SAFETY SCIENCE Monitor
ISSUE 1 2000
Article 1
VOL 4

RAILWAY SAFETY MANAGEMENT: THE CHALLENGE OF THE NEW MILLENNIUM

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Based on a keynote address to the Occupational Safety & Health Conference of the Union Internationale des Chemins de Fer (UIC). Paris September 1999

1. INTRODUCTION

1.1 The outsider's view

This paper is written from the point of view of a safety researcher with a background in the manufacturing, chemical and construction industries, and more recently in the airport and road safety areas. It looks at railway safety through those spectacles, based on some initial studies and discussions with railway safety experts.

An outsider has some advantages over insiders in what he can see of a culture or industry. Researchers into company and national culture, such as Schein (1992), and Hofstede (1986) define culture as an aspect of the way things operate in a company or country which is almost invisible to the people working or living there. It consists of the basic assumptions of how things are and should be done, assumptions which are unquestioned by the insiders, because they simply see them as the right way, and often the only way to do things. The outsider has the advantage that a number of these basic assumptions will so contradict the assumptions he brings with him from his own experience in other cultures, that they beg to be questioned. Anyone who has worked for any length of time in another country or has changed from one big employer to another will recognise that experience, and will also know that, after a year or two, most of these initial surprises no longer seem so strange or remarkable. That is a clear sign of absorption into the culture. This paper is written during that critical transition period and offers discussion of the "surprises" which have been encountered.

1.2 The challenge of the new millennium

Figures for transport in all its guises show that we are still in a period of major growth. Despite the attempts of some governments to discourage travel as one way of easing the congestion of roads, rail and air space, we can see annual growth of several percent in all modes. This is partly a result of the globalisation of business, generating much more transport to bring goods from the cheap labour economies to the high consumption societies of the developed world. Globalisation creates much more business travel also, as international companies try to keep control over their empires; travel which expands despite the possibilities of information technology to make the message travel without the person needing to. But also it is travel for pleasure which is driving the market; foreign holidays, a moneyed class of early retirees with time on their hands and a dispersion of families across countries. The challenge is to manage this growth with a commensurate increase in safety per kilometre travelled.

As a response to this railways are expanding rather than cutting lines. The high-speed train network is spanning Europe and forcing technical harmonisation as never before. Interoperability of trains on the underlying intercity networks is becoming increasingly vital. New forms of rail (or rail-like) transport are being introduced, from the Maglev (Transrapid, Swiss Metro) to the light rail hybrids with trams. Technologies such as tunnelling are being extended to new applications, such as the tunnels in the Netherlands to spare the above ground space or to reduce nuisance, and to new challenges, such as the Channel tunnel. GPS and other positioning techniques, together with better en route communication are changing traffic control techniques radically. New technology always brings with it new safety challenges.

Globalisation also means that national markets, such as for railways, are being opened up to foreign ownership, which brings with it new ideas of how to manage, including how to manage safety. Competition also is increasing, bringing other cold winds of change into the newly privatised railway companies. The response in many industries has been a major reorganisation of company boundaries, outsourcing much peripheral work, while core businesses seek to grow by acquiring their direct rivals, whilst at the same time splitting their own activities into (local) business units. Slogans such as "think global, act local" summarise this new concern for explicit competitive management. With new boundaries come new needs to define how safety can continue to be achieved in this rapidly changing world. I want to address these trends and challenges. First I want to look at how we define safety and then how we are changing the ways we manage it. The challenge to the railway industry is how to ride the crest of this wave of change in safety.

2. THE STATE OF SAFETY

2.1 Figures and trends

It is both traditional and convenient to start by reviewing measures of safety and trends in them. From the UIC and other figures (UIC 1998, see also Railtrack 1999, Rumar 1999) we can look at the fatality and injury rates for passengers and the workforce. Figure 1 (taken from Rumar 1999, based on the ETSC figures) shows that rail on both measures is the safest form of passenger transport in the European Union. Bus transport comes a close second, with air travel, at least on a passenger kilometre measure. Van Poortvliet (1999) in his more detailed analysis of both the statistics and the practices of rail (in NL), ferries (NW Europe) and air transport (Europe) comes to the same conclusion. Figure 1 shows fatalities. Injury figures are likely to give a slightly different picture. Air and ferries, and to a lesser extent trains will come out with relatively lower figures than road, since a smaller percentage of passengers will survive the crash.

Mode		Fatalities/10^8 Person km	Fatalities/10^8 Person hours
Road:	**Total**	1.1	33
	Bus	0.08	2
	Car	0.8	30
	Cycle	6.3	90
	Motorcycle/moped	16.0	500
	Pedestrian	7.5	30
Train		0.04	2
Ferry		0.33	10.5
Air		0.08	36.5

Figure 1 Estimates of passenger safety in the EU

The picture in relation to workforce injuries is far less encouraging for rail. The fatality rate reported in the UIC figures for 1995 ranges from 1 to 30 per 10^5 employees, and the injury rate from 700 to 6100 per 10^5 employees, across the EU countries (Figure 2).

