Organising to prevent failures of a high reliability system – lessons from the Santiago de Compostela railway disaster

Norman Kellermann
Freie Universität Berlin
School of Business & Economics
Management Department
Boltzmannstr. 20, 14195 Berlin, Germany
Email: norman.kellermann@fu-berlin.de

KEYWORDS

Railway disasters, normal accidents, high-reliability organisations, safety

ABSTRACT

This paper addresses severe accidents and catastrophes as a central spinoff of passenger transportation by rail. It analyses the Santiago de Compostela disaster from the perspectives of high reliability and inevitable accidents theory. Though, at first sight, there seems to be a single cause for the accident, the extent of the harm resulting from the derailment of the train has been influenced by a multitude of unfortunate factors. The central lessons to be drawn from the catastrophic event are improvements in redundant safety systems and the necessity of setting limitations to overly sophisticated technical solutions in interoperability.

1. INTRODUCTION

Severe accidents and catastrophes certainly represent the central spinoff of every mobility system. Accordingly, the railway system is one of the transport technologies affected by this detriment. Since the early days of the railway age, accidents have occurred in railway operations. In his book on the world's first long-distance railway, the Liverpool & Manchester line, Donaghy (1972: 120) notes: "Those in charge of the trains did not realise what could possibly happen to their trains and the passengers should the train jump the track, go over an embankment, run into another train or come against buffers without the application of brakes". Donaghy's observation already points out some of the central causes of railway catastrophes in the past and today. In his 1966 book on railway disasters, Nock lists "elements of disaster" that caused severe incidents and catastrophes in the early days: First, the early trains had strongly insufficient brakes. Second, the practice of an open time interval which allowed trains to circulate at a defined time after the previous train had passed represented a latent danger of collisions. Third, early signals were constructed unfavourably for situations of darkness and malfunction. Furthermore, a lack of means of communication and non-existent rules for track repair works caused many nearby-accidents as well as a number of disasters such as the Tidal boat train disaster of June 9th, 1865 (cf. Nock 1966: 2 ff.).

Over the years of railway history, as growing networks become closely coupled, complexity arising from technical improvements made the railway system even more vulnerable to catastrophic events. As a reaction to this, there was a gradual development of safety measures designed with the aim of reducing the risk of fatal accidents (cf. Nock 1966; Forsberg & Björnstig 2011). From an organisational science perspective, the technological revolution of railways can be regarded as a turning point that lead to the development of the first hierarchically structured modern enterprises (cf. Chandler 1977). These enterprises coped with the problem of uncontrollable complexity by developing routines representing deeply embedded rules of risk avoidance. The most important element was to establish a “clear cut set of rules” (Nock 1966: 3) which beforehand had been unnecessary in a world of fragmented small enterprises. Railways developed operational routines enabling them to deal with intense traffic on their lines, supported by sociotechnical improvements like signals and telegraphs. Among the technical and organisational principles introduced, interblock-spaces to avoid collisions and track magnets to avoid unintended running through signals stand out. Railways and regulatory bodies also underwent a learning process triggered by a number of nearby and fatal accidents. Over the decades, railways in Europe emerged to high-reliability organisations. Today, passenger transportation by rail is one of the safest forms of transportation with a fatality risk of 0.156 cases per billion passenger kilometres (cf. European Railway Agency 2013).

Transport mode used by user	**Fatality risk (2008-2010)** **Fatalities per billion passenger kilometres**
Airline passenger	0.101
Railway passenger	0.156
Car occupant	4.450
Bus/coach occupant	0.433
Powered two-wheelers	52.593
Vessels passenger	n/a

Table 1: Fatalities of railway passengers compared to other modes of transport in the EU-27.
Source: European Railway Agency 2013: 1

However, as demonstrated recently by the Santiago de Compostela disaster killing 79 passengers on July 24th, 2013, even a technologically advanced high-speed railway system bears the risk of causing death and injury. It appears that the main causes of railway accidents of the early days in some form persist in the present; therefore, any accident may reveal vulnerabilities of the safety instruments currently in use. Weick (1990: 571) writes: “We know that single cause incidents are rare, but we don’t know how small events can become chained together so that they result in a disastrous outcome”. The aim of this paper is to analyse the case of the Santiago disaster from two perspectives: from the one of high-reliability theory as well as from “normal accidents” (also referred to as inevitable accidents) theory in order to derive recommendations for organisational improvements from that catastrophic event. Hence, this work tends to synthesise previously published research and to put it into the context of a specific event (cf. Denyer et al. 2008).

