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MANAGEMENT OF SAFETY RULES: THE CASE OF RAILWAYS

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ABSTRACT

Every technology and activity has safety rules, which are usually formulated explicitly, taught to those operating in the system and imposed on them. Safety rules also determine liability after accidents. Yet there is very little systematic scientific or management literature on how to devise and manage safety rules.

This paper uses a simple framework to draw together what is known of good and bad practice in this area, particularly in deciding what rules should be explicitly formulated and imposed. It draws on the literature on violations, on rule learning and on organizational control.

The paper concludes with a case study of safety rules in the railways, derived from a larger European study of safety rule management for railway operations. It shows that the nature of the system dynamics and the current communications within railway operations result in a largely open loop operation of the system. This makes it vulnerable to any form of deviation from strictly defined operations. Safety rules are part of the apparatus to render the behaviour of the various people in the system sufficiently predictable that this open-loop operation can succeed in a large proportion of situations. However this requires that adherence to rules is very strict and has great problems coping with any deviations, even those required to respond to situations which cannot be dealt with following the existing rules. This requirement conflicts with much of the available literature on organisational control and high reliability organisations. However, the more interactive derivation of rules specific to the range of system conditions requires a far greater communication between system operators than the railway system currently requires. The room for manoeuvre in optimising safety rule use in railways is therefore currently limited.

1. INTRODUCTION

Safety rules are a universal phenomenon of any technological activity. Newcomers are taught them from rules books, or are expected to pick them up from working with experienced operators. In complex and dangerous organisations they can form many volumes of a safety manual, with procedures running into scores and applying to operations, maintenance, design, selection, training, purchasing and storage. When accidents happen, one of the first recourses of the investigation team is commonly to find out if safety rules have been broken. If they have, there is a prima facie case for allocating responsibility and liability, and often also for focusing change to improve prevention. The response to tragic accidents in activities which have not, up to now, been subject to any regulation, is often to formulate rules for them too, so that dangerous hobbies and even public pastimes such as hill walking, canoeing or swimming get to resemble more and more the traditional dangerous occupational pursuits. Safety rules are therefore seen as central to all attempts to

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prevent accidents and achieve safety. The meta-analysis made by Guldenmund (2000) of safety culture and climate studies showed that more than half identified safety rules and attitudes towards their use and violation as significant dimensions of safety culture (see also Hale et al 2002, Swuste & Guldenmund 2002 for more recent studies confirming this importance). Yet it is surprising how little literature there is about how to manage safety rules effectively, how to decide what rules are needed, how to prepare and formulate them and how to promulgate them and ensure they stay appropriate.

The standard safety management texts only rarely (e.g. de Reamer 1980, Geller 2001) have a chapter on safety rules. The ILO Encyclopaedia on Occupational Safety & Health (Mager Stellman 1998) has no chapter or index entry. The main emphasis, where rules are dealt with, is on discipline and enforcement, not on the positive contribution which rules make and how that can be maximised. The predominant view from reading such texts is a scientific-rationalist one; rules are simply seen as an essential and natural phenomenon, expressing how the system should be operated, as conceived by its designers and managers. Those operating in the system are seen as passive actors who should simply obey out of common sense, self-preservation and a duty to comply (see e.g. Dien 1998). This is a legal-paternalistic view, bolstered by the practices of regulators and law makers, who have dominated thinking in safety ever since the early 19th century.

Yet this view is being increasingly challenged. The revolution in regulation, ushered in under the title of self-regulation in the 1960s and 1970s, questioned the imposition of strict rules at government level and advocated the development of framework rules formulated as goals, to be filled in lower down in the system hierarchy with detailed action rules. The 1980s saw an extensive study of rule violations conducted within the framework of cognitive theory by Reason and his colleagues and followers (e.g. Reason & Free 1993, Free 1994, Reason et al 1995, 1998). These showed comparable disutilities in detailed rules imposed at organisational level, which lead to enforced violation to get the work done in real life. It made clear what was bad in current practice, but got no further than generating general guidelines for the formulation of safety rules, concentrating largely on the process of writing them, rather than on how to decide what to write rules for. At the same time the work of researchers looking at high reliability organisations (HROs) (e.g. Roberts 1990, Rochlin 1989) showed that these were characterised by a lack of detailed written safety rules, but the presence of highly trained experts and by intense consultation, mutual checking and communication about safe actions.