Country	LTA frequency rate per 10^3 staff (1995)/Rank		Fatality rate per 10^6 staff (1993-1995)/Rank	
Britain (BR/Railtrack)	26	4.5	6	7
Luxemburg (CFL)	60	13	30	15
Greece (CH)	7	1	8	8
Ireland (CIE)	35	6	13	10
Portugal (CP)	26	4.5	23	14
Germany (DB)	48	9	4	3
Denmark (DSB)	60	13	5	5
Italy (FS)	55	10	5	5
Netherlands (NS)	24	3	15	12
Austria (OSS)	40	8	16	13
Spain (RENFE)	61	15	14	11
Sweden (SJ/BV)	15	2	1	1
Belgium (SNCB/NMBS)	59	11	3	2
France (SNCF)	36	7	5	5
Finland (VR/RHK)	60	13	9	9

Figure 2 Occupational safety statistics for rail staff in EU countries

These figures need to be viewed with some caution, since there are differences between countries in whether contractors working on such activities as track maintenance are included, or whether the figures are confined to rail company staff. Inclusion or exclusion of contractors usually makes a huge difference to rates. A company can optically improve its accident rate enormously by contracting out work and not reporting the contractors accidents, even though they occur on the company property. The figures of chemical companies over the last decade show clearly the greater accident rates among contractors. Whatever the caveats, however, these figures for railway workers are quite high. Comparisons in the Railtrack figures (1999) between railway track workers and other occupations show that only forestry and coalmining have higher fatalities, and only those industries plus construction, sewage and refuse and other mining have higher major injury rates in the UK. A similar comparison in 1989 in the Netherlands (Hale 1989), produced an uncomfortable surprise for the Dutch railway company, when they found that track maintenance work was more dangerous than the building and construction industries and only surpassed by agriculture and North Sea fishing. Rail companies may pat themselves on the back for their transport accident figures, but should realise they have a lot of hard work to do to get themselves out of the top ten of the most dangerous industries in which to work.

If we look at trends through the most recent years the picture is positive[1]. There have been dramatic improvements in both passenger and worker safety in railways in many countries, though there is some indication that the trends since 1996 have been less favourable, flattening out, or even showing small increases in some indicators. These positive trends are paralleled in a large number of industries and transport modi over the last two decades, so the railways are nothing special here. We have been getting better and better at preventing accidents over that period. High profile disasters in a number of technologies have focussed media, public and regulatory attention on safety issues and we have put enormous resources into prevention. But, above all, we have focussed attention on the primary role of management in all organisations to make explicit provisions for safety management.

[1] I surveyed the figures from the following countries either from their annual reports or the internet sites of the regulators: USA, Canada, UK, New Zealand, Australia, Hungary, Netherlands.

We should also make two very important caveats at this stage, about what we mean by improving safety.

Firstly, the figures quoted in the passenger death tables take no account of how many people are killed at a time. Road deaths (and the railway occupational figures) are generally single deaths. All the other transport modes tend to produce accidents which kill many at once. We know that this is much less publicly acceptable. For example Dutch "acceptable risk" contours for the chemical industry use a power of two to express this: for example, accidents causing 100 deaths must be 100 times less likely than accidents causing 10 deaths.

Secondly, the indicators in the transport modi which have been consistently dropping are the accidents per kilometre or travel hour; for workers it is the accidents per workforce or hours worked. This is true, for example, of traveller deaths in rail, road and air transport. Where the transport modi differ is in the trends in absolute numbers of accidents. Air traffic has shown such phenomenal increases in passenger kilometres and hours that the absolute numbers of crashes are at a plateau or even rising. The same trend has recently become visible in road deaths in, for example, the Netherlands. Where rail networks and use are expanding, we need to watch out for the same phenomenon. At least in air transport it is clear that the companies involved fear that the public and regulators respond more to the absolute number of crashes than to the accident rate. There are clear moves to commit the industry to targets of keeping the absolute numbers at least constant, despite increasing travel. The railway industry should consider if it too should make this commitment to keeping the absolute numbers of casualties at least constant, if not dropping.

2.2 Boundaries

The next question an outsider asks is what these figures actually cover. How representative are they of the total safety management problem in the industry? My first contacts with the railway industry, going back to the 1970s in the UK, showed me a picture of an industry which was focussed purely on passenger safety. The employees, still quaintly called then in the UK "railway servants", did not figure much. Even their fatal accidents were the subject of a much less detailed enquiry than passenger deaths. The railway companies also had much less professional expertise employed in the occupational safety area than the passenger safety area, despite the fact that they were killing and injuring more workers than passengers in many years. Luckily the balance of attention has now been redressed considerably, but the impression is that it is only slowly that the two areas of safety are being seen as something to be managed together in one unified policy. There is a sign of a change in thinking about boundaries for study and management in the industry. The UIC has recently adopted a proposal to expand its annual conference and its associated working parties from purely *occupational* safety and health to *person* safety and health, which includes passengers and third parties as well as workers. This is a welcome move, but is only one step towards a truly unified system safety management concept.

This is therefore a time to look closely at what the boundaries are and should be. What is it useful and productive to manage together in unified policies and management structures, either because of the overlaps between them, or because they need to be explicitly weighed against each other? What areas is it valuable to discuss together in conferences, working parties, reports, internet pages and networks? We can see such boundaries along three different types of dimensions.