2. THEORETICAL FRAMEWORK: HIGH-RELIABILITY VS. INEVITABLE ACCIDENTS THEORY

Charles Perrow’s seminal book on the inherent risk of complex technical systems put researchers’ attention to the necessity of managing complexity and anticipating possible system failures (cf. Perrow 1984). Perrow argues that “no matter how effective conventional safety devices are, there is a form of accident that is inevitable” (ibid: 3). He terms this form of inevitable accidents “normal accidents”. Building on the insights of his analysis of the Three Miles Island catastrophe, he refers to the special characteristic of complex, tightly coupled systems that they can be threatened by an interaction of failures. Although Perrow explicitly doesn’t assume these failures to occur frequently (cf. ibid: 5), “the risk will be there no matter how much attention is paid to safety” (ibid: 126). Dividing risk into two separate components, Perrow (ibid: 78) defines the risk component of complexity by interactions of “unfamiliar sequences, or unplanned and unexpected sequences [that are] either not visible or not immediately comprehensible”. The second component of risk, tight coupling, is defined as “a mechanical term meaning there is no slack or buffer or give between two items. What happens in one directly affects what happens in the other” (ibid: 89 f.). Concerning technical innovations to prevent failures, Perrow adopts a sceptical perspective. In his chapter that comes closest to the issue of railway accidents – the one on airlines and aircraft – he claims: “[a]s the technology improves, the increased safety potential is not fully reali[s]ed because the demand for speed, altitude, manoeuv[]rability, and all-weather operations increases” (ibid: 128).

Opposed to that view, a group of scholars around Todd La Porte conducted research on the factors making organisations highly reliable (cf. La Porte 1996; La Porte & Rochlin 1994; Rochlin et al. 1987). In fact, organisations like railways proved to have developed strategies to reduce the negative effects of complexity and tight coupling. These organisations have a very low tolerance of failures and found ways to keep prepared to unexpected events. From her case study on U. S. Navy vessels, Roberts (1990) comes to the conclusion that organisations achieve high reliability through continuous training, the deliberate installation of redundancy, and, finally, through the development of a safety culture. In line with these findings, Rijpma (1997) lists four central strategies highly reliable organisations apply. First, *redundancy* meaning that "if one component fails, another backs it up; if one operator fails to carry out his task, another one takes over his position; if danger lurks, multiple channels are used to transmit warnings" (ibid: 17). Second, *decentralisation* in the sense that low-level operators can insure to solve a problem without depending on any form of intermediate support. This can only be implemented if all members of the organisation are culturally socialised with "clear operational goals, decision premises and assumptions" (ibid). Third, derived from the work of Schulman (1993), Rijpma (1997) names *conceptual slack* as a source of high reliability. This refers to a firm's strategy to use the protective functions of organisational slack, thus, to maintain "some range of individual action unconstrained by formal structures of coordination or command" (Schulman 1993: 354) and to withhold some resources like time, personnel or money "from commitment to ongoing organi[s]ational projects or activities (ibid: 353). Fourth, Rijpma (1997: 17) states that high-reliability organisations have undergone a process of "long, trying, costly and, sometimes, lethal trial-and-error learning". Thus, *organisational learning* forms the fourth reliability-enhancing strategy.

