2015

Human Factors

VY Safety Letter Spezial V

DFS Deutsche Flugsicherung

Vorwort

Robert Schickling

Das vorliegende Heft ist der fünfte Band unserer Reihe des Safety Letter Spezial zum Themengebiet Human Factors.

Ich freue mich, dass diese Reihe beständig fortgesetzt wird. Sie bietet die Gelegenheit, das Themengebiet in der DFS umfassend darzustellen. Neben den eigenen DFS-Beiträgen sind es besonders die Gastbeiträge, die uns namhafte Wissenschaftler zur Verfügung stellen, die zu dem hohen Qualitätsniveau der Reihe beitragen.

Das Thema Human Factors hat sich in der DFS etabliert. Wir haben auf diesem Gebiet gute Fortschritte gemacht und wir werden weiter intensiv daran arbeiten. Es ist mir ein Anliegen, das Themengebiet auch in den höheren Managementebenen noch deutlicher in den Blickpunkt zu rücken.

Nachdem die letzten SL Spezial die Theorien eines modernen Human Factors und Safety Verständnisses im Fokus hatten, geht es in diesem Band jetzt darum den Transfer in die Praxis darzustellen. Das ist nicht einfach, da es neben der Veränderung in der Aufmerksamkeit von einzelnen Systemkomponenten zu einer integrierten systemischen Sichtweise – das Heft mit dem Schwerpunkt Automation hat das eindringlich gezeigt – auch um eine Veränderung im Grundverständnis von Safety in komplexen Organisationen geht.

Bisher stehen bei Safety die Analyse von Vorfällen und das Lernen aus Fehlern im Vordergrund. Da aber die Anzahl der Vorfälle in unserer Organisation sehr gering ist, ist der Umfang an Erfahrung, der aus deren Analyse gezogen werden kann, entsprechend klein. Auch hat es sich in anderen Disziplinen längst gezeigt, dass man aus Fehlern nur begrenzt lernen kann.

Wir sind sehr erfolgreich in unserem Business und sollten unseren Erfolg messen und aus den erfolgreichen Handlungen lernen.

Es geht beim Praxistransfer daher immer auch darum, den Fokus auf das tägliche Arbeiten und den Erfolg zu lenken. Wir sind sehr erfolgreich in unserem Business und sollten unseren Erfolg messen und aus den erfolgreichen Handlungen lernen. „Mach mehr von dem, was funktioniert“, wie es einst Paul Watzlawick formuliert hat.

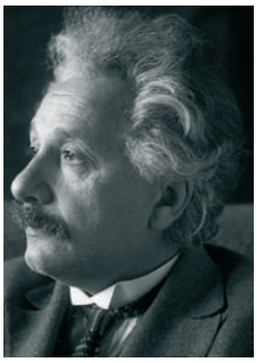
Es gibt Ansätze in der DFS, in denen uns dieser Wechsel gelingt. In der Integration von HF und Ergonomie in Systementwicklung und Automation sind wir sehr gut aufgestellt und mittlerweile gefragter Partner und Benchmark. Das Projekt „Weak Signals“, das der Bereich VY/D mit einigen Center und TWR-Niederlassungen angestoßen und erprobt hat, geht in die richtige Richtung und ist vielversprechend.

Ich begrüße diese Entwicklungen sehr, da es unser Unternehmen zukunftssicher macht und die bereichsübergreifende Zusammenarbeit stärkt.

Robert Schickling


SAFETY FIRST

Inhalt



Sie halten den fünften „Safety Letter, Human Factors Spezial“ in Ihren Händen. In den vergangenen Ausgaben haben wir stets einen Themenblock hervorgehoben und anhand mehrerer Beiträge illustriert. In dieser Ausgabe haben wir uns dazu entschieden, das Thema Komplexität von einer theoretischen und praktischen Seite zu beleuchten. Sie finden dementsprechend sowohl theoretisch eingefärbte als auch praktische Implikationen zu dem Thema in diesem Heft.

„Man muss die Dinge so einfach wie möglich machen. Aber nicht einfacher.“
(Albert Einstein)

Eine häufige Antwort auf das Problem hoher Komplexität lautet, sie zu reduzieren und möglichst in einfache lineare Systeme umzuwandeln. Wir müssen jedoch erkennen, dass diese Antwort lediglich die Tür zu einfachen Antworten und Lösungen öffnet, die auf längere Sicht ineffektiv sind. Wenn bereits ein Flügelschlag eines Schmetterlings ausreicht, um einen Tornado auszulösen (der sogenannte „Butterfly“-Effekt), muss die Antwort dann lauten, dass man die Finger von solchen Systemen lässt? Für die Praxis ist dies keine zufriedenstellende Lösung. Unternehmen, die keine andere Wahl haben als in Systemen zu arbeiten, in denen Komplexität vorherrscht, müssen Strategien entwickeln, diese zu bewältigen und zu managen. Lediglich eine Reduzierung anzustreben erscheint nach heutigem Wissenstand nicht erfolgsversprechend zu sein.

Der erste Artikel dieser Ausgabe stammt von **Prof. Klaus Mainzer** und gibt einen grundsätzlichen Überblick über das Thema Komplexität, das in vielen unterschiedlichen Lebensbereichen allgegenwärtig ist. Was können wir aus den Dynamiken, die in der Natur, Wirtschaft und Gesellschaft vorherrschen, lernen? Wie unterscheiden sie sich?
Und noch viel entscheidender: Welche Konsequenzen bedeuten diese Erkenntnisse für das Management einer komplexen Organisation?

Prof. David Byrne ist ein weiterer anerkannter Experte auf dem Gebiet der Komplexitätsforschung. Sein Artikel zentriert sich um das Fallbeispiel eines 17 Monate alten Kindes, das nach vielen Verletzungen schließlich zu Tode kam und einen Aufschrei in der englischen Presse verursachte. Komplexität ist auch im öffentlichen Sektor zu finden, das heißt, dass sie eine sogenannte Emergenz zeigt. Ein System kann nicht anhand der Analyse ihrer bestehenden Komponenten verstanden werden, sondern aufgrund ihrer Interaktionen und Beziehungen untereinander. Der Text schließt mit Parallelen und Implikationen für das System Luftfahrt.

Ein spezifisches Beispiel aus dem Transportsektor veranschaulicht **Prof. David Slater**. Anhand eines Zugunglücks werden Schwachstellen unterschiedlicher Unfallmodelle veranschaulicht. Ein besonderes Augenmerk liegt dabei auf der Betrachtung von Arbeitsbedingungen, die angenommen werden („work-as-imagined“), und jenen, die in einer Situation tatsächlich vorhanden waren („work-as-done“). Am Ende zeigt Slater einen Weg auf, wie anstatt isolierte Komponenten, Systemfunktionen benutzt werden können, um ein komplexes System zu beschreiben.

Diesen ersten theoretischen Artikeln folgt eine Übersichtsarbeit, die die wissenschaftlichen Erkenntnisse in zehn Handlungsprinzipien komprimiert. Der Text von **Steven Shorrock, Jörg Leonhardt, Tony Licu und Christoph Peters** nimmt eine systemische Perspektive ein und leitet aus den unterschiedlichen Studien komplexer Systeme eine Reihe von praktischen und konkreten Handlungsanweisungen ab. Diese Prinzipien stehen nicht isoliert, sondern sind untereinander verbunden. Sie ermuntern Systeme, Personen und Ereignisse mit einem anderen Blick wahrzunehmen.

Nach dieser theoretischen und praktischen Beleuchtung des Themas Komplexität stellt der Artikel von **Jörg Leonhardt** eine Standortbestimmung dar. Seit vielen Jahren hat die Abteilung Human Factors im Unternehmens-sicherheitsmanagement einen Perspektivenwechsel angestoßen, der nicht nur in der Ausbildung neuen Personals seine Spuren hinterlassen lasst. Auch die Abteilungsorganisation orientiert sich an den Prinzipien des sogenannten

„Resilience Engineering“ (RE), in dem Komplexität berücksichtigt wird und es darum geht, Sicherheit proaktiv zu managen.

Einer der Gründungsväter des Resilience Engineering, Prof. Erik Hollnagel, fasst zusammen, dass viele Organisationen die Bedeutung der gestiegenen Komplexität ihrer Systeme noch nicht verstanden haben, indem er sagt:

> *„It is the dilemma of Safety Management and Risk Management that we inadvertently create the problems of the future by trying to solve the challenges of the present with the mindset (model, theories & methods) of the past“.*

Diese Ausgabe möchte daher einen Beitrag leisten, dass unser Blick und Verständnis zukunftsorientiert bleibt. Dafür ist es auch nötig, ein tieferes Verständnis zu entwickeln, was Komplexität heißt und was dies konkret für unsere Systeme bedeutet. Wir sind uns darüber bewusst, dass die Texte nicht immer einfach zugänglich sind, da sie eine Mischung aus Wissenschaft und Praxis reflektieren. Sie spiegeln aber auch unseren Anspruch auf ein fundiertes wissenschaftliches Fundament wider, das am Anfang eines Perspektivenwechsels steht. Dieser Perspektivenwechsel ist sicherlich noch nicht abgeschlossen und wird uns die nächsten Jahre weiterhin beschäftigen.

Wie immer freuen wir uns über Anregungen, Kritik und einen regen Austausch.

Viel Spaß beim Lesen!

Christoph Peters und Jörg Leonhardt

Komplexität ist und bleibt ein Schlüsselthema im 21. Jahrhundert. Erfolgreiche Unternehmen werden immer stärker daran gemessen, wie sie den hohen Grad an Komplexität ihres Unternehmens und Systems, in dem sie operieren, bewältigen. Der vorliegende Artikel beleuchtet die Dynamik komplexer Systeme in unterschiedlichen Bereichen und gibt somit ein differenziertes Bild über daraus resultierende Implikationen, die für das System Luftfahrt und Flugsicherung eine immer größer werdende Rolle spielen.

Chaos und Selbstorganisation: Zur Dynamik komplexer Systeme

Von Klaus Mainzer

Komplexe Systeme sind ein hochaktuelles Forschungsgebiet in Natur-, Technik-, Wirtschafts-, Sozial-und Geisteswissenschaften. Täglich erleben wir Labilität und Risiko in Natur und Gesellschaft, aber auch die Entstehung von Neuem. Können wir aus Chaostheorien, aus der Entstehung von Ordnung und Selbstorganisation in der Natur lernen, komplexe Prozesse unserer technischen und sozialen Systeme zu steuern? Wo sind grundlegende Unterschiede in der Dynamik von Natur und Gesellschaft? Welche Konsequenzen lassen sich aus der Wissenschaft vom Komplexen für unser Handeln ziehen? Komplexitätsforschung wendet sich an Naturwissenschaftler, die sich für die Dynamik komplexer physikalischer, chemischer, biologischer und ökologischer Systeme interessieren, an Ingenieure, die sich mit komplexen Netzwerken und der Kontrolle rückgekoppelter Systeme beschäftigen, an Ökonomen und Sozialwissenschaftler, die im Zeitalter der Globalisierung komplexe Märkte, Verkehrs- und Transportsysteme oder urbane Systeme (z.B. Stadtmetropolen) untersuchen und schließlich an alle, die verstehen wollen, welche komplexen Prozesse ihre Lebenswelt bestimmen. Was wir dringend benötigen, sind Frühwarnsysteme für extreme Ereignisse in komplexen Systemen, um auf die verheerenden Auswirkungen sowohl z.B. eines Tsunamis als auch einer Finanzkrise vorbereitet sein. Nur so sind nachhaltige Entscheidungen in einer global vernetzten Welt möglich.

Komplexe Systeme bestehen aus vielen Elementen, deren Wechselwirkungen kollektive Ordnungen und Muster, aber auch Chaos und Turbulenz erzeugen.

Chaos und Komplexität in der Natur

Komplexe Systeme bestehen aus vielen Elementen, deren Wechselwirkungen kollektive Ordnungen und Muster, aber auch Chaos und Turbulenz erzeugen. Die Gesetze dieser dynamischen Prozesse untersucht die Komplexitätsforschung – von komplexen atomaren, molekularen und zellulären Systemen in der Natur bis zu komplexen sozialen und wirtschaftlichen Systemen in der Gesellschaft. Komplexitätsforschung beschäftigt sich fachübergreifend mit der Frage, wie durch die Wechselwirkung vieler Elemente eines komplexen Systems (z.B. Moleküle in Materialien, Zellen in Organismen oder Menschen in Märkten und Organisationen) Ordnungen und Strukturen entstehen können, aber auch Chaos und Zusammenbrüche.

Man spricht dann von „emergenten“ Eigenschaften komplexer Systeme, die nicht auf Verhalten der einzelnen Systemelemente zurückgeführt werden können. Komplexitätsforschung hat das Ziel, solche emergenten Eigenschaften in komplexen Systemen zu erkennen. So ist „feucht“ eine emergente Eigenschaft einer Flüssigkeit, die sich aus der kollektiven Wechselwirkung der vielen Flüssigkeitsmoleküle ergibt. Ein einzelnes Molekül ist nicht „feucht“. Von besonderem Interesse ist es in sozialen Systemen, Chaos, Spannungen und Konflikte zu erkennen und ihre Ursachen zu verstehen, um daraus Einsichten für neue Gestaltungspotentiale der Systeme zu gewinnen.

Dazu werden neue Grundbegriffe, Messmethoden, Modelle und Algorithmen eingeführt. So lassen sich kollektive Ordnungen durch Ordnungsparameter charakterisieren. Ordnungen entstehen ebenso wie Chaos und Zerfall in

kritischen Zuständen, die von Kontrollparametern eines Systems empfindlich abhängen oder sich selber organisieren. Diese ausgezeichneten Zustände werden häufig auch Attraktoren genannt, da die dynamischen Entwicklungen eines Systems quasi wie in den Wasserstrudel eines Abguss hineingezogen werden. Komplexe Muster von Zeitreihen und anderen Kriterien dienen dazu, im Vorfeld kritische Situationen aus Prozessdaten zu erkennen und rechtzeitig Vorkehrungen zu treffen. Dabei spielen Computermodelle eine entscheidende Rolle. Die dynamischen Prozesse komplexer Systeme in Natur und Gesellschaft lassen sich erst seit wenigen Jahren in Simulationsmodellen analysieren, die durch die gesteigerten Rechenkapazitäten von Computern möglich wurden.

Komplexität bestimmt die Wissenschaft des 21. Jahrhunderts. Die sich abzeichnenden Schlüsselthemen dieses Jahrhunderts haben mit diesen komplexen Prozessen zu tun. Globale Klimaveränderungen, Erdbeben und Tsunamis werden in Computermodellen komplexer dynamischer Systeme untersucht. Die Nanotechnologie entwickelt neue Materialien aus komplexen molekularen Strukturen. Wie konnte aus diesen „toten“ Bausteinen Leben entstehen? Im Laufe der chemischen Evolution entstanden auf der Erde geeignete Makromoleküle, deren Wechselwirkung unter mehr oder weniger zufälligen Bedingungen kollektive Zelleinheiten mit Lebensfunktionen bildeten. Leben ist also eine emergente Eigenschaft biochemischer Systeme, die nicht durch ihre molekularen Bausteine alleine erklärt werden kann, sondern nur durch ihre Wechselwirkung. Die komplexen Netzwerke der molekularen Zellbausteine (z.B. Proteine) untersucht die Systembiologie in komplexen Computersimulationen. Sie arbeitet daher gewissermaßen an der Schnittstelle von der „unbelebten“ zur „belebten“ Natur. Die Gentechnologie analysiert DNA-Programme, die Zellen sich selber reproduzieren lassen. Dabei spielen wieder Zufallsfluktuationen eine Rolle, die als Mutationen zur Entstehung veränderter Organismen führen.

Komplexe Prozesse bestimmen auch die moderne Medizin. Krankheiten wie z.B. Krebs, Herz-Kreislauf- und Gefäßerkrankungen hängen von hochkomplexen zellulären Wechselwirkungen ab. Viren mutieren und schaukeln sich zu globalen Infektionen auf, die sich wellenartig über den Erdball ausbreiten. Das Herz ist ein komplexes Organ aus Herzzellen, die elektrisch wechselwirken. Beim gesunden Menschen erzeugen die elektrischen Impulse ein kollektives Verhaltensmuster, das sich in den rhythmischen Zeitreihen der EKD-Daten niederschlägt. Diese Oszillation entspricht den Pumpbewegungen des Herzmuskels. Im Fall von Herzkammerflimmern bricht der kollektive Rhythmus zusammen, die elektrischen Impulse sind nicht mehr koordiniert und das Herz gerät in einen Chaosattraktor, aus dem es sich selber nicht mehr befreien kann. Defibrillatoren versuchen durch einen äußeren elektrischen Schock, das Herz wieder in sein altes Verhaltensmuster zu versetzen.

Komplexitätsforschung kann helfen, Gräben zwischen Natur-, Geistes- und Sozialwissenschaften zu überwinden. Vom Standpunkt der Komplexitätsforschung ist das Gehirn ein komplexes dynamisches System aus Milliarden von Nervenzellen. Seine komplexen Prozesse zeigen uns, wie aus den vielfältigen Wechselwirkungen seiner Elemente Ordnung und Struktur entstehen kann – der menschliche Geist mit seinen vielfältigen Fähigkeiten und Begabungen, aber auch mit seiner Gefährdung von Chaos, Desorientierung und Krankheit.

