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Does liberalization increase systemic risk in the railway sector?

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Does liberalization increase systemic risk in the railway sector?

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Abstract

In recent years various large-scale blackouts and incidents have shown that failures can have serious economic and social consequences in network industries. A large body of literature covers critical infrastructures (and their protection), but most of it is confined to a relatively restricted number of sectors such as electricity and information and communication technologies (ICT). In addition, much of this literature discusses questions of systemic risk in complex networks from an engineering perspective, attempting to mitigate risk through quantitative techniques.

While considered a critical infrastructure and sharing a number of characteristics with electricity (e.g. interconnection), the railway sector has received much less attention when it comes to systemic risk. In the wake of the creation of the single European railway market, legitimate questions to ask are whether/to what extent the liberalization of the railway system increases the sector’s systemic risk. The broader issue of the governance of systemic risk in the railway sector also deserves attention as existing mitigation of risk tends to be limited to risk management, often from a technical perspective, leaving aside an institutional dimension.

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\textsuperscript{2} Important sections in this paper are inspired from on-going research on systemic risk in network industries conducted with Dr. Ian Bartle.
I – Introduction

Network industries – electricity, transport or communications – are commonly seen as ‘critical’ infrastructures: they provide services without which modern society could not function properly. These ‘systems’ or ‘systems of systems’ which, by their nature, are subject to whole system risks are often referred to as ‘systemic’ risks. Broadly, ‘systemic risk refers to the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components, and is evidenced by co-movements (correlation) among all or most parts’ (Kaufman and Scott, 2003: 371). Systemic risk is also often used to refer to risk of failure of vitally important systems.\(^3\)

There are arguments and some evidence that network industries are increasingly vulnerable to systemic failures. For (Kröger, 2008; Kröger and Dietz, 2008) these highly complex and interdependent large-scale technical systems are subject to rapid change posing risks to themselves but also causing disruptions through cascading effects. Similarly, technological change can be disruptive to established steady states, ‘innovation trajectories … can cascade in unforeseen ways’, particularly when technological systems rapidly expand into other systems and areas or life (Hellström, 2007: 417).

In the extensive academic and practitioner literature on risk in banking and finance, systemic risk is frequently and explicitly addressed and analyzed and is one of the most important concepts in the sector (Kaufman and Scott, 2003; Kambhu, Weidman et al., 2007). In contrast, while safety and reliability in the network industries and critical infrastructures is extensively analyzed, systemic risk is only referenced briefly in the literature and not subject to extended and explicit analysis (IRGC, 2006; Zimmerman and Restrepo, 2006; Gheorghe, Masera et al., 2007)\(^4\). The associated term, ‘cascading’, is referred to more frequently and subject to intensive analysis from the engineering (and physics\(^5\)) community. It tends however to be analyzed mostly through a technical lens (e.g. reliability engineering).

Because of the increased utilization of the railway infrastructure over the past years, the railway system in many countries has become quite vulnerable to disruptions (Vromans, Dekker et al., 2006; Törnquist, 2007). In a majority of European countries, railway infrastructures are already operating at the limit of their capacity. The expected increase of “priority” trains crossing borders in Europe following liberalization of the international passenger segment is bound to further put pressure on the railway capacity. The unbundling of the railway sector, pushed by the European Commission, has not only the effect of adding new actors in the system, it also adds new functions (e.g. independent slot allocators) further increasing its complexity. These developments, coupled with the political will to increase the share of intermodal freight transport, may put an unduly high pressure on the railway sector without means (other than technical) to cope with it. On a more positive note, the standardization work conducted by the European Railway Agency (ERA) in the framework of the European Railway Traffic

\(^3\) The OECD refers to it as ‘one that affects the systems on which society depends - health, transport, environment, telecommunications etc’ (OECD, 2003: 30).

\(^4\) Power grids, telecommunication networks and railway systems face quite different risk situations due to different behaviors (physics) and different topologies.

\(^5\) For small-world properties in the railway sector, see (Sen, Dasgupta et al., 2003).
Management System (ERTMS) has forced many of the old and new European railway actors to sit at the same table and to find common answers to increasingly complex problems\textsuperscript{6}.