Potentially dysfunctional characteristics and processes	**Organisational strategies and processes used to each of these dysfunctionalities**	**Strategies used to reduce the negative effects of both complexity and tight coupling**
Complexity		
potential for unexpected sequences	continuous training	redundancy
complex technologies	continuous training	accountability
potential for systems serving incompatible function to interact	job design strategies to keep functions separate	responsibility
indirect information sources	main direct information sources	"culture" of reliability
Tight Coupling		
time dependent processes	redundancy	
invariant sequences of operations	hierarchical differentiation	
only one way to reach goal	bargaining	
little slack	redundancy	

Table 2: Organisational responses to risk
Source: Roberts 1990: 170

The research on organisational responses to risk has been significantly influenced by Karl Weick. In his analysis of a crash of two airplanes in Tenerife, Weick (1990) puts an emphasis on the vulnerability of presumed risk-avoiding systems. What is more, Weick's (1996) famous "drop your tools" allegory reminds safety specialists that overly sophisticated instruments might be harmful instead of protecting. With their concept of “collective mindfulness”, Weick et al. (2008) present a framework of organisational processes that lead to high reliability. A recent publication on risk and organisation is Duchek’s & Klaussner’s (2013) analysis of the way material science experts in Germany deal with the risk of damaged high-speed train wheelsets. In his later work, also Perrow seizes the suggestion of the high-reliability research programme and seeks to find an adequate organisational response to risk (cf. Perrow 1999). However, there are limits of any reliability-enhancing strategy, as Busby (2006) demonstrates with his work on two disastrous train collisions on the British railway. Another catastrophe that affected a reliability-seeking organisation – the Santiago de Compostela disaster – will be examined in more detail below.

Sagan (1993) was the first scholar to link the theoretical streams of “normal accidents” and “high-reliability” by applying both theories in his analysis of accidents and near-accidents in the U. S. nuclear weapons system. It is the contribution of Rijpma (1997) to provide a balanced, integrated approach between the two schools. In essence, he raises the question what interactions there are between complexity and tight coupling on the one hand and the four reliability-enhancing strategies on the other. Put in other words, he analyses how a reliability-enhancing strategy itself can be impeded by the forces of complexity and tight coupling subsumed to make accidents inevitable.

Though at first sight, redundancy reduces the risk of failure through increasing the probability for an organisation to receive adequate information, it can bring the disadvantage of making a system even more opaque and more complex. Redundancy may create ambiguity and differing perceptions. In the realm of decentralisation, according to Perrow (1984), it is impossible to combine individual freedom of action with strict centralised rules. High-reliability organisations respond to this challenge by a culture of safety transmitting decision premises and assumptions to each individual member of them. However, when it comes to non-anticipated events which are not covered by the individual’s action repertoire, the effectiveness of a culture of reliability is degraded. Not only that they degrade safety, decision premises that have not been designed for a certain situation but are followed anyhow may have fatal consequences (cf. Vaughan 1996). In an urgent situation, “time may be too short to negotiate the proper course of action” (Rijpma 1997: 18). Hence, conceptual slack can turn out to be problematic instead of being reliability-enhancing if it creates confusion. Weick’s (1990) example of the Tenerife air disaster can be regarded as an illustration for this. Though experience with a technology increases over time, and hence, “the potential for surprising interactions” (Rijpma 1997: 21) gets reduced, this does not necessarily mean that occasional failures are immediately understood. Especially in the case of tightly-coupled organisational processes, organisations can face extensive difficulty in making their system more loosely coupled as a consequence of operational non-reliability. The example of the Dutch railways being very reluctant to install a traffic control system shows that learning can be impeded by this situation (cf. ibid: 19).

3. THE SANTIAGO DISASTER FROM BOTH THEORETICAL PERSPECTIVES

The Santiago de Compostela disaster occurred on the Ourense-A Coruña high-speed line in the evening of July 24th, 2013. Train no. 4155 operated by the Spanish National Railways RENFE running from Madrid to Ferrol in the northwest of Spain crashed at a curve before entering the station of Santiago de Compostela. 79 passengers died, many were badly injured. Hence, the Santiago disaster was the most severe railway catastrophe in Europe since the Eschede disaster killing 101 persons on June 3rd, 1998 (cf. Kühlwetter et al. 2009). According to subsequent investigations made by the Spanish authorities, the train entered the curve “A Grandeira” at a speed of 179 km/h instead of the 80 km/h permitted for this section (cf. CIAF 2014: 97 f.; ERI 2013: 534 f.). A precise description of the events directly preceding the accident is available in the final accident report published by the Spanish commission on railway accidents (CIAF 2014: 95 ff.). The crashed train was a Talgo combined electric and diesel traction composition including two power heads with generator cars aligned next to them. This type of train can run on the normal gauge of the Spanish high-speed network as well as on electrified *and* non-electrified parts of the Iberian broad gauge network.

