where life and health of people is threatened, the traditional emergency services (e.g. Rescue service, Police, Ambulance) are involved in the response phase. Consequently, when failures occur, a number of different actors, both private and public, are involved in the response and recovery operations, and deregulations have contributed to an increased diversification of actors involved in this type of operations. The case study presented below highlights challenges related to resuming infrastructure operations in this multi-actor context.

3. METHOD AND MATERIALS

The empirical data used as a basis for the paper are collected from interviews and document studies relating to two rather frequently occurring types of incidents in the Swedish railway system. The first type relates to situations where a person has been hit by a train (referred to in this paper as incidents involving unauthorised persons on railway tracks, in line with how these incidents are usually called in official statistics). This type of event often turns out to be suicides (or attempted suicides). The other type of incident relates to failure of traction power lines, i.e. events where the pantograph of a train accidentally tears down the overhead power line (e.g. due to insufficient maintenance of the trains by the train operators).

The two types of incidents were mainly selected due to their frequency and impact on railway operations; they occur at regular intervals and should therefore not be seen as one-off events. At the same time, they generally give rise to substantial consequences in terms of delays, cancellation of trains and goods, and affect many passengers and industry partners. As such, their cumulative effect represents a major cost to society. A geographical demarcation of the case study was set to the railway system in the southern part of Sweden (the Skåne region), which includes some of the busiest railway lines in the country (Swedish Transport Administration, 2011).

To summarise, response and recovery operations following these two types of incidents involve multiple actors, including the infrastructure provider (the Transport Administration), train operators (private companies running freight trains as well as passenger trains and the regional public transport provider procuring services from some of these train operators), emergency services (Police, Ambulance and Rescue services), infrastructure maintenance providers (private companies) as well as other sub-contractors to these organisations.

Data collection was mainly performed by semi-structured interviews. The respondents were identified through a snowballing process and included representatives from the Transport Administration (from three different organisational branches, including one maintenance manager, one safety department representative, and one operations coordinator), three of the largest passenger train operators, one maintenance contractor, one local rescue service, and the regional public transport provider. In total, 8 respondents were included in the study and interviews lasted between approximately 1 h 30 min and 2 h 15 min. Some respondents were contacted several times (by arranging follow-up meetings, or contacts per e-mail or telephone) as a way of clarifying and adding questions that came up during the data collection and analysis process.

At an early stage of the data collection process it became clear that different respondents in some cases have divergent views on how the two types of incidents are, and should be, managed. In order to capture diverse viewpoints, our aim was to understand each actor's experiences and perspectives related to the two types of incidents. For this reason, each interview was structured around open questions where each respondent was asked to explain and, by using a whiteboard or similar, to draw a flow chart of the way the response and recovery operation works in practice from the respondent's perspective. This process was supported by a set of pre-defined questions and prompts raised when appropriate. These questions related to which actors are involved in the response and recovery process, their roles and mandates and the challenges and constraints characterising this process. Frequently, this explanation resulted in descriptions of what was considered challenging or problematic in current work practices and how these problems could be resolved.

Data were collected for generic "type cases", i.e. interviews focused on how these two types of events normally are managed, rather than how a specific incident was managed (although the experience from the responders obviously was drawn from real events). The interview study was complemented by a document study of official incident investigations following a number of incidents, relevant sets of legislations, routines and other internal documents, as well as media coverage of the studied types of incidents.

4 CASE STUDY

This section presents the findings drawn from interviews and document studies with regards to how response and recovery operations typically are performed for the two types of incidents. As mentioned in the previous section, the differences in the respondents' descriptions and illustrations mainly related to expectations, varying degrees of experience from managing these types of incidents, and lack of knowledge of each other's roles and mandates. The results presented are based mainly on first-hand data about the actions of a particular actor. Moreover, descriptions of work processes that were only raised by one respondent, and that contradicted the accounts given by other respondents, were not included in the schematic representations of response and recovery operations. In this sense, the results represent a synthesis of the statements that were considered most credible or reflected by most respondents.

