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Ladbroke Grove, Or How to Think about Failing Systems

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The Accident

This is a paper about the Ladbroke Grove train disaster.

The facts are these. On 5th October, 1999, a three-carriage Thames Train diesel unit ('165') was in collision with a First Great Western High Speed train ('HST') at Ladbroke Grove, two miles outside London's Paddington railway station (P76:0042) (1). The Thames train had just started a journey from Paddington to Bedwyn in Wiltshire, and was travelling at about 50 miles an hour (P76:0294). The Great Western train, the 6.03am from Cheltenham to Paddington, (P81:0416) was in its final approach to Paddington travelling at 95 miles per hour (P2:2495). Though the driver of the Thames train applied the emergency brakes two seconds before the collision, the closing speed of the two trains was about 145 miles per hour (P81:0475). The impact was virtually head-on, and this was reflected in the dreadful scale of the destruction. The leading power car and the two leading coaches of the Great Western train (coaches H and G) together with the leading two coaches of the Thames train (coaches B3 and B 2) were all very severely damaged (P76:0338), though the greater damage was to the carriages of the less heavily built Thames train. The scope of the destruction was compounded by the outbreak of a ferocious fire, in part caused by escaping diesel fuel, which completely destroyed the interior of coach H of the high speed train.

The human results of this tragedy are stark. Mr Robert Owen, Senior Counsel to the official Ladbroke Grove Rail Inquiry in his opening statement to Part 1 of that Inquiry on 11th May, 2000, described them so:

> 'It has been established that a total of some 575 people were travelling in the trains. 31 people died in the crash or from the injuries sustained in it. 23 of the dead were passengers on the Thames Trains' 165, 6 were passengers in the High Speed Train. In addition, the drivers of both trains were killed. Approximately 414 were injured, many very seriously. It follows that over 75 per cent of the passengers either lost their lives or were injured to a greater or lesser degree. The figures for the 165 are even more stark. The best estimate is that it was carrying some 148 people. Of those 23 died and 116 were injured. Only 6 emerged unscathed. 227 were taken from the scene to hospital. Many are continuing to suffer from their injuries and from the shock of exposure to scenes of horror and of devastation.' (P2:0303)

What went wrong?

The overwhelming view is that the driver of the Thames train passed through a signal, codenamed SN109, which was showing a red aspect. This led his train onto a line which merged with the up main line, the line on which the Great Western train was running, after 700 metres (P81:0071). The collision occurred at or near the points where the two lines joined. But *why* did he do this? *How* could it have happened? This is one of the major topics of Part 1 of the Ladbroke Grove Rail Inquiry (others include the cause of the fire, the crashworthiness of the rolling stock, and the conduct of the rescue operation). This inquiry, set up immediately after the disaster by Deputy Prime Minister John Prescott, is chaired by Lord Cullen (2). It has not yet reported its findings, but the evidence has been heard. And it is about that evidence – or parts of it – and what it tells us about the character of cause and explanation (including the causes and explanations of disaster) in large technical systems that we offer our commentary (3)

Spatiality

Why did the driver pass through SN109 at red aspect?

There are many substantive responses to this question. To these I can add nothing for I am not an expert in railway safety. Instead I attend to the *character of explanation*, the nature of the causal narratives, as these appear in the substantive responses. My argument is that attention to the character of explanation and cause is relevant in thinking about safety-critical sociotechnical systems such as railways. The particular way I choose to do this is to attend to the *spatial* implications of those stories, and of sociotechnical systems in general.

There is a crass way in which a collision is necessarily about space: different trains are not supposed to occupy the same space. But there are also rhetorics of spatiality embedded both in the stories and the workings of railways and other large technical systems. These are visible in the Ladbroke Grove Inquiry. Thus many of the questions and responses about what went wrong are posed, either explicitly or implicitly, in terms of *location*. Examples. *Where* does responsibility lie?

> 'Thames Trains could be prosecuted if an incident occurred where driver error was partly to blame.' (P 4: 11mayam.txt - 4:86 (532:533))

Or:

> 'Q. Was that the overall feeling? If a SPAD [Signal Passed at Danger] happens, that it is essentially a driver problem?
>
> A. Well how can it not be? If a person at a traffic light goes through red light, is it not his fault?'
>
> (P93: 30maypm.txt - 93:13 (1931:1934))

Or *where* might changes be made?

> 'The report identified two key areas where substantial improvement was required' (P 3: 10maypm.txt - 3:33 (1863:1864))

The argument, then, is that much of the accounting for failure assumes, if only tacitly, that the world can be understood as a set of distinct pigeon-holes or compartments. To which one might add: those compartments also belong to domains or to regions: for instance, to the technical, the managerial or the psychological.

This is one version of the spatial: to think of it as a terrain divided into *regions*, units or compartments. But there are others. For instance there are explanatory idioms and forms of spatiality which derive from *systems*.

> 'To the best of his recollection the train was performing as he would expect and he cannot remember any fault in any of the safety systems.' (P 2: 10mayam.txt - 2:87 (453:459))

System space responds to questions about where things went wrong by delocalising these geographically. Instead location is treated as a set links and relations in a system. 'Where' becomes function or location in a network of connections.

Ladbroke Grove Inquiry wrestles with these two explanatory idioms, these two spatial forms. In what follows I argue that there are difficulties in both. Systems responses to the 'where question' usually erode regional answers – but since it turns out that there are lots of incomplete and unstable systems they also tend to erode one another. This suggests that location, the *where* of cause and responsibility, is no better modelled in system space than it is in regional space. The world is simply too fluid and disarticulated for this to be possible much of the time. But this lesson is not entirely clear when people start worrying about an accident. Often remedies are sought by fixing location either regionally or relationally. For instance:

> 'the immediate cause of the collision was that Driver Hodder passed SN109 at danger.' (P 3: 10maypm.txt - 3:1 (10:12))

Or:

> 'Problems such as those presented by SN109 should be approached and resolved as a whole rather than on a piecemeal basis.' (P 4: 11mayam.txt - 4:55 (2220:2227))

A regional and a system response respectively. So the question is: is there any way of doing better? And this is the question I consider in the last part of this paper: the question of how to imagine more fluid responses to the 'where question', and what implications this might have for thinking about the design and operation of safety critical systems. (4)

Regions

There is a regional dimension to the Ladbroke Grove Rail Inquiry. There are pigeon-holes for this, and pigeon-holes for that. Different days deal with different topics. And different bodies with an interest in the outcome of the Inquiry are represented, bodies which occupy a patch of socio-technical space, together with the rights, duties, responsibilities, problems and benefits which go with that space (5). But these pigeon-holes lie within larger domains:

> 'The immediate cause of the accident appears to be that the Thames Train passed a red signal (a "signal at danger") some 700m before the collision point.' (P75: HSE Interim 1 991008.txt - 75:28 (49:55))

We've already seen a version of this. Cause or responsibility is provisionally being located in the person of a driver. But the person belongs to the larger domain of the *human*. Other domains include objects or non-humans:

> 'Once an AWS receiver passes over the permanent magnet, the on-train equipment needs a message from the electromagnet within one second or will sound the horn. WS Atkins suggest that if during that second a lateral shock is experienced in the order of 7g to 15g, it is possible that this can produce an effect similar to the effect produced by the electromagnet, and, if it does so, the AWS bell will sound instead of the horn. In other words, Driver Hodder may have heard a bell indicating to him that the signal ahead, SN109, was green.' (P 3: 10maypm.txt - 3:5 (275:293)) (6)