Current knowledge about safety rules and their management still suffers from this fragmented approach. Detailed rules have a bad name; thick rule books are seen as symptoms of system pathology (Hale 1990), yet rules are still seen as essential ingredients for controlling system safety. The cry is for better rule use and management, but there are still not very clear ideas of how and of how to avoid the main pitfalls in producing workable safety rules.

This paper reviews the main strands of literature and proposes a framework of steps in good rule management. It offers a number of suggestions of good practice and illustrates a number of the dilemmas through a case study of railway safety rules. This shows how the characteristics of the system to be regulated present specific challenges to rule management.

2. A SIMPLE FRAMEWORK

A rule can be defined as a correct or preferred way of carrying out a task in defined circumstances to achieve a defined goal. The majority of human behaviour is rule-based according to this definition and cognitive psychologists have written much about the basis of this behaviour and its learning (e.g. Reason 1990). Only when facing wholly new situations is behaviour not rule-based and must it be derived from deeper structures of knowledge. In the grey area between these two states are found heuristic rules of how to proceed to arrive at decisions and actions in situations which are not previously known. The controversies in rule management come from the question as to where these rules come from. They may be derived from practice, more or less triggered by the design or structure of the situation being faced, or they may be proposed or imposed from outside, by colleagues, work groups or people in authority. This paper deals only with rules in this last category, which are imposed from outside the individual and which, by definition, are limitations on individual freedom of choice.

We consider an ideal rule management system to consist of a number of logical steps which have to be carried out (see figure 1). How they are carried out and how they link one to another to form a closed loop will determine how good the rule system is and how well it is followed and controls the risks of the process.