4.1 Case I: Incidents involving unauthorised persons on railway tracks

This type of incident, where a person is hit by a train[2], represents a major operational problem area for European railways (European Railway Agency, 2013). Figure 1 illustrates a schematic representation of the sequence of events following an incident involving unauthorised persons on railway tracks, derived from the data collection process. The tasks/activities illustrated in Figure 1 include:

1. The train driver reports to the Transport Administration's traffic management centre that a person has been hit by the train.
2. Rescue service, Police and Ambulance are called to the site. An Accident site commander appointed by the Transport Administration often arrives to the site, although usually later than the other actors.
3. The train operator begins to call replacement staff (train driver and conductors) and they head to the site as soon as practically possible. At the same time, a telephone meeting is set up by the Transport Administration involving all train operators affected by the incident. Based on these meetings, which take place at regular intervals during the response and recovery operation, information is provided to passengers (both in the affected trains and passengers waiting on platforms for other affected trains).
4. As soon as emergency services arrive to the site, a rescue operation is initiated if the person is alive, with the Rescue service in charge of the operation. If the person is deceased, the Police are in charge of the operation and conducts an investigation of whether a crime is suspected or not. In the latter case, the Police contact a funeral agency to remove the deceased person.
5. A funeral agency heads to the site and removes the deceased person. The Accident site commander is then formally in charge of the operation.
6. The rescue service cleans the train and tracks, normally after cutting electrical traction power to the train. In some cases, passengers are evacuated and transported by bus.
7. Train operation on the affected railway section and other affected railway sections in the system is resumed.

[2] This event often involves suicides or suicide attempts and indisputably constitutes a terrible tragedy to all parties involved. While this is fully acknowledged, focus of this paper is placed on the response and recovery operations following this tragic type of incident.

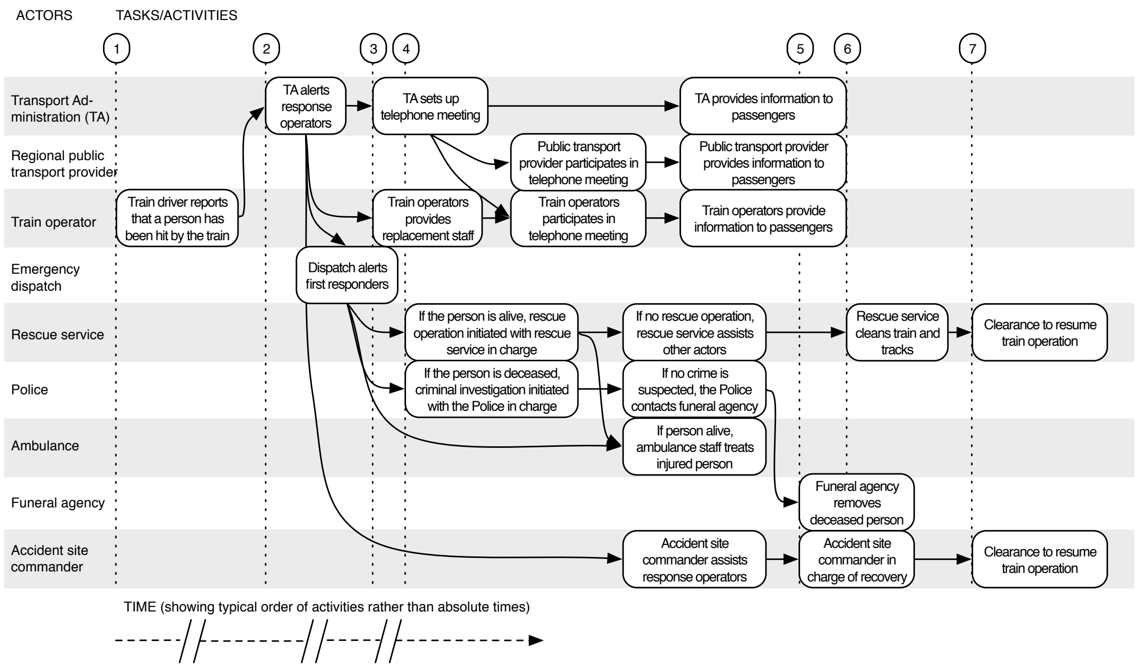

Figure 1. Schematic illustration of key actors and activities involved in the response and recovery operations following incidents with unauthorised persons on railway tracks.