Auf der Mikroebene des Gehirns sind die Wechselwirkungsregeln der Neuronen einfach. Wie die Bitzustände in einem Computer kann jedes Neuron nach dem digitalen „Alles-oder-Nichts"-Prinzip nur „feuern" oder „nicht feuern", das heißt, neurochemisch über Botenstoffe (Neurotransmitter) eine Oberflächenspannung der Zellmembran entladen oder ruhen und dabei durch Impulse benachbarter Neuronen eine Spannung aufbauen, die sich bei einer bestimmten Reizschwelle wieder entlädt. Feuern benachbarte Zellen immer wieder gleichzeitig, bauen sie ein kollektives Verschaltungsmuster auf, das in Computerbildern beobachtet werden kann. Die Neuropsychologie zeigt uns, dass unterschiedliche kollektive Muster solcher Neuronencluster mit mentalen Zuständen wie Wahrnehmung, Denken, Bewusstsein und Emotionen verbunden sind. Hier sind wir also gewissermaßen an der Schnittstelle von Geistes- und Naturwissenschaften: Mentale Zustände sind emergente Eigenschaften des Gehirns. Das einzelne Neuron kann weder denken noch fühlen.

Organe wie Herz und Gehirn sind komplexe Systeme aus Zellen. Populationen sind komplexe Systeme von Organismen. Ökologische Systeme bestehen aus Populationen und vielen anderen Klima- und Umweltbedingungen. Während der Evolution hat sich ein komplexes System von Gleichgewichten zwischen Umwelt, Tier- und Pflanzenpopulationen entwickelt. Lokale Störungen (z.B. Aussterben von Tier- und Pflanzenarten) können sich im Sinn des Schmetterlingseffekts zu globalen Veränderungen (z.B. Störung der Nahrungskette) aufschaukeln.

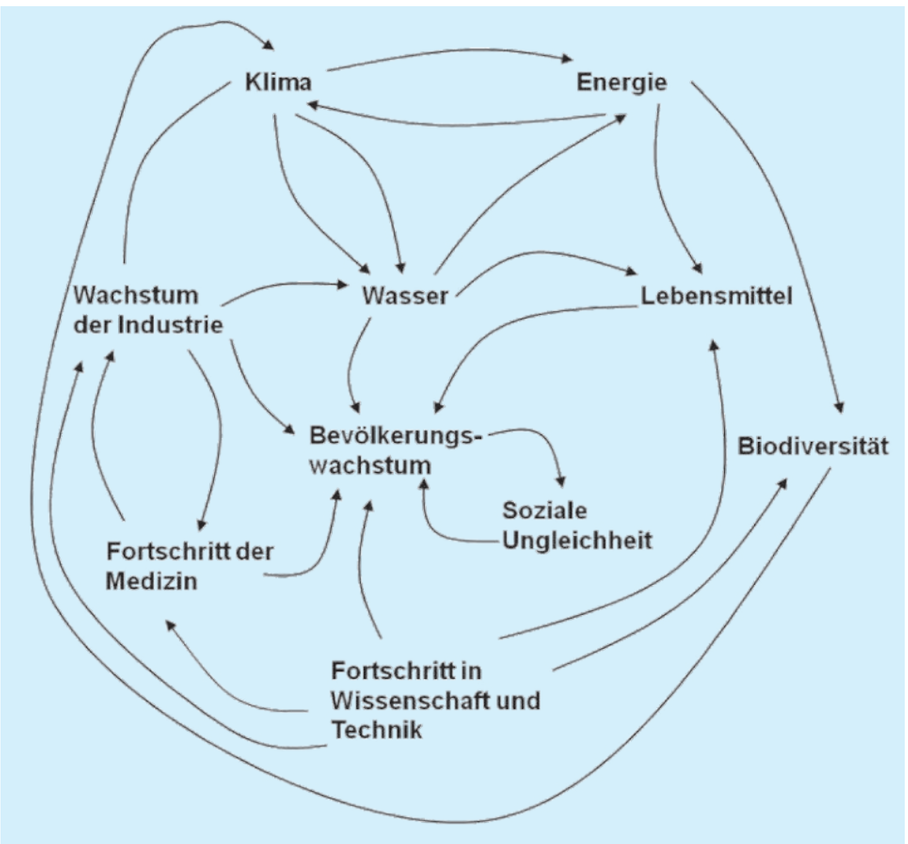


Abb1 Komplexe Rückkopplungen des Erdsystems

Ökologische Systeme sind selber Teil des gesamten Erdsystems, in dem Klima und natürliche Ressourcen mit der menschlichen Zivilisation verbunden sind (Abb. 1). Wachsende Erdbevölkerung, Anpassung der Lebensstile auch in Schwellen- und Entwicklungsländern führen zu einer immer stärker werdenden Übernutzung der Ressourcen und Verschmutzung von Wasser, Boden und Atmosphäre. In diesem komplexen System von Rückkopplungsschleifen lösen extreme lokale Störungen (z.B. Erdbeben, Tsunami, Nuklearkatastrophen) eine kaskadenhafte Ausbreitung von Effekten aus, die das gesamte System erschüttern (Abb. 2). Wir benötigen daher Frühwarnsysteme für Krisen und Katastrophen im komplexen Erdsystem. Natur, Umwelt und Leben lassen sich zwar aufgrund ihrer Komplexität nicht total berechnen und kontrollieren. Wir können aber ihre Systemgesetze analysieren und verstehen, um die Selbstorganisation nachhaltiger Entwicklungen zu ermöglichen.

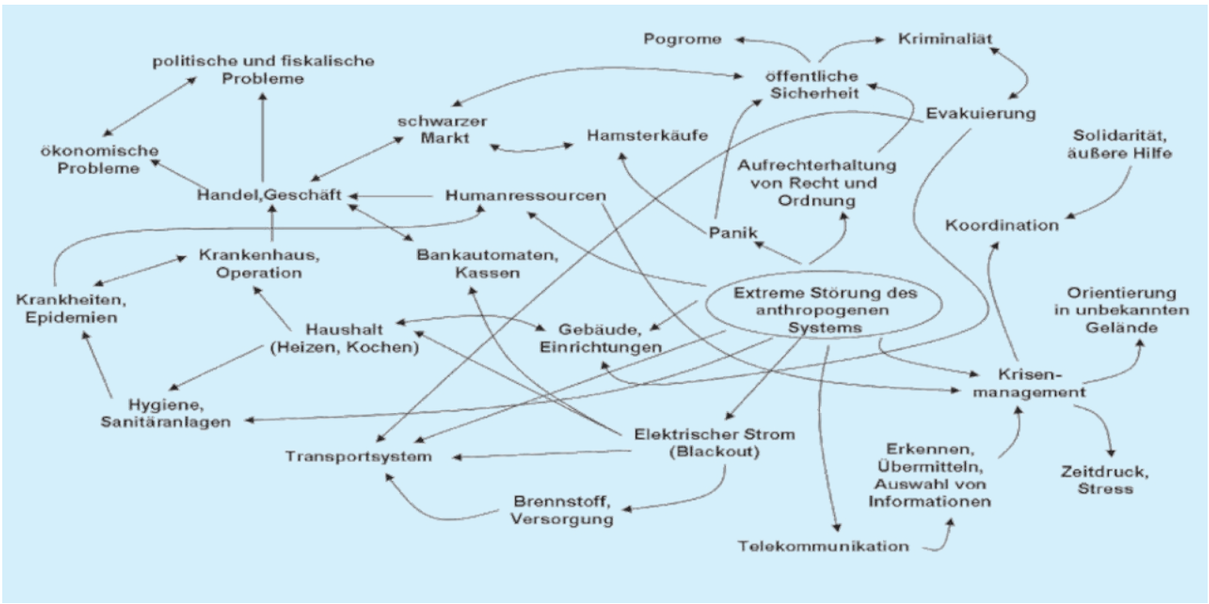


Abb. 2 Extreme lokale Störungen lösen in komplexen Systemen globale Krisen aus (Quelle: nach Albeverio u.a. 2006, Fig. 15.6).

Chaos und Komplexität in Wirtschaft und Gesellschaft

Menschen agieren heute in komplexen Organisationen und Gesellschaften. Was wissen wir über deren Dynamik? Wie ist Handeln und Entscheiden in solchen komplexen Systemen möglich? Menschen verhalten sich in Gruppen und erzeugen dabei typische Verhaltensmuster, bauen soziale Ordnungen auf oder lassen das ganze System instabil werden und stürzen ins Chaos ab.

Bei sozialem Verhalten von Menschen stellen sich zwar bemerkenswerte Analogien mit Modellen der Natur (z.B. Schwarmintelligenz) heraus, die aber in anderer Hinsicht völlig verschieden sind. So sind bereits Börsendaten Messungen von subjektiven Glaubensannahmen, Meinungen und Hoffnungen, die Wirtschaftsdynamik beeinflussen, das heißt, etwas verändert sich messbar, weil wir es wünschen, glauben, hoffen oder befürchten. Dabei kommt es zu charakteristischen Rückkopplungen zwischen Handelnden, ihren Absichten und Modellen sozialer Wirklichkeit. So können die Voraussagen des Vorstandsvorsitzenden eines DAX-Unternehmens über die Zukunft seiner Firma zu deutlichen Verhaltensveränderungen von Investoren und Mitarbeitern führen. Solche Rückkopplungen sind in der Naturwissenschaft nicht bekannt. Molekülen und Zellen ist es buchstäblich egal, wie wir sie modellieren und was wir über sie voraussagen. Wenn wir uns solcher Rückkopplungen unserer Modelle bewusst sind, können sie durchaus zu wichtigen Einsichten für geeignete Entscheidungen beitragen.

Märkte und Unternehmen sind Beispiele für komplexe ökonomische Systeme, in denen Menschen in vielen ökonomischen Funktionen interagieren. In der Tradition des klassischen Liberalismus und analog zur klassischen Physik des 18. und 19. Jahrhunderts wurde häufig eine lineare Gleichgewichtsdynamik angenommen, nach der die freie Selbstorganisation ökonomischer Kräfte automatisch zum „Wohlstand der Nationen“ führt. Im Zeitalter der Globalisierung liegt den Finanz- und Wirtschaftsmärkten tatsächlich eine Nicht-Gleichgewichtsdynamik zugrunde, deren Phasenübergänge mit Turbulenzen und Chaos, aber auch neuen Innovationsschüben verbunden sind. Attraktoren komplexer Dynamik entsprechen wieder Ordnungsparametern und Potenzgesetzen zwischen Zufall und starrer Regularität. Damit kann Komplexitätsforschung Signale erkennen, um sich rechtzeitig auf wirtschaftliche Umbrüche und Chancen vorzubereiten.

So ist die Finanzwelt ein komplexes System aus Millionen von Menschen, deren einzelne Reaktionen und Handlungen uns unmöglich alle bekannt sein können. Dennoch erzeugen ihre vielfältigen Wechselwirkungen Effekte, die wir messen und beobachten. Dabei schlagen sich Veränderungen von Preisen, Börsen und Wechselkursen in Zeitreihen aus mehr oder weniger schwankenden Zickzack-Kurven nieder.

Daher liegt es nahe, das unbekannte Einzelverhalten von Millionen von Menschen mit den Molekülen einer Flüssigkeit zu vergleichen, für die wir zwar keine Einzelprognosen, aber dennoch statistische Trendaussagen abgeben können. Der französische Mathematiker Louis Bachelier (1870-1946) beschrieb die Auf- und Abwärtsbewegungen des Kurses einer Anleihe mathematisch wie eine Brownsche Zufallsbewegung, bei der ein Pollenkorn auf einer Flüssigkeit durch viele molekulare Stöße vorwärts getrieben wird. Die Leistung von Bachelier ist umso bedeutsamer, da die Brownsche Bewegung in der Physik erst fünf Jahre später durch Einstein mathematisch beschrieben wurde. Einstein war Bacheliers Anwendung auf den Finanzmarkt nicht bekannt.

Wie beim fairen Münzwurf stellte Bachelier sich den Anleihemarkt als faires Spiel vor. Da in diesem Fall der Ausgang eines Münzwurfs immer vollständig unabhängig vom vorherigen Münzwurf ist, wird auch jede Kursbewegung als unabhängig von der vorausgegangenen angenommen. Der Markt, so können wir anschaulich sagen, hat nach dieser Annahme kein Gedächtnis. Ferner nahm Bachelier an, dass die Kurse einem Gleichgewicht von Angebot und Nachfrage entsprechen.

Zeichnet man nun die Änderungen der Anleihekurse über einem bestimmten Zeitraum auf, breiten sie sich in der Form der Gaußschen Glockenkurve aus (Abb. 3). Die vielen kleinen Änderungen häufen sich im Zentrum der Glocke, die wenigen großen liegen am Rand. Der Kursverlauf, der einer Gaußschen Normalverteilung entspricht, verzeichnet meistens nur kleine zufällige Änderungen, die sich innerhalb einer Standardabweichung bewegen. Man spricht deshalb auch von einem „milden" Zufallsrauschen, das den Börsen- und Finanzmärkten zugrunde liegt. Das hat etwas Beruhigendes an sich und vermittelt den Eindruck von berechenbaren Prozessen. Jedenfalls glaubte man, sich auf diese Art von Zufall, der vom vertrauten Gesetz der großen Zahl regiert wird, einrichten zu können.

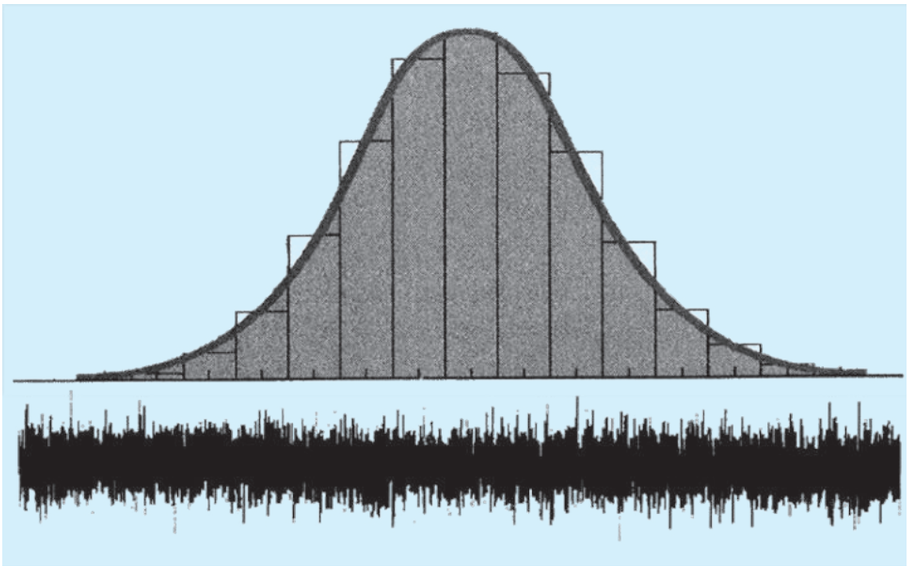


Abb.3. Normalverteilung der Kursänderungen von Börsendaten (Gaußsche Glockenkurve) (Quelle: Mainzer 2008, Abb. 15)

Bereits der berüchtigte Schwarze Freitag von 1929 mit seinen dramatischen Kurszusammenbrüchen war ein extremer Ausreißer aus der gemäßigten Normalverteilung der Zufallsänderungen. Der milde Zufall ist eine Illusion des Bachelierschen Modells und der darauf aufbauenden Finanztheorie. Die Finanzwelt ist rau, gefährlich und unberechenbar wie das Wetter des Pazifiks mit seinen Taifunen (Abb. 4).