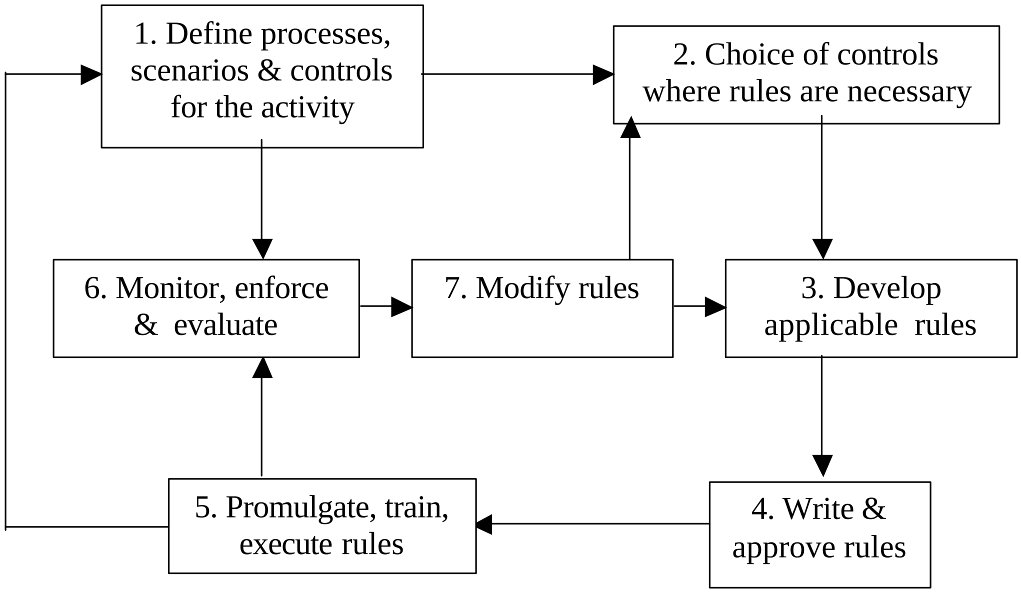

Figure 1: the rule management process

Initially the processes to be controlled must be modeled as a set of system objectives and functions in a coherent process or set of processes, allowing for all relevant steps in the life cycle from design and construction, through use, maintenance, modification and eventually demolition. This step indicates the crucial system transitions, the functions to be carried out and the system actors who conduct them (and hence the communication necessary to operate effectively and safely. The accident scenarios, which are known or considered credible, can then be derived from this model, together with the barriers and controls which prevent them from developing (see Johnson 1980 for the systematic formulation of these found in the MORT system). It is these barriers and controls which form the basis for defining the desired behaviour of the system and its actors. The barriers, which can be physical or behavioural, must be put in place, maintained, used and optimised. This requires certain behaviour from the system actors, which they must show spontaneously or be 'forced' to show. This is the total repertoire of system 'rules' in the sense of an 'instruction manual' for the system (Hale 1990).

The next step is the most controversial and one where there is the least guidance, the decision as which of these 'rules' needs to be explicitly defined and imposed to one degree or another on the system actors. Hopwood (1974, see also Reason et al 1998) defines four ways of imposing such behaviour:

- Technical forcing functions, through design, layout, etc., which prevent or elicit specific behaviour. Ergonomics has studied these extensively in the form of stereotypes, triggers and warnings.
- Administrative standardisation in the form of defined and imposed rules. Hopwood distinguishes two sub-sets, output or goal standards, and process standards. Hale & Swuste (1998) extended this categorisation to three by splitting the process rules into procedural rules, which tell you how to arrive at a decision on what to do, and action/state rules which tell you exactly how to do it (see also Dien 1998).
- Self control through expertise and competence based on practice and acquired knowledge (or internalised administrative rules), which may not be explicit or accessible to the person possessing it. Full self-control includes self-monitoring against the rules.
- Social group regulation, in which the rules reside at the group level, more or less articulated, but in any case imposed by group pressure. In the case of new situations the group debates and decides the course of action.

Once it has been decided what rules are appropriate, the rules must be developed, written (or formulated in another way which can be communicated) and approved for application. Here must be decided who is involved in these processes and how, and what expertise and experience is brought to bear in what way in testing the appropriateness and applicability of the rules. The form of the rules must be decided, including how rigid they are and how and by whom deviation from the rules can be decided, worked out and sanctioned.

The next steps are to inform and train those who have to carry out the rules and to ensure that everyone is aware of them and of any changes made to them. Here decisions have to be made about what to include in training, what in rule books and other means of access to the total set of rules and what media to use for promulgation.

Once the rules are introduced there is a phase of operation in which the rules must be monitored, deviations dealt with, new insights into the working of the rules gathered and decisions made about what may need changing. Here the decisions are about supervision, dealing with situations not envisaged by the rules and requiring adaptations and action after deliberate or inadvertent deviation from the rules in cases where the outcome is either positive or negative for the system or the individual.

The final step to complete the circle is the modification process in which the activity, processes or technology may change, in which the lessons from experience may suggest that rules for previously unregulated situations are necessary, or that rules can or should be removed or relaxed, or simply changed for better rules. Here the issues are again of who is involved, what processes are needed to approve a change and how to avoid the processes of rule accretion and calcification described in the next section.

3. RESEARCH EVIDENCE

A number of studies, particularly by Reason and his co-workers (Reason et al 1998, Free 1994, Lawton & Parker 1999), have looked at the circumstances under which people violate rules. They have identified three main types of violation: routine, situational and exceptional. The first two are both concerned with mismatches between rules and reality.

1. In routine violations short cuts have crept in, which give the person concerned advantages in effort, time or some other valued outcome such as prestige. If they are not ‘punished’ by the system, either by the occurrence of an accident or near miss, or by some disciplinary action or disapproval by others, they become incorporated into the normal way of working. They become routine and the margin of safety between the real danger zone of the system and the operating situation has decreased. In Rasmussen’s terms (1997) people are routinely working nearer the edge. When additional factors bring the system further into danger an accident can occur. Expanding the margin by making stricter rules or improving the intrinsic safety of the system merely gives more room for the routine violations to occur and be routinely rewarded and so reinforced. Only careful formulation of the rules (blocks 2 & 3 in figure 1), coupled with conscious monitoring of them can keep the margin free of violations.