So-called 'human factors':

> ‘The Inquiry will also hear evidence from Professor Roger Watt, who has been instructed on behalf of Thames Trains to report on aspects of visual perception with regard to SN109 and the signals on the surrounding gantries. … Professor Watt identifies three factors affecting the visibility of SN109, general atmospheric effects, including illumination by the sun, second the occlusion and, thirdly, the background against which the signal is seen. These factors may all affect the visibility, conspicuity and the interpretability of the signal.’ (P83: 10maypmbak2.txt - 83:39 (1830:1842))

Something which we might think of as organisational culture:

> "My instruction is only to depress these [signals on] buttons when I have a total computer system failure. They are to be held down for 15 seconds, otherwise it has the effect of data corruption. These buttons must only be used when I cannot determine a reality situation and my display screen 'locks up'." (P 2: 10mayam.txt - 2:85 (3223:3301)) (7)

And finally (distinct from organisational culture) an area which one might think of as managerial responsibility:

> ‘Human errors there were, but those mistakes moved to the very background of the picture that has emerged of this crash and its causes. It is a picture dominated by Railtrack's institutionalised inertia and obsession with performance. This disaster, above all else, is a story of an abject failure of management.’ (P84: 27julpm.txt - 84:37 (227:235))

Regions, Causes and Responsibilities

To distinguish between distinct regions is obviously to oversimplify but it catches something important. In common-sense it is often said that ‘this person’, ‘this organisation’, or (perhaps more controversially) ‘this technology’ caused some event or other. Much of the talk at the Inquiry is in this idiom. It is about locating a cause or a responsibility in some regional pigeon-hole or another. *Somewhere definite*. There are many technical examples – the possible malfunctioning of the Automatic Warning System cited above is one. Another has to do with the questionable visibility of the signals in the area of SN109:

> "The addition of overhead wires and insulators...in some instances obstruct drivers' views of signals. This makes going in and out of Paddington more difficult than before in terms of signal sighting. Before the installation of these electrification wires, I would have looked at a particular signal and been sure that I had seen it properly. Following the installation, however, signals which had been easy to sight are obscured or come in and out of vision. This often causes me to doubt the sighting of a particular signal, which means I have to double check those signals." (P 3: 10maypm.txt - 3:19 (957:977)) (8)

Here two regions are involved, the technical (signal visibility) and (behind this) management responsibility. And the latter keeps on cropping up. The last citation but one above locates it here – and in the Railtrack pigeonhole. It does this because in Britain’s privatised railways, Railtrack is the company which owns and has responsibility for the infrastructure over which the trains run – including the possibly questionable signalling. But in these movements between pigeon-holes the buck may stop nowhere in particular. Here is the Counsel for Railtrack picking it up and pushing it on again:

> ‘it was not the layout, it was not the signals, nor the complexity, nor past bad management, nor past failure to correct known Railtrack problems that caused this disaster. It was a complex mixture of factors in which two things predominated: one was the use of the Driver Reminder Appliance [] on the move and the other was Mr Hodder's deficient training and deficient experience. (P85: 28julam.txt - 85:3 (316:323)) (9)

Here responsibility belongs to the (the management) of Thames Trains who didn’t train their driver properly. But it doesn’t stop there for long. This is Counsel for Thames Trains:

> ‘When it comes to the action or inaction within the Great Western Zone of Railtrack, there stand out from all the detail perhaps four simple facts: no Signal Sighting

> Committee was convened for this signal, as was required; no overall review of Paddington signalling was carried out, although more than once intended and even instructed; no measure was implemented to the signal itself at 109 from 1994 with the exception of the prior yellows being removed; and the gantry remained where it was without mitigation. (P84: 27julpm.txt - 84:45 (1603:1619))

Causes, responsibilities – these all stop in locations and pigeon-holes, except that they don't stop for very long, but tend to move on.

Systems, Complexities and Relations

The spatial vocabulary of regions and pigeon-holes is everywhere, and it is important in the thinking (and the working) of the railways. But this is too simple. Straightforwardly, nothing is that simple. Everyone recognises that there are endless interactions between causes derived from different locations. This is clear if we put one of the citations above in context:

> 'The immediate cause of the accident appears to be that the Thames Train passed a red signal (a "signal at danger") some 700m before the collision point. The reasons why the train passed the red light are likely to be complex. [Her Majesty's Railway Inspectorate] … will be looking at the underlying causes as well as any more obvious ones. Our belief is that it is a systems failure and that any action or omission on the part of the driver was only one factor.' (P75: HSE Interim 1 991008.txt - 75:28 (49:55)

First, let's think about the idea of 'complexity'. Here it is again:

> 'all the experts have emphasised that the search for the root cause of the accident, the probability is that there was a combination of factors which led to the collision and searching for these causes could be a complex matter.' (P84: 27julpm.txt - 84:15 (746:761))

This is Counsel for the trades union of the drivers, ASLEF. First Great Western's advocate talks in similar terms:

> 'The fact that a signal is passed at danger more often than other signals indicates that the underlying cause is likely to be more complex than mere driver error. This has been insufficiently appreciated by the industry over many years.' (P 4: 11mayam.txt - 4:53 (2210:2214))

What to make of the talk of the complex? One answer is that matters become complex if there are many of them: in this case, many explanations which interact together. Things becomes complex if there are many partial explanations which derive from different regions or pigeon-holes. Put spatially, *something is complex if it escapes the ordering language of regional spatiality*.

This is where systems comes to the rescue. To talk of a 'systems failure' is to offer an explanation based on emergence. It is to seek accounts for breakdown that cannot be located in – that specifically fail to fit with – a spatiality of region or locality. Such is the promise. So what does this mean?

There are answers to this question in the literature of the discipline of Science Technology and Society (10). So what do these stories tell us? The answer is, two things. First, they insist on the *primacy of the relational*: elements don't have attributes by virtue of belonging to a region or a pigeon-hole. Instead they are shaped or made by virtue of their location in a system. They belong in a web rather than in a patch. This means that if we ask where they are, we get network rather than geographical answers. And, second, system stories (and system realities) usually insist on a corresponding *need for overall design, co-ordination and oversight of the system*. A definite response to the question 'where in this web of relations is …?' I will return to this issue in due course. For the moment I will attend to the primacy of the relational.

This is more or less explicit within many of the citations above. Here it is again:

> 'Another significant feature of the aviation and other industries' approach to accidents is to move away from a blame culture with procedures for disciplining. Such a culture detracts from the real investigation. It ignores the context of the blameworthiness and

> it inhibits employees admitting an error, which can often be the clue to a future disaster. The management needs to know the possible errors [which] can occur in order to improve the system. It is so easy to say "Driver error" and leave it at that, without ever inquiring into what circumstances caused the error to be made.' (P 4: 11mayam.txt - 4:83 (2517:2527)) (11)

To blame the pilot, or blame the culture, this is a regional move. It locates responsibility in a specific pigeon-hole and confines it there. It builds, or presupposes, a barrier or a boundary between one location and the next, for instance, between the driver and his surroundings (12). By contrast, to insist on the importance of 'the circumstances' is to erode this spatiality of locality and regionality. It is to *propose and trade on the alternative relational or system version of the spatial*. This, as I have just noted, says that the elements in a system are shaped or made by virtue of their location in that system: indeed, they are synonymous with that location. In this space, to seek an explanation is to locate a person, an object, whatever, in a system. To talk about his/her/its relations. To reduce her/him/it to those relations.