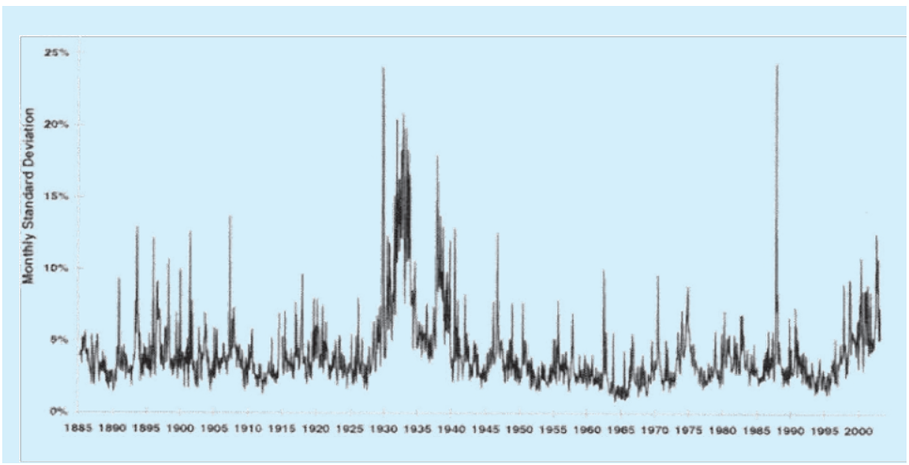


Abb. 4 A Turbulenzen in der Atmosphäre (Quelle: Mainzer 2008, Abb. 16)

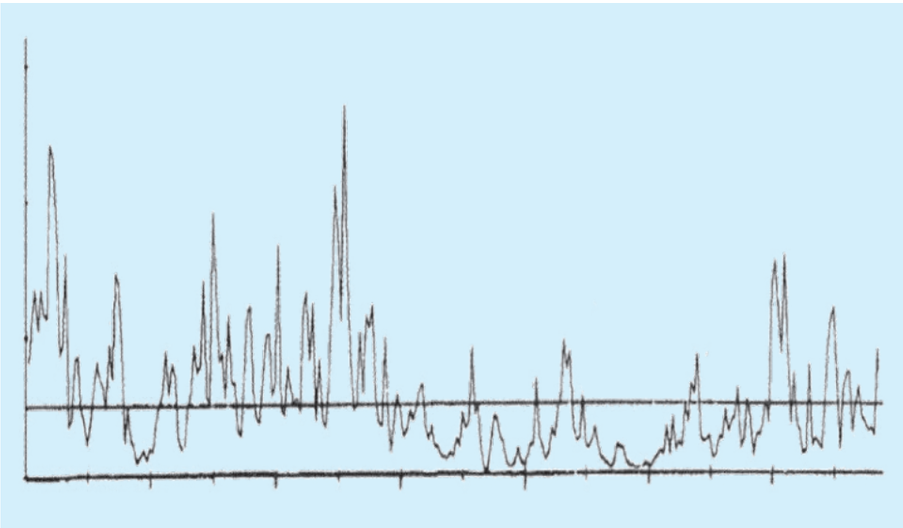


Abb. 4 B Turbulenzen in den Finanzmärkten (Quelle: Mainzer 2008, Abb. 16)

Wilde Ausreißer von Kursen widersprechen der Hypothese von Bachelier, wonach Kurse sich ändern sollten, als wären sie durch Münzwürfe ermittelt worden. Die Auf- und Abwärtssprünge folgen dann vielmehr der Verteilung eines Potenzgesetzes. In der Ökonomie wurde ein Potenzgesetz erstmals von Vilfredo Pareto (1848-1923) eingeführt. Er nahm eine Verteilungsfunktion $y \sim x^{-v}$ des Wohlstands einer Gesellschaft an, wobei y die Anzahl der Menschen mit Einkommen x oder größer als x ist und v ein Exponent, den er bei 1,5 einschätzte. Paretos Einkommenskurve sollte zeigen, wie sich Reichtum in jeder menschlichen Gesellschaft in einem beliebigen Zeitalter und einem beliebigen Land verteilt. Sie wurde Anfang des 20. Jahrhunderts in verschiedenen Gesellschaften und Orten empirisch ermittelt und zeigte überall überraschende Gemeinsamkeiten. Pareto fasste sie deshalb als universales Gesetz auf.

Auch die jüngste Finanzkrise hing wesentlich von falschen Annahmen über Normalverteilungen ab. Für die Verteilung vieler kleiner Risiken, wie sie z.B. Immobilienkredite an untere Einkommen mit geringer Eigenkapitaldeckung darstellen, wurde wieder statistische Unabhängigkeit und damit nach dem Gesetz der großen Zahl eine Normalverteilung angenommen. In diesem Fall ist die Wahrscheinlichkeit hoch, dass viele Kreditnehmer auch rückzahlfähig sind. Auslöser der weltweiten Krise war tatsächlich der lokale amerikanische Immobilienmarkt. Um die Risiken von vielen kleinen Immobilienkrediten zu streuen, verkauften sie amerikanische Banken in sogenannten verbrieften Portfolios mit anderen mehr oder weniger riskanten Wertpapieren auf dem internationalen Markt. Andere Banken im Ausland, die diese Papiere, aufkauften, gaben die Risiken weiter, indem sie die riskanten Papiere wiederum „verbrieften“ und mit anderen Wertpapieren weiterverkauften. In vielfachen Verbriefungsaktionen entstand so ein weltweites komplexes Netz von Abhängigkeiten und Risiken, die von den Betroffenen im Einzelnen nicht mehr durchschaut wurden. Als schließlich der amerikanische Immobilienmarkt kollabierte, übertrug sich dieses lokale Ereignis im Sinn des Schmetterlingseffekts blitzartig über den Globus und löste zunächst eine weltweite Bankenkrise und in deren Folge eine globale Wirtschaftskrise aus. Die Risiken waren, entgegen der ursprünglichen Annahme, nicht normalverteilt, sondern in einem komplexen Netz von Abhängigkeiten verbunden.

Die klassische Hypothese von Bachelier eines uniformen Finanzmarkts ist also dringend reformbedürftig, um die Komplexität von tatsächlichen Verhaltensweisen zu erfassen. Die jüngste Finanz- und Wirtschaftskrise hat uns gezeigt, dass wir in komplexen Prozessen Risiken nicht beliebig verstreuen können, um sie quasi durch mathematische Tricks verschwinden zu lassen. Alles hat seinen Preis: Es gibt keinen „free lunch“. Physikalisch gesprochen gibt es kein Perpetuum Mobile der Finanzen, das aus Nichts Gewinne produziert. Kredite müssen durch hinreichend großes Eigenkapital abgedeckt sein. Dazu bedarf es weltweiter Regeln in neuen Banken- und Wirtschaftsabkommen.

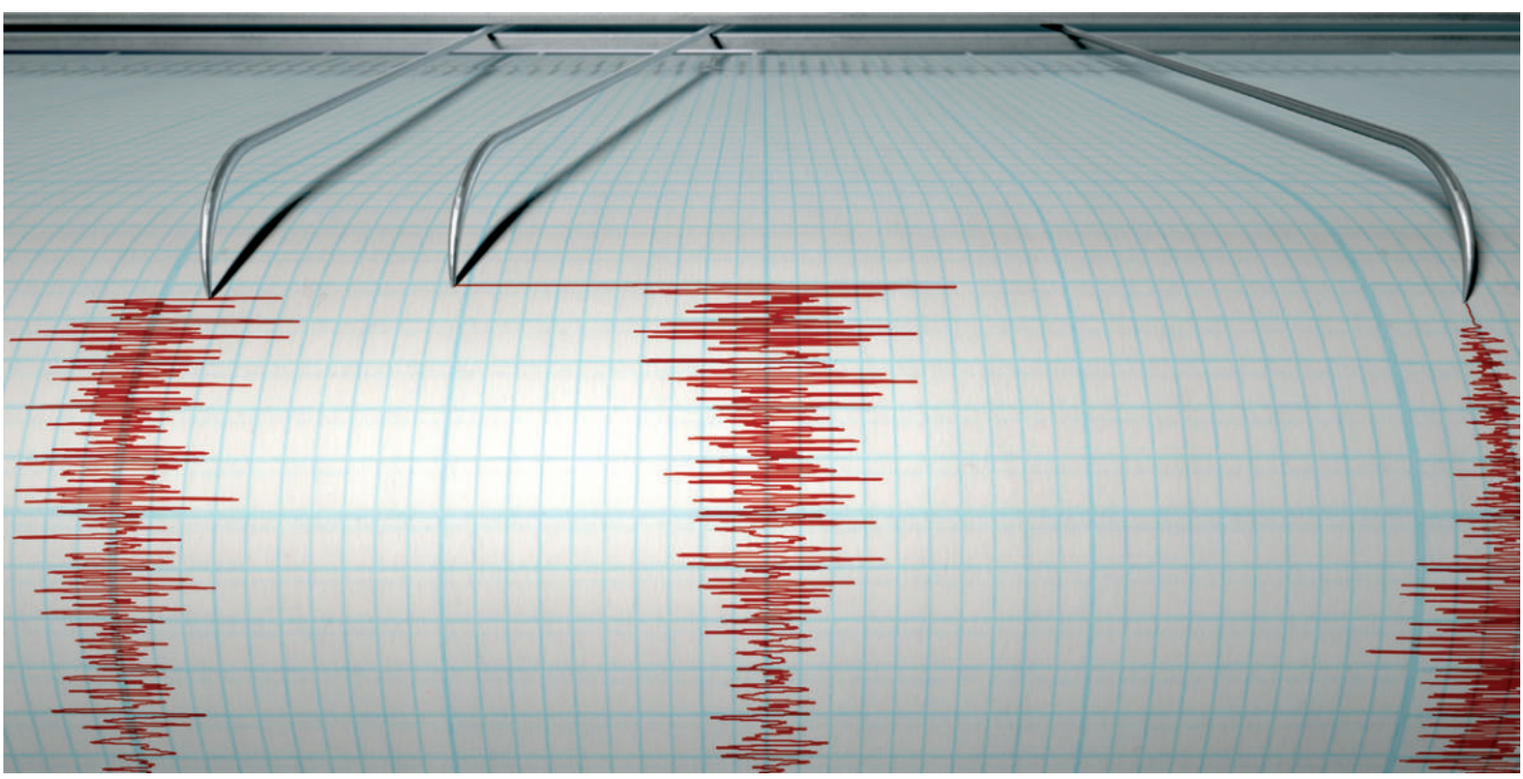
3. Chaos und Komplexität in Kommunikations- und Versorgungssystemen

In der biologischen Evolution bildeten sich Kommunikationssysteme von Tierpopulationen heraus, um die Interaktion untereinander zu ermöglichen. Kommunikation in der Evolution reicht von neurochemischen Signalen in Insektenpopulationen bis zum artikulierten Gesang von Vögeln. Primaten, die mit Ästen Alarm schlugen, benutzten erstmals Werkzeuge zur Nachrichtenübertragung. Nach Trommeln, Rauchzeichen, Morsen und Telefonnetzen kommunizieren wir heute in Computernetzen wie dem Internet. Es ist mittlerweile das komplexe Nervensystem einer globalisierten Welt, in der wir Nachrichten in Echtzeit (d.h. mit Lichtgeschwindigkeit) austauschen.

Das Internet zerfällt aber nicht nur in die Summe einzelner vernetzter Computer. Mit plattformunabhängigen Computersprachen wie z.B. Java ist das Netz selber ein gigantischer Computer, in dem die Menschheit wie in einem Supergehirn ihre Dokumente speichert und multimedial animiert. Ende der 1980er Jahre prophezeite Mark Weiser von der Firma Xerox den Trend zu einer komplex vernetzten Gesellschaft, in der eine Vielzahl von einfachen Endgeräten den Alltag der Menschen unterstützen. Diese virtuelle Welt des „Ubiquitous Computing“ ist längst Wirklichkeit. In einem nächsten Schritt verbinden sich intelligente Informationssysteme mit der komplexen Infrastruktur unserer globalen Welt. Die Rede ist von „Cyberphysical Systems“ (CPS), die sich nicht nur durch eine starke Kopplung von physischem Anwendungsmodell und dem Computer-Steuerungsmodell auszeichnen, sondern auch in die Arbeits- und Alltagsumgebung eingebettet sind (z.B. integrierte intelligente Energieversorgungssysteme von Ländern und Erdteilen).

CPS bestehen aus vielen vernetzten Komponenten, die sich selbständig untereinander für eine gemeinsame Aufgabe koordinieren. Sie sind damit auch mehr als die Summe der vielen unterschiedlichen smarten Kleingeräte im Ubiquitous Computing, da sie Gesamtsysteme aus vielen intelligenten Teilsystemen mit integrierenden Funktionen für bestimmte Ziele und Aufgaben (z.B. effiziente Energieversorgung) realisieren.

Ein erstes Beispiel sind intelligente Stromnetze (smart grids), die neben dem herkömmlichen Stromtransport auch Datenkommunikation erlauben, um den Anforderungen für einen hochkomplexen Netzbetrieb zu genügen (Abb. 5). Der Trend geht zu globalen und länderübergreifenden Netzstrukturen, in dem Blockheizkraftwerke zur Erzeugung von Strom aus fossiler Primärenergie ebenso vertreten sind wie erneuerbare Quellen mit Photovoltaikanlagen, Windkraftanlagen, Biogasanlagen. Verbraucher wie z.B. Wohnhäuser oder Büroanlagen können mit Voltaikanlagen zugleich lokale Stromerzeuger sein, die sich selbst oder ihre Umgebung mit Energie versorgen. Die Diversität dieser Netze ist eine Herausforderung für die Komplexitätsforschung.



Intelligente Stromnetze

Die Zukunftsvision: ein Netzwerk integrierter Mininetze, das sich selbst kontrolliert und repariert.

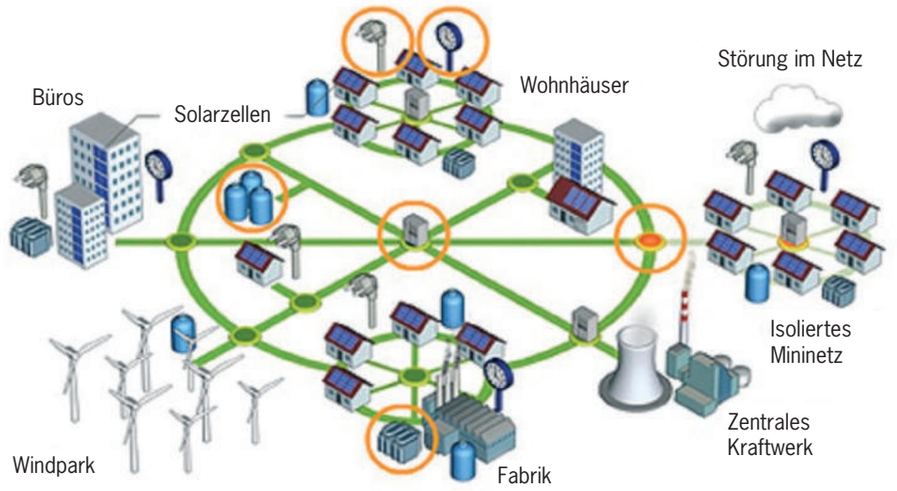


Abb. 5. Komplexes Netzwerk eines Smart Grid (Quelle: Greenpeace)

Was lernen wir aus der Dynamik komplexer Systeme?

Zusammenfassend stellen wir fest: Die Theorie komplexer dynamischer Systeme untersucht nichtlinearer Prozesse in Natur und Gesellschaft. Als Beispiele seien die Herausforderungen der Globalisierung, von Umwelt und Klima, Life Sciences und Informationsflut genannt. Veränderungen, Krisen, Chaos, Innovations- und Wachstumsschübe werden durch Phasenübergänge in kritischen Zuständen modelliert. Ziel sind Erklärungen und Prognosen dieser Prozesse, aber auch Frühwarnsysteme für extreme Störungen. Selbstorganisation ist zwar notwendig, um die zunehmende Komplexität dieser Entwicklung zu bewältigen. Sie kann aber auch zu unkontrollierbarer Eigendynamik und Chaos führen. In komplexen dynamischen Systemen bedarf es daher Monitoring und Controlling. Die Natur hat uns das in der Evolution der Organismen gezeigt. Das gilt auch für technische, soziale und ökonomische Systeme. Ziel sind nachhaltige Infrastrukturen als Dienstleistung für uns Menschen, die helfen, eine immer komplexer werdende Welt zu bewältigen und lebenswerter zu gestalten.

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Komplexität findet sich heutzutage in vielen Bereichen. Der Gesundheitssektor, die Luftfahrt und Flugsicherung oder Kernkraftwerke sind offensichtliche Bereiche, in denen das komplette Systemverständnis immer schwieriger geworden – wenn nicht sogar unmöglich – ist. Aber auch der öffentliche Sektor ist von einer hohen Komplexität betroffen, so dass traditionelle Ansätze schnell an ihre Grenzen stoßen. Im vorliegenden Artikel stammt das Fallbespiel aus dem englischen Kinderbetreuungssystem (childcare system). Unangemessene Zielsetzungen einer nicht zielführenden Auditkultur, in der negative Feedbacks vorherrschend sind, schaden dem System sowohl kurz- als auch langfristig. Der Autor zieht abschließend Parallelen zur Luftfahrt im Allgemeinen und zur Flugsicherung im Speziellen.

What the public sector (especially in the UK) needs to learn from the management of risk in high reliability organisations

By David Byrne

When Christoph Peters approached us to write something for him on our take on complexity theory it was a serendipitous encounter. As academics working in the field of Social Policy in the UK we had been thinking for quite some time about the implications of the way in which piloting and air traffic control deal with 'negative experiences' for an assessment of the general tendency in UK public sector management towards a combination of what we might call 'The Audit Culture' (Strathern, 2000) and 'New Public Sector Management'. The first we regard as a deformation of the entirely proper view that organisations should be managed towards the achievement of definable objectives and that their success in doing so should be measured in some way. This was the principle underlying the move towards Output Budgeting, the management of the allocation of resources in a system towards outputs and even outcomes of the 1970s. The second is a consequence of the neo-liberal ideological emphasis on market rationales as the only proper way to organise public sector services.

Our attention had been drawn to the way flying is done and air traffic is controlled by the admirable efforts of Martin Bromiley, a UK airline pilot whose wife had died as a result of complications in what should have been a minor surgical procedure, to draw on his experience of flying and air traffic management to reform the way things are done inside a surgical operating theatre. The Clinical Human Factors Group which Bromiley was instrumental in founding has developed a clear understanding of how teams must function in contexts of near disaster, that is, as teams, not as hierarchies. This approach is certainly being generalised in surgery and has done much good. The crucial point is that Bromiley approached the death of his wife, not to blame and shame, but to use the experience to get things done better.