2.2.1 Physical boundaries

The passenger, the track and the train have been the traditional focus, with the emphasis there on collision and derailment. Even within this focus attention is now shifting to include fire (particularly in tunnels, since the Channel Tunnel disaster) and above all stations, where one third of the fatalities occur (UK figures). Railway companies are also becoming conglomerates, moving into the property business, with shops on their stations and office and leisure complexes around them. There are opportunities, and perhaps obligations to think about the influence the rail companies can have on this broader range of potential hazards.

The interfaces between the rail system and its surroundings have always been the subject of some debate about the share of responsibility to be taken by the rail companies. Level crossings, trespassers and animals on the tracks, bridges over the track, which can be swept away by a crashing train, or from which things can be dropped onto it, all sit at this boundary. All offer the temptation to push the responsibility for action onto the other party, but also the opportunity to have a major positive influence on risk in society as a whole if that responsibility to stimulate and coordinate action is grasped. The challenge for the rail companies is to grasp this opportunity to take an active, if not the leading, role in tackling these boundary problems, by bringing all the other parties, such as community groups and local authorities together to create solutions.

2.2.2 Accident vs. intent

The safety profession has conducted long debates about its role in the prevention of damage where there is intent involved. The Loss Control movement in the 1960s in the USA was one of the first to group together all causes of non-speculative loss to the company under one policy and staff department. This included fire, security, theft, vandalism/sabotage and product damage, and in some cases even industrial action. The debate over this boundary is very much alive today. For the railways the questions are about the inclusion of, or the priority given to the following:

- aggression to staff,
- vandalism,
- trespassers (such as tunnel tourists and disaster spectators) both as potential victims and as disrupters of safety and emergency management,

and above all

- suicides, who usually form 60% or more of the annual deaths related to trains.

Looking at the range of indicators being discussed in rail company safety reports, it is clear that there is a tendency to take a broadly inclusive view on this dimension also. It is good to find targets related to all of them, including reducing suicides, at least in some companies. However, not all companies are yet willing to embrace all of them as part of the full field of system safety to be managed together as a unified area.

One of the main questions in thinking about both this dimension and the previous one is the degree to which the railway companies have influence on, or control over the risk factors. We can plot the safety in a number of industries or activities along such a dimension of influence of the company or government (figure 3).

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      Home  Road              Rail Sea          Air          Industry
  |---------x---x--------------------x--x-------------x--------------x---------|
Little influence from company/                  Complete influence from company/
government.                                      government.
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Figure 3 How much can the operators influence safety factors

This spacing is purely guesswork on my part, and should not be taken too seriously. It is intended to provoke thought. It is a combination of how many factors are determined independently by the behaviour of the public and other groups with only a diffuse relation to the central actor (customers, suppliers, designers, planners, contractors, visitors, neighbours), and by relatively uncontrollable factors such as weather. We have seen a tendency the last years to place more and more emphasis in the last decade on the responsibility of the central actor, especially the large company, to exert more influence on all of these groups in the name of safety. There is an obligation not to hide behind either the government or narrow legal definitions of contractual responsibility. This makes use of the great influence of the large company and underlines the social responsibility to use that influence on behalf of society. This trend is very clear for industrial companies, for example in influencing their contractors, suppliers and customers. The moves to create an integrated safety management system at Schiphol in the Netherlands to involve all the players at the airport in one system, shows that the trend is reaching air transport. The rail companies can therefore expect to be increasingly pressed by government and public to exert their influence on the rather large number of players and accident factors only partly under their direct control. UIC and the rail companies should be welcoming this challenge with open arms and should aim to stay ahead of the pressures by making their own plans and proposals for these hitherto peripheral areas of safety.

2.2.3 Safety, Health, Environment, Sustainability, Quality

A final dimension on which the most intense debate has been conducted in the last decade is that of which types of harm to manage together. Surveying the papers at a recent UIC conference on Occupational *Health* and Safety shows that there is far more of an emphasis on safety than health. There was some attention to ergonomics, and a fair emphasis on trauma/stress and on alcohol and drugs. However, most, if not all of this, was because these factors either give rise to, or arise from accidents. There were no papers on occupational disease, such as long term injury from work loads and postures, exposure to toxic materials or physical environments (heat, cold, noise, vibrations, etc.), stress from working hours, conditions or relations among staff or managers, life style risks such as smoking, drinking and drugs. In other industries too, there is considerable debate about which of these health risks to include in management policies on health and safety, and on whether to place the expert advisers on them in the same department as the safety experts. The clear trend in European countries in other industries seems, however, to be that health policies and experts should be integrated with safety policies and experts. We need to manage and treat the whole person, the whole work process and the whole technology with all its possible harmful effects.

The process industry (chemicals and energy production and distribution) now almost universally combines its management systems for safety with those for environment. The link there is very obvious, with external safety risks from their processes shading seamlessly into environmental pollution risks. The controls for preventing the two also overlap, and may compete for resources or attention. The step beyond that merger is to add the issue of sustainable development (e.g. energy and raw material use). This addition is still controversial, but increasingly accepted in those industries. This shifts the perspective strongly towards influencing the basic design of the technology, so as to minimise in one go raw materials, energy and land consumption, visual "pollution", noise and vibration, smell, air, water and soil pollution and external and occupational safety and health risks. In the transport area this integration is also visible, for example in the recent report on the health effects of major airports (Dutch Health Council 1999), which covers all but the fuel and raw materials consumption aspects on the above list.