At first sight, the Santiago disaster doesn’t appear as a “normal accident” in the sense of Perrow. It does not seem to be a case of an unexpected interaction of failures, but rather a simple case of vast consequences of a single human error. Once again in railway history, a disaster seems to have been caused by ignoring signals. Observers may conclude that the train driver bears the full responsibility for the accident because he failed to follow the rule of reducing the train’s speed after leaving the high-speed section of the line. In fact, according to the investigations carried out after the accident, the driver was distracted by a telephone conversation with the conductor at the moment he passed the signals indicating that the train was leaving the high-speed section (cf. CIAF 2014: 89). He was blamed to be fully responsible for the tragedy.

From the perspective of high-reliability theory, the reason for the accident can clearly be seen as a lack of redundancy. It could occur due to the lack of a safety technology monitoring the (non-)actions of the locomotive driver. Though the Spanish infrastructure provider ADIF together with the Spanish minister of transport claimed that all safety installations were functioning correctly at the time of the accident, and that those installations corresponded to the EU and Spanish national regulation, it turned out that there was no technical installation for assuring that a train approaching the “A Grandeira” curve from the high-speed section of the line effectively reduces its speed in order to pass safely. According to the accident report, this was due to malfunctions of the high-speed train control system at its transition to the conventional train control system (cf. CIAF 2014: 85). Consequently, trains entering Santiago de Compostela were running in a “responsabilidad del maquinista” (ibid) mode. A reliability-seeking organisation should have arranged a redundant safety mechanism in case the “reduce speed” signal is ignored by the train driver no matter if this is prescribed by regulation or not. Consequently, as a reaction to the catastrophe, ADIF immediately installed three track magnet balises controlling the trains’ speed reduction before it enters the curve at which the accident happened. ADIF took the same measures on other lines of its network with similar geographic characteristics. Thus, from the viewpoint of high-reliability theory, the infrastructure provider bears a part of the responsibility for the catastrophe as it has not implemented redundancy as a basic element of a reliability-enhancing strategy.

Anymore, regarding the Santiago disaster more closely, more factors that influenced the severity of the accident can be identified. According to “normal accidents” theory, many independent factors culminate in a severe disaster. Concerning the consequences of the excess speed which wasn’t reduced by a redundant traffic control installation, some more features of the crashed train made the event a catastrophic one.

Firstly, the train was equipped with many redundant systems allowing it to run on nearly all parts of the Spanish railway network. A video of the crash[1] shows that the locomotive almost remained on track, while the very heavy generator carriage immediately derailed, which subsequently caused the derailment of all the remaining carriages. From this point of view, technological redundancy backfired by reducing the trains’ capacity to brake safely in an event of derailment. The construction of a concrete sidewall along the curve could have prevented the carriages to be wedged together. This may constitute a special case of “perverting redundancy” (Rijpma 1997: 20) which, according to the author’s knowledge, has not been addressed in the literature before. According to the official report on the accident made by the Spanish commission on railway accidents, there had been similar accidents before in which a similar speed excess did not have the same consequences (cf. ICAF 2014: 94). Continuing this argument, what made the fatal redundancy necessary? It is the fact that the Spanish high-speed network (still) has isolated

[1] Video available at http://www.bbc.co.uk/mundo/noticias/2013/07/130725_espana_ accidente_tren_santiago_compestela_mapa_vj_.shtm

parts which require transition between different train control systems. Additionally, there seems to be a strong need to run high-speed trains on lines that are not electrified.

Secondly, the unfortunate alignment of the track made the “A Grandeira” curve very vulnerable to severe accidents. High-speed trains arrive to it from an almost perfectly straight track, but the high-speed line suddenly ends in front of the Santiago station to re-begin later in direction of A Coruña. Trains enter the problematic curve right after exiting a small tunnel. If the speed excess had occurred on a more straight part of the track, chances to break the train sufficiently to pass the dangerous curve section would have been higher. In fact, running at 195km/h, the locomotive driver succeeded to activate the emergency brake shortly before entering the curve and thus reduced the speed in the curve to the 179km/h reported above. No reflections on the general infrastructure planning or the alignment of the track can be found in the accident report published by the Spanish authorities (cf. CIAF 2014).