2. Situational violations occur when the rule cannot be carried out in the circumstances which occur in practice. Free (1994) found many examples of these in her study of shunters’ accidents, due to the layout of specific shunting yards, the particular composition of trains, etc. These exceptions mean that the operators have to improvise and may not think carefully enough or consider enough factors to do so safely. They fail to cope adequately with the boundary between rule- and knowledge-based behaviour (Hale 1990). Better formulation of rules in blocks 2 and 3 of figure 1 is again called for. It is vital that the boundaries of the validity of rules is specified (Dien 1998) and what to do if the situation falls outside the boundary.

3. Exceptional violations occur in exceptional situations, thus in knowledge-based operations, where time pressure, emotion and other immediate factors may result in people violating even basic survival rules (e.g. accidents where colleagues have gone down into a pit to save someone overcome by fumes and have themselves been overcome). Protection against this sort of violation does not lie in the formulation of the basic rules, but in strongly inculcated meta-rules which enforce a thinking pause before action.

The factors which encourage violations have been summarised by Hudson et al (undated) in a booklet for Shell managers:

1. People who expect that they will not be able to perform the activity if they follow all the rules
2. People who consider they have the skills and knowledge to work out for themselves how to operate outside the rules
3. Opportunities to take short cuts with impunity
4. Inadequate planning and resources, so that people are brought into situations in which they have improvise

Other studies (e,g, Reason & Free 1993, Reason et al 1995) have shown that young males are particularly likely to fall into the first two categories, a major contributor to their high level of violations and accidents in driving. However, questionnaire studies of Shell managers and employees showed that over 60% of this much broader population either admitted to being rule violators or said they would violate if the incentive was there. Williams (1997) identifies low probability of detection, lack of disapproval by authority and copying behaviour or pressure from the group or authority figures as additional important factors encouraging violations in nuclear operations.

The preferred actions to decrease the violations are formulated as: planning, supervision and setting of good examples, analysis of violation potential of rules, analysis and learning from violations and better design of procedures, including meta-rules to cope with exceptions. This last point is discussed in detail by Bourrier (1998) in her comparison of French & US nuclear plants. She describes the system in one US plant where an experienced plant engineer is available full time during maintenance activities to devise (with the workgroup) and approve any deviation from the strictly laid down safety rules. No uncontrolled improvisation is allowed by the workforce, nor did it occur, since the organisational solution was immediately to hand and the disciplinary and liability consequences of unauthorised deviation were clearly emphasised. These and other authors also emphasise the need to analyse the gains and losses from rule following and violation (Battman & Klumb 1993, Leplat 1998), in order to understand when opportunities for deviation will be used. They summarise these as low constraint and high pay-off for violation, conflicting objectives (particularly between global production and local safety and between long term and peripheral negative effects and short term gains) and delayed and ambiguous feedback about violation.

In the Shell booklet (op. cit) disciplinary actions to control deviation are a less preferred strategy, because discipline requires constant vigilance and investment. However most authors indicate that the short-term disadvantages of rule violation must be increased in such ways to counter the poor feedback from actual accidents and near misses which guard the margin of safety. Rule violation, outside the carefully controlled organisational pathways discussed above, must therefore be socially and managerially disapproved of, and no blind eye must be turned (especially not based on the notion that a rule violation which has a good outcome is ignored). Many authors (e.g. Leplat 1998, berg 1998) emphasise this need to manage deviation control and discipline carefully, so that the rule system does not become seen as a way of covering the back of managers when things go wrong, and something to be ignored if all goes well. A number of studies (Elling 1991, Lawton & Parker 1999) have shown that cynicism about this use of rule systems is widespread among both skilled and professional workers.