There are only minimal signs of this integration step in railways. The Oslo Declaration of 1998 (UIC 1998) does call for attention to such sustainability targets, but does not couple them with safety, despite the obvious links via consideration of basic technology and infrastructure design. The interaction of all these factors and the need to balance them against each other is, however, illustrated by the debates triggered in the Netherlands by the decision to place long stretches of the HSL and dedicated goods lines underground for environmental and visual pollution reasons. This raises major issues for fire safety and rescue. Decisions must be made on how to balance these conflicting issues. Only integrated risk models and management systems can tackle that challenge.

In a number of industries ranging as widely as chemical plants and hospitals some or all of these "harm" factors have been linked to the management of product and process quality and we have seen the arrival of QESH (quality, environment, safety and health) managers. International standards also show this convergence, with the ISO 14001 norm for environmental management being modelled on the ISO 9001 quality management norm. In turn the British Standard 8800 for occupational safety and health management is based on ISO 14001, as is the UIC occupational safety and health management guideline.

One of the major factors in this shifting of the boundaries of the subject area is to be found in a shift in paradigms of how to understand and manage the problems concerned. Attention began a century and a half ago based on the types of outcome; injury vs. physical damage vs. sickness vs. pollution. It was an "end-of-pipe" view, looking back from the undesirable outcome and trying to mitigate its worst effects. It led to bolt-on solutions, personal protective equipment, health checks and limits on exposure time for people, bursting disks and bunds for tanks, no-go areas around dangerous processes (like the free room around trains), filters and precipitators for smoke stacks. This was all technology- and problem-specific and there was little to be gained from integration across problem areas. In the second age of safety (Hale & Hovden 1998) the attention shifted to the role of the individual in precipitating or recovering from the processes leading to harm. The links between occupational safety and health immediately became clear; the same sort of behaviour was involved with both. In the third age of safety the paradigm has shifted still further. The design process and the management process have moved centre stage. We have entered an era of systems management in which we look at the fundamental building blocks of the organisation and try to get their design and management right for all output criteria in parallel. With this perspective the differences between many of the risks, which previously looked great with our technological spectacles on, now look relatively small seen through management spectacles. For all of them we need to take a hard functional look at the primary processes of design and operations to identify threats and deviations to be avoided or minimised. These form the focus for the management systems in both life cycle phases, and, as we look at the management systems for each area we find many common features.

As summary of this discussion of boundaries, it is perhaps opportune to issue a challenge to the railway industry. If rail companies want to win and hold the trust of the public and government, they must project themselves as responsible societal players, who care about their whole impact on society in all its diverse aspects. The chemical industry has launched its "Responsible Care" programme to do just this. It unites under one umbrella the responsibility for the environment, for process, product and external safety, for sustainability and for business ethics. UIC could follow suit and launch a campaign to promote "global care" in all the areas sketched above, including a pro-active role as a focus for initiatives on all of the boundary areas.

The next section of the paper addresses some of the themes in more detail. The theme of boundaries will return, but I want to concentrate more on the paradigms for safety management which need to guide our work for the next decade. These are; the shift from reactive to proactive management, the explicitation of risk, the change from top-down bureaucracy to bottom-up participation and self-regulation, and the emphasis on knowledge management and the learning organisation.

3. APPROACHES TO MANAGEMENT

The last decade has ushered in the third age of safety (Hale & Hovden 1998). After the technical and human factors focus of the two previous ages, the dominate concern is now the company organisation and the role of its managers. How do they make sure that the hardware and people do what they should, when they should, to keep all risks under control? Making the role of management explicit has resulted from, but in turn also results in, a shift from reactive to proactive concern for safety. Management is all about planning and control. It looks forward and tries to anticipate and avoid problems. It is future-oriented and driven by clear goals and the need to survive and prosper. The textbooks of the management gurus are all about infusing this orientation for market success and survival, for quality and for economic success. By linking safety to this engine also, we try to take advantage of its drive. In this section this shift will be made explicit for a number of areas.

3.1 From one-off fixes to continuous attention

One of the themes that we can read into the concern for technology and hardware safety in the first age of safety is the belief that we can design intrinsically safe processes. If we get it right at the beginning, we can then stop worrying about safety and get on with the important things in industry like operations and making profits. The early inspectors of factories, mines and railways were usually engineers, whose main interest was in the technology. They concentrated on the technical failures in accidents and on technological fixes for them. This focus can be seen in more modern times in the almost knee-jerk reaction to automate a process if the people working in it make a lot of errors and have accidents. I would not want to denigrate or undervalue the need to focus on hardware and system design and to adopt intrinsic safety and the elimination of hazards as a first option. However, almost two centuries of experience indicates that this is only a starting point. Ergonomics and cognitive psychology (e.g. Bainbridge 1987) have shown that this approach has its limits and can add problems elsewhere (e.g. automated systems are more complex and unpredictable in emergencies, danger may be displaced from operators to maintenance staff). The history of automatic train control is a good case of this continuing battle to optimise the role of the driver and the technology for safety. Our experience is that the technology-fix does not stay fixed.