In this piece, we will develop an account of an episode which is but one in a series of scandals in the English childcare system, the death of Baby P, to illustrate our argument that the approaches characterising the operations of high reliability organisations, of which air traffic control stands as almost an ideal type, can be used to identify what has gone wrong with public sector organisations dominated by an audit culture and the New Public Sector Management.
First, let us establish a general description of the kinds of things we are dealing with. These organisations are complex systems. That means they are characterised by emergence – they cannot be understood by any analytical strategy which simply attempts to describe them in terms of their component parts. Rather we have to understand them as at any given point in time, that is location on their trajectory of existence, as having a nature which is the product of interactions among all their components, of their components with the system as a whole, and of the system and its components with other systems. This is well recognised in the literature on 'high reliability organisations' (see for

example Woods & Cook, 2002) but is not recognised by the set of policies and directives underlying both the audit culture and new public management. We must add another word to our description which is 'social'. That is, these organisations are composed of people, of individual human beings who are complex systems in and of themselves and who have the power of agency. This issue of agency and how it is conceived by management structures and enacted in practice is the fundamental issue for us.

High Risk Organisations have to stop catastrophes from happening. They have to keep planes up in the sky and get them down safely. They have to cut people up on an operating theatre table and get them out alive and in a better condition than they were before they went into surgery. In catastrophes, which in complex systems' terms can be understood as radical changes in system state (not always in the strict use of the word negative changes) bad things happen: the plane crashes, the patient dies or is very severely disabled. Sometimes catastrophes are uncommon. As reasonably frequent flyers, we are glad to say that this is particularly true for air traffic. Sometimes they are quite common. A lot of people die in surgery. Since they were often very ill to start with, this is not surprising but it shifts attention from the individual very uncommon event to a consideration of the rates of negative events in a whole series of events where negative events are to be avoided but can never be wholly eliminated. This is the basis of the important and useful practice of clinical audit in surgery where, in ideal form, the performance of surgical units in relation to a specific set of procedures, with the patients being risk loaded to take account of the severity of their condition, is measured across all instances of the procedure and the rate of success / failure is compared across teams. Here we are looking at relative rates of successful outcome rather than the one specific negative effect.

Almost all public sector health and care organisations have to deal in success rates but they can also be affected by individual catastrophic events. English childcare is, we do not hesitate to say, notoriously poor at achieving good outcomes across the whole process. 'Looked after children' do not do well in terms of their entry into adult life and successful entry should be the outcome of the process. However, it is not the failure at that point which generates 'catastrophe' but rather the death of or serious injury to a child who is in the system in terms of being defined as 'at risk'. This is in part a consequence of the vile character of the UK tabloid press and the way in which it seeks to 'blame and shame' and generally requires a specific and limited set of individuals as targets for this. At the same

time, that word 'targets' has become a mantra of governance with targets defined in terms of achievements by systems. If the targets were outcomes, this might be a good thing, but in fact the audit culture deals in terms of throughputs as targets – for example, waiting times for access to treatment rather than the outcome of treatment as such. That is not so bad. What is much worse is the specifying of the performance of inappropriate – it is important to say inappropriate because bureaucracy has its place and uses – bureaucratic recording procedures as targets. We will develop an account of the implications of this now, and then conclude by considering how things might be done differently, with reference to what health and social care systems have to learn from High Risk systems in general and air traffic control in particular.

The importance of Agency

There has been a shift to a language and appreciation of systems in UK social policy. This has been important but it has been ill served by the crude and undertheorised model of agency employed to people those systems. Attempts to understand and manage human action in policy formation depend on foundational, but usually implicit, beliefs about what motivates it. Different mechanisms for driving action have been dominant at different periods in the post war welfare state with a general shift from reliance on professional knowledge to managerialism. This change has been identified with the decline of deference to professional authority and the rise of claims to legitimacy based on the market. Le Grand (1997, 2006) has described the public sector in terms of agents acting as 'knights' 'knaves' and 'pawns'. He characterises the post war welfare state as "one designed to be financed and operated by knights, for the benefit of pawns" (p157, 1997), suggesting that the knave tendency is the more relevant. It is a description that sits well with the increasingly marketised and individualised, consumer based model that neoliberalism implies. Le Grand has attempted to develop an account of the links between this version of 'human nature' and four mechanisms for ensuring quality, naming them choice, voice, targets and trust. Choice and voice represent the well-recognised market based power to select, reject, modify or change products. Targets have become widely used (and criticised) methods seeking to drive policy outcomes while, Le Grand suggests, 'trust' relies rather naively on professional orientation to achieving goals. That this construction of motivation is ideological rather than evidenced, based in a neoliberal model of the human actor as simply a rational actor, is never acknowledged. The danger in not questioning it is that it influences the way we try to understand and manage systems. A little further examination alerts us to the fact that the four mechanisms are not of the same kind. Choice and voice may seem attractive as mechanisms but their operation in practice is far from ideal. To be effective they rely on an idealised perfect market which, as Richard Titmus argued so convincingly in the 1960s, in no way characterises public welfare. The inherent power relations aside, the irreversible and complex nature of health and welfare processes make this obvious. Despite the marketisation that has occurred thus far, nobody has perfect knowledge as a consumer of services, nor do they have a simple redress in relation to many catastrophic failures. These are not simple market goods but are rather shot through with power relations.

By concentrating on one source of motivation to action, we argue, policy makers have ignored valuable information and discouraged the manifestation of behaviour orientated toward other rational goals. Le Grand dismisses professional autonomy as 'trust'. We think this is premature and will return to it later. First, we want to deal with targets, a mechanism for identifying and monitoring desired outputs and simple outcomes, although we have to reiterate actual 'outputs' are often at best throughputs and almost never outcomes.

While applauding Le Grand's attempt to identify motivations with mechanisms, therefore, what becomes apparent is the essentialist conception of individual motivation it relies upon. More important is the way that these underlying ideological constructions of motivation have been generally absorbed into the 'common sense' of policy makers. This is a crude and partial construction of agency and we need to make visible its ideological status to justify the search for a more nuanced account of action to help us to understand ways of harnessing motivation and creating and documenting change. What we need if we are to design for, monitor and shape change is to engage in a more careful analysis of these grounds for behaviour than the vulgar characterisation of motivation as simply self-interest.

We begin by examining the use of targets and its associated measurement by audit, drawing on the investigation in the case of Baby P.

Targets and Audit

The primary framework now deployed in policy design and monitoring is the framework of audit. The notion of audit, drawn from finance and accounting, is based on an assumed ability to bring together concepts of economic efficiency and good practice (Power, 2003). The assumption forms part of a hierarchical and reductive approach to understanding the production of public service. The role and effect of this ideology in shaping practice and determining the goals and outcomes of policy has been long acknowledged (Bourdieu, 1999). They 'are not simply innocuously neutral, legal-rational practices: rather they are instruments for new forms of governance and power' (Shore & Wright, 1997). Audit encourages top-down direction and a mechanistic view of roles of the workers within the organisation, more in line with a Fordist production process than the post-modern shift heralded in many commentaries. It pays attention to 'first stories' (Woods & Cook, 2002) stripping out context and treating action, through hindsight, in mechanistic ways. While this management style was identified as a source of the problem in the Baby P case (Caulkin, 2008) it is aligned in that account with the metaphor of assembly line social work. In many respects, however, the parallel is a false one, for while Fordist workers were not required to embrace an ideology to perform their task, the politics of this new form of evidence is more invasive "they are agents for the creation of new kinds of subjectivity: self-managing individuals who render themselves auditable (Power, 2003, p. 57)". It involves a notion of agency, but one that perversely sees agents only as those signed up to the vision.

This way of thinking about professional practice reflects a disillusionment with the belief that professionals can be relied on to work for the policy goal for its own sake and a conviction that appropriate professional behaviour can be achieved by prescribing a set of transparent standards by which they can be judged. It is a view that is not even borne out on its home ground of accountancy where research suggests that "accounting systems in their broadest sense function often more to legitimate individual and organisational behaviour than to support efficient and rational decision making" (Power, 2003, p. 379).

The literature on audit society and audit culture recognises the neoliberal basis of targets, as a method of monitoring, responding to ideas of transparency, simplicity and rational, individualised view of action (Strathern, 2000, Power, 2003). The constructed nature of this evidence is coming to be recognised to be as true of financial audit as it is of the sectors of human activity involved in public services (Power, 2003).

The shift to the neo-liberal audit culture has changed the way organisations and people are accountable and has indeed shaped behaviour as a result (Bevan & Hood, 2006). Relying on simple indicators to performance manage for complex outcomes has caused numerous well-publicised distortions in public service delivery. For example a target of time limits in admitting emergency patients to a hospital ward has led to corridors being re-designated as wards, with patients lying on trolleys in them being classified as having been admitted. Such distortions are the result of a system relying exclusively on self-interested rational economic motivations. The very 'common sense' status of such assumptions has been powerful in facilitating their unquestioned adoption across the fields of policy implementation. In consequence, methods of knowing and control are represented as merely technical issues while the significance of power, authority and legitimacy that play through these mechanisms are ignored. Yet we have the resource for a more nuanced analysis of human agency by appealing to sociological rather than rational economic models in concert with complex social systems. This would enable a more sophisticated approach to learning about services.

As the primary mechanism of New Public Management with emphasis on performance and accountability, the use of targets and indicators has been taken to embody scientific rationalism (Niessen et al., 2000). The use of public service agreements targets, key to governance mode of performance management, has also been identified as scientific reductionism (Hough, 2004). Targets achieve accountability in relation to throughputs and /or outputs rather than outcomes and can work for simple and linear rather than complex (in other terms, transactional rather than transformational) processes. They have become embedded and claimed as the most effective approach to policy implementation, while measurement in relation to them is taken to be the most authoritative evidence. Since the only evidence considered to have value relies on these forms of monitoring there is a circularity in their proven effectiveness. Those services that are unable to provide evidence in this form are consequently less likely to be funded (Newman et al., 2008). Rather than simply being ineffective ways of ensuring desired public outcomes, their dominance has brought about distortions in what is done according to how it can be measured.

The differences of type between financial audit and complex service delivery have been ignored as services have been encouraged to adopt inspection rather than learning approaches to their work. In doing so, they have missed the point. Recent commentators on the Baby P case have pointed to the excellent audit trail that can be identified to demonstrate decision-making and inspection processes, which nevertheless failed in its prime objective, to protect the child. Rather than learning from these failures, in evidence to the committee of enquiry, the chief officer of OFSTED (the English national inspection agency for Education and Child Care) proposed a further level of auditing – a whistle-blower line for social workers. These mechanisms of accountability may enable some things to be learned about professional activities from a hierarchical standpoint but they discourage learning from those activities by the workers in the process of providing public service. While the Baby P case has been a dramatic example, the problem this approach poses is a much more pervasive and mundane failure to use one available, and potentially valuable, mechanism to understand and improve policy interventions.

This mechanism, that Le Grand summarily dismisses as 'trust' operated by 'knights' continues to emerge in the actual documenting of behaviours of those implementing policy, although as we have suggested above it is frequently ignored because it does not fit the target/audit evidence frame. It is nonetheless crucial to understanding public service processes and supports systems approaches based on learning by encouraging review and responsibility. This has obvious implications for evidence gathering. The direction of most effort thus far has been to accept the inevitability of targets and to attempt to redress the power imbalance by giving users a purchase on defining them. Contrary to the conclusions drawn by some writers that we need to seek more user-oriented targets, our argument

focuses on reframing thinking about what counts as evidence for complex social interventions. We see both audit rationales and some rethinking about professional knowledge in the discussions that followed Baby P's death.

Baby P

The case of Baby P is instructive in so far as its examination found inadequacies in service response that have recurred throughout the history of child protection. They can be traced as far back as the wartime evacuation of Denis O'Neil whose death stimulated the passing of the 1946 Children Act seeking to prevent the reoccurrence of deaths of vulnerable children through neglect or cruelty. Famous cases such as those of Maria Colwell in 1974 and Victoria Climbie in 2000 proved that hope to be a false one and themes of lack of communication by professionals accountable for the child's safety consistently recurred. Following the Climbie case, Children's Trusts were created in 2004 to address these issues but did little or nothing to resolve those problems of fragmentation and miscommunication (Audit Commission 2008). Part of the problem lay in relying on what Woods and Cook (2002) described as a 'first story' of blame based on individualised failings and inadequate communication by professionals. Confidence among politicians, in the ability to monitor and shape professional action through technology and targets seemed to have been misplaced (Garrett, 2009). Wood calls for attention to 'second stories' that acknowledge the context and how the systems work to encourage or discourage appropriate action. From a second story point of view what is absent in those child protection enquiries is the acknowledgement of system factors and the role of those processes in creating "dis-welfares". In the Baby P case, the defensive stance of social services meant that, prior to Baby P's death, a whistle-blower had famously been sacked for warning of the catastrophic potential of current practice. The Joint Area Review in Haringey in 2008 identified the problems of steering a system based on an overly heavy reliance on quantitative evidence and the existence of computer allocation of cases without discussion with social workers. The solution to these deficiencies was suggested by the Munro Review of Child Protection (2011). Rephrasing its later findings in our terms, the Munro review found an absolute need to develop the mechanism of 'trust'. Reporting on service change following the Baby P tragedy, Munro identified problems with defensive social work practice and the failure of existing systemic solutions, pointing to the need to move away from a subsystem that has become over bureaucratised and focused on compliance to one that values and develops professional expertise (p. 6, item 1). The target driven method of ensuring practice is explicitly rejected in a recommendation to replace prescribed timescales with 'an underlying principle of timeliness' (p. 7, item 6) A recognition that the management of such systems cannot be

adequately conducted through an audit style mechanism could not be more clearly articulated. The emphasis in the Munro report is on organisational arrangements that support rather than replace professional decision making.

Returning to professional accountability, characterised by Le Grand as a simple matter of 'trust' vested in the largely discredited persona of the 'knight', we can suggest a systematic approach to what knowledge can contribute towards positive outcomes. We have seen that, rather than any inherent dysfunctionality, it is the failure to examine and deploy knowledge that has left us with the unsatisfactory notion of 'trust'. It seems timely then, to re-evaluate the dismissal of workers' knowledge and ways of learning and to consider its role in critical terms. Rather than placing reliance on professionals to have the motives of "knights" and giving them free rein to run the system as a result, we need to explore these multiple bases for action from which to develop evidence for social intervention. One motivation to professional action is the achievement of objectives that are valued in terms of the correct application of their expertise. This comprises both a technical element and a value relation.

An alternative to 'trust'

Given the diminished but still powerful role that professional knowledge plays in public service delivery, the lack of interest in its potential for actually improving public service is remarkable. Not only do we have long-term experience of delivering complex public service to draw upon, we have lessons to learn by analogy from some of the private sector activity most concerned with complex processes.

On the basis that in complex systems causality cannot be tracked along linear trajectories, the action required to create intended effects cannot be simply predicted. Were this not the case, the professional task would be a simple technical one. This is important because of the direction it points us to seek evidence and to make attempts to control the future. It supports a close appreciation of the system and its working based on local and reflexive learning. The mechanism to replace 'trust' needs to recognise the significance of process and of the evidence that is created therein that informs the professional practice across the span of activity. Such knowledge is used by professionals routinely but usually fails to achieve the status of evidence in a system dominated by economistic rationality. Yet we have examples of the crucial importance of its operation in existing evaluation and monitoring regimes where it has been explicitly developed. In air traffic control, a context of complex practice in which dramatic consequences follow failure, the importance of encouraging learning has been incorporated into systems for reporting and review. Aircraft 'near misses' are reported in a non-punitive system to raise awareness of incidents based on the notion to learn from those events (Dekker & Laursen, 2007).

We have a number of places to look to begin this process. In social work interventions, 'practice theory' (Curnock & Hardiker, 1979) has been identified as an embodied approach to professional action based in theoretical knowledge that is built upon and developed through experiential learning. Thus far, there has been no attempt to develop systematic evidence of a relationship between these largely implicit professional practice theories and the change achieved. Such theories could be developed as evidence by working in terms of the 'theories of change' (Weiss, 1995) approach that is already well established in evaluation practice. Action research similarly contains methods for achieving a reflexive and systematic relationship between intervention and evidence at the programme level. These existing approaches point us toward a direction to pursue. Rather than positing the straw man of 'trust', it suggests there is potential to develop a clear and systematic relationship between action and evidence in complex social interventions. We are suggesting an approach to developing evidence that, rather than encouraging representations of faultless practice to demonstrate the achievement of targets, uses the knowledge available as feedback for the system learning about itself.

Conclusion

It might be considered that air traffic control has very little to learn from public sector management in child care. Certainly it has nothing to learn by positive example. However, it is generally worthwhile to consider examples at the


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limiting end of the negative since their very negativity points us towards things which we need to know in order to get procedures and processes right. Air traffic control operates within a culture of openness and lack of hierarchy which sets up a frame for the actors within it which fits exactly with the requirements of effective management in complex organisations. Sure, air traffic control has a much simpler and more immediate specification of outcomes – that of getting planes up in the air, through the air, and down from the air without mishap. Moreover all the supporting elements of the system in terms of engineering and flight crew management are designed and maintained in the best way to support this procedure, and this can include appropriate bureaucratic procedure for example in careful and accurate recording of maintenance in the engineering processes. Human actors have little problem with sensible bureaucracy when that form of organisation is fit for the purposes. This applies equally to medical recording for example and good records always help. Although some clinical areas, notably surgery, are rather similar the very 'sickness' of the patient, compared with the 'health' of a plane and its competent crew, makes for a different incidence of negative outcomes. However, that incidence can be reduced if human agency is allowed to function in a way which makes sense to the front line staff, as it so patently is for flight crew and air traffic controllers. The final concluding point is that in human social systems agency matters and if management and accounting procedures seek to control that agency in inappropriate ways based always on negative feedbacks, then things will go wrong, often catastrophically in the short term and with long term negative potential outcomes going forward.