4.1.1 Unclear responsibility, lack of experience and issues of power and trust

As this type of event is undoubtedly a traumatic experience to the on-board train staff, the driver and the conductor(s) are replaced with new staff. In addition, staff providing psychological support are normally sent to the site. Depending on when and where the event takes place, it may take considerable time to contact replacement staff and for them to reach the site (since the site may be a remote and inaccessible area). Due to scarcity of extra resources (such as limited pools of replacement staff) and competition between streamlined train operators, these operators are generally unable to assist one another to ensure rapid resumption of railway operations. This is, according to our respondents, further complicated by the fact that train operators use different train models that require different training.

In addition to traditional emergency services, an Accident site commander with specific knowledge about the rail infrastructure system (officially appointed by the Transport Administration but employed by a private contractor) is also called to the site. At this initial stage, the event is defined as a rescue operation, which means that the Rescue service is in charge. Once on site, the person is given immediate treatment. If the person is deceased, the Police formally take over command and initiate an on-site investigation of whether a crime is suspected or not. As soon as it is confirmed that no crime is suspected, the event neither constitutes a rescue operation, nor a criminal investigation. Instead, formal responsibility rests on the Accident site commander, who leads the recovery operation (both in terms of infrastructure repairs and decision-making about the need to evacuate passengers).

This allocation of roles means formal responsibility may shift between three organisations within the initial response phase. This division of responsibility is not always clear to the people and organisations involved, which from time to time gives rise to problems to the overall response and recovery operation. For example, some respondents explained that, when the rescue leader is more experienced with these types of events than the Police officers at the site (which seems typically to be the case), this person acts as in charge throughout the entire operation and makes decisions affecting all other actors, even though this may not be in line with the formal distribution of responsibility. In cases where this is not communicated or agreed between all actors, responsibility may be unclear, which, in the words of our respondents, sometimes can result in a state of confusion and passivity since several actors are uncertain who is formally in charge of the operation and who has the mandate to make decisions. Consequently, although formal responsibility may be clear in theory, this is not always the case in practice due to a number of reasons, including issues of power, trust, experience and lack of communication.

4.1.2 Misalignment of interdependent tasks

Once the Police have confirmed that the person hit by the train is deceased and no crime is suspected, the body needs to be removed and the train and tracks cleaned before train operation is resumed. Responsibility for taking care of the deceased person formally rests on the Police, but this task has been subcontracted to funeral agencies. This means that no train operation is possible until the funeral agency has arrived to the site and carried out their tasks, which, according to our respondents, often takes considerable time as their main focus is to perform a respectful and dignified handling of the deceased person. Once this is completed, the tracks and train are cleaned, which is normally carried out by the Rescue service.

In order to clean the train and tracks, the Rescue service normally requires that electrical power in the overhead traction power lines is turned off, due to the danger associated with spraying water close to these power lines. In some cases, the Rescue service makes the request to cut power at a very early stage (e.g., already on their way to the site). From a Rescue service point of view, this is locally rational since the same request simultaneously guarantees a safe workplace (by cutting off power) and speeds up their rescue operation (by making the request already before arriving at the site). However, in this situation, the decision to cut power has some highly negative side-effects for the railway system as a whole. Since power cannot be cut remotely only for the accident site, a larger part of the railway system loses power supply when the Rescue service makes their request. This means that all other trains on the same railway line are left standing on the track. Before cleaning of the train and tracks can be carried out, the body of the deceased person needs to be removed. Yet in the funeral agencies' contracts a maximum time for arrival to the site is normally 2 hours. Taken together, this means that when the Rescue service decides to cut power at a very early stage, several hours may pass from the decision is taken until cleaning begins, and during this entire period no trains can operate the affected railway line. In this way, the case highlights the value of looking beyond traditional response organisations in order to understand challenges related to recovery from Critical Infrastructure incidents.