The second line of defence in many systems, if the human could not be eliminated, has been to try to turn the human into a robot by specifying rules and imposing them rigidly. The railway industry has been one of the main protagonists of this approach, alongside the nuclear, and to lesser extent, the chemical industries. Accidents were then analysed up to the point where it became clear that someone had broken a rule (at which point discipline was appropriate) or that there was no rule for this eventuality (in which case a new one was made). In this way rulebooks continually grew and never diminished. This rules-fix is also a hankering after certainty. Ultimately we get a rule for everything and safety is seen as something which requires no thinking any longer, but simply good training, a prodigious memory, a large safety manual or computer to refer to, and an iron discipline. Management does not need to do any more thinking or planning, because it is all fixed in the rule system. Reason (1990, 1997), among others has shown clearly how this approach ossifies an organisation and forces its staff into being habitual and professional violators of rules, just to get their work done. Elling (1991) showed what railway workers think of these rulebooks.

- 80% considered that the rules were mainly concerned with pinning blame.
- 79% thought there were too many rules, 12 % thought there were too few; i.e. only 9% had no complaints on this score.
- 77% found them conflicting.
- 95% thought that work could not be finished on time if the rules were all followed.
- 85% found it hard to find what they wanted in the rulebook.
- 70% found them too complex and hard to read when they had found them.
- 71% thought there was little motivation given to follow them
- not one could remember ever having referred to the rules in a practical work situation in the last six months

Again, I would not want undervalue the importance of rules. They are needed to create predictability in a complex system where on-line communication between the various parties and system elements (train position, controllers, driver, track maintenance gangs, etc) is not (yet) very direct, but the way they are regarded by the workforce is worrying. Rail companies need to face this issue squarely and do something to revolutionise their use of rules.

What has killed the belief in the one-off fix as the whole answer has been the increasing pace of technological, market and organisational change. The system is never stable and so no fix will stay fixed. We constantly have to adjust and steer the system to adapt it to the changes. It is ironic that modern management now operates within a philosophy that is not far removed from Mao's concept of "constant revolution". The emphasis therefore is on self-regulation and the ability to function as a learning organisation (Senge 1990).