Here this means that we are no longer talking about the driver of the Thames train and his personal failings. We are dealing, instead, with the driver of the Thames train in relation to (and as an effect of) a whole bunch of other factors. An incomplete list would include his training (incomplete, too rapid?); his experience (too limited?); the position of the sun in the early morning (affecting the visibility of the signals?); the layout of the cab (distracting?); the layout of the signals on gantry 8 (insufficiently clear, too confusing?); the complexity of the bi-directional track layout coming out from Paddington (too complex to memorise? too confusing in terms of signalling?); the working or otherwise of several safety systems including the Automatic Warning System (did it give a false positive?) and the Driver Reminder Appliance (did it appear to give a false positive?); and so on.

To talk systems is to talk relations and relational effects. It is to perform location – and so spatiality – in an alternative mode. Location becomes relational, about how elements function in relation to one another, and about how that that functioning produces those elements and gives them the attributes (a competent driver, a less than competent driver) that for the moment they display. Profoundly erosive of regional answers to questions about 'where', this way of reasoning undoes pre-constituted explanatory pigeon-holes while promising an alternative relational explanatory universe (13).

Shifting Systems and Spatialities

Things are effects of relations. This is the argument. But it is an argument that works best if relations are held stable. (This is one of the reasons for the argument about the need for the design and overall coherence of systems). But is this achieved? Are the elements in the railway system stable? The answer is: yes and no. Yes, because most of the time it would seem that the elements in the system stay more or less in place. Or are made to stay in place. Here is Gerald Corbett, Chief Executive of Railtrack, talking about the number of times signals were passed at danger (SPADs) in the Paddington area:

> 'I think it is hugely significant that following the removal of the flashing yellows and the action on the empty coaching stock the number of SPADs in the next nine months was only one, whereas the previous year there was ten. I can quite understand why the managers of the Great Western Zone, given the decline in the number of SPADs, and at 109 and SN63 there were no SPADs at all, I can quite understand why they thought that the action they had taken had been effective in mitigating the problem.' (P89: 18julam.txt - 89:17 (1850:1859))

This describes a system, a set of relations, more firmly staying in place as the result of Railtrack action. There are thousands, indeed tens or hundreds of thousands, of non-SPADs against one SPAD. Experienced signalmen might only meet a SPAD three or four times in their careers. But then again, this apparently stable set of relations can also be dissolved. The Ladbroke Grove disaster is a spectacular and horrific demonstration of such a dissolution. And arguments can be made about other SPADs at Paddington:

> 'There was a long history of SPADs. There was no proper investigation. No one spotted the relevance of these SPADs. No one drew conclusions from them. No one

> applied any statistical analysis to them to see what lessons could be drawn.' (ASLEF) (P84: 27julpm.txt - 84:21 (1020:1024)) (14)

But once we enter the sea of argument and counter-argument we find that we're standing on shifting ground. We've already seen that the 'where question' doesn't get a stable answer in terms of pigeon-holes. Regional location has been eroded by the relational dynamics of system spatiality. But now it seems that systems are no more stable because *any particular attempt to locate an explanation in a web of relations is in turn susceptible to erosion*. Why? The answer is that systems fail. Or, perhaps, because relational spatialities of system come in the plural. There are different systems which locate things differently, even if they sometimes manage stay in place.

Reinforcing Systems

But what to *do* about all this? This, to be sure, is what the Inquiry is all about. And there are two general responses. The first is that *systems should be failsafe*:

> 'SN109 is one of the many signals that is required to be fitted with a train protection system, such as the Train Protection Warning System (TPWS), by 31 December 2003 by virtue of the Railway Safety Regulations 1999. The accident was likely to have been prevented by TPWS.' (P81: HSE Interim 3 000414.txt - 81:23 (278:283)) (15).

The argument is that if TPWS had been installed at SN109, then the Thames Train would have been brought to a halt automatically whatever the actions of the driver. It might have passed SN109, but since the track runs for 700 metres before joining the up main line (which carried the approaching First Great Western train), this would not have mattered. The Thames Train would have been stopped before the danger point.

The second, linked as we have noted to system thinking, is the belief that *there should be overall control of the railway system*, an overall design, overall coherence and overall responsibility. For instance, there are complaints about organisational fragmentation following the privatisation of British Rail which has, or so it is said, led to:

> 'reduction in the clarity of responsibilities of duty holders. This was a consequence of the loss of a single focus in the main rail network for making improvements in safety. There was a further lack of clarity in the duties of different regulators and standard setting bodies, and in the experience and expertise available in the industry – of owners, operators, contractors, maintenance staff, drivers and others.' (P79: HSE Railtrack A Review 00022.txt - 79:15(254:264))

Then there are complaints about Railtrack's lack of grip in the management of safety:

> 'The people that should have held the [Signal Sighting] committees did not hold them or make sure that they were held, and the people managing those people did not chase them up and pursue them. There should have been a process which enabled us at a higher level to be able to see that.' (P90: 18julpm.txt - 90:14 (475:487)) (16)

Here is another example, to do with SPADs:

> 'Instead of vigorous action a plethora of meeting groups were established which did little more than discuss and disagree about options.' (P84: 27julpm.txt - 84:9 (361:363)) (17)

This kind of complaint draws attention to the second feature of systems thinking: the need for overall design or co-ordination of the system. The argument is that a system needs a strong centre ('a single focus', 'a process which enabled us at a higher level to be able to see that [meetings weren't being held]', a capacity for 'vigorous action'.) It is the assertion of the need to create a proper set of relations, and keep them stable. Or, put spatially, it is the assertion of the need for things to stay in place relationally. To function as they should and where they should in the web of relations which makes up the system. With a centre keeping everything in place.

I don't want to argue against failsafe procedures or strong centres. But I do want to argue that there are drawbacks – indeed limitations – to both approaches. *Sometimes, perhaps often, they simply don't work*. The web will not stay still. I'll deal with each in turn.

Internal Dissolutions

Failsafe systems are important in the context of the Ladbroke Grove accident. First, as I have noted, it is probable that the accident would have been averted if a particular protection system, the TPWS, been fitted to the Thames train. Second, it appears that the use of the Driver Reminder Appliance (DRA) by the driver of the Thames train was an important contributory factor to the accident.

The DRA is primarily intended for use when a train has come to a halt:

> 'If the train has been standing, for example at a station, there is a risk of the driver forgetting to check the signal before departing. The device prevents the train from starting until the driver has reset it, which should remind him to check that the signal has cleared.' (P91: HSE Train Protection Systems.txt - 91:1 (32:42))

Once the DRA is set the driver cannot apply power until s/he has cancelled it. Setting it also lights up a red button – in the Thames Train at eye level to the left of the driver. Strictly speaking it is not a failsafe device. This is because it is both set and cancelled by the driver. Nevertheless, it is a safety device, an additional mechanism that the driver can (and should) use to remind her/himself that he or she has stopped for a good reason.