The paper argues that the traditional studies on risk management in the railway sector (see for example Haile, 1995; Leighton and Dennis, 1995) should be extended to explicitly include the concept of systemic risk. Our understanding of systemic risk and the answers we bring – in addition to the prevalent technical perspective – could largely benefit from a qualitative approach. After specifying our conception of systemic risk, we look at how relevant the concept is to the railway sector and potential avenues to broaden the discussion on the governance of systemic risk.

\textit{II – Definition of systemic risk}\textsuperscript{7}

Before considering systemic risk in relation to the railway sector we review what the concept of systemic risk refers to. The concept of risk itself is not easy to delineate and in modern usage is closely associated with the notion of hazard. While the latter is the capacity or potential to do harm, risk is more to do with ‘possibilities, chances or likelihoods of events, often as consequences of some activity or policy’ (Taylor-Gooby and Zinn, 2006: 1). Nevertheless in most risk analysis and debate risk is associated with harmful outcomes and is thought of as the likelihood of a harm occurring combined in some way with the extent of the harm. Risk therefore involves two elements: (i) the likelihood or probability of a particular event occurring and (ii) the extent of the harmful consequences of the event.

A standard \textit{technical} definition involves quantification and is the statistical probability of the occurrence of the unwanted event multiplied by its severity (Hansson, 2007). However, there are extended debates on risk and uncertainty in the literature, particularly between a scientific view which sees risk as a statistical probability of harm and uncertainty when probabilities cannot be quantified and a social science view which sees risk and uncertainty in most practical situations as difficult to separate and is skeptical about the quantification of outcome probabilities\textsuperscript{8}.

The concept of systemic risk refers to \textit{breakdowns of whole systems} rather than their component parts. Systemic risk therefore appears to be distinguishable from other kinds of risk primarily in terms of the widespread and potentially damaging consequences. System breakdown risks are characterized by a \textit{break in a causal chain}; the threat of system breakdown is a feature of an interconnected world and it exists at many levels, from local to global\textsuperscript{9}. Nevertheless, definitions of systemic risk often focus on the cause of the harm, processes involved and the uncertainties in assessing the likely outcomes. For instance, in the financial sector, systemic risks have been divided into macro and micro risks (see Table 1: Types of systemic risk).

\footnotesize{6} As we are seeing now, technical standardization is only one facet of railway interoperability.

\footnotesize{7} This section draws largely on (Bartle and Laperrouza, 2008).

\footnotesize{8} For more detail on these debate see Bartle (2008) and Bartle and Vass (2008).

\footnotesize{9} Renn (2003) further differentiates system breakdown risks and systemic risks.
Table 1: Types of systemic risk

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro</td>
<td>A single big shock which impacts on all or most of the parts of a system – a common cause (e.g. earthquake, typhoon)</td>
</tr>
<tr>
<td>Micro (i) direct</td>
<td>A single shock which impacts on only one or a small number of system parts. The systemic effect is a result of a chain reaction between physically interconnected elements – a ‘domino effect’ (e.g. power lines cascading failures)</td>
</tr>
<tr>
<td>Micro (ii) indirect</td>
<td>A single shock which impacts on only one or a small number of system parts. The systemic effect is a result of human interaction with other elements, in particular the result of loss of confidence and herding or contagious behavior</td>
</tr>
</tbody>
</table>

Source: (Bartle and Laperrouza, 2008) adapted from (Kaufman and Scott, 2003).

Kröger (2008) proposes a different taxonomy for potential of triggered events, including cascading events, escalating events, common cause events and confined events.

**Complexity and systemic change**

Moving beyond causation towards process, there are some other important distinguishing features of systemic risk associated with the inherent complexity of systems. ‘Complexity’ is a widely used term to describe the difficulties of analyzing large systems with many components. Complexity is more than just ‘complicated’ (Sajeva and Masera, 2006: 381); it is qualitatively more than the difficulty involved in analyzing systems with many sub-components with complicated behavioral functions. It refers to systems which have features which make the prediction of system behavior extremely difficult even if the properties of the component parts are well understood. Schläpfer, Dietz et al. (2008) find that breakdowns of complex networks are often the result of a relatively slow system degradation escalating into a fast avalanche of component failure.

The features of complexity include ‘nonlinearities, multiple stable states, hysteresis, contagion, and synchrony’ which ‘are features common to all complex adaptive systems’ (Kambhu, Weidman et al., 2007: 6). Complex systems also manifest the characteristics of ‘chaos’, one reading of which is high sensitivity to initial conditions meaning outcomes can be practically impossible to predict. Abrupt regime shifts can occur which in the economy, for example, can lead to a ‘transition to an inferior but stable equilibrium’ (Kambhu, Weidman et al., 2007: 2).