These findings illustrate that the different actors involved in the response and recovery operation define the event differently due to their various roles and mandates. This is manifested in how they rationalise their work, i.e. what actions they take, why, and in what order. Yet, the way these locally rational decisions and actions interact with one another spurs side-effects that are sometimes not ideal from the perspective of sustained railway operations at the overall system level. In many of these incidents, passengers have been left sitting in the affected trains for hours without access to food or water and with deteriorating indoor climate as well as limited access to toilets, which has resulted in media outcries (e.g. GP, 2013). In addition, in incident reports there has been criticism of the lack of communication as well as lack of clarity regarding who can make decisions about evacuation of the train and other matters, which has resulted in recommendations on, for example, more training exercises for the actors involved (Swedish Transport Administration, 2012).

4.3 Case II: Failure of traction power lines

The second case relates to failure of traction power lines. The traction power line (contact wire) is the overhead electrical power line that feeds the train with electricity. Transmission of electricity occurs when the traction power line is in contact with the pantograph on the roof of the train. Due to the mechanical contact and friction between the power line and the pantograph, the pantograph eventually wears out, causing a risk that the power line gets stuck in the pantograph and tears down the traction power line. This results in an electric short circuit, which leaves the entire railway line without power, as relays operate in order to de-energise the line due to safety reasons. In Figure 2, a schematic representation of the activities carried out by each actor involved in this type of incident is illustrated.

1. The train driver reports to the Transport Administration's traffic management centre that the traction power line has been torn down.
2. A maintenance contractor and Accident site commander are called to the site. Time to arrival normally ranges between 30 to 120 min after being called. The rescue service is normally also called to the site.
3. A telephone meeting is set up by the Transport Administration involving the train operators affected by the incident. Based on these calls and meetings, which take place at regular intervals during the response and recovery operation, information is provided to passengers. In addition, buses are ordered to the site.
4. The site is secured by maintenance contractors. The Accident site commander is in charge of recovery operation.
5. Passengers are allowed to evacuate to buses. The Rescue service assists in evacuation.
6. Recovery work is undertaken and the train is towed to service.
7. Train operation is resumed.