As we have just seen, the DRA system was created for use on stationary trains. But in practice many drivers – and certainly Michael Hodder, the driver of the Thames train – also used it with signals showing a single yellow (that is a warning) aspect (18). Why? The evidence suggests that they did this in order to remind themselves to be alert that the next signal would be red – for such is the significance of a single yellow aspect. In short, they did it *because they wanted to drive as safely as possible*. And all the evidence shows that Michael Hodder was a defensive driver.

So how would this work in practice in the context of a single yellow signal? The answer is that two things would be going on. First, as the driver passed through a single yellow, the Automatic Warning System would activate. This would sound a horn to warn the driver that s/he had passed through a signal that wasn't showing green. It would also activate a visual signal – a yellow and black disc in the cab colloquially known as the 'sunflower' which would continue to show yellow and black until the train passed through a signal set at green. The driver would turn the horn off (thereby preparing it to sound another warning when approaching the next signal not set at green). At the same time, s/he would turn on the DRA. This, as we have seen, would prevent application of further power, and also light up the red button in the cab. By this time the train would be approaching the next signal – the one at red. The horn of the Automatic Warning System would sound again. The driver would see the red signal. And (this is the crucial point) *if there were any doubt about the aspect of the signal s/he would have the illuminated red button of the DRA to confirm that the signal must be red because it was a reminder that the previous signal had showed a single yellow*. Now let's pick up this story in the words of Roger Henderson, Counsel for Railtrack:

> 'Suppose that [Michael Hodder] was taught to use the DRA whenever he saw a single yellow, which is what we believe the evidence shows. Suppose that for one reason or another his attention was on something else for a moment when he quite properly is passing through a single yellow and he forgets to do what he has been taught. Suppose, therefore, that the red button at eye level to his left is never used and never lights up. Now suppose that he attends fully again to his driving and takes stock. He can tell that he has passed a yellow or a double yellow because the AWS sunflower shows him this. But it is the unlit red button that tells him that it must have been a double yellow not a single yellow and, therefore, the signal ahead cannot have been at red. There is the trap.; (P85: 28julam.txt - 85:6 (442:516))

'There is the trap'. The argument is that a procedure intended to increase safety actually led directly to catastrophe.

This is a phenomenon widely recognised in the literature on safety, and is one of the reasons why those involved in the safety business tend to react cautiously to safety panaceas proposed by grieving relatives or campaigning journalists (19). Adding complexity to the relations which make up a system in order to strengthen those relations may actually dissolve those relations in practice (20). The horror of the Ladbroke Grove accident is something all would want to avoid. But the lesson is that trying to fix things in terms of their location in a single system, their location in a single functional network of spatial relations, is not self-evidently the best option. *Systems are never failsafe*. System space is never secure. Indeed they may, with the best will in the world, dissolve themselves from within as they attempt to increase their reliability.

Diversity

So there are difficulties with the failsafe argument. But the alternative mentioned above – the call for strong centres to well-structured systems – though prominent, raises analogous difficulties. The complaints about the organisation of the railway system and the flaccid character of Railtrack's management of safety illustrate the relative absence of overall control in the system. Four examples.

First there is the fragmentation of the industry. The privatisation of British Rail, the former state owned rail monopoly, produced nearly 120 private companies.

> 'The former BR network was thus subject to sweeping change and fragmentation and the extensive spread of contractorisation. Train and station operations were allocated to 25 separate train operating companies (TOCs) which were subject to licence under franchises granted by the Office of Passenger Rail Franchising (OPRAF). The passenger rolling stock passed into the ownership of three rolling stock companies (ROSCOs) which lease rail vehicles to train operators'. (P78: HSE Internal Inquiry 000417.txt - 78:11 (312:346))

And this is not to mention the Regulator, the Health and Safety Executive, the users, the Unions, the locomotive and rolling stock builders, and the many subcontractors also involved.

Second, if there are many parties involved, then there is diversity of interests between those parties:

> 'The first three years following privatisation was very difficult for the industry. Everyone was operating behind contractual matrices which were totally new. Everyone had a totally different set of incentives. Everyone was trying to do different things and it was quite adversarial.' (P90: 18julpm.txt - 90:23 (1393:1407)) (21)

Third, even within individual parties it turns out that there are diverse and possibly incoherent pressures or versions of the good:

> 'Railtrack had a conflict between safety and the need to make a profit. But Railtrack should not be blamed for that, it is a company which has a duty to make profits to its shareholders and this is exactly what happens when you privatise a public service.' (P 4: 11mayam.txt - 4:75 (2602:2606)) (22)

Fourth, again within individual parties there are diverse cultures. This is Gerald Corbett, Chief Executive of Railtrack, once again:

> 'When I arrived at Railtrack it was obvious that the organisation had huge challenges coming up on it. If you are the Indian Customs Service and all you do is rubber stamp 10 million passports each year, you do not have to change and you can do it through the hierarchical command and control mode. You also can manage command and control if you are in a crisis for a short period of time. But if you are a big organisation, trying to achieve a lot across a variety of different dimensions, you cannot do it that way.' (P90: 18julpm.txt - 90:28 (2248:2285))

He's talking, as is obvious, of a cultural division between a version of bureaucratic culture on the one hand, and what has been called enterprise ordering on the other (23). The latter, in his account, is to be preferred because in this people take responsibility and initiative (24) while in the former they follow rules, or commands – an approach which doesn't work in a world with (a revealing phrase this) 'a variety of different dimensions'.

But are these diversities and incoherences a problem? The predominant response is yes, they are. Diversity is something to be overcome. One needs some overall way of managing the different dimensions. A strong centre and a single system are needed if safety is to be assured. And here the Inquiry matches its concern with fragmentation with narratives of hope. For instance, we learn that the railway is becoming less fragmented:

> 'I think in the last year and a half the industry has come together a bit and is working better with each other.' (P90: 18julpm.txt - 90:30 (1401:1403))

We learn that performance (and profit) can indeed be reconciled with safety:

> 'the majority of the things you do to improve performance actually improve safety. And, of course, the better performance is, then the less red signals there are for trains to pass.' (P90: 18julpm.txt - 90:19 (833:836)) (25)

This is an instance, then, when the different dimensions, though seemingly in conflict, are actually reconciled. And finally we learn that the culture of Railtrack is moving in the direction of adaptable coherence, even if this is uphill work:

> 'I am afraid that anything to do with the railways, when one gets into it, one does identify a lack of urgency and attention. It is a characteristic of it and it is one of the things that I have been working most hard to address in the last three years.' (P89: 18julam.txt - 89:15 (1749:1753)) (26)

These, then, are stories about movement in the direction of coherent systems. They are stories about how things can or might be located and held in place in a web of appropriately stabilised relations. The 'where' question can (it is being suggested) be answered in terms of system space. But how realistic is all this? The answer seems to be, only partially. The last quote reveals the 'cultural' limits and resistances to the adaptable coherence sought by Gerald Corbett in the organisation of Railtrack. And the extent to which 'the industry' works well together remains uncertain:

> 'the relationship between Railtrack and Great Western was not working properly prior to 5th October 1999. Warnings and suggestions made by Great Western were falling on deaf ears and the relationship was characterised as much by confrontation as by collaboration. Evidence given on behalf of Thames Trains demonstrated that this difficulty was not confined to Great Western. (P84: 27julpm.txt - 84:34 (1914:1920))

And, as one of the earlier citations reveals, there is also widespread scepticism about Gerald Corbett's suggestion that profits, performance and safety go well together. Many dispute this.