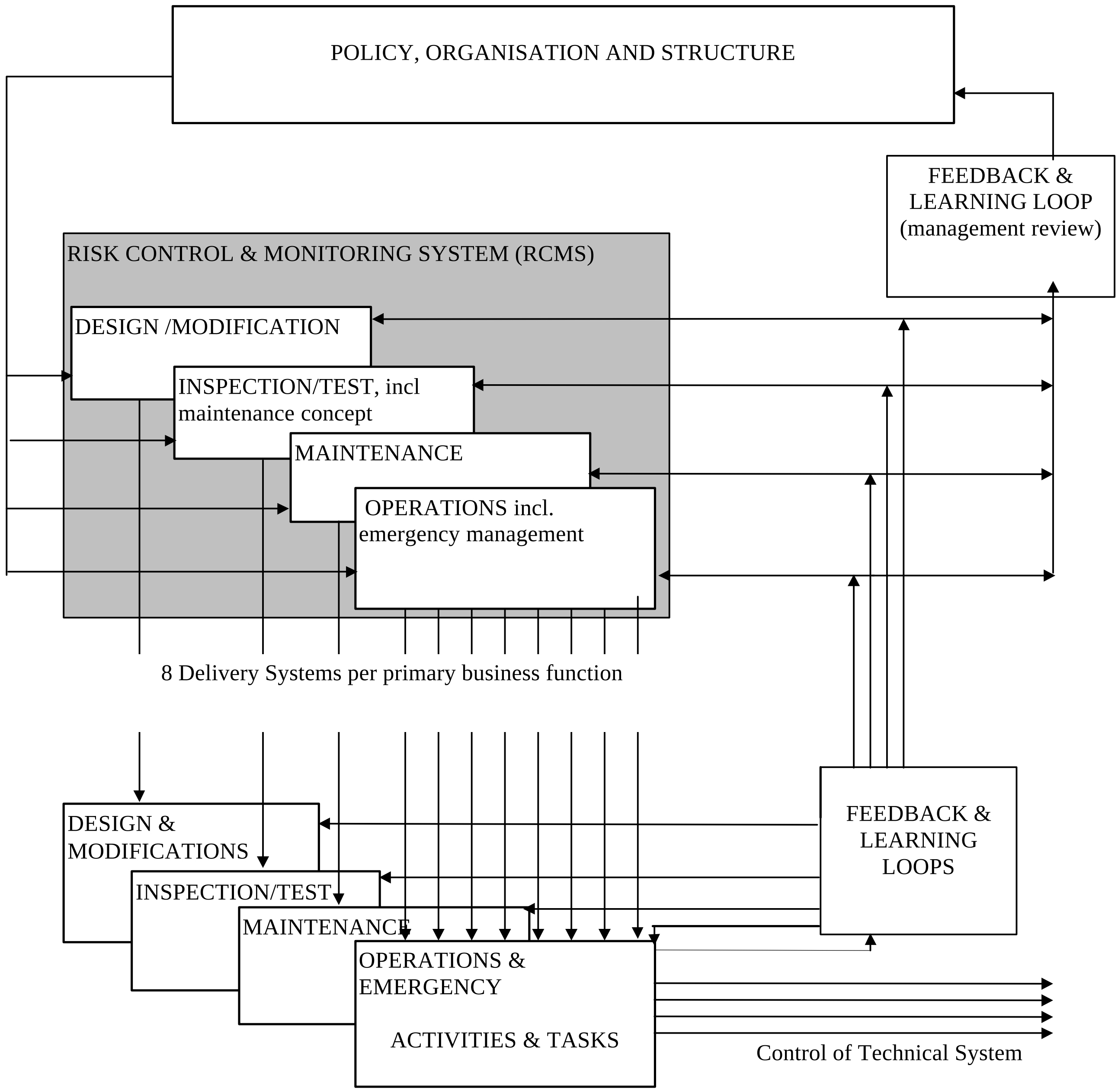

Figure 3 Functional safety management model

The difficulty we have for the future is to decide how much and what we should set down in rules, but above all how we can audit whether an organisation is managing its safety well, if it does not have a massively detailed rule book. We have to avoid the mistake of writing detailed management systems, which are simply replacing the rules for workers with equally inflexible rules for managers. Some audit systems make that mistake (Hale et al 1994) and impose detailed ways of managing, rather than emphasising a set of functions and tasks which must be carried out in whatever way the organisation (and accumulated good practice elsewhere) finds best. Figure 3 shows such a functional model of an integrated safety management system developed recently in a project for the chemical industry (Hale et al. 1997, 1999).

The essence of the model is of an explicit risk control and monitoring system (RCMS) set up under the aegis of the overall management policy This carries out risk assessments and sets up the structure and functioning of the risk control in all the life cycle phases of the system. It then delivers the necessary resources and controls to the operation of each of those phases to ensure the set standard of safety. The 8 delivery systems envisaged specify and deliver the following:

- hardware and interfaces to work it
- spares to maintain it in operations
- procedures and rules, goals and plans to govern its operation
- competent persons
- available at critical times
- committed to safe operation
- communication systems to coordinate their work
- systems to resolve any conflicts arising between safety and other objectives.

The system needs to know which are the safety-critical activities and tasks at the operational level in each life cycle phase. These are the ones which ensure that the technical system is kept in a safe state and operated within its safe design envelope.

The system learns by its three levels of feedback and learning loops.

How exactly any given company operationalises the various functions can be left to them. The auditor can operate with this framework (if necessary worked out to a further level of functional detail per box and delivery system) and the question whether the company can provide a convincing argument and evidence that its implementation of the framework works. This places high demands on the auditor and on the company representatives, to carry out their dialogue and evaluation at this level of abstraction, but it does get away from a rule-bound approach.

The UIC Guidelines on occupational health and safety management (UIC 1997) are at this level of functional abstraction. They emphasise also an aspect not so explicitly indicated in figure 3, namely the process of setting up a management system explicitly for the first time. This might be seen as the first operation of the "management review" feedback and learning loop. UIC needs to develop these guidelines further and turn them into an auditable management system for use in peer review across countries.

This emphasis on the need for constant change and adaptation of the management of safety is also reflected in the way we have come to realise that laws, standards and norms are also not one-off agreements on the best way to work. The laws relating to safety in most countries now commonly require companies to meet specified minimum standards, but then to adapt their practice to achieve risks which as low as reasonable practicable or achievable (ALARP or ALARA). There is often a specific mention of needing to comply with the known state of the art of technology, management, etc. in doing this. This clearly shows that the goalposts in the game of safety are constantly moving. No manager can afford to think that safety decisions are one-offs. They must be constantly monitored and worked on.

An added complication in abandoning the certainty of hard and fast rules and standards in both design and operations is that staff have to think in terms of risk. Our experience in our studies of tunnel safety confirms what has been found in studies of designers everywhere (e.g. Wulff et al. 1999, Swuste 1997). They like to be able to simplify their work by referring to concrete standards. "If I design or do it like this, it is safe enough and I do not have to worry any more." We have found evidence of very compartmentalised thinking. An engineer responsible for any one aspect of the tunnel infrastructure, operations or emergency response has a tendency to want to respond to and improve on every risk factor our studies find. They do not stop and first ask the question whether the probability or consequences of the risk justify the expenditure in comparison to improvements elsewhere in the system. On the other hand they tend only to accept that something is a risk if it has already happened before. If there is no instance in a rather comprehensive data base (for example the MISOS system of Dutch Railways) the feeling is that not only the lower bound of the probability of the event is zero, but also the upper bound. Risk thinking and broad systems thinking still have to gain credence. This requires quite a culture change. It requires the acceptance of the idea that safety decisions must take account of the complexity of the interactions in the system, rather than closing their eyes to it. It also requires the acceptance of cost-benefit analyses (e.g. Maidment 1997, Bäckman 1999) to decide on priorities. This approach requires thinking about costs and benefits rather broadly, and may meet objections on moral ground, because it requires putting a value on human life.

Designers and project and operational managers need training in this new way of thinking. UIC, or its constituent companies should take the initiative to ensure that suitable courses are made available, both in the first degree engineering courses, and in conversion courses for existing staff. Just such an initiative by Dutch Railways led to the Rail Systems course we have recently started in Delft.

