Management of safety rules and procedures

A review of the literature

Report submitted to the IOSH Research Committee

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Abstract

A review was conducted of the literature on the management of rules and procedures that affect safety, concentrating on rules at the workplace level. A literature search in the scientific and grey literature revealed 180 key references for study. The literature fell into two contrasting paradigms. The first is a relatively static, rationalist, top–down view of rules as the one best way of working, devised by experts distant from the workplace, imposed on operators as a way of constraining incorrect or inadequate behaviour, where violations are seen as aberrations to be suppressed. The second is a relatively dynamic, bottom–up view of rules as local, situated, socially constructed, devised by those at the sharp end, embodying their tacit knowledge from their experience of diverse reality. The report explores these two paradigms, the evidence from theory and field studies which supports or fills them out, and their consequences for procedure management. It proposes a model of procedure management that attempts to draw the lessons from both paradigms and combine their strong points. This is a nine-step dynamic cycle, driven by the central task of monitoring rule and procedure use in order to optimise it through a combination of learning and procedure modification, rule scrapping and rule enforcement. This framework forms the basis for the stand-alone 'Notes of guidance',* including a summary intervention plan to review and improve practice in organisations.

* Hale A, Borys D and Else D. *Building sound foundations: notes of guidance on managing safety rules and procedures*. Wigston: IOSH, 2012. www.iosh.co.uk/rulesandprocedures.

Executive summary

The IOSH Research and Development Fund commissioned this report from Professor Andrew Hale, Emeritus Professor at Delft University of Technology in the Netherlands and Chairman of HASTAM, and Dr David Borys of the University of Ballarat in Australia, with the assistance of Professor Dennis Else, also of the University of Ballarat.

The objectives of the report were to learn lessons from the scientific and professional literature on the management of safety rules and procedures over the past 25 years. The review considers all rules that have an effect on safety, either exclusively or alongside objectives of production, efficiency, quality, environment and so on. These lessons are presented in a theoretical and a practical form. The theoretical form consists of a scientific review of the literature to present what can be concluded from empirical and theoretical studies of rule-making and rule management from the diverse literature of safety science and related psychological and organisational fields. The practical form consists of stand-alone guidance notes distilled from the scientific review and aimed at senior safety professionals, together with a summary intervention plan to help organisations and their consultants review and improve their safety rule and procedure management system.

The literature search was conducted using 27 search terms in all relevant combinations in 25 different single or multiple databases. This revealed an initial trawl of 301 relevant papers in the period since 1986, which were whittled down to 180 to be studied in detail.

The literature review presented a summary of the theoretical approaches to rule use and management, and distilled this into a framework of the process of rule management consisting of nine steps, coupled with proposals of good practice at each step. This was presented at various stages of development to workshops and conferences of safety researchers and practitioners in order to refine the structure and the conclusions to be drawn. The final review paper formed the basis for a workshop the authors held with 23 senior safety professionals, at which the objective was to confront the scientific theory with the lived practice. A summary of the issues raised at the workshop is included in the Appendix. Workshop participants were asked to critique the framework of rule management and provide practical examples to complete or challenge the proposed good practice. The discussions were used to turn the proposed framework into draft 'Notes of guidance' on managing safety rules and procedures, containing a set of principles for considering rule management and descriptions of good practice for each of the nine steps. This was sent out for comment and revision. The final version is given in the 'Notes of guidance'. As part of the Notes, the experiences of the safety professionals in making changes to rules and procedures were distilled into a summary intervention plan for review and improvement of rule management.

The literature review starts by presenting some theoretical notions concerning the nature and objectives of rules, and the relation between the different objectives that rules, including safety, may have, as well as those relating to other rules, such as those governing production. The review depicts safe work as navigating within an 'envelope' demarcated by safety barriers and rules, which aim to prevent movement outside the envelope. Rules are part of the armoury of the operator to conduct a task successfully. The reviews also puts forward a categorisation of types of rule into performance goals, process rules and action rules, which present increasing limitations to freedom of choice and discretion. These notions recur in the body of the review.