Complexity has become a significant feature of the whole modern science and technological infrastructures. Science and technological developments progress in an incremental manner and not in a systemic or holistic way. Products and processes are added incrementally to a complex whole of science, technology, life, environment, society, politics and the economy. However, as is well known in systems analysis, there can be unexpected and unforeseen ‘emergent’ phenomena.

These emergent phenomena tend to increase the vulnerability of network industries. Vulnerability can be divided into physical (i.e. the propensity to suffer damages when subject to an external stress) and into functional (i.e. the propensity of an element to suffer loss in functionality. These vulnerabilities can be extended to include systemic vulnerability which designates the propensity of an element to endure a loss of functionality not only to the effect of
a stress on its physical structure, but also to its *connections to other elements* (Minciardi, Sacile et al., 2006)\(^\text{10}\).

### III – How does systemic risk apply to the railway sector?

In the railway sector, the notion of risk is widely used but it usually refers to non-systemic types of risks. For example, the Swedish railway authority highlights that significant risks exist within areas such as new technology for signal systems, EU standardization of the railway’s infrastructure, price trends for metals and electrical energy, very high utilization of railway capacity primarily within the city regions, as well as the implementation of railway investments on time and within the calculated cost framework (Banverket, 2006). When mentioned, the concept of systemic risk remains restricted to safety issues (Santos-Reyes, Beard et al., 2005; Santos-Reyes and Beard, 2008).

The railway system is part of the set of critical infrastructures, and interruption can have immediate and far-reaching consequences on society and on the economy of a country, as it is used by people to go to work and to move essential goods for industry (often just-in-time). In countries with high population density or metropolitan areas, substitution of railways is extremely difficult. Nevertheless the degree of criticality is moderate, as impacts of failures, losses and unavailabilities will in most cases be limited in scope (local to regional), magnitude (minimal to moderate) and effects of time. At the same time, the rail transport infrastructure depends on other critical infrastructures to different degrees, in particular energy supply and ICT systems (IRGC, 2006), whilst the energy sector may depend on fuel transported by rail and the ICT systems may use data transmission lines that are often routed along rail rights-of-way (see Table 2: Interactions of the railway sector with other critical infrastructures).

#### Table 2: Interactions of the railway sector with other critical infrastructures

<table>
<thead>
<tr>
<th>Electricity</th>
<th>ICT</th>
<th>Urban water system</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>Disruption of ICT systems that control rail system or manage reservations and dispatch</td>
<td></td>
</tr>
<tr>
<td>Many electrified rail systems have their own power supply but some rely on the general power grid</td>
<td>Disruption of coal supply to generators (typically delayed effect)</td>
<td></td>
</tr>
<tr>
<td>Out</td>
<td>Many communication lines follow rail rights-of-way and can be disrupted by rail accidents or attacks</td>
<td>Contamination from derailment and hazmat spill</td>
</tr>
<tr>
<td></td>
<td>Disruption of ICT systems that control rail system or manage reservations and dispatch</td>
<td></td>
</tr>
</tbody>
</table>

Source: adapted from IRGC (2006).

Note: 51.7% of the electricity in the US and 30.4% in the EU is generated by burning coal (in most cases delivered to the plant by rail). Dependency of critical infrastructures is divided into dependence on other infrastructures (In) and dependence for other infrastructures (Out). Need to include intra-infrastructure dependence.

More recent work (TNO, 2008) on critical infrastructure dependencies also finds that most cascades originate from only a limited number of critical sectors (energy, telecommunication) and that interdependencies occur far less often than most theoretical studies assume. The

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\(^\text{10}\) For (Kröger and Dietz, 2008) the characteristics of interdependencies can be subdivided into types of interdependencies (input, mutual, co-located, shared, exclusive), interaction levels (physical, cyber, geographic, logical) and coupling (order of, tightness of linkage).
criticality of the railway infrastructure appears particularly evident in the (few) cases of complete shutdown of the network (see Table 3: Recent rail failures in Europe)\(^{11}\).