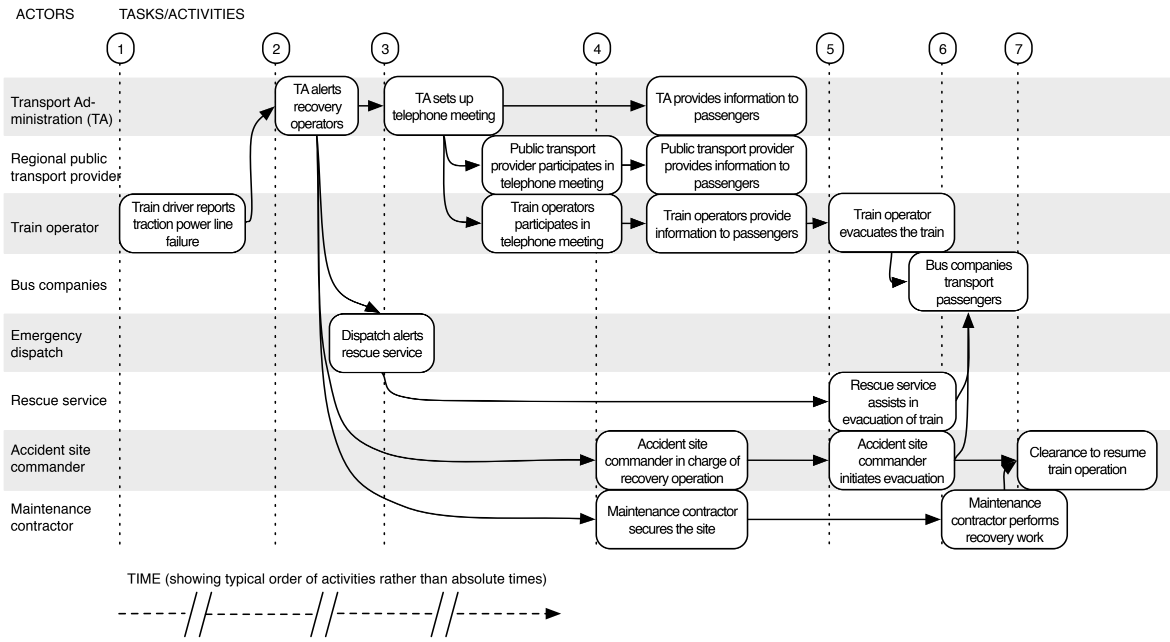

Figure 2. Schematic illustration of key actors and activities involved in the response and recovery operations following a failure of a traction power line

When the traction power line is torn down, the passengers of the train always need to be evacuated, since the train cannot be moved and recovery of the infrastructure takes several hours. Buses are ordered by the train operator, and the time for their arrival depends on the availability of spare buses as well as their respective bus drivers, which have varied depending on time of the day and location of the incident. Regardless when the buses arrive to the site, passengers are not allowed to leave the train until the site has been secured due to the potential danger that the power line that has fallen down might still be live (i.e. due to possible incorrect operation of relays). Responsibility for securing the site as well as repairing the infrastructure lies with maintenance contractors appointed by the Transport Administration. One maintenance contractor is responsible for a certain section of the railway network. Maximum time for arrival to the site for these maintenance contractors are specified in the contracts, and these times vary between 30 min to 120 min for different railway sections. When the maintenance contractors are on site, the work with securing the electricity line or lines affected is initiated. Following this work, passengers can evacuate the train and leave the site by bus. Normally, the Transport Administration has an agreement with the local Rescue service to assist in evacuating passengers from the train. When passengers have been evacuated, the train is towed to service. This often takes considerable time since many of the diesel trains used for towing that were strategically deployed at many different places prior to the deregulations have now been significantly reduced (both in numbers and in places), and the individual train operators usually do not have other incentives to acquire their own ones. Once the passengers are evacuated and the train is removed, the recovery work of the infrastructure is initiated, which according to our respondents normally takes an additional 6-8 hours (and a lot longer in complicated cases).

In addition to the immediate response and recovery activities carried out by the different actors, this type of event (as well as the type of event described in Case I) gives rise to a significantly increased workload in the time period following the event. This is, for example, due to the substantial re-scheduling of tasks required for all train operators in the affected region. The same thing happens to the staff who were supposed to work on a specific shift; once they are stuck on a train they are not able to make it for their next shift (e.g. when they work extended hours and are not allowed to start the next shift due to work hour regulations).

4.3.1 Work-arounds and goal trade-offs

From the interviews, interesting insights can be gained with regards to the way maintenance contractors use work-arounds to strike a balance between profitability and productivity. These contractors have slimmed down organisations and need to divide their work across planned maintenance operations and more urgent and unplanned recovery operations, giving rise to several challenges when incidents occur. One challenge is that the maintenance contractors are required to be on site within the timeframe stipulated in their contract. In cases where they do not have sufficient staff to initiate the recovery work within this timeframe, they are, according to some respondents, required to send any member of staff, i.e. without the requisite skills or equipment, to the site. By reporting to the infrastructure provider that they are on site (although not ready to start the recovery operation), they fulfill the terms of the contract and receive full compensation. As mentioned in the previous section, this time amounts to 120 minutes for some railway sections. In practice, however, it takes much longer until staff with the required competence and equipment arrive and initiate the recovery operation, and to repeat, passengers are not allowed to leave the train until this staff has secured the site. This resulting media outcries by passengers (e.g.