Elling (1991), who studied rules and rule writing in railways, steelworks and chemical companies, also emphasised the need to provide clarity about this grey area of the safety margin. He distinguished a number of functions of rules (see also Hale 1990, Perin 1993, Baram 1993) such as prohibitions, warnings, specifications of responsibility and advice about good or correct practice. He advocated the use of clear differences in language, particularly verb use, to distinguish these and so indicate which rules should never be violated and which could be. He proposes that the safety rules to be used on-line during work should be limited to absolute prohibitions or requirements and specifications of responsibility and authority. The other functions (warning, informing, advising) should be kept physically separate as a sort of ‘instruction book’ to be used in training and as a reference work. He strongly advocated involvement of the ultimate users of the rules in deciding what rules to specify and evaluating them – although not always in writing them, since clear formulation is a skill often not present in work floor personnel. He also warned that participation of the ultimate user can result in too many rules at too detailed a level, if this process is not well managed.

Grote (2002) analysed rules from an organisational perspective and emphasised the need to abandon the idea of rules as rigid behavioural straightjackets, with deviation equated with punishment. The more modern view of organisations (see also studies of HROs by Roberts 1990, Rochlin 1990) sees deviation and exceptional situations as an opportunity to learn and improve rule systems, which should be devised and negotiated in the working groups, within boundaries set by the organisation. Simard & Marchand (1997) showed that rule compliance in manufacturing industry was best predicted by how good social relations in the workgroup were and how participatory the style of the supervision was (coupled with top management commitment to safety).

Such studies (see also Perin 1993) point out the dangers present in proceduralising activities in a too rigid way. This can result in people blindly following rules simply because they are there, rather than thinking about what they are doing. In a system with many rigidly formulated rules this can result in system paralysis if the staff 'work to rule' (Hale & Swuste 1998). Such a view echoes Reason et al (1998) in proposing that a decision about rule formulation should be based on reviewing the balance between the costs and benefits of not only correct compliance vs. incorrect deviation, but also correct deviation and incorrect compliance.

Lawton & Parker (1999) have shown that this conflict between detailed rules and professional competence lies deep in organisations. They studied health care professionals and found, despite overwhelming belief that protocols are a good thing and should be widely used, around 50% of the staff indicated that they did not make use of the protocols which were present. Protocols were seen as taking second place to professional judgement (see Norros 1993 for a similar reaction from nuclear operators). Introduction of protocols will therefore not, by itself, achieve compliance. The reasons for the protocols have to be well known and accepted and time has to be invested in involving staff in devising and evaluating them, so that they incorporate best practice. A study of pilots (Brito et al 1998) showed that compliance and satisfaction with checklists were then very high. What violations then remain are those where the situation deviates from that for which the rule is made, or through slips in attention.

A number of these authors (see also Fleury 1993, Keijzer 1999) also warn against the uncontrolled growth of rules, driven by the discovery of exceptions to existing rules and dealt with, as a knee-jerk reaction, by adding extra rules and codicils. They see the need for a method of regular rule review and spring-cleaning to weed out obsolete rules and check the compatibility of all rules in the set.

Hale (1990, Hale & Swuste 1998, see also Rasmussen 1993) propose that the hierarchy of rule types (from goal, through procedural to action/state rules) should parallel the organisational levels in a system. Goals should be set high in the organisation, translated in a level below into procedures for arriving at decisions, and, where necessary, as close as possible to the work floor (or other on-line risk control point) translated into specific action steps. This translation process needs to be explicit and conducted by staff who are seen to be expert (Norros 1993, Perin 1993), otherwise goals in the safety policy may be written independently of task-based detailed rules, which then conflict with each other. Only when there are overarching reasons should action/state rules be specified high in the organisation. The reasons for this could be harmonisation of detailed rules across a distributed system (such as the railways), but this creates special problems for gaining acceptance which need to be explicitly addressed with extra efforts to involve and inform the rule followers of how and why the final rules have been arrived at.