The literature review revealed two contrasting paradigms of rules, which are labelled 'model 1' and 'model 2'.

Model 1 is the classic, rationalist view of rules as constraints on the behaviour of those at the sharp end of operations imposed by experts situated higher in the hierarchy and removed from the day-to-day work. Following rules is seen as the best way of behaving in all situations that can be envisaged, while rules constitute constraints on the errors and mistakes of fallible operators, who are portrayed as not having the time or competence to come up with those rules. This is an essentially top–down view of a static set of rules that should not be violated. Not following the rules is seen as essentially negative and to be discouraged, or at most learned from and corrected. The literature researching this paradigm comes largely from technical safety science and from psychology. Much, but by no means all of it, deals with relatively simple workplaces and actions.

Model 2 emerges from sociological and ethnographic studies and from management science, and focuses on predominantly complex, high-technology operations. According to this model, rules are socially

constructed patterns of behaviour, deriving from experience with the diversity of reality. Rules are local, situated and have many exceptions and nuances. The experts in this paradigm are the operators, and this view is essentially bottom–up and dynamic. This model sees written rules as necessarily simplified abstractions of this complex reality, to be used as generic guidance, but adapted to each different situation in real life. The imposition of externally derived rules are characteristically seen by the 'expert operators' as unwarranted limitations on their freedom of choice and slurs on their competence. Violations of such rules are seen as inevitable and knowing how to violate safely is regarded as a badge of mastery of the activity.

The review begins with an examination of the research evidence supporting model 1 – the classic model which still pervades much thinking in safety management and regulation. This includes clear positive evidence that such a paradigm can work, as proven for a range of simple and easily observed behaviour by the success of behavioural monitoring, based on behaviourist psychological theories. There is a need to define what that range is and what falls outside it. The majority of the literature in this paradigm is concerned with studying the prevalence of, and reasons for, violations. The review presents a table of factors which have been found to increase violation, categorised into factors related to the individual, the activity, the rules and the organisational climate of which the rules form a part.

The review moves on to examine the reasons for dissatisfaction with model 1, which have led to the interest in model 2. These included the fact that not only is rule-following correlated with better safety, but also with worker creativity and participation, implying the need to adapt rules to the diversity of real-life situations. This literature portrays that diversity and unpredictability, particularly in the work of professionals such as pilots, fire-fighters, doctors and other medical staff, maintenance fitters and the like, and the impossibility of devising rules to cope with all eventualities. This places the emphasis on learned competence and the ability to devise and adapt generic rules to specific situations and to know when and how to 'violate'. This literature demonstrates the gap between work as envisaged by the rule-makers (designers, managers, subject experts) and work as experienced by those on the frontline.

The review continues with an exploration of the more sociological and ethnographic literature underpinning model 2. This portrays the process of development of the tacit knowledge of experts as a learning of mastery and explains why imposed rules are resented by such experts as meddling with their competence. It also shows that, if this knowledge stays tacit, there is no clear basis for the necessary critical review which can counteract the weaknesses which still lead, at times, to an erosion of competence, including the normalisation of deviance which can lead to disastrous failures. The review also describes the clashes between different groups in the same work environment who hold model 1 (nurses, midwives, hospital managers, technicians, railway signallers) as opposed to model 2 views (doctors, surgeons, shunters, pilots, air traffic controllers). The sociological literature is linked closely to the study of 'routines' in organisational science and the notions of sense-making in the literature on high-reliability organisations, which show parallel findings.