Figure 1: The isolated position of the Ourense-A Coruña high-speed line. Source: ADIF (http://www.adifaltavelocidad.es/es_ES/infraestructuras/lineas_de_alta_velocidad/lineas_de_alta_velocidad.shtml)

Thirdly, in what concerns the distraction of the train driver by a telephone conversation with the on-board personnel at the moment of leaving the high-speed line, it has been argued that the train driver was in fact victim of an “information overload” because he received too many inputs arising at the same time (cf. Vazquez Sande 2014). The train driver talked 100 seconds to the conductor about the question on which track the train would arrive at Puentedeume station (cf. CIAF 2014: 89). Again, it has to be scrutinised why the regulation of a reliability-seeking railway like RENFE previews communication between the conductor and the train driver about such issues. The natural point of contact for the conductor would be the traffic controller at the infrastructure provider as she/he is the person to control signals leading a train to a certain track of a station. The train driver can coercively only have an intermediate role of transmitting the information she/he gets from traffic control.

A final enigmatic question of the case is why, although the train driver realised that he had to activate the emergency brake shortly before entering the curve – and did so – the brakes had no effect of speed reduction for almost three seconds (cf. CIAF 2004: 88). This appears even more problematic because the special characteristics of the train imply two very heavy generator carriages. Observers may be reminded of the locomotives in the early days of railways that were not equipped with brakes. However, the accident commission did not conclude that improvements in the brake system of the respective train series were necessary.

Time	**Event**
20:40:56	The train passes the balise of announcement (km 83+876) of the entrance signal E7 of the "A Grandeira" junction […] at 195 km/h
20:40:59	Application of the emergency brake through the train driver (at the brake handle) at 195 km/h
20:41:02	The train passes the balise (84+171) of the entrance signal E7 of the "A Grandeira" junction […] at 195 km/h
20:41:06	Beginning of derailment sounds (according to audio recording) of the train at 179 km/h.

Table 3: Extract from the reconstruction of events occurring shortly before the accident.
Source: CIAF 2014: 88, translated by N. K.

4. LESSONS FOR ORGANISATIONAL MEASURES TO BE PERFORMED BY THE RAILWAY INDUSTRY

Altogether, the Santiago accident was not inevitable. The disaster was clearly caused by the train driver who missed a number of signals indicating him to reduce the speed of his train. However, in what concerns the fatal consequences of the driver error, there is a more complex combination of causes that led to the disaster.

Firstly, the speed excess could have been avoided by the installation of technical systems ensuring that the trains running on the line of the "A Grandeira" curve do not exceed the maximum speed. Secondly, the special characteristics of the RENFE train made the potential impact of the speed exceedance more fatal than they would have been with other rolling stock configurations. That is, the heavy generator carriage next to the electric power head was prone to derail in circumstances of irregularity. As both ends of the train were equipped with generator carriages for running on non-electrified lines, there were all chances of a severe crash in case of a derailment of the train. Thirdly, the alignment of the infrastructure combining straight high-speed lines that thread into previously existing infrastructure made junctions very vulnerable to accidents. Finally, the train driver bore the unnecessary role of a communication intermediate between the infrastructure provider and the on-board personnel which created a potential of distraction from his original duties.

Following an investigation of almost one year, the Spanish commission on railway accidents, CIAF, has published a final report including recommendations for measures to be derived from the Santiago disaster (cf. CIAF 2014). A central recommendation is the installation of balises at points where a significant speed reduction needs to be ensured. Among other points, the commission also recommends technical facilities excluding distractions of the train driver by on-board communication. Finally, the commission recommends to extend the coverage of audio recording systems in the driver's cabin and to consider the installation of video recording systems. A translated extract of the list of recommendations originally published in Spanish is cited below.