**Recent breakdowns of railway systems**

Whereas as (IRGC, 2006) rates the criticality of railways (either from a physical, operational or speed of change perspective) as medium, the main argument developed in this paper is whether or not this should be revised in light of the fundamental transformations the sector is undergoing. Recent structural changes in the railway sector – unbundling, introduction of competition, increased interoperability – warrant a questioning of whether the probability of a systemic failure of the network has increased or decreased. For the time being, there is only anecdotic evidence that incidents of systemic nature are more prevalent than before. In contrast to the extensive reports published after major (electricity) blackouts, there is little communication from the railway operators/infrastructure managers to shed light on the causes and consequences of the breakdowns. A number of large-scale failures in Switzerland’s railway system, often considered as state-of-the-art, attest of this.

<table>
<thead>
<tr>
<th>Country</th>
<th>Date</th>
<th>Downtime</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switzerland</td>
<td>22.06.2005</td>
<td>3-4 hours</td>
<td>The shutdown was caused by a power failure at 5:45 p.m. local time on part of the track in the southern Italian-speaking part of the country. Around 2,000 trains and over 200,000 passengers were affected. Financial claims amounted to around CHF 5 millions</td>
</tr>
<tr>
<td>Switzerland</td>
<td>07.02.2005</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>France</td>
<td>22.08.2004</td>
<td>2-3 hours</td>
<td>A local train dragged and broke the cable from which trains obtain overhead electricity, requiring all power to the line to be cut off.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1997</td>
<td>40 min.</td>
<td>Trains were stranded for 40 minutes affecting 15,000 people.</td>
</tr>
</tbody>
</table>

Source: compiled from Factiva

Switzerland's railway-officials blamed licensing procedures and "not-in-my-back-yard" behavior blocking new power lines as the underlying cause for a major power cut affecting the national rail network on June 22 2005\(^{12}\). The railroad has been trying to build additional transmission cables for backup for three decades, but its progress has been slowed by citizen protests. In this case, feeder lines from Germany proved inadequate and the systems of many other countries are not compatible. In addition to the complete shutting down of the railway network (e.g. the June 2005 incident), there are also accidents of systemic nature with relatively limited incidence\(^{13}\), as shown by the railway’s punctuality statistics: in 2005, the punctuality\(^{14}\) of Swiss freight convoys was 93.6% for national traffic and 74.4% for international traffic.

In our view, one of the important cause of increased vulnerability lies in the fact that the railway system was designed, built and operated under public ownership in a non-competitive environment and is suddenly expected to operate in a quite different way in a competitive, albeit

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\(^{11}\) Railways are also highly vulnerable as a territorial target as exemplified by the November 2008 « attacks » on the French TVG tracks which resulted in the stranding of thousands of passengers.

\(^{12}\) The Swiss network is not linked in circuits, meaning there are few opportunities to re-route power in the event of a breakdown.

\(^{13}\) In Switzerland, one estimates that there are around 100 incidents per day on the important lines.

\(^{14}\) Punctuality is defined as trains arriving at their final destination with less than 5 minutes of delay.
regulated, market. Networks were formed geographically at local, regional and long-distance level. For example, the main railway companies in Europe still make use of different electricity systems and different track gauges. Traditionally, these networks were largely separate and, in Europe, each owned and operated by one – often state-owned – company. Nowadays, larger networks have been formed by linking networks physically (same infrastructure) and organizationally (timetables, ticketing). These “isolated” railway systems which have been built at local, regional and state level in a fairly uncoordinated and inconsistent manner have now to interact with each other. For the OECD (2003), the central issue is whether and to what extent these developments also place pressure on operational safety margins, on the transparency of reporting on safety issues, or on the capacity of market players and their regulators to render their vast network systems sufficiently resilient to withstand major disruption (e.g. national rail networks)

<table>
<thead>
<tr>
<th>Table 4: Systemic risks in the railway sector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Railway crisis</strong></td>
</tr>
<tr>
<td>Natural event (lightening, strike) or device failure (loss of power), voltage collapse, protection system failure(^1), relay system mis-operation, inadequate right-of-way maintenance</td>
</tr>
<tr>
<td>Sector vulnerability</td>
</tr>
<tr>
<td>Potential dangers</td>
</tr>
<tr>
<td>Type of systemic risk</td>
</tr>
<tr>
<td>Transmission channels</td>
</tr>
<tr>
<td>Requirements for contagious systemic risk</td>
</tr>
<tr>
<td>Recent changes in systemic risk</td>
</tr>
<tr>
<td>Historical evidence of contagious systemic risk</td>
</tr>
<tr>
<td>Corrective policies</td>
</tr>
</tbody>
</table>

Source: Based on Kaufmann (2000) and adapted by author.