4. SOME GUIDANCE FOR AN IDEAL SYSTEM

The pathology of bad safety rule systems can be turned on its head to formulate guidance about ideal rule systems (see table 1):

Table 1. Ingredients for an ideal rule system

Regular & well managed involvement of rule users in deciding on and evaluating rules	Hierarchy of types of rule (goal, procedural, action/ state) matched with level of formulation in the organisation
Rules limited to essentials - predictable, clear cut situations at rule-based level	Indication of status of each rule in a hierarchy from compliance to advisory
Meta-rules (procedural) for situations for which existing rules cannot apply	Assessment of violation potential & cost-benefit of correct & incorrect compliance
Agreed system for approving exceptions or deviations from agreed rules	Clear, unambiguous language. Linked to task/function steps
Structured way of learning from rule violations and coping with changes to the system	Clear specification of objectives, area of application and ownership of each rule. No complex cross-referencing
Regular review of rule system to weed out unnecessary or contradictory rules and review total compatibility of rule set	Clear structure & indexing of rule book/ computer retrieval system, so that rules are easy to find when on-line use essential
Clear system for monitoring rule compliance and applying sanctions	Resources & planning available to formulate good rules[2] and to work according to rules

These general rules for guidance fill in the various steps in figure 1 with more detailed criteria for assessing how good a safety rule management system is.

We turn in the next section to the case study of safety rule management in railways. This section concentrates on the first three steps in figure 1 and discusses further what are the constraints within the technology and organisation of the railway system which determine what the current use of safety rules is, and how these constraints make it difficult to implement a number of the ideal characteristics of a good safety rule system.

5. RAILWAYS: A CASE STUDY IN SAFETY RULE USE

This case study is based on interviews in diverse organisations operating in the Dutch railway system in passenger and goods transport, in infrastructure provision and maintenance and in regulatory roles. It is part of an ongoing study of rule management in the railway system, which has been set up in the context of a European study of the requirements for good safety management in railways in the light of increasing interoperability and privatisation. This has led to the introduction of many new companies into railway operations and maintenance, with a limited history of railway experience, and to the operation of companies used to one national set of rules on networks in other countries with other safety rules and operating philosophies.

The interviews showed that the safety rule system in use in Dutch railways has many of the hallmarks of a system which has grown by accretion over a long history of trial and error, some of it through major accidents. Despite some attempts to rationalise the system (e.g. Keijzer 1999), there is still no explicit use of the steps set out in the framework in section 2 of this paper. In particular the processes, critical life cycle transitions, accident scenarios and risk control barriers have not been specified in a comprehensive and systematic way. The information about them is largely present in the system, but scattered, sometimes only present in the heads of experienced staff, and, above all, is not used as an explicit basis for deriving safety rules. This means that rules as now formulated are not comprehensive or tested for their compatibility or violation potential.

[2] Perin 1993 identifies the low status of rule writers and writing as an important factor

The research team has conducted an analysis along the lines of section 2 of this paper for part of the system, as part of the study. This shows that railway operations have a number of particular characteristics distinguishing them from many other high hazard, high technology systems:

1. Whilst the objectives of the system can be simply stated [the safe and efficient transport of goods and passengers over the infrastructure provided (or to be built), using the power supply and under control of a traffic control system], the achievement of the objectives takes place in a system with many boundaries and life cycle transition steps which are concentrations of vulnerability.

2. Many of the accidents happen at boundaries with other systems: suicides, trespassers and animals on the track invade the system for their own individual purposes; other transport systems cross the railway track at bridges and more particularly level crossings; vandals can use these crossing points to throw objects onto the track; passengers entering and alighting from trains at stations are more at risk. This means that the railway system has to negotiate risk controls with other systems, or impose them on them.

3. The railway system has been designed and built with only a limited concern for the maintenance and modification phases of the life cycle. Maintenance is not incorporated into the initial design of the train timetable and has to be dealt with as disturbance to it. The sharing of parts of the system between operations and maintenance and the transfer from one system state to another (also non-nominal operations and emergency situations) lead to many potential accident scenarios which have to be controlled by rules.

4. Above all the communications between the various parties to the system is quite limited and largely intermittent. Figure 2 shows this.