What is the conclusion? It is that for much of the time the ordering of the railway is indeed imagined and performed in terms of a system with a more or less strong centre. But the extent to which there is in fact a centre, let alone one that is strong, is open to question. Even the British Rail monopoly which preceded privatisation was not a monolith: there was, let me hasten to add, no golden age. No doubt the management changes introduced by Mr Corbett make a difference. No doubt centres sometimes become stronger instead of getting weaker. But there are always matters out of control. Diversity. Diverse and incomplete centres. Unstable relations. *This is the chronic state of being: system space is never secure.*

Fluidities

Is this a problem? As we have just seen, the general response is: yes. Mr Corbett is not alone in seeking a robust and responsive system where the important relations stay in place, the important actors, human and otherwise, behave in the way that they should, and the whole web is controlled from, and transparent too, a strong centre. And in the aftermath of an accident like that at Ladbroke Grove the urgency attached to stabilising functions and keeping them in place is all the greater. Instability may be chronic, but it is to be hunted out wherever it appears.

But there is a counter-view. The counter-view is that the world simply doesn't fit this way of representing and managing it – or at best does so only partially. Furthermore, though this is not easy to say in the aftermath of catastrophe, *the partial disorder of these not very coherent arrangements does just fine a good deal if not all of the time*. Let me insist on this point against the emotions provoked by death and injury. For every case of a Ladbroke Grove there

are endless 'system breakdowns' which have no serious consequences. Indeed, there are endless system failures which help to keep the wheels turning. So what's the argument here? The answer is: it's an argument about *imperfection*. About its *unavoidability*. But also about the *advantages* of practising, imperfection. Of working in a way that is fluid.

On Managing

If we read it right, fluidity is crucial to many of Gerald Corbett's (Railtrack) arguments. For instance, we have seen that there was a SPAD problem outside Paddington Station. We have also seen Railtrack that the number of SPADs had fallen from ten over a year to one in a nine-month period. He noted (we cited this earlier) that:

> 'I can quite understand why the managers of the Great Western Zone… thought that the action they had taken had been effective in mitigating the problem.' (P89: 18julam.txt - 89:17 (1850:1859))

This is very uncomfortable for Mr Corbett. After all, the Ladbroke Grove disaster was to follow. But read in the way I'm suggesting Mr Corbett is, in effect, saying that imperfection cannot be avoided. That there are always many imperfections. And that to make perfection in one place (assuming such a thing were possible) would be to risk much greater imperfection in other locations:

> Did you appreciate the seriousness of the [SPAD] situation?
>
> A. Everywhere throughout the network is serious.(P89: 18julam.txt - 89:39 (2511:2513))

And again:

> Q. I must press you on this: you appreciated that there was a particular problem in the Paddington area by reason of the number of SPADs?
>
> A. Yes, but let us put it into context. There were ten SPADs in the Ladbroke Grove area in the Paddington area in 1998/9, there were 660 across the network. There were 970 broken rails. There were hundreds of suicides. There is 20,000 miles of track and each mile of track has its own specific risks that have to be managed ... (P89: 18julam.txt - 89:37 (2320:2333))

The argument is that entropy is chronic. The web will not stay still. Here, as a good entrepreneur Mr Corbett is presenting a brave, management-oriented face. He's saying, in essence, that he knows this. And then he's telling us that if relations are always failing and systems falling apart, then *a good management is also one that will necessarily fail*. Some things *will* go wrong. Some parts of the system *will* dissolve. In which case the art of management is that of accepting some failures by wisely choosing which to try to put right. For a manager accepting imperfection is not a failing. It is an advantage. Indeed a necessity. Perfectionism would be dangerous.

On Signalling

But lack of perfection is not simply the prerogative of higher management. Here's another example, this time to do with the configuration of the signals, including the fateful SN109:

> 'The signals on gantry are of unusual design, being in a reverse "L" formation with the red aspect offset to the bottom left. At the time this "L" formation was installed on the gantry (1994) the appropriate standard showed permissible arrangements of aspects in cases where the preferred vertical arrangement could not be accommodated. These did not include the "L" shape or the reverse "L". Furthermore the permissible horizontal arrangements indicated that the red aspect should be closest to the axis of the driver's eye. This is not the case with any of the signals on the gantry.'(P81: HSE Interim 3 000414.txt - 81:9 (122:135))

Here (at least on this account) the rules are broken. The signals are out of place. But why? Why is this imperfection accepted?

> 'The Head of the Technical Division … describes … the configuration of signal SN 109 and other signals mounted on the gantry, as 'unusual' and suggests that the

> particular configuration may have been chosen because of the location of a large bridge and its potential for particularly obscuring the view of the signals'. (P78: HSE Internal Inquiry 000417.txt - 78:48 (1154:1194))

The issue of 'sighting' – a term we have come already come across in passing – is important for the fateful SPAD. Most drivers (and the train operating companies) were anxious that the drivers' lines of sight for the signals on gantry 8 were less than ideal: wires, other gantries, overhead electricity equipment, curves on the lines, a mass of signals close together, and a low bridge, all of these were criticised. But the anomalous – or fluid – signal arrangement, was, it becomes clear, an attempt to improve matters. The HSE is going to come to the view that the imperfections didn't matter, but the citation is stronger. It suggests that seeking perfection here would have produced a worse result.

On Avoiding Panic

Imperfections producing good results – a third example concerns the arguments about what happened in the signal box and Slough in the seconds after the fateful SPAD at SN109 was detected. Was there delay, for instance, in trying to phone Michael Hodder, the driver of the Thames Train to tell him to stop? Why was the 'signals on' button, the 'panic button' mentioned earlier not pressed? Was there undue delay?

The evidence on balance tends to suggest that

> '… vital seconds were lost as Signaller Allen waited to see whether … [the Thames Train] would stop of its own accord. On any view, that cannot be justified, although it can perhaps be explained by the prevailing practice at Slough IECC.' (P85: 28julam.txt - 85:22 (1217:1221))

There is debate about this, as there is about the time needed to work the various signal and warning systems. There is argument about the training of the signalmen for such emergencies (David Allen, an experienced signaller, had only previously encountered three SPADs in the course of his career). There is also argument about whether, in any case, the accident could have been prevented by the signalmen even if they had acted instantaneously. But what's important is the term 'prevailing practice'. Here is David Allen under cross-examination:

> '[A.]The prior SPADs I had, they have all stopped and the drivers have contacted me.'
>
> Q. Yes.
>
> A. Before I have had to do anything, they have all realised a mistake.
>
> Q. Right.
>
> A. And they have contacted me within sort of like, inside 20 seconds or whatever of going past a signal.
>
> Q. Right. So your experience is do nothing, hang on and within 20 seconds or so you will get a phone call and an explanation?
>
> A. No.
>
> Q. I am not suggesting to you that is the advised course of events, but that is actually what has happened?
>
> A. Yes.' (P93: 30maypm.txt - 93:10 (1284:1300))

Most SPADs (this is generally accepted) are either 'technical' (the train passed the signal by a metre or two), or are rapidly corrected (the driver realises what has happened and stops within a few hundred metres at most). Almost no SPADs involve a 'runaway train'. The formal rules ('the advised course of events') treat all SPADs as if they were potential runaway trains, which is how it was with the Thames Train. But the practice, perhaps, is otherwise. And if this is the case, then (though this does not emerge explicitly in the transcript of the Inquiry) there is also, perhaps, a reason. It is that it minimises disruption. What would happen, for instance, if the 'signals on' button were pressed?