There is a relatively vast literature looking at reliability of railway services (Vromans, Dekker et al., 2006). Its emphasis lies mainly on punctuality – and the associate concept of delays – which is one of the key performance measures of a railway system. According to (Vromans, Dekker et al., 2006) one way to increase the reliability is to reduce the propagation of delays due to the interdependencies between trains – for example by decreasing the interdependencies by reducing the running time differences per track section and by thus creating more homogeneous timetables. When investigating railway reliability, it is important to make a distinction between primary and secondary delays. Primary delays are initial delays caused on a train from the outside and not by other trains. These delays are caused by malfunctioning rolling stock, malfunctioning infrastructure, bad weather conditions, excessive alighting and boarding times of passengers, accidents at road-railroad crossings, and so on. Secondary delays are those delays of trains that are caused by earlier delays of other trains. They are also referred to as knock-on
delays. Secondary delays appear because of the shared use of the same infrastructure, rolling stock connections. According to Olsson and Haugland (2004: 390) there is a well established belief that infrastructure capacity utilization above 75 or 80% reduces the punctuality. Even capacity utilization above 60% is not recommended unless for rush hour, since it limits the recovery ability of the railway system. In fact, there is an exponential relationship between adding trains onto a congested network, and the expected level of performance of a network (Gibson, Cooper et al., 2002). For the time being, most efforts have concentrated on solving small initial (primary) disturbances, “because no reasonable timetable is robust enough to handle large disturbances or disruptions without severe on-line adjustments of the railway traffic” (Vromans, Dekker et al., 2006).

Does interoperability decrease or increase systemic risk?
As noted above, one important development supposed to mitigate systemic risk in the railway sector is the ERTMS project pushed forward by the European Commission that aims to achieve interoperability of the European network by 2020. While interoperability may directly reduce a multitude of risks, it indirect effect could actually be to increase systemic risk first by making the European railway network more interconnected, hence prone to supra-regional disruptions. The second argument is slightly counter-intuitive. Interoperability – defined as the ability of two (or more) systems to communicate and work together without any problem – should reduce risks of reduced performance, stability or coherence. In fact, interoperable parts (system) are often thought as reducing risk opportunities. However, interoperability needs to be understood at different levels:

- Technical interoperability: This aspect covers the technical issues of linking systems and services. It includes the following sub-systems (key aspects such infrastructure, traction units and locomotives, energy, passenger carriages and telematics applications for passenger services. In the railway sector, this task is taken up by the European Railway Agency which acts as the system authority; the task is mainly conducted through the drawing up and revision of Technical Specifications for Interoperability (TSI)

- Operational interoperability: This aspect of interoperability is concerned with harmonization of “rules” (and their different level of implementation). For example various ERTMS implementations cause a huge range of degraded situations at the border, response to alarm calls is not harmonized, differences between national values which can be confusing in border crossing zones

There are special conditions for capacity in the rail system when operating long-distance rail services. Often trains have to pass several bottlenecks, and this naturally affects the punctuality of the infrastructure that the long-distance trains run on. The risk of delays is greater for regional

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15 Carey (1998) makes a difference between exogenous delays and knock-on delays. Exogenous delays are due to events such as failure of equipment or infrastructure, delays in passengers boarding or alighting – also known as primary delays. Knock-on delays are due to exogenous delays and the interdependence in the schedule – also known as secondary delays.

16 Compatibility is something less than interoperability. It means that systems/units do not interfere with each other’s functioning. It is important to distinguish between the fundamentally different concepts of compatibility, interoperability and integration.
than for local rail traffic as the time and distance are longer. This is reflected in the punctuality statistics for different types of train (Banverket, 2007). The addition of more traffic, without matching it with an increase of capacity will most likely render the existing bottlenecks even more problematic.

While the understanding of interoperability in railway sector is only now starting to shift from a technical to an operational meaning, we argue that a performing (and safe) railway sector will require institutional interoperability. This will move the debate outside of the engineering domain and into the political realm where harmonization is much harder to achieve. Indeed, in some European countries, the same company that manages the railway infrastructure also provides the railway services. In other countries such as Sweden, the railway market is partly or fully deregulated with different stakeholders managing the infrastructure and the railway services. In Sweden, the railway traffic management is a neutral authority governing the overall use of the infrastructure while various private and public companies are operating the trains for freight and passenger traffic.