3.2 Making safety explicit

If managers are to manage safety consciously and proactively they must have performance indicators to do that. The indicators quoted in the first section of this paper are the old reactive ones of accidents. They are still necessary to act as a final check as to whether safety is improving or not, but we cannot steer by them. For process safety (passengers and goods) the figures are already too low to show reliable trends in many of the smaller operating companies (Groeneweg 1992). Soon they will only make sense as trends if the data for several countries are combined. This gives rise to the need for indicators related to earlier steps in the processes which finally lead to accidents if not blocked and recovered. We can look to near miss and incident data, hardware failure and maintenance data, behavioural monitoring, operational anomaly logging, inspection of the presence and working of preventive measures, audits and management reviews. The possibilities are legion. Railtrack is an example of a railway company which has gone far along this path in its safety plans and reports (1998, 1999).

This development is to be praised and encouraged. Other rail companies should be following suit, both to give their own managers targets and to demonstrate to the public and government that they are serious about safety objectives and are achieving results in managing it. We have ample evidence to know that managers respond to management by objectives and alter their behaviour according to what is rewarded (e.g. Chaplin & Hale 1998). However, I would like to sound three notes of caution.

1. The indicators need to be kept comprehensible and transparent. The more there are, the more likely it will be that they show apparently contradictory measurements or trends. They must be linked to a very clear set of models or frameworks about how the safety management system works, so that all concerned can see at a glance what aspect the indicators are measuring. This is not easy in complex systems and special modelling techniques may be necessary (Hale et al 1994, Hale 1998).

2. We need to be careful that the persons being assessed by the indicators really do have influence over them. A small study was carried out recently in the Netherlands (Wielaard 1999) of the possible indicators to monitor the control of factors relevant to passengers being injured getting on and off moving trains at stations. Using a fault tree modelling approach it became clear that most of the factors relevant to this sort of accident were under the control of managers remote in the organisation from the station or train staff (e.g. rolling stock designers). Indicators relating to this sort of accident could not be used as the basis for the "safety contracts" with station managers.

3. As with all performance indicators, we need to think in advance of how manipulable they are (see also Rozendal & Hale 2000). If the stakes are high, because managers are judged on the indicators for the purpose of deciding their bonus, salary increase, promotion, etc. there will be a strong incentive to bend the measurement system. At the very least it will become a bone of contention, where safety staff may need to control and arbitrate about the measurements. Safety staff should be ready to jump into such a role.

The industry needs to use its working parties to establish best practice and spread good ideas on viable performance indicators.

Another motivation which has been driving the process of making safety explicit is the privatisation and decentralisation of many railways (Maidment 1998). Instead of one monolithic company in which staff moved around from department to department and often stayed for their whole carriers, there is now a set of separate companies with less permeable boundaries. In the old system safety issues could permeate activities without being made explicit. Now they have to become the subject of contractual agreements between independent companies, to resolve liability issues. They are even becoming the subject of internal contracts between senior and middle managers (NS). They are also the basis of explicit safety cases in which companies bid for franchises or contracts, or which are formally assessed before a company receives a license to operate (e.g. Cramer 1997, Railned 1997). Because these developments make safety explicit and controllable, perhaps we need to fear less the possibility that privatisation will increase the conflicts between the safety and economic performance goals of companies to the detriment of the former. However we do well to remember my third caution above, that high stakes provide high incentives for distorting performance indicators. Safety indicators are sadly more manipulable than economic ones.

What I have said so far is about safety as explicit issue within the company for the managers. As a small test of how explicit rail companies are to the outside world about safety, I searched on the internet pages of four major operators in four countries. In only one of the four did I find anything explicit about it which was available to the public. For that sort of information, the public has to turn to the rail regulators in each country, or to accident investigation or transport safety boards. Safety is clearly not yet a selling point for railways in most countries. Perhaps it should be

3.3 From authoritarian to participative

Another concomitant of the move from the technical- or rules-fix to a continuous process of control and learning is that it demands much more participation. Rules can be imposed from above. They engender the culture that the experts know best and that the shop floor should be, or at least should play, dumb and simply obey the rules. Creativity and initiatives from the shop floor to improve are stifled in such a climate.

Once rules become more conceptual and goal-oriented, rather than prescriptive, this cannot work. Nor can it work if the technology is changing or there are many abnormal situations to be coped with. It is hard to have an expert around all the time to make up new rules or modify old ones (Bourrier 1998). The only other alternative is to delegate the rule making and changing to the work group. There needs to be a feedback loop to ensure that the written rulebook keeps up with the changes, so that new trainees are not taught old knowledge. However, we have radically altered the location of initiative and power from top-down to bottom-up. Studies of so-called High Reliability Organisations (e.g. Roberts 1989) show that this is one of their characteristics. They have very explicit and central safety philosophies which emphasise the value of safety, but they do not have detailed rulebooks. The operating personnel constantly evolve, modify and pass on the safe working practices. Safety is a constant topic of conversation and incidents are informally reviewed to extract learning from them, making safety a live issue the whole time. There is also a high degree of cross-checking between individuals, creating an operational redundancy.

The contrast between the rule-bound and the participative cultures could hardly be greater. It will be many years before railway companies will be able to realise such a shift, but it is an essential one in becoming a learning organisation. Learning in organisations is essentially driven from the bottom up (Schein 1992). If the operational level does not learn and drive organisational learning from the spin-off from its flywheel, it is hard to get change implemented at the shop floor. Rail companies need to look at this dilemma of the place of rules in their culture. They need to reconcile the predictability and harmonisation, which come from centrally agreed rules, with the need to empower their workforce. It requires hard thinking and the willingness to experiment.