Addressee	Number	Recommendation
ADIF (Spanish infrastructure provider)	54/13-1	Prescribe that all speed reductions in a certain range must be signalled by fix installations at the track indicating the speed limit
ADIF (Spanish infrastructure provider)	54/13-2	Implement balises for speed control at points of significant speed reductions
General directorate of rolling stock (DGF)	54/13-5	For the bringing into service of new railway lines, perform a risk analysis on the possible dangers arising from the interaction of different subsystems in normal and degraded operational conditions […] Where required, effectuate that risk analysis for the lines currently in service
General directorate of rolling stock (DGF)	54/13-6	Implement necessary dispositions to ensure that the communication between the train driver and on-board personnel is effectuated in a safe manner in line with the aim of avoiding possible distractions.
RENFE Operadora (incumbent railway operator)	54/13-7.1	Increase the number of implementations of audio recording systems in the train driver's cabin and analyse the feasibility of implementing a video recording system.

Table 4: Recommendations of the Spanish commission on railway accidents
Source: Extract from CIAF 2014: 109 ff., translated by N. K.

From the analysis outlined above, it can be concluded that railway safety takes its initial point in infrastructure planning. If straightening of high-speed lines is impeded in some case, special attention has to be taken to the transition between high-speed sections and urban (or limited speed) sections of a line. These intersections are very vulnerable to technical failure and, likewise, to human error. As mentioned above, following the Santiago accident, the Spanish railway infrastructure provider has started to install technical backups to prevent speed excesses. It may also be considered to abstain from equipping trains with too many technical features. In the sense of Weick's "drop your tools" allegory, being prepared for too many areas of operation can increase the danger of severe catastrophes (see also Smart et al. 2003). At least, multi-equipped trains should be tested on their crash behaviour in order to counterweight the "perverting redundancy" of the different technological systems installed in them.

This paper was to derive managerial lessons from the specific transportation accident of Santiago de Compostela by putting it into a broader context of historic experiences with railway disasters as well theoretical concepts of "normal accidents" and high-reliability organisations. It appears clear that absolute safety of transport systems can never be attained. Railway disasters will continue to happen even though railways and railway institutions are continuously reviewing regulations and technical standards in order to prevent accidents and casualties. However, organisational measures that can help reduce the dangers arising from complexity and tight coupling exist. Thus, although "normal accidents" can never be completely avoided, the proneness of the railway system to severe accidents and disasters can be reduced by introducing a set of safety measures suggested by the research on high-reliability organisations. Though regrettably, the Santiago disaster was evitable, it can be used as an insight for preventing future similar failures of high-speed transportation by rail.

***

REFERENCES

Boin, Arjen, ed., Crisis Management. Volume III. London: Sage.

Busby, J. S. (2006), "Failure to Mobilize in Reliability-Seeking Organizations: Two Cases from the UK Railway," Journal of Management Studies, 43 (6), 1375–1393.

Chandler, Alfred D. (1977), The visible hand. The managerial revolution in American business. Cambridge, Mass: Belknap Press of Harvard Univ. Press.

CIAF Comisión de investigación de accidentes ferroviarios (2014), "Informe final sobre el accidente grave ferroviario nº 0054/2013 occurido el día 24.07.2013 en las proximidades de la estación de Santiago de Compostela (A Coruña)," Madrid: CIAF.

Clarke, Sharon (1999), "Perceptions of organizational safety: implications for the development of safety culture," Journal of Organizational Behavior, 20 (2), 185–198.

Denyer, David, David Tranfield, and Joan E. van Aken (2008), "Developing Design Propositions through Research Synthesis," Organization Studies, 29 (3), 393–413.

Donaghy, Thomas J. (1972), Liverpool & Manchester Railway Operations 1831-1845. Newton Abbot: David and Charles.

Duchek, Stephanie and Stefan Klaußner (2013), "Temporärer Umgang mit Unerwartetem: Die Analyse einer gebrochenen ICE Radsatzwelle durch die Bundesanstalt für Materialforschung und –prüfung," in Organisation von Temporalität und Temporärem. Managementforschung, Jochen Koch and Jörg Sydow, eds. Wiesbaden: Springer Fachmedien Wiesbaden, 49–82.

European Railway Agency (ERA) (2013), Lowest death toll recorded on EU railways since 2006, but collisions and derailments on rise in 2012.

Forsberg, Rebecca and Ulf Björnstig (2011), "One Hundred Years of Railway Disasters and Recent Trends," Prehospital and Disaster Medicine, 26 (05), 367–373.