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David Byrne *is professor of applied social sciences at Durham University. He attended the University of Newcastle and LSE before teaching at Durham from 1970-74. He was a research director of the North Tyneside Community Development Project from 1974-77. Reader in Sociology Ulster Polytechnic 1977-80. Since at University of Durham. In 2012, he received the Social Policy Association (SPA) Special Recognition Award. His recent publications include "Applying Social Science" (published in 2011) and (with Gill Callaghan) "Complexity Theory and the Social Sciences - the state of the art" (published in 2013).*

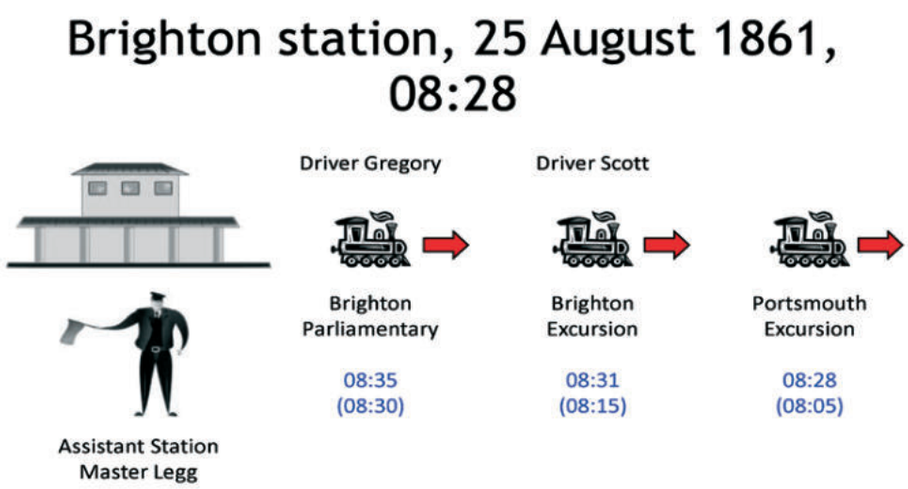
Im Jahr 1861 ereignete sich unweit der englischen Küstenstadt Brighton ein Zusammenstoß zweier Züge im sogenannten Clayton-Tunnel. Dies markierte den bis dato schwerwiegendsten Eisenbahnunfall der britischen Geschichte. 23 Menschen Personen kamen bei dieser Tragödie ums Leben, ungefähr 176 zum Teil schwer verletzt. Das wirkliche Leben ist komplexer als wir häufig annehmen, dies ist schon vor über 150 Jahre der Fall gewesen. Um zu verstehen, was dort passiert ist und wie solche Situationen in Zukunft möglichst gut verhindert werden können, benötigen wir ein Verständnis, dass auf den tatsächlichen Arbeitsbedingungen fußt. Um der Komplexität dieser Situation gerecht zu werden, reicht es nicht nur die niedergeschriebenen Verfahren und Vorschriften zu betrachten, sondern die tatsächlichen Gegebenheiten zu beleuchten. Es geht in anderen Worten darum, erst den Unterschied zwischen „work-as-imagined" und „work-as-done" herauszuarbeiten und dann geeignete Maßnahme zu ergreifen, um diesen Unterschied zu verringern oder neu auszurichten. David Slater illustriert mit dem vorliegenden Fall die Probleme klassischer Analysemethoden und zeigt die Notwendigkeit auf, neue Wege zu beschreiten, um der Komplexität in unseren Systemen zu begegnen.

The Clayton Tunnel Incident

By David Slater

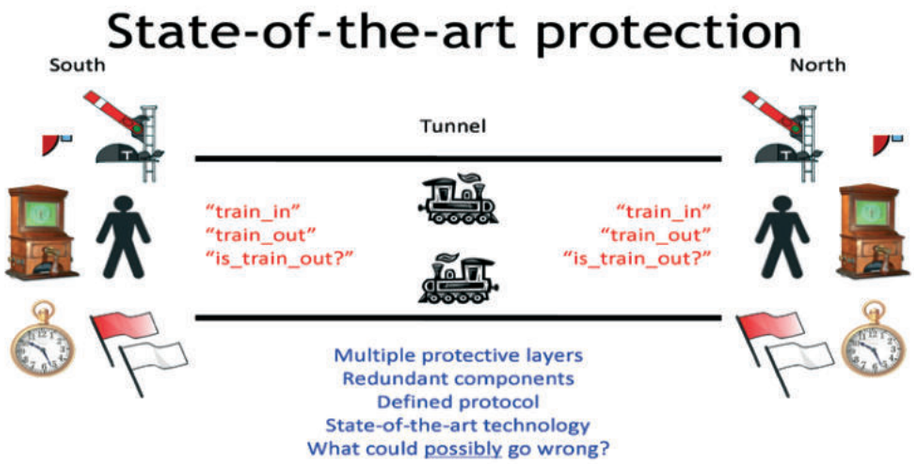
Overview

"The Clayton Tunnel rail crash, which took place on Sunday 25 August 1861 five miles from Brighton on the south coast of England, was the worst accident in the British railway system to that date. Two trains collided inside the tunnel killing 23 and injuring 176 passengers. The disaster scenario actually involved three successive northbound trains on the same track, which all left Brighton station within a few minutes of one another. The signalman at the south end of the tunnel tried to stop the second train from entering the tunnel before the first one had left it, but wrongly thought his red flag had not been seen, and then misinterpreted a telegraph signal from the north end of the tunnel as referring to the second train instead of the first. Assuming that both trains had cleared the tunnel, he signaled the third one to proceed, but in fact, the second train was trying to back out (Wikipedia, 2014)."

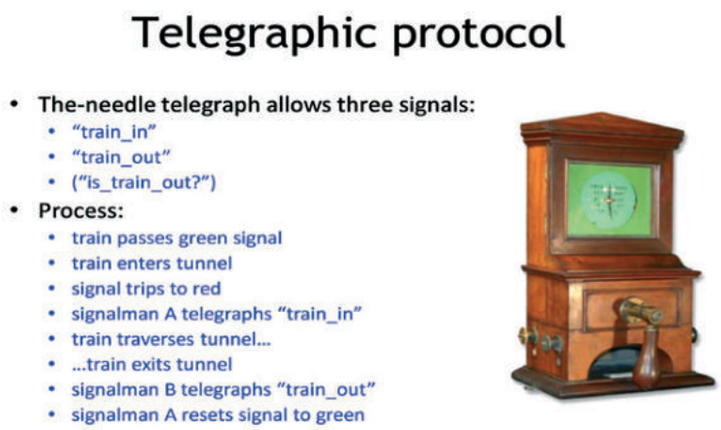


Systems in operation

"Signalman Henry Killick had an alarm bell linked to a signal, a needle telegraph and a clock in his cabin close to the south entrance of the tunnel. He could control the signal by a wheel in the cabin, but it would normally be at the «danger» position unless he approved a train to enter the tunnel. When a train passed, the signal returned automatically to «danger», but if it did not, the alarm bell would ring (Wikipedia, 2014)."



The needle telegraph instrument connected signalmen at the portals of the tunnel and was used for both lines. The telegraph had been installed in about 1851. This was the time that telegraphs were first used through long tunnels, on steep inclines and at junctions. The method of use is explained below.



The telegraph was linked to the north signal box, and would have shown there was a train in the tunnel if the signalman at the other box had activated it by pressing and holding down a switch. Otherwise, the needle would hang vertically. A deflection of the needle to the left signified ‹train in,› and a deflection to the right, ‹train out.› When a train entered the tunnel, the signalman displayed «danger» and sent a «train in» message to the man at the other portal. When this train left, a «train out» message was returned, and the signal was turned to «safety». The signals were momentary, and during the time in question, the signalmen may have been involved in conversation and the situation may have been further complicated by unrelated signals for a train in the other direction.

The accident sequence

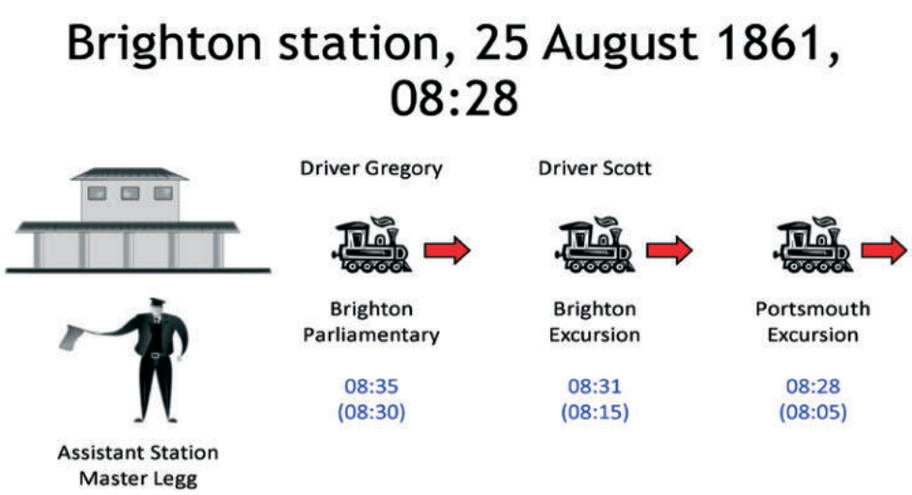
In modern parlance, the accident that occurred on 25 August 1861 was an accident waiting to happen. It was certainly a profound shock to the LB&SCR, as well as to railways in general, and what made the shock to the Victorian mind-set worse was the fact that the collision occurred on a Sunday.

Two excursion trains were due to set out from Brighton station ahead of a timetabled 8:30 am departure. These two were a late-running Portsmouth to London train that had been due to depart Brighton at 8:05 am and a Brighton to London train due to depart at 8:15 am. In those days, the LB&SCR was not known for its punctuality and the erosion of the time intervals between the trains was nothing uncommon. The line was worked on a time interval basis, which was quite safe, providing the rules were strictly obeyed, and the interval between trains sufficient for a guard to protect his train in the event of any incident. Assistant Stationmaster Legg, realising it was some six minutes after the due departure time of the 8:30 train, sensibly began dispatching the trains in their rightful sequence as the two excursion trains had a faster schedule than the ordinary train.

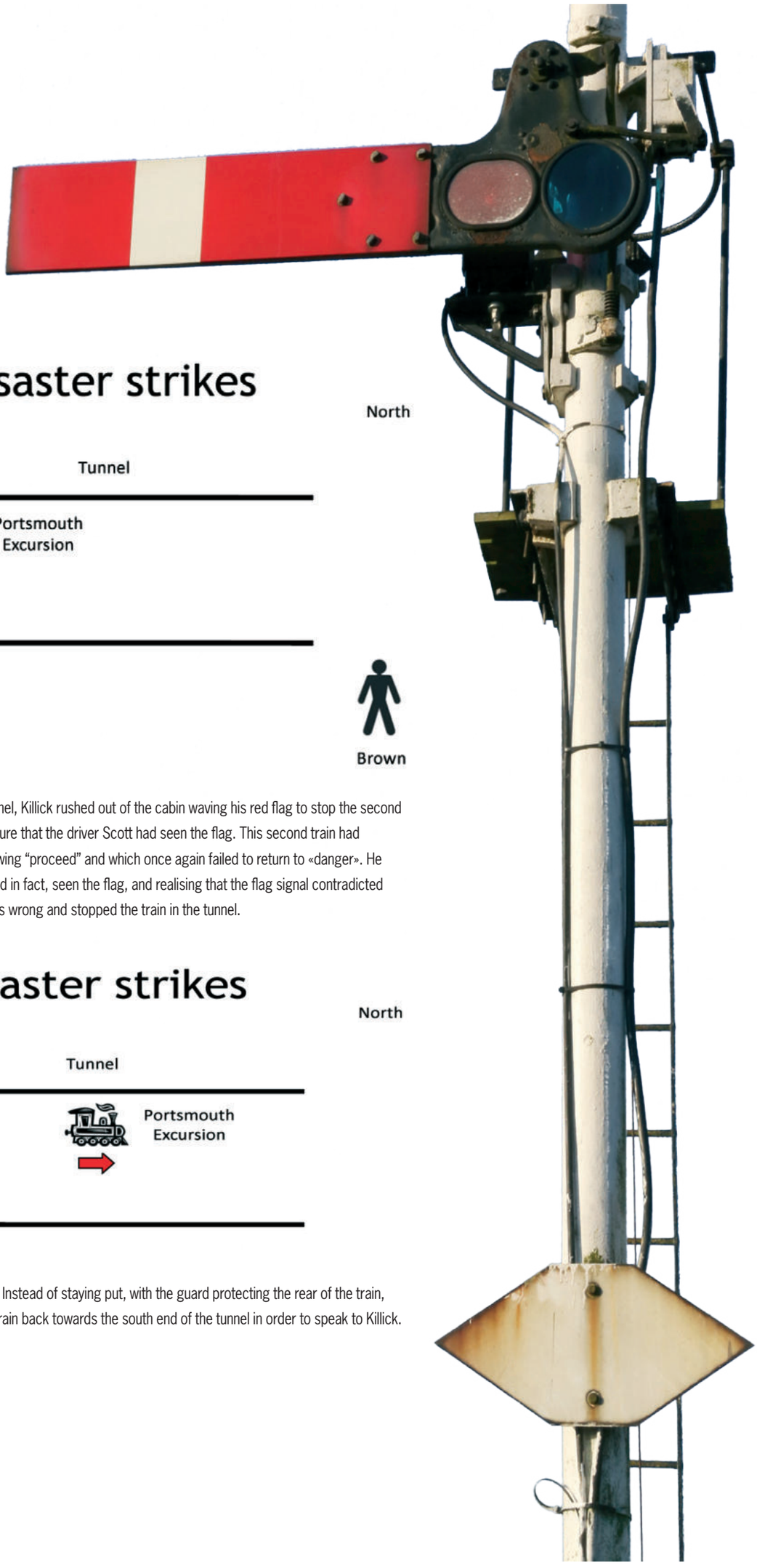
The time-interval system required trains on the same track to be separated by five minutes. On this day, the three trains left Brighton within seven minutes of each other:

- Portsmouth Excursion left at 8.28 am
- Brighton Excursion left at 8.31 am
- Brighton Ordinary left at 8.35 am

Although a time interval was used on the open part of the route, the line within Clayton Tunnel was controlled by a block section, worked by the single needle telegraph and protected by a Whitworth automatic revolving banner signal. The word automatic refers to the signal being activated mechanically when a train ran over a treadle, requiring the signalman to pull off the signal once more for the following train. In this location, there was a signalman at either end of the tunnel, each working a 12-hour shift. Ironically, to alternate between day and night shifts, it was the practice to work 24-hour shifts on Sundays. On the day in question, the south side of the tunnel was manned by Signalman Killick, whilst at the north end was Signalman Brown.

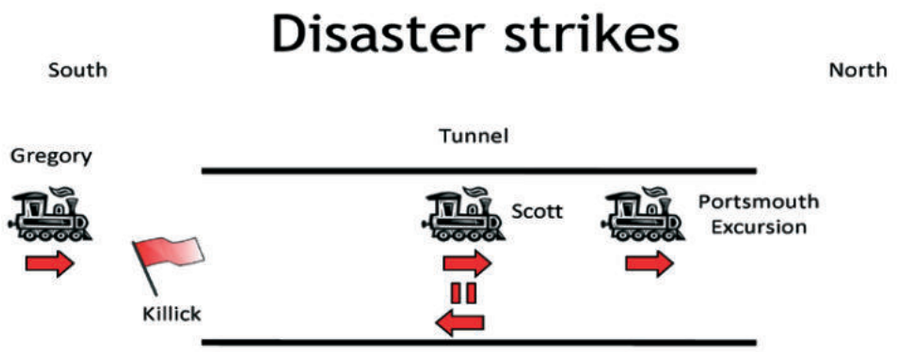


The first train to pass Signalman Killick was the Portsmouth Excursion, which passed over the treadle and continued to enter the tunnel. At the tunnel mouth, this first train passed the signal at «clear». The automatic signal, however, failed to return to «danger» and the alarm bell rang to warn Killick. He sent a «train in tunnel» message to Brown in the north cabin, but did not return the signal to «danger» in time to stop the second train from passing the signal and travelling into the tunnel. It was only three minutes behind and may well have caught up with the first train.

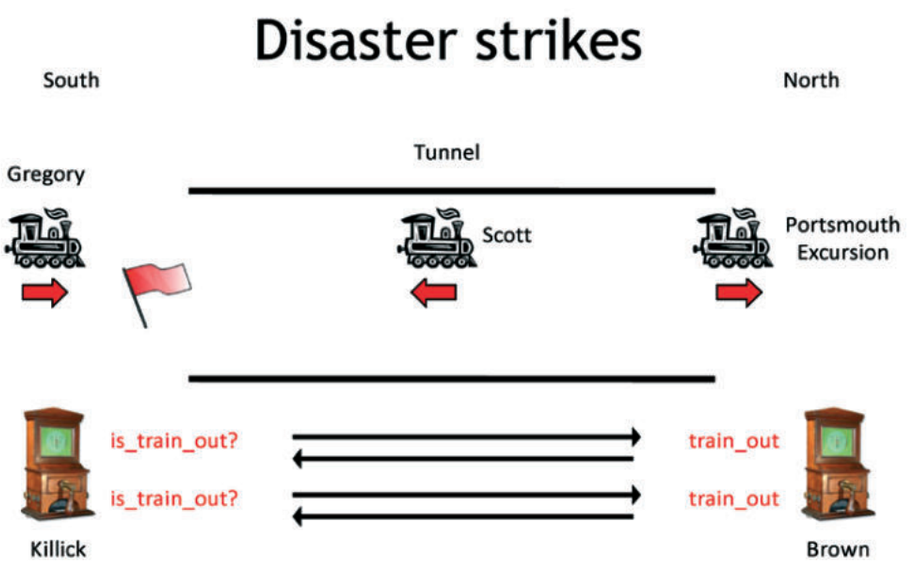


Realising that the first train was still in the tunnel, Killick rushed out of the cabin waving his red flag to stop the second train just as it was passing. He could not be sure that the driver Scott had seen the flag. This second train had passed the signal, which was incorrectly showing “proceed” and which once again failed to return to «danger». He telegraphed Brown «is tunnel clear?» Scott had in fact, seen the flag, and realising that the flag signal contradicted the Whitworth signal knew that something was wrong and stopped the train in the tunnel.