3.4 Learning and knowledge management

If we put together all of the trends sketched in this paper, they add up to a revolution in the way safety is, or should be, managed in railway companies compared to a decade ago. The keywords are: systems thinking, explicit risk comparisons, integrated management systems across different types of harm, continuous concern for safety from management, participation from operational levels and finally the need to develop into a learning organisation in order to manage safety in a changing world.

This adds up to a great demand for knowledge management in the rail companies and in the industry as a whole. Railway companies have been very good in the past at collecting data. Bureaucratic organisations often are. Not only rules are meticulously documented, but also performance and deviations from performance targets. I have seldom seen more comprehensive databases in any industry to compare with those such as the MISOS system of the Dutch Railways and its counterparts elsewhere. What is much less clear is whether the data are, or can be, turned into information. To do so, it is vital to impose some structure on them. They need to be linked to models of how the system should, or is considered to work. For example: to construct fault trees from them we vitally need data on conditions of failure and exposure: to link incident data to safety management there needs to be an explicit accident model. Intelligence needs to be built into the data systems. Otherwise we are reduced to the crude tools of data-mining; fishing expeditions to dredge up a catch from the murky bottom, instead of illuminating that bottom by shining the lights of intelligence on it. If we can do no more than data mining, then the intelligence needs to be explicitly present in the heads of those who interrogate the data and turn them into information. We cannot leave that function to junior staff, or to those without a deep knowledge of the technical and operational processes of the industry.

The need for knowledge management is accentuated by the breaking up of the national monopolies. The dedicated railway employee with a career wholly inside the industry will become less the rule. Already companies with no rail experience are bidding to run lines in countries such as the Netherlands. The first licence was issued to a company which had until recently run canal boats. There is also an increasing interchange at technical and higher management levels between the rail industry and other technologies. This provides some fresh winds of change and challenges to unquestioned old ways. It also requires that the knowledge about how to run safety needs to be made much more explicit, so that it can be learnt by such newcomers quickly, and not absorbed by an almost invisible process of osmosis over the years. Rail companies need to explore ways to accelerate the process of learning on the job, by developing explicit courses in safety management, philosophy and practice. Here too it may pay to open the door to collaboration with other industries, or to send staff on open courses run at universities or other training establishments.

4. CONCLUSIONS AND CHALLENGES FOR THE NEW MILLENNIUM

This paper concludes by summarising some of the challenges for the new millennium.

1. The rail industry is well into a period of major technological innovation, of which a number were listed earlier in this paper. Bell (1998) has shown the negative side of such multi-billion projects, which almost routinely go over budget, under target performance and run into unexpected safety problems. These will form the major challenge for the emerging safety management systems of the railways. They will determine whether rail transport comes through with flying colours to retain public trust, or acquires the dubious aura of the nuclear industry. Both rail companies and UIC should be actively exploring how safety management should respond to these new developments.

2. The issue of public trust, media attention and regulatory searchlights on performance will challenge not only the quality of the safety management, but also its ability to communicate its message to the public. In Beck's "risk society" (1986) there will be no hiding from this scrutiny. Risk and its control have move irreversibly to centre stage, paradoxically just at the moment at which our life expectancy has dramatically increased. The remaining risks in our lives, particularly those we have less personal control over have become less acceptable. Keeping quiet about risk, in the hope that the public will not get alarmed, is no longer an option. Sooner or later an industry will get found out and torn to shreds for that approach. The only viable option is free and frank discussion of the levels and type of risks, but above all of the way in which they are managed. The objective must be to convince all concerned that risks are being constantly and explicitly assessed, managed and controlled. Trust will not be given unquestioningly. It must be won by information and demonstration.

3. I have indicated the challenges of culture change needed to adapt to the current best practice in safety management. The role of rules and dogmatic certainty will need to change. Many watertight barriers within companies between functional areas will need to become more permeable to allow systems thinking to prevail. The top of the organisation will also have to learn to listen to and take notice of the bottom much more. What was rigid and solid will have to become flexible, but still robust and adaptable. The management of knowledge and competence will need to play a central role, also in the safety area. Again, both rail companies and UIC have a role to play: companies in developing new policies and practices and new training courses to achieve this; UIC in its working parties by stimulating and disseminating the results.

4. As safety and its related areas of risk and sustainability become more explicit in management systems and become more integrated, there will be the challenges of how to audit them. This challenge will need to be met across a much more decentralised and competing set of companies. Perhaps the industry should look to the sorts of international peer review of management systems which the IAEA has set up in the nuclear industry, which certification authorities operate under the auspices of the European Accreditation Councils and which the Joint Aviation Authority and ICAO are moving

gingerly towards in air transport. UIC could take such an initiative based on its guidelines, though they would have to be expanded beyond their current concern only with occupational safety and health. In doing so UIC should liase with the working group which has recently published OHSAS 18001 (BSI 1999) as the first certifiable general occupational health and safety management standard. It seems likely that this standard will ultimately form the basis of an ISO standard in this area, once the opposition of some employers organisations on the ISO committee have finally been overcome.

5. Finally the industry needs to face the discussion about the boundaries it sets around and between the various areas of management as sketched in this paper. I am a convinced advocate of system safety as a broad integrated management area. I therefore hope UIC and its working groups will implement the step to broaden their remit and to face the new millennium as an integrated management group.

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