Sydsvenskan, 2014) is especially prominent in those cases when trains have stopped closed to a railway station and passengers still have not been allowed to evacuate.

5. DISCUSSION

5.1 Micro-efficiency and macro-inefficiency

The previous sections' findings suggest that, while each actor involved in the response and recovery operations are more or less successful in optimising their individual tasks and actions, this by no means is ideal for the recovery operation as a whole seen from the perspective of Critical Infrastructure protection. By way of our previous example, when the Rescue service is called to the site, they sometimes demand a non-electrified traction power line already before they arrive. From their point of view, this request both guarantees a safe workplace and speeds up their operation, which normally defines a successful emergency response. However, as our respondents underscore, this gives rise to additional, sometimes large-scale effects to other parts of the railway system not directly affected by the incident, since electric power is also cut to other trains along the same railway line. Consequently, many trains (and passengers) are left standing on the tracks for a long period of time, causing problems to more passengers than the ones initially affected by the incident.

Another example of the ways in which locally rational behaviour of an individual actor causes a less favourable outcome for the recovery as a whole relates to that way maintenance contractors strive to meet the requirements set out in their contracts. Pressure towards economic efficiency have generally pushed these organisations towards tighter operating margins (cf. IRGC, 2006). As we have already seen, demands in the contracts are sometimes met by simply sending a staff member to the site without the required skills or equipment. Thus, for these operators one of the key markers of success of a recovery operation is to reach the site within this timeframe, while the speed of the total recovery operation seems to be subordinate.

Common to these adaptation strategies is that adjustment and optimisation of performance occurs from the individual actors' local points of view in pursuit of their respective goals. While each organisation meets their individual goals (such as goals related to efficiency, safety and productivity), deficiencies are manifested in terms of globally aligning these diverse (and sometimes even irreconcilable) goals and incentives. Since the various actors primarily establish their goals from a local point of view, there are few incentives for any of them to ensure rapid recovery of rail operations. As further discussed in the next section, this tension between micro-efficiency in terms of the behaviour of each individual actor and macro-inefficiency in terms of the recovery of the infrastructure service as a whole has consequences for better understanding resilience.

5.2 Scalability of the concept of resilience

While the concept of resilience as such has shown a dramatic increase in popularity in the previous decade, and thus become somewhat of a "buzzword" (Alexander, 2013; Boin, Comfort, and Demchak 2010), it has also been highly criticised for being vague and difficult to operationalize. We share this criticism, but also recognise the benefits of highlighting the connotations on flexibility and adaptation in dynamic and complex systems, often associated with the concept.

One obvious implication for resilience in relation to the findings presented in this paper is that the presence of resilient organisations managing and operating a Critical Infrastructure system does not necessarily equate with the resilient service of the same system. The type of strategies of adaptability and flexibility that are used as a means to meet the performance variability characterising modern complex systems is highlighted by many researchers as a foundation for organisational resilience

(Hollnagel, 2006; Nemeth, 2009). However, due to interconnections and interdependencies between and across the different organisations, problems arise on the inter-system level in terms of quickly restoring railway operations.

The results presented in this paper therefore highlight the problem of cross-scale interactions and the fact that resilient behaviour on the level of organisations does not necessarily correlate with resilient service on the level of the infrastructure system; while performance may be locally adaptive, it seems to be globally maladaptive in terms of functionality of the infrastructure system as a whole (cf. Branlat & Woods, 2010).

The typical response is to call for better alignment of incentives between the local and global levels. However, it is important to point out that this paper does not provide a clear answer to whether the problems reported are derived from deregulation and privatisation as such, or instead due to an institutional inability to adapt to the changing conditions of these organisational reforms via a principal mechanism like the better alignment of incentives.