IV – Discussion

Complexity has become a significant feature of the whole modern science and technological infrastructures. As shown by system analysis, it comes with unexpected and unforeseen ‘emergent’ phenomena that not only pose risks themselves but also cause disruptions which may cascade. Systemic risk may be heightened by the fact that there is no longer a single owner, operator or regulator of the infrastructure and that, in the unbundled market paradigm, the agents’ decisions are based on different logics and incentives. In addition, interoperability may have unforeseen consequences.

It is far beyond the scope of this paper to propose means to mitigate risk in the railway sector. However, adding clarity to our understanding of systemic risk in railway systems is a first and necessary step to improve their governance. For example (Luijf, Nieuwenhuijs et al., 2008) it is important to avoid confusion between common cause vulnerabilities (e.g., an earth quake causing simultaneous, but unrelated effects in two critical infrastructures) and dependencies. They also emphasize the necessity to recognize the multi-dimensional nature of dependencies.

For the time being, a vast arsenal of quantitative methodologies propose various models to minimize cascading failures. We believe that these tools should be supplemented by an improved qualification of the risk. Some of the existing specific policy recommendations on critical infrastructure protection already go into this direction:

- Upgrading and revision of intergovernmental standards is needed on security, quality assurance, education, and training, etc., in order to cope with the more challenging use of the railway system (higher density of timetables, tighter safety margins) and new threats (trans-border transport of dangerous goods and devices).
- More effective technical, organizational and socio-political measures against malicious attacks should be carefully considered and balanced against social values such as privacy, open society and comfort.

Regulating systemic risk?
Much of the banking regulation that was put in place was designed to reduce systemic risk (Allen and Gale, 2005). In many countries capital regulation in the form of the Basel agreements is currently one of the most important measures to reduce systemic risk. If one pushes the comparison with the banking sector, it is interesting to note that in the early 19th century, assuring financial stability was primarily the responsibility of central banks. The Great Depression led the US to impose many types of banking regulation to prevent systemic risk. The recent events in the financial sector are a powerful reminder that one needs to question whether regulation, as currently implemented, increases financial stability. As pointed out by Allen and Gale (2005) poorly designed and implemented capital regulation can lead to an increase in systemic risk. However, one of the problems in devising policies to reduce systemic risk is the relatively sparse number of events/ incidents leading to a complete breakdown of a system (e.g. blackout).

For Renn (2003) the coping mechanisms in place to manage risks vary across countries and at global level. Due to the interconnected nature of the risk, a national forum would be insufficient. The ideal societal response to these types of risks could be a pan-European risk-management institution even if there are a number of major constraints on achieving such a risk management board. Every system invites free-riding, and a global system that managed and enforced standards would also threaten the advantages for free-riders. Similarly, there are always winners when a system collapses, so there would be countries or institutions that stood to gain by not participating, or by obstructing, the creation of a comprehensive response to these system breakdown risks. An idealized societal response to systemic risks would be the formation of cross-disciplinary risk-management agencies (even situated within existing institutions). Such agencies would be required to link the physical, financial and political (governance) links between the risks. One potential avenue to mitigate systemic risk would be to create a pan-European railway regulator. For the time being, regulation of the European railway system is ensured at several levels. At the national level, Member-States had to create an independent regulator (in line with Directive 2001/12). In addition, Directive 2001/14 provides that the infrastructure manager publish a network statement, which contains information on the (technical) nature and limitations of the network, the access conditions to the network and rules on capacity allocation. At the pan-European level, the European Railway Agency (ERA) plays a role of regulation when it comes to safety and interoperability. Finally, RailNetEurope (RNE) is making significant progress in establishing, shaping and improving a harmonized timetabling process for international train path requests.