> ‘Q. It would cause every train in the Paddington area to come to a halt? .
>
> A. Yes. Whilst you were holding those in for 15 seconds you cannot answer those calls.
>
> Q. But my point is if it was done in the morning rush hour it would take a very long time to sort out the resulting mess?
>
> A. Yes, because we have to identify where the trains are.’ (P92: 30mayam.txt - 92:20 (1855:1865))

In short there would be disruption. But also many other breaches of the rules, not to mention possible passenger injuries:

> ‘Q. Are you aware of what consequences might ensue from putting signals back to red in front of other trains that are not expecting it?
>
> A. Well, you could cause possible SPADs, technical SPADs, drivers applying emergency brakes. Yes, there are consequences, yes.
>
> Q. Is that something you would do lightly?
>
> A. No, sir.’ (P93: 30maypm.txt - 93:2 (317:324))

It is possible that what those hostile to Railtrack call the ‘wait and see’ policy at the Slough signal box meant that action which might have averted the accident was not taken in time. This delay, if there was a delay, is obviously hard to defend. But if it is the case that the signalmen didn’t quite work to rule, this testimony also suggests that they failed to do so for very good reasons. If the signals on button were pressed every time there were a SPAD, then it would have been pressed 660 times across the rail network in the UK in 1998/9. The result? There would have been dozens if not hundreds of addition technical SPADs. There would have been an unknown number of passenger injuries caused by emergency braking, together with massive disruption to the railway timetable and delays to the travelling public. And there would have been financial penalties for Railtrack and the relevant Train Operating Companies. The conclusion: if the prevailing practice of the signalmen across the network was in fact to ‘wait and see’ then this was a system imperfection which actually helped to keep the wheels turning almost all of the time (27). Or, more generally, that fluidity or system imperfection are necessary if systems are to run at all. They are not simply chronic failures. They are built into the (hidden logic) of systems.

Conclusion

To focus on a disaster is to attend to what went wrong. This paper has considered two kinds of explanations for what went wrong in the case of the Ladbroke Grove railway accident. One explains failure by locating it in a pigeon-hole: the driver, Railtrack, whatever. The other treats it as a system attribute in which many factors combine together: in this the actions of (for instance) the driver are here explained as a function of circumstances, personal, technical, and all the rest.

These explanatory approaches imply different versions of space. This is because each asks us to think about where what went wrong might be located. But the two versions of space are very different. To pigeon-hole is to think in regional terms: a flat surface (or perhaps a volume) is divided into little territories separated by boundaries. The ‘where question’ is answered by pointing to a pigeon-hole, or by arguing about the right pigeon hole. The ‘where question’ is tackled differently in the space implied by systems. It works by locating failure functionally and relationally. ‘Where’ is turned into a matter of how things relate together in terms of an overall single logic – or don’t.

These two spatial/explanatory systems interfere with one another. Explanations posed in terms of relations erode the self-sufficiency of pigeon-holes. (‘The driver is not really responsible, we need to understand his context’). But they also erode one another because there are many different system logics – or logics working within the system – and these locate things in different ways because they build different webs of relations. In thinking about the causes of the accident this is seen as a difficulty, and there are terms – for instance ‘fragmentation’ – for talking about that difficulty. And since system thinking is more prominent

than the regional alternative, in the wake of disaster it tends to become urgent to repair the system, to put it back together again, to ensure that there is a single logic, a single functional answer to the question of location. The assumption is that things would stay in place if there were better train protection systems, better systems of management, better systems for training, better designed signal gantries, better track layouts, and all the rest.

This is not exactly wrong, but at the same time something important is missing. This is a way of thinking about system imperfection as anything other than a curse. Of thinking about failure as something other than sloppiness. But, though it is hard to make this argument when people have been killed or injured, it is important to say, and to say loudly, that *system imperfection is not necessarily a curse*. That this is the case becomes visible if one picks through the testimony of the Ladbroke Grove Inquiry. And if one does this, as I hope I have shown, several tentative lessons emerge.

The first is that the search for system perfection is not only impossible but, more strongly, it may be *self defeating*. The use or misuse of the Driver Reminder Appliance on the Thames Train illustrates this. It reminds us that safety systems may lead to disaster – as I earlier noted, a classic finding in the literature on safety. No logic can predict all the eventualities.

The second is that system imperfection is not only chronic but also, and more strongly, *necessary* to the effective functioning of systems. I have tried to show this for three separate empirical instances. First, I suggested that if management is to be effective then it will necessarily fail in some places: Gerald Corbett didn't put it in this way, but it is nevertheless implicit in his testimony. Different logics co-exist. Second, I argued that rigid application of the rules stands in the way of the best layout for signals under certain circumstances, and that it is better to go for the best despite its imperfection. And third, I suggested that while there is evidence that the safest possible signalling response to a SPAD would be to immobilise considerable parts of the railway system each day, this does not happen in practice: again the rule-breaking allows the system to function more effectively than would otherwise be the case. There are several different logics at work here.

There are various social science vocabularies for talking of this flexibility and non-coherence (28). But if we think of it spatially then what we learn is that while mapping something like the railway either as a set of pigeon-holes or as a system may have its uses, it is also going to fail. Matters are too complex. Even if they work adequately well in practice most of the time (mercifully, there are few accidents like Ladbroke Grove), they can be fully located neither in regional nor relational space. So what does this imply?

The first is that *new forms of cartography* are required: forms of cartography that are better able to represent instabilities, fluidities and partial coherences. These would be ways of thinking about and mapping flows, flexibilities, and variations, that do not simply treat these as if they were more or less disastrous failures to locate themselves within the relations defined by a system. Though I cannot explore these here, there are occasional hints of such cartographic projects in the social science literature (29). Importantly, what these have in common is the shared conviction that any hope of mapping everything using a single technique to obtain one overall view is misplaced. The new cartographies will be *specific, modest, located in particular contexts and situations*.

The second is that there is need for finding ways of talking about, working on, and working within systems that are only partially coherent. Here *the practice of partial ordering is ahead of talk or theory*. We have seen this for the railway system. If this is only partially ordered, most of the time it works adequately, some might say very, well. Partial orderings or partial coherences, these are the stuff of life. Mr Corbett knows this as he talks of competing pulls and priorities. But so too do the signalmen with their many different pressures and demands. After a disaster everyone is troubled and defensive. When they are asked: was everything done by the book? did you have control over everything in the way you were supposed to? they respond defensively. This means that partial (in)coherences are downplayed, or treated as errors. But this also loses or marginalises the practices routinely needed for working on and within partially coherent systems. Indeed, it renders them illegitimate. Makes them look sloppy. Dangerously fluid. The issue, then, is how to render legitimate the practices of multiple, partial ordering. Mr Corbett has one particular solution – a language for prioritising multiple demands. But there are hints in the social science literatures of other possibilities.