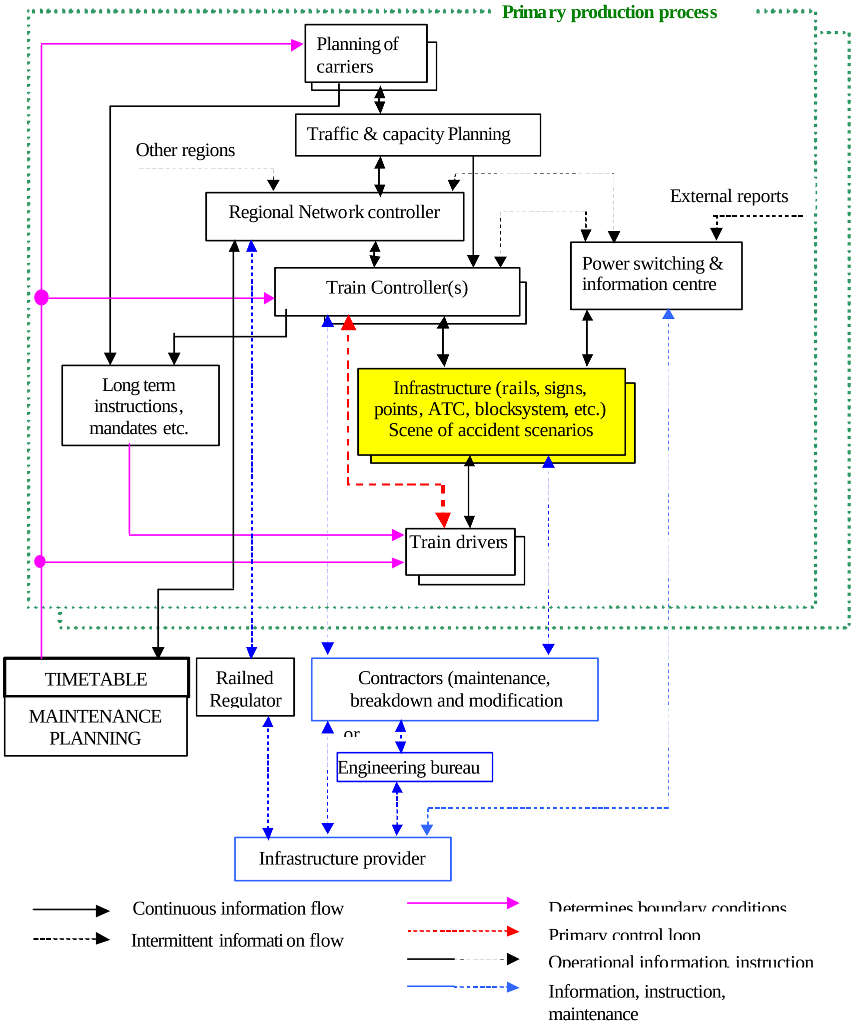

Figure 2. The railway control system

The train controller, the train drivers in his section of the system and the contractors working on the track are the main protagonists in on-line risk control. There is no direct communication between any of them and the external parties threatened by the system (motorists at level crossings, trespassers, suicides, etc). It is only through the physical infrastructure that their behaviour is controlled (crossing controls, fences, barriers). This limitation is perhaps to be expected. What is more striking is that the main protagonists also 'communicate' largely through the physical infrastructure (signals, lookout men, ATB) or through off-line means (the information sheets issued to drivers daily about work in progress, restrictions). For example, the controllers do not know exactly where any train is, only in what block it is present; there is no direct contact between train driver and maintenance crew.

5. By its nature the system is distributed, with several regional train controllers dividing the country, many trains operating with little communication between driver, train crew and controller. The staff in the trains is constantly travelling and there is only limited group communication and cohesion because of the lack of opportunities to meet with colleagues or for supervisors to monitor behaviour or communicate with their subordinates.
6. The main regulator of the system is the timetable, filled out with the maintenance planning. If all goes according to this, within certain margins, the system functions well, but only provided everybody complies very strictly with the expected behaviour and the signals.
7. There has been a strong resistance to increasing the local communication in the system (telerail is a limited and not very reliable system, mobile phone use has been discouraged, communication between train and track workers is seen as a dangerous loss of central control)
8. Because of all this the system works to a significant extent on open loop (feed forward control), with a considerable delay in feedback. If anything happens which causes significant deviation from the timetable and expected planning the system rapidly reaches overload, because the communication demands suddenly increase and the communication means are very limited. In order to guarantee the margins for predicted operations and to cope with deviations, there are wide margins of space and time built in between trains. The basis of the rules for much of the operation is also that actions or movements are only permitted if there is positive confirmation through the infrastructure that the system state is safe – lack of communication means that this cannot be checked otherwise with other parties. This means that a major disturbance can often only be coped with by stopping that part of the system and resetting and restarting it. With increasing pressure on the system capacity, through government policy to transfer more road traffic to public transport, and higher demands on system performance, these margins are coming under increasing pressure.