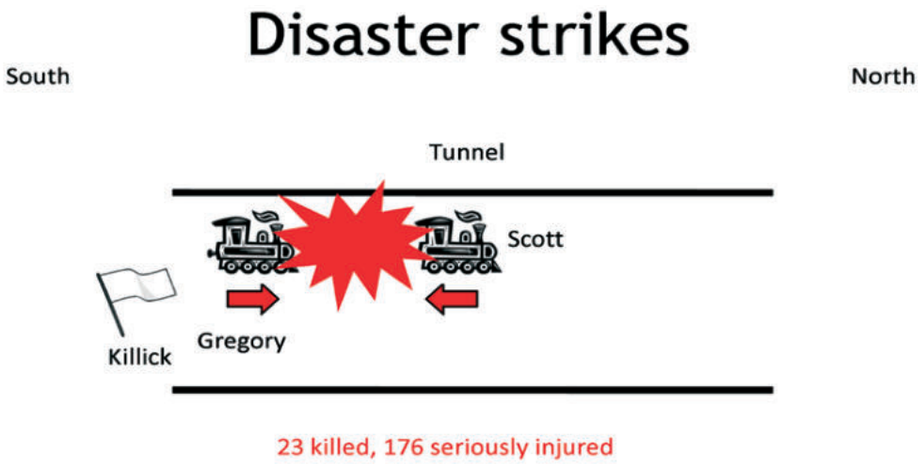
After this, things started to go terribly wrong. Instead of staying put, with the guard protecting the rear of the train, Scott decided to set back and propelled his train back towards the south end of the tunnel in order to speak to Killick.



At that moment, the first train cleared the tunnel, so Brown signaled back «tunnel clear» to Killick. Unfortunately, Killick thought that Brown was referring to the second train and not the first. In fact, the second train›s driver having seen the red flag and stopped about half a mile into the tunnel, was then reversing back to return to the south end.



Meanwhile, Killick now saw a third train approaching and stopping at his signal. It seemed to be working correctly at this point. Thinking that the tunnel was clear, he waved his white flag for it to proceed (reinforcing signal).



The second and third trains then collided in the tunnel with great force. The second train was pushed forward, and the locomotive crushed the guard›s van at the rear before smashing into the last carriage. It then rode up over the carriage roof and smashed its chimney against the tunnel roof before stopping. Many of the 23 deaths were in this last carriage, where passengers were burnt or scalded to death by the broken engine.

The crew of the second engine were lucky in that Driver Gregory sustained only minor injuries whilst his fireman escaped injury altogether. Gregory was commended for his prompt action, which surely prevented a far higher death toll.

Aftermath

"A nine-day inquest was held at Brighton town hall into the deaths of the 23 victims (Wikipedia, 2014)." Neither Killick, the south end signalman, nor Brown were found negligent by the jury (The Times, 1861). Killick was not held responsible and thus not charged; but Assistant Stationmaster Legg was judged to have acted recklessly in dispatching the trains too close together (against the rules of the company); he was charged with manslaughter. Legg went to trial, but found not guilty (The Times, 1861).

As for his top manager, Craven, who had had a very bad reputation for the way he treated his men, he defended his department fiercely and on this occasion convinced the court that Scott›s action in setting back his train was quite in order. The Board of Trade inspector, Captain Tyler, concentrated on the time interval method of working. The railway countered that better mechanical safeguards would be self-defeating as they would lead to the men being less alert. They pointed out that this accident was caused by the failure of a mechanical safeguard. Another aspect of this accident was that Signalman Killick was working a continuous 24-hour shift that day, rather than the regulation 18 hours. He was doing this to get a complete day off duty.

In his report on the accident, Captain Tyler stated, «it was disgraceful that a man in so responsible a position as Signalman Killick should be compelled to work for twenty-four hours at a stretch in order to earn one day of rest a week (Rolt, 2009)." The ultimate blame for the accident, however, was placed on traffic. Captain Tyler recommended adopting absolute block working and continuous brakes. The railway, however, did not act on the recommendation at that time.

The incident entered railway history as Britain›s worst ever railway accident until the Irish Mail disaster six years later. The catastrophe publicised the problem of trains travelling too closely together, with signalmen having to appraise the situation too quickly. A simple communication mistake between the two signal boxes wreaked havoc that Sunday,

but the telegraph was also blamed for the accident because it did not register without continual pressure on the switch. The signal, too, was at fault for not returning to the «danger» position immediately after the train had passed. The accident did, however, lead to the use of the block system (rather than the time interval system).

Insights

They asked the perennial question - What was the cause? The answers were the same standard ones you would hear today:

- Human Error - signalman, driver, assistant stationmaster
- Equipment malfunction - telegraph, signal
- Procedures - signal passed at danger
- Root causes – Shift length/ time-off policy, communications, lack of leadership/ management failure
- Swiss cheese holes - procedures, training

Alternatively, one could seek a more objective and constructive approach. For example, the question could be raised if the key factor was the time element. The time element was, however, taken into consideration at the inquest. Several factors could be taken into account, e.g.:

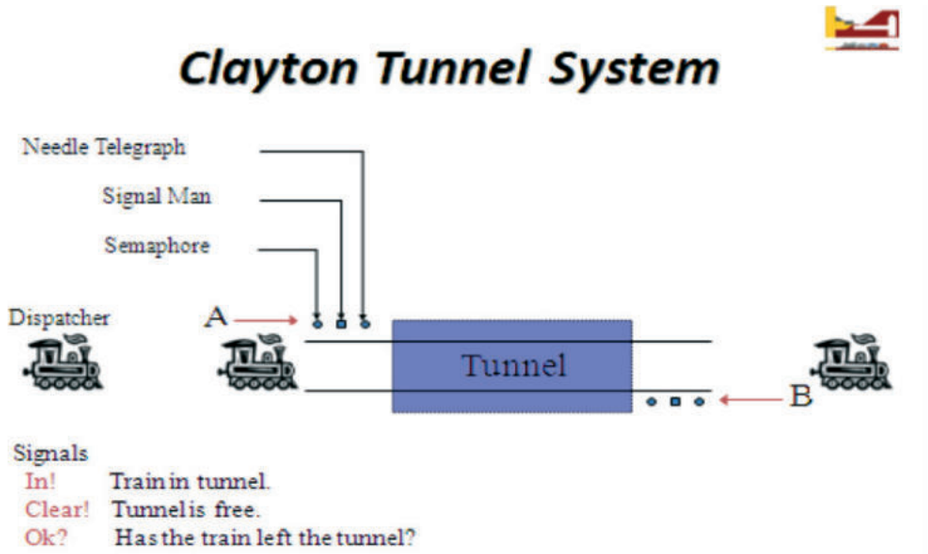
- Signalman's reflexes dulled (24-hour shift)
- Station master not observing time slots – (possible target pressure)
- Time taken to react to alarms and operate telegraphs in emergency too long
- No automatic procedure for signal passed at danger
- «Überlingen» response by drivers - one believes signal / one backs out because he is not sure

All of these factors are easily demonstrable. If only they had had a way of simulating the dynamics of the situation and had had the foresight to run emergency exercises, but none of these were common practices in those days. The inquiry only partially ascertained that there was a dynamic interaction between these functions. There was a situation where the time was insufficient for intelligent operators to adapt to a previously unknown combination of

circumstances. In this situation, an unfortunate system engineered the crash. They did not learn everything they could have learned as the system was too complex. This was, as many accidents are, a classic example of a combination of a sloppily designed system, mechanical error and human fallibilities.

Could we have done any better?

This is a scenario in which a system has been designed to function mechanically like clockwork, provided all the parts work reliably. The Victorian determinists believed that it was all right to involve human beings provided they too worked like automatons. This would result in a system that was simple, predictable and safe.



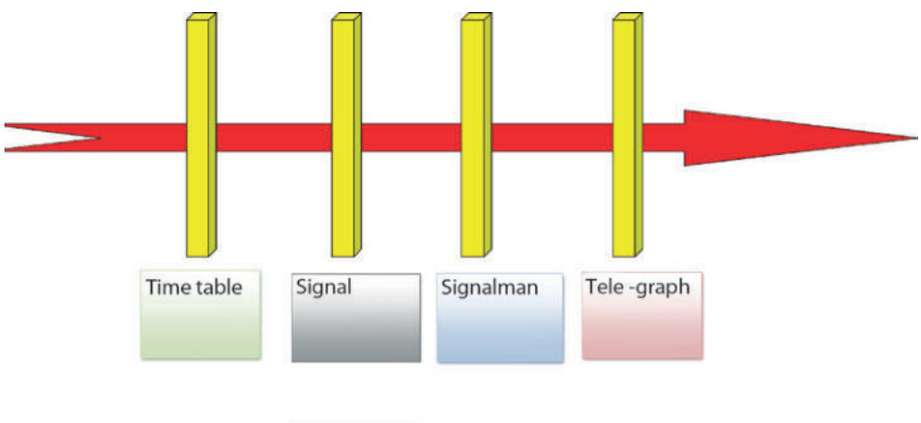
Looking at this system today, what would we have done better? Let us use some risk analysis tools.

Failure modes and effects

This tool would have picked up the signal failures and the reset mechanism. The Victorians also picked this up with an alarm and a back-up manual override. The telegraph was thought to have been fail-safe – no response, no progress. Thus, this tool, other than formalising the process, does not seem to be an improvement.

Dominoes, cheese, bow ties and barriers

Using one of these approaches, we would have had plenty of dominoes or cheese slices between the trains and the accident. Again, the tool would not have helped in the past either.



If we breach the procedures barrier, (the timetable), we have a second, hard equipment barrier, (the signal), followed by a manual override human response third – (the signalman), alerted by a fourth – a direct situation awareness communication link (telegraph), to a fail-safe monitor (second signalman N). If he does not see a train leave the tunnel, he will not give the all clear. According to the bow tie method, all the bow ties are at least straight.

Layers of protection analysis (LOPA) and system integrity (SILS)

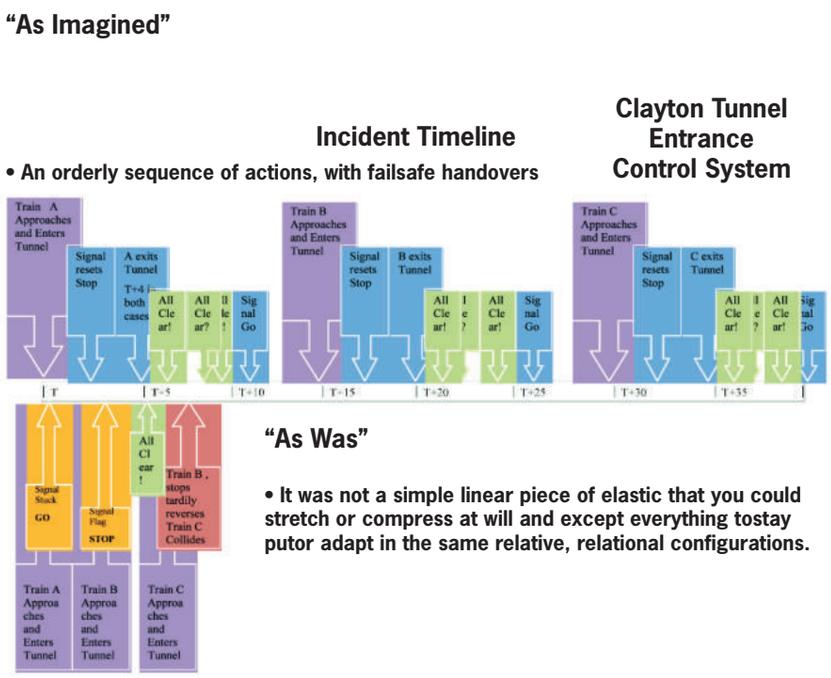
Using a LOPA approach might give the impression that there is an unacceptable System Integrity Level (SIL), which could document the reliability of the design as required by a safety management system. Putting in some illustrative numbers:

- Signal probability of Failure on Demand - (PFD) approximately 1x10-4
- Signalman PFD – approximately 1x10-2
- Telegraph PFD – approximately 1x10-4
- SIL = 1x10-10? -> very safe?

This does not seem right as the accident actually occurred. The previous would suggest that the accident would not have happened. Signals passed at danger are still a problem today and a factor in many recent incidents as well.

Human reliability questions and factors

It is clear that the human factor played a large role. In SAFETY II (Hollnagel, 2014) terminology, the "as imagined" sequence was very different from the actual "as was".



- The timeline shows the "As Imagined" cycle taking 10 minutes
- This probably allowed for three to five minutes for the reset cycle
- The reported time separation at dispatch was three minutes, close to the limit
- The "As Was" time available for the response to the signal reset failure was probably about a minute (Half a mile at 30 mph)
- Insufficient time for (tired) signalman to respond

A recent study (Kirytopoulos et al., 2014) used the Cognitive Reliability Error Analysis Method (CREAM) to assess the effect of operator response on road tunnel Probabilistic Risk Analysis predictions. In this Swiss Tunnel Risk Study, the tunnel operator's response time was found to affect two particular input variables of the model, namely:

- the time taken to activate the emergency ventilation
- the time delay to stop approaching traffic

This predicts that a tunnel operator with an inappropriate HMI (Human Machine Interface, appropriate procedures and inadequate training) will react in the range of 240 to 600 seconds (4-10 minutes). Thus, CREAM does suggest that there was insufficient time for a (tired) signalman to respond in the Clayton incident. We might have focused on the issue of HMI using modern methods, but not necessarily with some of the classic engineering approaches.

Conclusion

People are not robots; the outside world impinges in many intrusive and disruptive ways. A system needs to be recognised as real world and complex even when it looks simple.

One approach to modelling intended functions rather than the failure of components can be attributed to Hollnagel and his Functional Resonance Analysis Method FRAM, (Hollnagel, 2012). He pointed out that simple linear deterministic models cannot cope with the actual tightly coupled and intractable functions in real systems. Often these resonate in unintended and unexpected ways. There is a need for models:

- which can capture not only average situations, but cope with the inevitable variability of real systems
- which capture those interdependencies which occur with very low frequency, but often then lead to serious accidents
- which recognise that systems are increasingly complex and dynamic
- which recognise that there is time dependence, (e.g. in the degradation or ageing processes of technological, human and management sub-systems)

Safety II and FRAM type approaches are thus a necessary step in the evolution of Risk Methods to tackle real systems in real applications.

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I am grateful to David Porter for providing source material and contributions.

David Slater has a track record of significant achievement in the commercial and public sectors. He taught at Imperial College in the 1970s, and then founded the Risk Management consultancy Technica Limited following his experience leading the investigation into the Flixborough disaster. Technica pioneered the application of QRA techniques worldwide (UK, US, Australia and Far East).

He became a professional regulator as Chief Inspector of Her Majesty's Inspectorate of Pollution and subsequently Director at the Environment Agency.

In the five years from 1991-6, Slater's teams cut the UK Pollution Inventory by 50%. He was seconded to DGXI to work on policy for the new European Directives on PPC and REACH. His subsequent career has been involved in the start-up and establishment of companies addressing environmental and risk issues. (These include OXERA, Acona, Cambrensis, RLtec, Willworth and Intradependency Ltd.). He is now fully involved in the innovation think tank – Inqlab, bringing new ideas, technologies and products to market.

Introduction:

This article summarises a EUROCONTROL Network Manager White Paper called Systems Thinking for Safety: Ten Principles. The White Paper was a collaboration of EUROCONTROL, DFS, nine other air navigation service providers and three pilot and controller associations. The purpose is to encourage a systems thinking approach among all system stakeholders to help make sense of – and improve – system performance.

Systems Thinking for Safety

By Steven Shorrock, Joerg Leonhardt, Tony Licu & Christoph Peters

Only human

Imagine you are a health professional – a doctor or a nurse – working in a busy accident and emergency (A&E) department. You are highly trained and are experienced in your job, and you are motivated to do your best. But you work within a hospital A&E department that faces many challenges. Demand is very high, and it can vary significantly and quickly depending on the time of day, the day of the week, and the time of the year. At the busiest times, there are many patents waiting to receive care. There have been government funding cuts to social services and it can take days to get an appointment with family doctors/general practitioners, so patients come to A&E when they feel it necessary, often when their sickness has advanced significantly. There are often many older people, with a complicated range of conditions and medications.