Again, I cannot not explore these here, except to note that they imply that centred managerialism, even of the flexible and entrepreneurial kind proposed by Mr Corbett, is almost certainly both too simple and too hierarchical. If systems or organisations are partially connected multiples, then the devil will be in the detail, with how it is that those connections work and shift in practice. And trying to make sure that they work better will probably have less to do with command or hierarchical accountability than with quite specific and local interferences (30). This, then, is the managerial or organisational equivalent of the modest cartography proposed above, one that recognises its limits.

Third, the limits of regional and system cartographies and their managerial relatives also have more direct implications for safety-critical systems such as the railways. First, for instance, there is the matter of *speed*. If trains moved more slowly there would be fewer serious accidents. But the object of the track re-design at Paddington was precisely to reduce journey times and to increase carrying capacity: in part to increase speed. The Great Western train was running – as was intended – very fast for an approach to a major terminus. Had it been travelling more slowly, had there been less of a premium on speed, the scope of the disaster would have been reduced. Some of those working in Railtrack and the train operating companies were concerned that the track layout wasn't appropriate for such fast running. But the general view – shared by the companies, the general public and the government – that is speed is a good. Perhaps this needs to be challenged. (31)

Second, there is the matter of *speed of change*. The privatisation of the British railway system was, and remains, politically controversial. Certainly it churned the system up. But there are other sources of change. The issue of speed. The construction of the Heathrow Rail Link (more speed!) which meant more trains in the Ladbroke Grove area. An increasingly market-oriented approach to operation, even in the remaining state-owned industries, with their targets, financial and otherwise, and limited resources. The developing practice of putting out work of all kinds to contractors which then have to be supervised. The sense that new technologies might – often should – be introduced.

This is the context of Mr Corbett's ethnic slur about the Indian Customs Service. Bureaucracy, he is saying, works fine in a routine environment, but in a changing world this is no longer the case. He's right, but the idea that systems such as the railway should have to respond to rapid change – should indeed participate in it – also needs to be challenged. The argument is that change is not a good in and of itself. There are also reasons for relative stability. And, in particular, there are reasons for relative stability in safety-critical contexts where routines have proved workable in the past. And one of those reasons is that fluid practices which tolerate incoherences – the incoherences necessary in a working system – have evolved which stand the test of time. To put it simply: bureaucracies don't deal well with change, but, contrary to the popular view, they may be flexible and tolerant of error if the demands placed upon them are relatively stable. (32)

Behind these suggestions there is a third point. This is that speed and rapid change together push towards tightly-coupled systems with dense webs of self-sustaining relations. But *such systems are best avoided in safety-critical locations*. This is because, as we have seen, when things go wrong disruption is rapidly and unpredictably transmitted through the system. Failsafe mechanisms and the tight control of centralised management may work most of the time. But sometimes they will fail. And then they fail there is no play. No slack. Everything falls down. The conclusion is that partially connected, multiply ordered, ambiguous and not very coherent systems are usually more robust. And the corollary is that if we find that we are proposing technologies that demand tight systems then we need to stop and think. This the ultimate lesson of the Ladbroke Grove tragedy. It is that we have unwisely created a world which demands coherent systems (33).

Footnotes

* I am grateful to Kevin Hetherington, Peter Peters and Vicky Singleton with whom I have discussed many of the arguments developed in this paper. However, I owe most to Annemarie Mol for sustained intellectual support and friendship. The themes developed in this paper grow out of our joint long-term work on multiplicities, spatialities and complexities.

(1) Important actors, agencies, technical terms, and acronyms are explained in the glossary.

(2) Lord Cullen is eminent Scottish advocate who had previously chaired inquiries into the 1988 Piper Alpha oil rig disaster, and the 1996 Dunblane Primary School shooting.

(3) The data analysed are largely drawn from the web. The entire proceedings of the Inquiry, together with some of the witness statements, are available the the Ladbroke Grove Railway Inquiry website (www.lgri.org.uk). Other relevant documents are available at the website of the Health and Safety Executive, the British government agency responsible for safety on the railways and other public and employment locations. The relevant location in the site is www.hse.gov.uk/railway/paddrail/. There is also extensive media on-line coverage, for instance at the BBC (www.bbc.co.uk and in particular news6.thdo.bbc.co.uk/hi/english/special_report/1999/10/99/london_train_crash/newsid_465000/465503.stm), and the Guardian (www.guardianunlimited.co.uk). There are also a number of relevant special interest web sites including the Safety on Trains Action Group (http://www.staguk.org.uk/Ladbroke.htm) with further information and links.

(4) The argument developed in this paper is part of a continuing inquiry into the complexities of the spatial and its salience for sociotechnical ordering. Relevant citations include: Marianne de Laet and Annemarie Mol (2000) John Law and Annemarie Mol (2000), John Law and Vicky Singleton (2000) and Annemarie Mol and John Law (1994).

(5) Railtrack, First Great Western, Thames Trains, the Health and Safety Executive, the Associated Society of Locomotive Engineers and Firemen (ASLEF), the Ladbroke Grove Solicitors Group, the British Transport Police, the Inquiry itself, these and more are some of the actors represented by counsel.

(6) AWS stands for Automatic Warning System. It is intended to supplement the signals by making a sound in the driver's cab: an all-clear bell for green signals, a warning horn for signals at any other aspect.

(7) The 'signals on' button is a 'panic button' which turns all the signals to red. It wasn't pressed before the accident, and if it had been it might, just might, have made a difference. The issue is: why wasn't it pressed when it was clear that something was going wrong? I return to this later in the paper.

(8) This is from a driver witness statement.

(9) I will return to the question of the Driver Reminder Appliance below.

(10) Indeed, the vocabulary of large technical systems, and the 'heterogeneous engineering' of actor-network theory, mimic the systems stories we're finding here. For work on large technical systems see studies of electricity supply systems by Thomas P. Hughes (1979; 1983). Early actor-network's rather similar approach is exemplified in studies by Michel Callon (1980; 1986) and Bruno Latour (1983).

(11) These words come from the ASLEF union Counsel.

(12) Another example: 'But in practice when root cause is sought, is the natural bias in those investigating towards looking for driver error? And, if so, is that balance right? (P 4: 11mayam.txt - 4:46 (1913:1915))

(13) This 'relationality', implicit in large systems theory and in actor-network theory, is briefly outlined in the context of the latter by John Law in (1992). This paper is available electronically at Law (2000).

(14) This is the representative of ASLEF, the driver's union.

(15) 'The accident was likely to have been prevented by TPWS'. In this context this works like a police speed trap. If a train is moving too fast for safety - for instance it isn't slowing up at signal at red aspect - then TPWS detects this. The difference with the police speed trap is that it then stops (or if appropriate, slows) the train automatically. The driver cannot override it. TPWS and other train protection systems are briefly described in a document produced by the Health and Safety Executive. See *P91*.

(16) The words come from evidence to the Inquiry by Mr. Gerald Corbett, the Chief Executive of Railtrack.

(17) The words are from Counsel for the Ladbroke Grove Solicitor's Group.

(18) Signals on the British railway system show four aspects. Green, for all clear. Red for stop. And then a single yellow aspect, which means that the next signal showing red, and a double yellow aspect, which means that the next signal is showing a single yellow.

(19) The phenomenon is described in Charles Perrow's admirable book, Normal Accidents. See Perrow (1984).