Koch, Jochen and Jörg Sydow, eds. (2013), Organisation von Temporalität und Temporärem. Managementforschung. Wiesbaden: Springer Fachmedien Wiesbaden.

Kühlwetter, Hans-Jürgen, Jörg Solnerczyk, Bernd Uhlenhut, and Birte Sturm (2009), Der Prozess zum Unfall Eschede. Offprint from Schweizer Eisenbahn-Revue, Eisenbahn-Revue International, Eisenbahn Österreich 10/2002, 11/2002, 12/2002, 1/2003, 3/2003, 4/2003, 5/2003 und 6/2003. Lucerne: Minirex.

La Porte, Todd R. (1996), "High Reliability Organizations: Unlikely, Demanding and At Risk," Journal of Contingencies and Crisis Management, 4 (2), 60–71.

La Porte, Todd R. and Gene Rochlin (1994), "A Rejoinder to Perrow," Journal of Contingencies and Crisis Management, 2 (4), 221–227.

Eisenbahn-Revue International (ERI) (2013), "Zu schnell in die Kurve: Die Entgleisung bei Santiago," ERI Eisenbahn-Revue International (10), 534–535.

Nock, O. S. (1966), Historic Railway Disasters. London: Ian Allen.

Perrow, Charles (1983), "The Organizational Context of Human Factors Engineering," Administrative Science Quarterly, 28 (4), 521–541.
——— (1984), Normal accidents: Living with high risk systems: New York: Basic Books.
——— (1999), "Organizing to Reduce the Vulnerabilities of Complexity," Journal of Contingencies and Crisis Management, 7 (3), 150–155.

Rijpma, Jos A. (1997), "Complexity, Tight–Coupling and Reliability: Connecting Normal Accidents Theory and High Reliability Theory," Journal of Contingencies and Crisis Management, 5 (1), 15–23.

Roberts, Karlene H. (1990), "Some Characteristics of One Type of High Reliability Organization," Organization Science, 1 (2), 160–176.

Rochlin, Gene I., Todd R. La Porte, and Karlene H. Roberts (1987), "The self-designing high-reliability organization: Aircraft carrier flight operations at sea," Naval War College Review, 40 (4), 76–90.

Sagan, Scott D. (1993), The limits of safety: Organizations, accidents, and nuclear weapons: Princeton University Press Princeton, NJ.

Schulman, Paul R. (1993), "The Negotiated Order of Organizational Reliability," Administration & Society, 25 (3), 353–372.

Smart, P. K., D. Tranfield, P. Deasley, R. Levene, A. Rowe, and J. Corley (2003), "Integrating 'lean' and 'high reliability' thinking," Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 217 (5), 733–739.

Vaughan, Diane (1996), The Challenger launch decision: Risky technology, culture, and deviance at NASA: University of Chicago Press.

Vazquez Sande, Pablo (2014), "Infoxicación: de la presunción de inocencia a la culpabilidad," Ambitos (24).

Weick, Karl E. (1987), "Organizational Culture as a Source of High Reliability," California Management Review, 29 (2).
——— (1990), "The Vulnerable System: An Analysis of the Tenerife Air Disaster," Journal of Management, 16 (3), 571–593.
——— (1996), "Drop Your Tools: An Allegory for Organizational Studies," Administrative Science Quarterly, 41 (2), 301–313.

Weick, Karl E., Kathleen M. Sutcliffe, and David Obstfeld, "Organizing for high reliability: Processes of collective mindfulness," in Crisis Management. Volume III, Arjen Boin, ed. London: Sage, 81–123.

AUTHOR BIOGRAPHY

NORMAN KELLERMANN is a research associate in the management and marketing departments of the School of Business and Economics at Freie Universität Berlin. He received the doctoral degree in 2014 with his thesis on agent-based simulation of passenger transport markets. Born in Magdeburg, Germany, he studied Business Administration at Freie Universität Berlin, where he obtained his diploma degree in 2007. Following this, he worked as a business analyst for Germany's leading railway operator Deutsche Bahn AG. He specialised in intermodal mobility, regional passenger transport and sales.