All of this means that rules and strict adherence to them form a central prerequisite to the safe functioning of the system. Only if the rules are followed exactly is it predictable what will happen and can the open-loop system work with sufficient certainty. The system has been designed on this basis since its inception. It has always had paternalistic and even militaristic characteristics, whereby rules are devised and imposed from top down and unquestioning obedience is expected and has in the past been enforced. Obedience is therefore assumed, leading to great surprise and alarm (and strong disciplinary action) when it is shown that violations have occurred. So much is obedience expected that there are some surprising gaps in technical support. For example Dutch trains have indicators in the cab showing that they have gone through a yellow light; however there is no indicator that a red has been passed. The reasoning seems to be that this is forbidden, hence it will not happen and one does not need to indicate it. The automatic train system 'sees' this violation and responds, provided that the train is travelling at more than 40kph. Below that it does not work. The result is that a moment's inattention or attention directed at the wrong signal below this speed can result in an error which cannot be recovered, since there is no record of it for the driver to see a few seconds later.

The distributed nature of the system and the constant travelling of the majority of staff means that there is no such thing as a cohesive work group. The limitations imposed on communication between the main protagonists, added to the recent development that they are now all working for different companies rather than the old monopolist, makes it impossible for any cohesive relationship to develop between them. Indications from the interviews suggest that the privatisation has even led to more conflict in these relationships, since drivers are judged on performance criteria which emphasis punctuality, whilst their progress is governed by train controllers working to other targets of safety and capacity. The coherent communication necessary for the consensus on defining rules and the social control in carrying them out is therefore not easy to find. The task of communicating any changes in the rules, or organising refresher training is also a major logistic exercise.

Our conclusion from this stage of the analysis of the railway system and its use of safety rules is that there are a number of characteristics of the technology and the way it has been designed and managed up to now, which make it difficult to apply a number of the ideal characteristics of a rule system as set out in section 4.

It would be possible to gather together the existing fragmented information about the safety critical processes, scenarios and state transitions and to make them the explicit basis for identifying the barriers and control important for safety. These can then be used as an explicit basis for deriving the required behaviour of the various actors in the system. Use of the criteria defined for deciding which of these potential rules should be explicitly formulated as a safety rule can then provide a far more coherent basis for operational, task-oriented rules. Identification of the actor(s) responsible for each critical task and decision, particularly in the state transitions or during non-nominal or emergency states, can form the basis for the rules about responsibility and authority. This will improve the coherence and transparency of the rule system. What is clear is that the efficacy of the rules and their ability to control risk situations will only be radically improved if the means and possibilities for communication between the on-line actors in the system are improved. The developments in the ERTMS and in traffic control which are taking place are an opportunity to make this improvement, but its implementation will require a major change in the operating philosophy to give a far more active role to the ‘front-line’ risk controllers, the track workers and train drivers.

When it comes to deciding which rules should be made an explicit part of the safety rule system and to formulating and writing the rules, the major problems to be solved are the involvement of staff. There are currently increasing attempts to feed in this expertise (Keijzer 1999), but more needs to be done to create the feeling of ownership of the rules and a common attitude towards them by all the on-line risk control protagonists. This will involve a shift of emphasis from rules written in the office by specialists to a more distributed process of consultation and approval. To be effective in the dynamic environment of a rapidly changing and expanding railway system, this needs to include processes for regular review and adaptation of the whole set of rules appropriate to given activities.

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