(20) Again, the argument is to be found in Perrow where he makes a spirited defence of linear as opposed to complex and tightly coupled systems, on the ground that the behaviour of the latter is much more difficult - indeed perhaps impossible - to predict compared with that of linear systems.

(21) This is evidence given by Mr Gerald Corbett, Chief Executive of Railtrack, to Part 1 of the Inquiry.

(22) In the local context of the Ladbroke Grove Inquiry profit and safety sometimes seemed to be inconsistent. This is because the accident occurred at a complicated section of track where single-direction lines give way to (arguably more dangerous) bi-directional lines. But the bi-directional lines increase the traffic capacity of Paddington Station: 'why was not bi-directional movement abolished on this dangerous track of line? The answer was because it would have a commercial effect on Railtrack (P84: 27julpm.txt - 84:47 (1088:1091))

(23) For discussion of these and the links between them, see John Law (1994).

(24) 'Mr McNaughton and Mr Corbett both stressed that it would take years to rectify the problems in the zone and to change the safety culture to one in which individuals took proper responsibility for their actions.' (P85: 28julam.txt - 85:26 (1340:1343))

(25) This is again from Mr Gerald Corbett.

(26) A further statement of Mr Gerald Corbett's.

(27) I am grateful to Vicky Singleton for this argument. Her interest in the necessary variability in the implementation of rules is developed in the context of medicine in Singleton and Michael (1993), and Singleton (1998; 2000).

(28) And these come from diverse locations. The interpretive sociologies including symbolic interaction and ethnomethodology are particularly strong in their analysis of the way in which people following rules do so in necessarily creative and varying ways. For examples see Herbert Blumer (1969) and Roy Turner (1974). But the trend in such system-related approaches as actor-network theory has been in the direction of fluidity, multiplicity, and ambivalence (see, for instance, John Law and Vicky Singleton (2000), Annemarie Mol (1999; 2001), and the previously cited papers by Singleton.)

(29) Frederic Jameson proposes a new form of cartography for non-coherence which is based on physical location and displacement. See the comments on Gehry house in his (1991). I consider something similar, talking about 'knowing in tension' (see Law(1998)). Donna Haraway talks about the privilege of partial vision, vision which is also split. See her (1991a) together with other references in the bibliography. Bruno Latour experiments with multiple voices in a noteworthy study of another transport technology, Aramis. See Latour (1996).

(30) This argument is developed in somewhat related terms by Donna Haraway and Annemarie Mol. Haraway uses the term 'interference' (which she derives from physics), and insists on the situated character of all forms of knowledge. See her (1991b; 1996). Mol explores the interactions between different medical realities. See, in particular, her (2001).

(31) I thank Peter Peters who, a long time ago, first exposed me to arguments about the merits of slow transport.

(32) Others have recently defended bureaucracy in rather different terms - for instance Paul du Gay (2000) and John Law (1994). The argument we are making here implies that the flexibility of 'enterprise management' seeks (and ultimately fails) to displace a more subtle fluidity built into classic bureaucracy. To say this is not, of course, to defend the conduct of any particular bureaucracy.

(33) As I have already noted, this argument is developed by Charles Perrow. But there are resonances of it in other literatures. For instance, Langdon Winner, philosopher of technology, following Lewis Mumford, suggests that some technologies - he is particularly thinking of nuclear power - are inherently authoritarian. This is because their safe operation demands strong and hierarchical state power - in the case of nuclear power for up to 250,000 years. The argument that I have made here is related to this. See Winner (1999), which is a reprint of the paper in which the argument was first made. The features of partially disconnected systems are also explored in other post-structuralist philosophical contexts. See Bruno Latour's(1984) comments on colonial power, and (Lyotard and Thébaut 1985) on the importance of 'play' - understood as imprecision or slack.

Glossary

- 165: code name for the diesel car unit which made up the Thames train.
- ASLEF: see Associated Society of Locomotive Engineers and Firemen
- Associated Society of Locomotive Engineers and Firemen: the Trades Union of the train drivers.
- Automatic Warning System: a train-mounted system for detecting whether signal is set at a warning aspect (red, yellow, or double yellow) or all clear (green). If the signal is all clear it sounds a bell in the driver's cab and sets a circular dial to entirely yellow. If the signal is at a warning aspect it sounds a horn in the driver's cab, and the dial alternates yellow and black (like a 'sunflower' in driver parlance). The system is works by an on-board receiver picking up a magnetic signal from track equipment placed before the signal.
- AWS: see Automatic Warning System
- BR: see British Rail
- British Rail: the monopoly which owned and ran the railways before the privatisation process which started in 1992.
- British Transport Police: the police force responsible for criminal inquiries on railway property.
- DRA: see Driver Reminder Appliance
- Driver Reminder Appliance: a device which drivers set on coming to a halt which disconnects power and illuminates a red button in the driver's cab until it is cancelled. It is to remind drivers to check signals before they start. Widely used by drivers until after the Ladbroke Grove accident in order to remind them that they had passed through a yellow or a double yellow signal.
- First Great Western Trains: the operator of the high speed train from Cheltenham to Paddington. One of the 25 train operating companies created after the privatisation of British Rail with franchises to run services over designated routes .
- Flashing Yellows: warning aspect signals intended to warn drivers to drive slowly because they were approaching points with change of direction. Abolished in the Paddington area before the Ladbroke Grove accident because they added complication to driving.
- Gantry 8: the gantry on which signal SN109 was mounted, together with four more signals. Allegedly too complicated to read easily.
- Great Western Zone: the section of Railtrack responsible for the track and signalling from Paddington.
- Health and Safety Executive: the government body responsible for health and safety in and on most industrial and public locations in the UK.
- Her Majesty's Railway Inspectorate: after reorganisation in 1990, a section of the Health and Safety Executive responsible for safety on the railways.
- HSE: see Health and Safety Executive

- HST: High Speed Train. The First Great Western Train.
- Ladbroke Grove Rail Inquiry: inquiry set up immediately after the Ladbroke Grove accident, and chaired by Lord Cullen. Part 1 of the Inquiry was an investigation into the immediate causes, circumstances and lessons of the accident.
- Ladbroke Grove Solicitors Group: the group of solicitors representing the bereaved and injured.
- Prior yellows: see flashing yellows
- Railtrack plc: the company which owns the infrastructure of the railways – track, signals, stations.
- Signal Sighting Committee: a local committee convened by Railtrack, to investigate the adequacy or otherwise of the lines of sight for drivers on trains approaching signals.
- 'Signals on' button: a series of buttons in the electronic signal control box at Slough (responsible for signalling at Ladbroke Grove) setting all signals in the relevant area to red. To be used if the computer displays 'hang up' and are no longer reliable. Reboots the computer system.
- SN109: the signal controlling line 3 at Ladbroke Grove for trains leaving Paddington. The signal which the Thames train passed at red.
- SPAD: Signal Passed at Danger
- Thames Trains: the operator of the 165 from Paddington to Bedwyn. One of the 25 train operating companies created after the privatisation of British Rail with franchises to run services over designated routes .
- TPWS: see Train Protection Warning System
- Train Protection Warning System: an automatic system which can stop a train or limit its speed if it is approaching signals set at warning aspects, or speed limits on the track. Unlikely to be completely effective (trains travelling very fast would not be slowed or stopped sufficiently quickly). But would probably have prevented the Ladbroke Grove accident. Its introduction is now being accelerated.

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