A number of analyses are already moving towards a more socio-political approach, suggest the need to move towards ‘risk governance’ from ‘risk management’ (IRGC, 2006; Sajeva and Masera, 2006; Gheorghe, Masera et al., 2007; Kröger, 2008). Another study suggests that complex infrastructure systems should be analysed as ‘socio-technical systems’ in which technical systems themselves are not only complex but also involve the ‘variegated and penetrating involvement of human action, which, in all its forms, is able to affect, even critically to affect, the functioning of the system’ (Ottens, Franssen et al., 2006). Understanding and interpreting systems thus requires analysis of the relations between human actors and organisations and physical elements and systems

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17 One important point is that system breakdown risks are not affected by societal risk perception or cultural views – it is the ‘visible’ breakdown risks that have to be addressed and managed.
In a comparison of the railway and electricity sectors in the context of the significant regulatory reforms of the past two decades it has been suggested that there needs to be a coherence between the ‘critical institutional arrangements that support the technical functioning of the systems’ (Künneke and Finger, 2007b: 332). The European Union has included the notion of risk in the interoperability directives (European Commission, 2008). However, it is in the hands of the national safety authorities who “shall define, after consultation with the applicant, the scope and content of the additional information, the risk analyses and the tests requested”.

The question thus arises as to there is a need for any special forms of governance to address systemic risk in the railway sector? Clearly the most fundamental aspect of systemic risk is its system nature and this suggests the need for a system wide or centralized approach to governance. As discussed above perhaps the most important systemic risks have micro causes, e.g. trees falling on power lines or individual perpetrating malicious attacks on a portion of a track, which are then propagated through the whole system. This suggests that some aspects of systemic risk need to be managed on a decentralized basis. It particularly suggests that there needs to be a balance between centralized and decentralized governance depending on the type of risk.

As noted above, systemic risk appears to be replete with uncertainty; it appears to limit the effectiveness of statistical probabilistic analytical techniques and raises questions about how risk should be managed. It has been noted that ‘many quantitative risk management approaches rely too heavily on data from relatively benign periods and thus allow history to grant a false sense of security’ (Kambhu, Weidman et al., 2007: 18).

In the railway sector issues of systemic risk and the kinds of risks addressed are normally considered to be localized and bounded, albeit with severe consequences. As a result, the preparation and the coordination for such events remain limited. The work of (Künneke and Finger, 2007b) on coordination mechanisms could provide a useful framework to discuss coordination with the aim to mitigate systemic risk in the railway sector. For them, liberalization is likely to introduce a certain incoherence between technical coordination and institutional coordination. Indeed while from a technical point of view interoperability, capacity management, and system management will have to continue to be coordinated in a hierarchical manner, there is a certain pressure to allocate slots commercially and even to have competition among timetables. In other words, coordination problems are likely to significantly increase as a result of liberalization, which in turn will increase the incoherence between technical and institutional coordination.

<table>
<thead>
<tr>
<th>Coordination mechanism</th>
<th>Technical coordination</th>
<th>Institutional coordination</th>
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<tbody>
<tr>
<td>Centralized</td>
<td>Centralized control: top-down</td>
<td>Planned economy</td>
</tr>
<tr>
<td>Decentralized</td>
<td>Distributed control bottom-up</td>
<td>Market economy; classical contracting</td>
</tr>
<tr>
<td>Matricial</td>
<td>Integrated</td>
<td>Combined</td>
</tr>
</tbody>
</table>

Source: Adapted from (Künneke and Finger, 2007a)
Conclusion

The methods to deal with interdependencies need to capture the high complexity and interconnectedness of modern, open “systems of systems”, all kinds of human factors and the full spectrum of threats including malicious behavior and attacks, dynamic, non-linear, emergent behavior as well as the dependence from the contextual factors like market and operating environment.

Systemic risk is a matter of great concern to the financial sector (central bankers, regulators, politicians and firms) around the world. Like in the financial industry, research should focus on the mechanics and channels of the transmission shocks inter and intra railway networks. At the same time more attention should also be given to the regulatory nature of systemic risk. While the recent large-scale blackouts in Europe and the United States have left us with a sense of increasing rate of incidents, more research needs to be conducted to establish:
- the prevalence of systemic breakdowns in the railway sector
- the relationship between increased technical interconnection, market liberalization and systemic breakdowns

In order to avoid costly shutdowns a potential research agenda should be focused on the following questions:
- How is systemic risk currently governed at national and European levels in the railway sector, particularly in relation to technocratic and socio-political forms of management and governance?
- What are the strengths and weaknesses of current systemic risk governance and how might it be improved?
- What might governance institutions, structures and processes look like at national and international levels in the railway sector? In particular, which stakeholders should be involved in systemic risk governance of the railway sector?
- What sort of involvement should the various stakeholders have? Should it only be a limited form of information and dialogue, or should there be close consultation and co-decision making amongst wide ranging stakeholders?