Multiple factors, closely linked to the deregulation of the railway market, seem to have contributed to the problems identified. These include, for example, weaknesses in the governance of the sector, shortcomings in the regulatory framework, conflicting interests in the Transport Administration's mission, and deficiencies in the oversight of its role (Swedish National Audit Office, 2013; SOU 2015). In addition, several other factors not directly related to deregulations have also contributed to the identified issues. Long-term underfunding of maintenance, in combination with a dramatic increase in traffic volume in recent decades, have resulted in an infrastructure system that is aging at a pace faster than the current level of maintenance is able to counter (Swedish Transport Administration, 2011). Moreover, it should be noted that some of the coordination problems identified in this paper may have been present also before deregulations, e.g. between a single railway authority and the public emergency service organisations. Clearly, the need for better incentives may be true as far as it goes, but it most certainly does not go far enough in better addressing the multiple factors involved.

5.3 The role of contracts as a means to create resilient Critical Infrastructures

It is important to point out that, while the benefits of deregulation are primarily shown during normal operations, its disadvantages are mainly manifested during (response and recovery from) incidents and disturbances. Accordingly, it must be discussed whether a perspective of systemwide, let along inter-system, reliability and resilience was sufficiently considered prior to decisions to liberalise the market. Obviously, while challenges raised in this paper could be addressed in a deregulated market by increased service-level requirements on operators and contractors (with regards to, for example, equipment and staffing), this would most likely have happened at the expense of (some of) the cost savings that motivated deregulations in the first place.

On a more general level, this shows the challenges related to formulating contracts as a sole or even primary means to create resilient Critical Infrastructures. These contracts represent a symptom of an increasing "commoditization" of societal safety (Almklov & Antonsen, 2010). However, knowledge of factors influencing the way risks are allocated and managed in contractual relationships is limited (Selviaridis & Norrman, 2014). While the contractual arrangements prescribing the work of the various actors may be efficient in day-to-day operations (and that is an empirical question rather than *a priori* assumption), they seem to be more challenging to formulate, and have more problematic effects, for situations where disturbances occur above and beyond a single organisation. Obviously, it is not possible to specify in a contract what should be done in every possible situation, and at the time of formulating contracts all possible future scenarios are not known or imaginable. In this sense, contracts covering unforeseen contingencies such as recovery operations are always incomplete, which is a longstanding but still not fully acknowledged finding (e.g., Hart & Moore, 1998).

6 CONCLUSIONS

As a result of deregulation and privatisation, the previously state-owned railway monopoly in Sweden has been transformed into a competitive market involving a multitude of smaller companies working close to their operational margins. While this in many ways has contributed to increased day-to-day efficiency and cost savings, the examples presented in this paper show that the multi-actor setting characterising this infrastructure system is associated with challenges when failures and disturbances occur.

The case study presented in this paper also illustrates the important role of contractual arrangements for shaping resilience of deregulated Critical Infrastructures. While these contracts incentivise actors to certain behaviours, they also give rise to unintended side-effects and occur within a context of many more factors that complicate response and recovery. One example relates to the way maintenance contractors use work-arounds to strike the balance between profitability and productivity. In cases when they do not have sufficient staff to initiate the recovery work within this timeframe, they are claimed to send any member of staff, without the necessary competence or equipment, to the site. By reporting to the infrastructure provider that they are on site, they fulfil the terms of the contract and receive full compensation. However, in practice, it takes much longer until staff with the required competence and equipment reach site and can initiate the recovery operation. More generally, while such adaptability and goal trade-off can be seen as a characteristic of a "resilient" organisation, such decisions are causing more delays to other trains and passengers on adjacent railway lines.

These cross-scale interactions illustrate that resilient behaviour on the level of organisations does not necessarily correlate with resilient service on a higher level of the infrastructure system. These findings point to the need to rethink entirely the premise that individual resilience produces global resilience, which include far more complex coordination and communication issues than just "the need for better incentives." As for better incentives, the logically and empirically prior task ahead is to ensure that the already clear disincentives to better coordination and communication can actually be dampened in practice.

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