You are constrained by a lack of capacity in the hospital. You have to transfer patients to other parts of the hospital, but there are not enough beds, so they have to stay in A&E for longer, leading to a build-up of demand. You only have 10 beds in the A&E department, and occasionally ambulances have to wait outside, as there are no beds available for the patients. Despite this, you have a 4-hour target to meet – 95% of patients must be seen, treated, admitted or discharged in under four hours. The pressure is very high. Sometimes, there are not enough nurses or doctors.

You often have to work very long hours with little sleep and few breaks. You feel fatigued, too much of the time. You interact with a wide variety of equipment to diagnose, test and monitor, and some of it can be tricky to use. The manufacturers vary and the user interfaces can be confusing, or just subtly different. You have to prescribe a huge range of medicines, and some of these have similar labels, so that two very different doses or two different medicines actually look very similar. You are under time pressure most of the time, but each patient and nurse needs some of your time. Since there are only 10 beds, trade-offs have to be made. For instance, patients are sometimes kept in corridors temporarily. It is a difficult job, but everyone does their best to make things work.

This is not a fictional scenario. It is a scenario faced daily by many hospital A&E departments. It serves here to remind us that we may be highly skilled, experienced and motivated, but we only human, and we work in a system that has a powerful effect on our possibilities – for good or bad.

The fundamental attribution error

When we take the time to think about work situations in this kind of way, the difficulties and compromises faced by people in highly dynamic and complex systems become clearer. Yet often we do not think in this way; we are steered first by our first impressions or reactions. These can lead us astray when we seek to explain situations, events or occurrences that involve other people. Research has shown that we tend to emphasise internal or personal factors to explain someone else's behaviour, while ignoring or minimising external, contextual or system factors. When things go wrong in life – such as a tragic major accident, a near miss or an annoying minor occurrence – this bias seems to kick in. We tend to focus automatically on the person at the sharp end. We seem to think that they should really have

done better, perhaps been more careful, and then things would have been OK. The phenomenon is known as the fundamental attribution error, and explains why we so often blame other people for things over which they had little control, or were influenced by powerful systemic factors that affect most people.

Part of the reason for this is that individuals are obvious – we can see them, they are relatively unchanging. The context or system, on the other hand, is not so obvious and it changes quickly – it seems to be background. So when we try to explain events, we focus on what we can see – the person. This is our automatic or gut reaction – it is easy, and takes little effort to explain away an event as being something to do with an individual. (Additionally, it seems easier to direct our frustration, anger or outrage toward a person.) But considering the situational constraints is a complex activity which requires deliberate inquiry and conscious effort. Indeed, we slip into internal explanations when under greater cognitive load and lack the energy or motivation to consider situational factors. We may also think, without even realising, that the world is just and we all have control over our own lives, so people get what they deserve. Unsurprisingly, when we judge our own behaviour, we are more likely to explain negative outcomes in terms of the context or situation (and positive outcomes in terms of our own disposition) – sometimes known as the self-serving bias.

In organisations, there are a few problems with focusing on the person, especially when things go wrong. One is a problem of fairness. Contrary to our first impression, the context and system in which we work has an enormous effect on behaviour. This is why the celebrated management thinker, statistician and quality guru W. Edwards Deming wrote that *"most troubles and most possibilities for improvement…belong to the system" and are the "responsibility of management"*. When we dismiss the influence of the system – including the system goals, resources, constraints, incentives, flow of information, etc. – we are unfairly blaming an individual for a much bigger issue. The second, and perhaps more important problem, is more practical. When we focus our attention on the individual, we miss opportunities to address future problems and improve the system. Put another way, *"We spend too much of our time 'fixing' people who are not broken, and not enough time fixing organization systems that are broken"* (Rummler and Brache, 1995). What is surprising about the accident-and-emergency scenario above is not that there are accidents and incidents. What is surprising is that there are so few. Pit against a system with such high demand, with limited resources, with such difficult constraints, people somehow manage to make it work *most of the time*. But if we want to make improvements, we cannot simply rely on front-line staff to always compensate in this way. If we want to improve how things work – for safety but also for productivity, efficiency, human wellbeing – we must think about the system and how it works. This relates to the idea of systems thinking.

It's the system, stupid!

To make sense of situations, problems and possibilities for improvement, we need to make sense of systems. 'System' is a word we sometimes use to describe a technical system, but here we use the word much more generally, especially to refer to systems in which humans are an integral part. An A&E department is a system, and is part of a bigger system (a hospital), which is part of a bigger system (e.g. a private or government health service), and interacts with others systems (e.g. police service, transport system). In ATM/ANS, one might consider the working position or sector, an ops room or equipment room, a centre, an organisation, the airspace, the ATM/ANS system, the aviation system or the transport system. Systems exist within other systems, and exist within and across organisational boundaries. In practice, the boundaries of a system are where we choose to draw them for a purpose.

A system can be also characterised in terms of its purpose, the components and the patterns of interactions between the components (which produce characteristic behaviour). The purpose or goal of the system is critical, yet we often take this for granted, or recite some official purpose ("Safety First!") without thinking too much about it. In practice, there are several interdependent goals, but we can say that these relate to the customers or system users and their needs. These needs are not simple, however, and often conflict. For instance, as passengers, we need to arrive at our destination safely, but we also feel a need to arrive on time.

A system comprises a number of components. Some components are obvious and visible, for instance people, equipment and tools, buildings, infrastructure, and the like. Others system components are less visible, typically organisational components (such as goals, rosters, competency schemes, incentives, rules, norms) and political and economic components (such as pressures relating to runway occupancy, noise abatement, and performance targets). All of these have a powerful influence on how the system works – on what the people within the system do – and yet because we cannot readily see them, we sometimes don't realise this. These components – both obvious and less obvious – interact in characteristic ways or patterns, within an environment which may be more or less changeable, in more or less predictable ways.

Complex systems

The term 'complex system' is often used in aviation (and other industries), and it is important to consider what is meant by this. According to Snowden and Boone (2007), complex systems involve large numbers of interacting elements and are typically highly dynamic and constantly changing with changes in conditions. Their cause-effect relations are non-linear; small changes can produce disproportionately large effects. Effects usually have multiple causes, though causes may not be traceable and are socially constructed. This means that we jointly construct and negotiate an understanding of reality, its significance and meaning, though our models of the social world and through language. In a complex system, the whole is greater than the sum of its parts and system behaviour emerges from a collection of circumstances and interactions. Complex systems also have a history and have evolved irreversibly over time with the environment. They may appear to be ordered and tractable when looking back with hindsight. But in fact, they are increasingly unordered and intractable. It is therefore difficult or impossible to decompose complex systems objectively, to predict exactly how they will work with confidence, or to prescribe what should be done in detail. This state of affairs differs from, say, an aircraft engine, which we might describe as complex but is actually ordered, decomposable and predictable (with specialist knowledge). Some therefore term such systems complicated instead of complex (though the distinction is not straightforward). While machines are deterministic systems, organisations and their various units are purposeful sociotechnical systems.

If only everybody just did their job!

Despite these complex interactions and the nature of the wider system, the way that we try to understand and manage sociotechnical system performance (i.e. people and technology) is as a collection of components – a bunch of stuff that will all work together so long as each part does its job. This focus on components – a person or a piece of equipment – is common in many standard organisational practices. At an individual level, it includes incident investigations that focus only on the controller's performance, behavioural safety schemes that observe individual compliance with rules, individual performance reviews/appraisals, individual incentive schemes, individual performance targets, etc. This focus is a management trade-off, since it is easier to focus on individuals than complex system interactions!

You may be wondering, "how is this a problem?" Surely, if everybody does their job, it will be all right! A counter-intuitive truth seems to defy this idea. Deming observed that *"It is a mistake to assume that if everybody does his job, it will be all right. The whole system may be in trouble"*. That may seem like a curious statement. How can it be so? The famous strategy of industrial action known as work-to-rule gives one answer. In his book 'Images of organisations' Gareth Morgan wrote: *"Take the case of the old state-owned British Rail. Rather than going on strike to further a claim or address a grievance, a process that is costly to employees because they forfeit their pay, the union acquired a habit of declaring a "work to rule", whereby employees did exactly what was required by the regulations developed by the railway authorities. The result was that hardly any train left on time. Schedules went haywire, and the whole railway system quickly slowed to a snail's pace, if not a halt, because normal functioning required that employees find shortcuts or at least streamline procedures."* Fancy that! If everyone does only his or her job, exactly and only as officially prescribed, then the system comes to a grinding halt. As well as this, it is not possible to design exactly the interactions between all system components (people, procedures, equipment), so people – as the only flexible component – have to take up the slack; they adapt to the needs of the situation (the same situation that we often miss when looking from the outside, with hindsight). People are always needed to fill in the holes in between work-as-prescribed; to adjust and adapt to changing, unforeseen and unforeseeable conditions. These adjustments and adaptation are the reason why systems work.

Yet sometimes, such adjustments and adaptations are defeated by changing system conditions. While we accept the adjustments so long as the system is working, we decry them when the system fails. Going outside of the organisation, this is reinforced in the justice system, which seeks a person to put on trial when accidents occur (e.g. the 2013 train crash at Santiago de Compostela). The unwritten assumption is that if the person would try harder, pay closer attention, do exactly what was prescribed, then things would go well. Ironically, even when the individual and their sharp-end performance has been found to the 'primary cause', the recommendation of major investigations is rarely to remove the person from the system. The recommendation is increasingly to change the system itself (e.g. the train crash at Santiago de Compostela). This is, of course, very unfair, but while we cannot yet seem to shake off our simplistic causal attributions, we seem more capable of understanding that possibilities for improvement belong to the system. We seem to know, at some level, that simply replacing the individual with another individual is not a solution.

How to sub-optimise a system

A second counter-intuitive truth comes from organisational theorist Russell Ackoff, who wrote that *"it is possible to improve the performance of each part or aspect of a system taken separately and simultaneously reduce the performance of the whole"* (1999, p. 36). A practical example can be seen when each department or division of an organisation seeks to meet its own goals or improve at the expense of another, for instance creating internal competition for resources. In such cases, the emphasis may be on the function instead of the interactions and flow of work to satisfy customer needs. Ackoff quipped that *"Installing a Rolls Royce engine in a Hyundai can make it inoperable"*.

Organisations are not cars, obviously. Yet we often manage these complex social systems as if they were complicated machines. As well as making changes at the component level, we also have a habit of:

- assuming fixed and universal goals – the purpose of a car engine is fixed. Not so with organisations.
- using reductionist methods – we can break an engine down into parts, analyse each and model and test the result, with fairly reliable results. Not so with organisations.
- thinking in a linear and short-term way – we can think linearly for simple and complicated machines. Not so with organisations.
- judging against arbitrary standards, performance targets, and league-tables – it might make sense to have a league table of engines, and to have standards and performance targets for each part. Not so with organisations.
- managing by numbers and outcome data – everything in a car engine can be meaningfully quantified in some way. Not so with organisations.

We also tend to lose sight of the fact that our world is changing at great speed, and accelerating. This means that the way that we have responded to date will become less effective. Ackoff (1999) noted that organizations, institutions and societies are increasingly interconnected and interdependent with changes in communication and transportation, and that our environments have become larger, more complex and less predictable. We must therefore find ways to understand and adapt to this changing environment.

Treating a complex sociotechnical system as if it were a complicated machine, and ignoring the rapidly changing world, can distort the system in several ways. First, it focuses attention on the performance of components (staff, departments, etc.), and not the performance of the system as a whole. We tend to settle for fragmented data that are easy to collect. Second, a mechanical perspective encourages internal competition, gaming, and blaming. Purposeful components (e.g. departments) compete against other components, game the system and compete against the common purpose. When things go wrong, people retreat into their roles, and components (usually individuals) are blamed. Third, as a consequence, this perspective takes the focus away from the customers/service-users and their needs, which can only be addressed by an end-to-end focus. Fourth, it makes the system more unstable, requiring larger adjustments and reactions to unwanted events rather than continual adjustments to developments.

A systems viewpoint

A systems viewpoint means seeing the system as a purposeful whole – as holistic, and not simply as a collection of parts. We try to *"optimise (or at least satisfice) the interactions involved with the integration of human, technical, information, social, political, economic and organisational components"* (Wilson, 2014, p. 8). Improving system performance – both safety and productivity – therefore means acting on the system, as opposed to managing the people (see Seddon, 2005).

As design and management becomes more inclusive and participatory, roles change and people span different roles. Managers, for instance, become system designers who create the right conditions for system performance to be as effective as possible. System, actors, such as front line staff, also become system experts, providing crucial information on how the system works, helping to make sense of it, and providing the necessary adjustments.

The ten principles that follow give a summary of some of the key tenets and applications of systems thinking for safety that have been found useful to support practice. The principles are, however, *integrative*, derived from emerging themes in the systems thinking, systems ergonomics, resilience engineering, social science and safety literature.

The principles concern system effectiveness, but are written in the context of safety to help *move toward* Safety-II (see EUROCONTROL, 2013; Hollnagel 2014). Safety-II aims to "'ensure that as many things as possible go right', with a focus on all outcomes (not just accidents). It takes a proactive approach to safety management, continuously anticipating developments and events. It views the human as a resource necessary for system flexibility and resilience. Such a shift is necessary in the longer term, but there is a transition, and different perspectives and paradigms are needed for different purposes (see Meadows, 2009).

Each principle is described along with some practical advice and questions for reflection that apply to various safety-related activities. But following are some tips from a EUROCONTROL White Paper just published, Systems Thinking for Safety: Ten Principles. Each of these is described in much more detail in the White Paper, and in a set of Learning Cards. You can download both at SKYbrary, via www.bit.ly/ST4SAFETY.

The Foundation: System Focus

Most problems and most possibilities for improvement belong to the system. Seek to understand the system holistically, and consider interactions between elements of the system

Principle 1. Field Expert Involvement

The people who do the work are the specialists in their work and are critical for system improvement. To understand work-as-done and improve how things really work, involve those who do the work.

Q When trying to make sense of situations and systems, who do we need to involve as co-investigators, co-designers, co-decision makers and co-learners? How can we enable better access and interaction between system actors, system experts/designers, system decision makers and system influencers?

Principle 2. Local Rationality

People do things that make sense to them given their goals, understanding of the situation and focus of attention at that time. Work needs to be understood from the local perspectives of those doing the work.

Q How can we appreciate a person's situation and world from their point of view, both in terms of the context and their moment-to-moment experience? How can we understand how things made sense to those involved in the context of the flow of work, and the system implications? How can get different perspectives on events, situations, problems and opportunities, from different field experts?

Principle 3. Just Culture

People usually set out to do their best and achieve a good outcome. Adopt a mindset of openness, trust and fairness. Understand actions in context, and adopt systems language that is non-judgmental and non-blaming.

Q How can we move toward a mindset of openness, trust and fairness, understanding actions in context using non-judgmental and non-blaming language?

Principle 4. Demand and Pressure

Demands and pressures relating to efficiency and capacity have a fundamental effect on performance. Performance needs to be understood in terms of demand on the system and the resulting pressures.

Q How can we understand demand and pressure over time from the perspectives of the relevant field experts, and how this affects their expectations and the system's ability to respond?

Principle 5. Resources and Constraints

Success depends on adequate resources and appropriate constraints. Consider the adequacy of staffing, information, competency, equipment, procedures and other resources, and the appropriateness of rules and other constraints.

Q How can we make sense of the effects of resources and constraints, on people and the system, including the ability to meet demand, the flow of work and system performance as a whole?

Principle 6. Interactions and Flows

Work progresses in flows of inter-related and interacting activities. Understand system performance in the context of the flows of activities and functions, as well as the interactions that comprise these flows.

Q How can we map the flows of work from end to end through the system, and the interactions between the human, technical, information, social, political, economic and organisational elements?

Principle 7. Trade-offs

People have to apply trade-offs in order to resolve goal conflicts and to cope with the complexity of the system and the uncertainty of the environment. Consider how people make trade-offs from their point of view and try to understand how they balance efficiency and thoroughness in light of system conditions.

Q How can we best understand the trade-offs that all system stakeholders make with changes in demands, pressure, resources and constraints?

Principle 8. Performance Variability

Continual adjustments are necessary to cope with variability in demands and conditions. Performance of the same task or activity will vary. Understand the variability of system conditions and behaviour. Identify wanted and unwanted variability in light of the system's need and tolerance for variability.

Q How can we get and understanding of performance adjustments and variability in normal operations as well as in unusual situations? How can we detect when the system is drifting into an unwanted state over the longer term.

Principle 9. Emergence

System behaviour in complex systems is often emergent; it cannot be reduced to the behaviour of components and is often not as expected. Consider how systems operate and interact in ways that were not expected or planned for during design and implementation.

Q How can we ensure that we look at the system more widely to consider the system conditions and interactions, instead of always looking to identify the 'cause'? How can we get a picture of how our systems operate and interact in ways not expected or planned for during design and implementation, including surprises related to automation in use and how disturbances cascade through the system? How can we make visible the patterns of system behaviour over time, which emerge from the various flows of work?

Principle 10. Equivalence

Success and failure come from the same source – ordinary work. Focus not only on failure, but also how everyday performance varies, and how the system anticipates, recognises and responds to developments and events.

Q How can best observe and discuss how ordinary work is actually done? Can we use a safety occurrence as an opportunity to understand how the work works and how the system behaves? How can we best observe, discuss and model 'normal work'?

The principles do not operate in isolation; they interrelate and interact in different ways, in different situations. For instance, imagine an engineering control and monitoring position. There is variability in the way that alarms are handled, and some important alarms are occasionally missed. This must be understood in the context of the overall ATM/CNS system (Foundation: System Focus). Since success and failure come from the same source – everyday work – it is necessary to understand the system and day-to-day work in a range of conditions over time (Principle 10: Equivalence). This can only be understood with the engineers and technicians who do the work (Principle 1: Field Experts). They will view their work from their own (multiple) perspectives, in light of their experience and knowledge, their goals at their focus of attention, and how they make sense of the work (Principle 2: Local Rationality).

In particular, it is necessary to understand how performance varies over time and in different situations (Principle 8: Performance Variability). For this, we must understand demand over time (e.g. the number, pattern and predictability of alarms) and the pressure that this creates in the system (time pressure; pressure for resources) (Principle 4: Demand and Pressure). Through observation and discussion, it is possible to understand the adequacy of resources (e.g. alarm displays, competency, staffing, procedures), and the effect of constraints and controls (e.g. alarm system design) (Principle 5: Resources and Constraints) on interactions and the end-to-end flow of work (Principle 6: Interactions and Flow) – from demand (alarm) to resolution in the field.

It will likely become apparent that engineers must make trade-offs (Principle 7: Trade-offs) when handling alarms. Under high pressure, with limited resources and particular constraints, performance must adapt. In the case of alarms handling, engineers may need to be more reactive (tactical or opportunistic), trading off thoroughness for efficiency as the focus shifts toward short-term goals.

Through systems methods (see http://bit.ly/1DG1odH), observation, discussion, and data review, it may become apparent that the alarm flooding emerges from particular patterns of interactions and performance variability in the system at the time (Principle 9: Emergence), and cannot be traced to individuals or components. While the alarm floods may be relatively unpredictable, the resources, constraints and demand are system levers that can be pulled to enable the system to be more resilient – anticipating, recognising and responding to developments and events.

A systems perspective, and the ten principles outlined above, encourage a different way of thinking about work, systems, events and situations. Anyone can use the principles in some way, and you may be able to use them in different aspects of your work. We encourage you to do so.

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Eine Standortbestimmung

Von Jörg Leonhardt

Vor nunmehr zehn Jahren hat der Bereich Human Factors im Unternehmenssicherheitsmanagement der DFS begonnen, eine Veränderung im Verständnis von Human Factors einzuleiten. Am Anfang stand die Einführung von HERA (Human Error in ATM) als erstes standardisiertes Vorgehen in der Erfassung und Untersuchung des Faktors Mensch bei Vorfällen. Das strukturierte Vorgehen, das einer Methodik unterliegt, führte dazu, dass die „Human Errors" kategorisiert und zugeordnet werden konnten. Perception /Vigilance in Verbindung mit visueller Informationsdarstellung wurde als ein Schwerpunkt kategorisiert. Da es sich in erster Linie um Auffälligkeiten im oberen Luftraum handelte, vereinbarte der Bereich mit der Niederlassung Karlsruhe eine tiefergehende Analyse dieser Auffälligkeiten. Dieses Vorgehen führte zur Entwicklung des Design Process Guides und letztlich zu einer stärkeren Fokussierung auf ergonomische Gestaltung in der Entwicklung neuer ATM Systeme.

Parallel begannen wir, eine strukturierte und umfassende Ausbildung für Vorfalluntersucher - die Learning Labs - mit Professor Dekker aufzusetzen. Die DFS-Safety-Manager und Investigatoren wurden in den neuesten Theorien des Sicherheitsmanagements geschult. Die Diskussionen drehten sich um das Verständnis des Begriffs Human Error und darüber, ob der menschliche Fehler die Ursache für einen Vorfall sei. Des Weiteren wurde diskutiert, ob es zur Klärung des Vorfalls ausreichend erscheint, wenn der „Fehler" des Lotsens identifiziert ist. Die DFS entschied sich einem anderen Ansatz zu folgen und den *Human Error* als Symptom und nicht als Ursache zu verstehen. Symptome zeigen uns Defizite im Gesamtsystem und sind konsequenterweise der Einstieg in eine Analyse und nicht das Ende der Untersuchung.

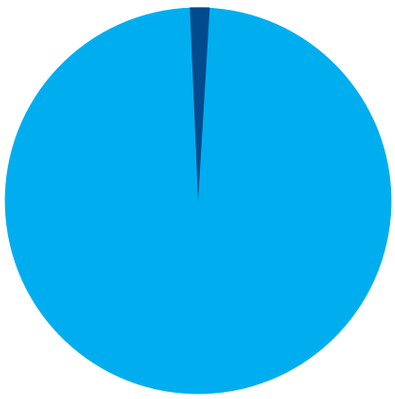
Die Grundlagen dieser neuen Sichtweise wurden geschult und vermittelt. Seither geht es darum, das systemische Verständnis im Unternehmen weiter voran zu bringen und gleichzeitig den Bereich Human Factors so umzugestalten, dass er weiterhin einen substantiellen Beitrag für das Unternehmen leistet.

Flugsicherung ist eine komplexe und interaktive Unternehmung. Alle Ebenen des Unternehmens stehen den Herausforderungen sich ständig wechselnder Situationen und Interaktionen der Systemkomponenten gegenüber. Ob operativ oder auf der Managementebene, der Unterschied liegt hauptsächlich in der Zeit und der Auswirkungsgeschwindigkeit. Am operationellen Ende des Systems – bei den Fluglotsen – ist Zeit limitiert und die Auswirkungen von Entscheidungen direkt spürbar. An der Spitze des Unternehmens – dem Management - muss in langen Zeitabschnitten gedacht werden und die Auswirkungen sind langfristig wirksam. Auf beiden Seiten ist es notwendig, den Systemzustand zu kennen um eine Analyse durchführen und basierend darauf, Handlungsoptionen ableiten zu können.

Die Kenntnis über den Systemzustand geht weit über das Erfassen von Zahlen hinaus, es braucht mehr als das Lernen aus Vorfällen. Die Informationen müssen so aggregiert werden, dass sie nutzbar sind und einen Systembeitrag leisten. Auf der operationellen Seite sind eine fundierte Ausbildung und gute Unterstützungssysteme mit einer ausgereiften Ergonomie entscheidend.

Auf der Managementseite muss der Informationsgewinn über die Aufarbeitung von Vorfällen hinausgehen.

Stellt man die Zahlen – gewünschte und ungewünschte Ergebnisse – gegenüber, ist schnell zu erkennen, dass wir als DFS im Bereich Safety exzellent dastehen. Die Anzahl der Vorfälle – die ungewünschten Ergebnisse – sind im Verhältnis zur Anzahl an Flugbewegungen verschwindend gering ist.



STU FS 2013* vs. IFR Movements

*Staffelungsunterschreitungen (STU) mit Flugsicherungsbeitrag (FS)

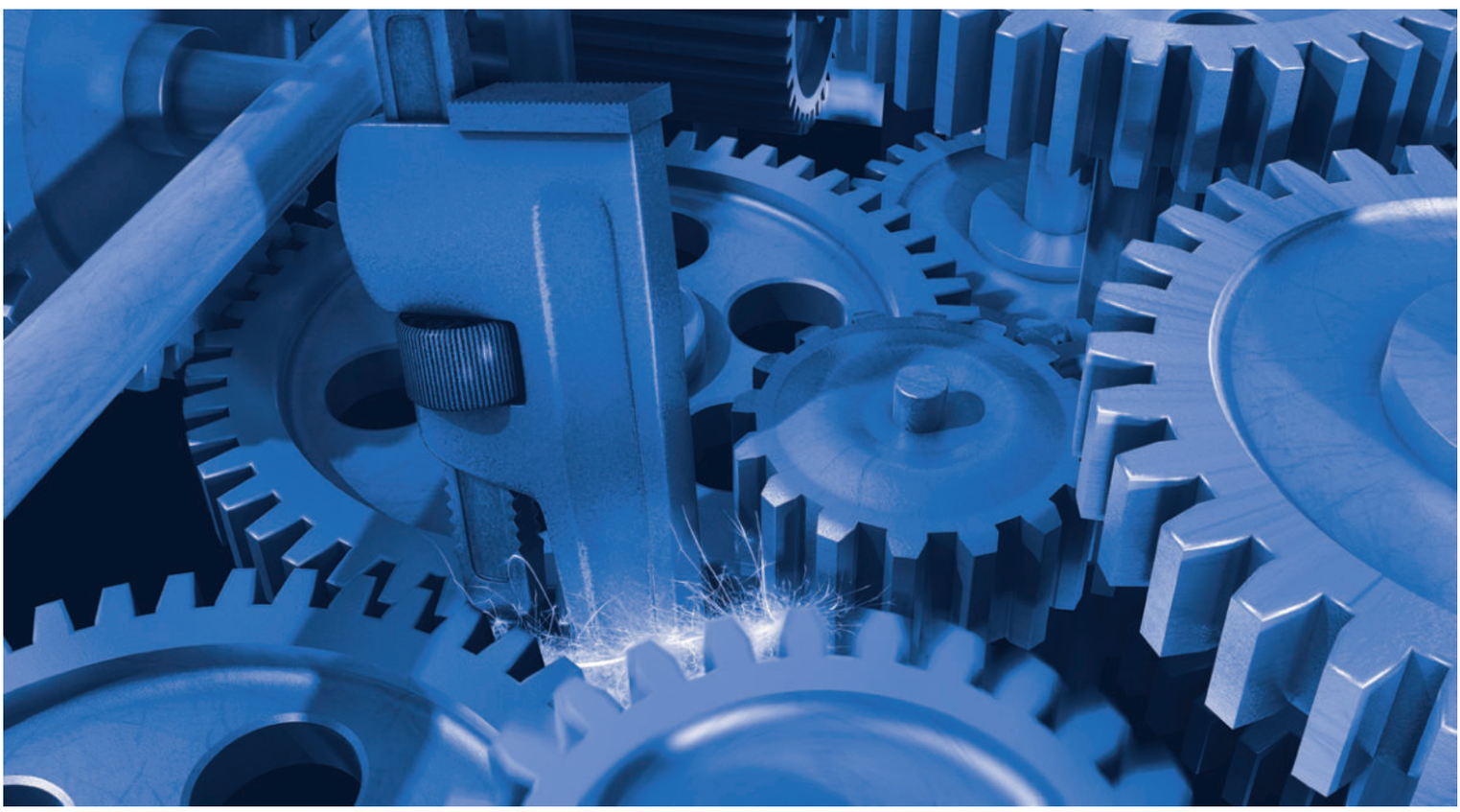
$$\frac{143}{2952624} = 0{,}0000484$$

Abbildung 1. Die Verteilung zwischen gewünschten und unerwünschten Ereignissen (idealisiert).

In einem Verständnis, indem Safety als die Abwesenheit ungewünschter Ergebnisse gesehen wird, stellt die obige Abbildung ein hervorragendes Resultat dar. Und es ist auch nicht klein zu reden, da es zeigt, wie gut die DFS arbeitet und wie sicher wir den Luftverkehr über Deutschland managen.

Aus einer Managementperspektive führt diese Sichtweise aber dazu, dass die Informationen über das System aus einer Datenquelle stammen, die kaum mehr messbar ist und daher nur einen sehr kleinen, nicht repräsentativen Ausschnitt darstellt. Die Unternehmenssteuerung in Bezug auf Safety basiert somit auf einer verschwindend geringen Datenmenge, die ausschließlich auf negativen Ereignissen fußt und erfolgreiche Situationen und Handlungen weitestgehend ausblendet.

Ein modern ausgerichtetes Safety Management nimmt sich neben den Vorfällen auch den gewünschten Ergebnissen, der Normalität im System, an, um zu verstehen, wieso das System erfolgreich ist und um Abweichungen früh zu erkennen – bevor etwas passiert. Notwendig dazu sind eine proaktive Ausrichtung des Safety Management Systems und eine veränderte Sichtweise.



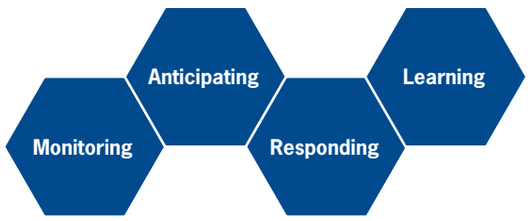
Flugsicherung gehört zu den sogenannten komplexen Systemen. Ein lineares Denkmodell von Ursache – Wirkung ist unzureichend und kann nicht die Interaktivität und Komplexität des Systems erfassen. Ein komplexes System braucht systemische Denkmodelle. Dies ist der erste, aber entscheidende Schritt, Bedingungen zu schaffen, die es ermöglichen, mehr über das System zu lernen und dieses System nicht beherrschen, sondern managen zu können. Systemische Denkmodelle basieren stärker auf qualitativen als auf quantitativen Daten. Qualitative Daten zu erfassen und in einen sinnvollen Zusammenhang zu stellen ist nicht einfach. Noch schwerer ist es auf der Basis qualitativer Daten ein Unternehmen zu steuern. Sich dieser Herausforderung zu stellen ist der zweite entscheidende Schritt. „Weil Du ‚eins' verstehst, denkst Du, musst Du auch ‚zwei' verstehen, weil eins und eins zwei ergeben. Aber Du vergisst dabei, dass Du auch ‚und' verstehen musst."

Lehrgeschichte der Sufi

Im systemischen Verständnis hört man mit dem Zergliedern in Einzelteile – Ursache-Wirkungsketten - auf und schaut stattdessen nach den Verknüpfungen – dem ‚und'. Die Verknüpfungen zeigen die Interaktionen im System und das Erkennen der Interaktionen führt zu dem Erkennen und Verstehen von notwendigen Adaptionen.

Adaption ist ein zentrales Wesensmerkmal komplexr, interaktiver Systeme. Je höher die Adaptionsfähigkeit, umso größer der Erfolg. Adaption benötigt Flexibilität und die Fähigkeiten zu antizipieren und zu erkennen, was sich ändert, um gegensteuern zu können. Wiederum auf beiden Seiten des Unternehmens, sowohl am operativen als auch administrativen Teil.

Die Fähigkeit zu antizipieren und zu adaptieren erhöht die Widerstandsfähigkeit – die Resilienz – im System. Widerstandsfähigkeit benötigt Elastizität. Wird diese dem System entzogen wird es brüchig und anfällig. Diese Brüchigkeit kann dazu führen, dass etwas was vorher schon hundertmal gut ging zu einem Unfall führt. Die Resilienz des Systems zu erfassen, Brüchigkeit früh zu erkennen und gegenzusteuern und letztlich daraus die Resilienz zu erhöhen ist der substantielle Beitrag eines modernen Safety Management Systems. Die zugrundeliegende Theorie ist das Resilience Engineering (RE), die auf vier Eckpfeiler basiert:



Monitoring *Zu wissen, wo das System steht (resilient vs brüchig)*
Anticipating *Zu wissen, was auf das System zukommt, welche Veränderungen sich abzeichnen*
Responding *Reagieren können, wenn es nötig ist und dazu vorbereitet zu sein*
Learning *Aus der Erfahrung lernen und sich verändern (adaptieren)*

„Systeme müssen nicht nur auf Produktivität oder Stabilität, sondern auch auf Widerstandsfähigkeit ausgerichtet funktionieren – also mit der Fähigkeit, sich von Störungen zu erholen, sich selbst wieder herzustellen oder zu reparieren"
Donella H. Meadows (2010)

Monitoring muss aktiv ausgerichtet werden. Aus einer Wartehaltung, die Informationen passiv erhält, muss sich das Safety Management in eine aktive suchende Haltung entwickeln. Erste Ansätze hierzu liefert das von VY mit EUROCONTROL und den DFS-Niederlassungen in Entwicklung befindliche „Weak Signals"-Vorhaben.

Anticipating wird als Fähigkeit entwickelt. Zu wissen, wo man steht, um zu erkennen, was sich ändert oder bereits in der Veränderung ist. Die Informationen aus dem Monitoring müssen so aufbereitet werden, dass sie den aktuellen Zustand einer Organisation beschreiben und Entscheider unterstützen, das Unternehmen steuern zu können. Eine neue Methode zur Erfassung des Systemzustandes und zum Erkennen von Resonanzen, die durch Veränderungen hervorgerufen werden, soll erprobt werden. Vielversprechend erscheint die Methode FRAM – (Functional Resonance Analysis Method), die nicht auf negativen Ereignisse fokussiert ist, sondern analysiert, wie normale Arbeitsabläufe funktionieren.

Responding die richtigen Ressourcen zur richtigen Zeit in ausreichender Menge bereitzustellen sind Grundvoraussetzungen. Flexibilität im Ressourceneinsatz auch über die direkten Einsatzgebiete und Bereiche hinaus. Das frühzeitige Erkennen der *„operational boundaries“*, um den gezielten Einsatz von Ressourcen steuern zu können.

Learning Um lernen zu können müssen Erkenntnisse gewonnen werden, die Potentiale aufzeigen. Lernen wird hierbei nicht auf das Lernen aus Fehlern reduziert, sondern erweitert auf das Lernen von Erfolg. Das Ergonomie Board und die damit zusammenhängenden „Lessons Learnt“ -Workshops bieten hier wertvolle Ansätze.

Das Unternehmenssicherheitsmanagement hat sich die vier Eckpfeiler des Resilience Engineering zur Grundlage genommen, um sich neu auszurichten. Unterstützung seitens der Geschäftsführung und enge Kooperation mit den Bereichen wird dazu beitragen, dass wir die Resilienz im Unternehmen erhöhen und das Unternehmen damit insgesamt widerstandsfähiger machen.

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