The final part of the review attempts to reconcile the two paradigms and draw the strengths from both. From model 1 we draw the need for an explicit process of development, management and use of the rules, open to audit and the need, in some cases, for strictly imposed 'golden rules' that should never be violated. From model 2 we draw the need for extensive initiative and participation of the eventual rule users in rule-making, monitoring and modification, and the need for the type and formulation of the rules to be calibrated with the discretionary competence and trustworthiness of the rule users. This section of the review presents a nine-step framework of rule management and use to describe the whole process of rule design, implementation, use, monitoring and improvement. It proposes to place explicit rule monitoring and adaptation as central to an interactive dialogue between the frontline and the management hierarchy. This guarantees that tacit knowledge is made explicit and can be scrutinised and kept up to date. This emphasises the dynamics of rule use and management, and fits with the concept of a safe envelope of operations within which an operator navigates with the help of competence, rules and safety barriers.

The categorisation of rules presented in the first part of the paper is used in the framework to recommend which level of rules to use. This should match the circumstances and capabilities of the rule users, either to have the competence to translate generic goal or process rules to their circumstances, or to need the support of externally devised action rules.

The framework emphasises the need for participation of rule users in rule design and approval, regardless of their level of competence, and advocates the explicit consideration in all cases as to

whether rules and procedures are the most efficacious risk control measure. In the stand-alone 'Notes of guidance', we add, for each step, the good practice from the literature review and the workshops, emphasising that this will be dependent on matching good practice to the characteristics of the rule users and the situations the rules are required to be used in.

1 Introduction

In 2010, Professor Andrew Hale (HASTAM) and Dr David Borys (University of Ballarat in Victoria, Australia) were commissioned to carry out a review of the scientific literature on safety rules and procedures and their management. This formed part of the Research and Development funding by IOSH that year. The commission built on the work already done by the researchers into the literature as presented at the Working on Safety Network conference in Røros, Norway in September 2010.

The objective of the project was to review the scientific and professional literature on how safety rules and procedures can best be used and managed, to present that review for critical comment by researchers and practitioners, to distil from that some notes of guidance on rule management. and to develop a skeleton intervention plan to take a company interested in improving its management of rules through a critical assessment and improvement process. The term 'safety rules' is used here in its widest sense. These are all rules that have the objective, among others, to keep the rule user – or others affected by their actions – safe from risks of injury or damage. Many rules have objectives additional to safety, or even more important than safety. These may be objectives directed at production, efficiency, quality, health, environmental control or sustainability. We focus in this review on their safety objectives, but recognise the need to integrate them into rule sets based on the organisation's processes and activities, rather than separating out those safety aspects.[1]

This report describes how the project was carried out and the deliverables were constructed. The main outputs of the project were:

1 a scientific review of the literature, in a format suitable for publication in the scientific literature, for use by researchers and practitioners at the forefront of safety management
2 stand-alone 'Notes of guidance' on good practice in the management of safety rules, for use by practitioners
3 an outline intervention plan for critically reviewing and improving rule management, for use by consultants.

The main body of this report is the literature review. The 'Notes of guidance' and the intervention plan are given in a separate document. In addition, a chapter was prepared for publication in a book edited by Mathilde Bourrier and Corinne Bieder, based on the deliberations at a New Technology and Work Workshop entitled 'How desirable and avoidable is proceduralization of safety?', which was held in Sorèze, near Toulouse, in December 2010.

2 Methodology

Review of the literature

The literature search was carried out using the following search terms, individually and in all relevant combinations, going back to 1986: adapt*, bend, break*, compliance, control, decision making, exception, flexible, gap, follow*, management, paperwork, practice, prescript*, procedure, risk, routine, rule, safety, sharp-end, standardise*, standardize*, trust, uncertain*, unplan*, unexpect*, violation.

The databases searched were:

- Google Scholar
- Metalib (multiple databases covering sociology, psychology, the humanities, human behaviour, multidisciplinary subjects)
- OHS Update, including the following databases: BSI Standards, CISDOC, CCOHS, EU Legislation, European Agency for Safety and Health, HSELINE, ILO, International Bibliographic (Sheila Pantry), Irish HSA, Irish Legislation, IRSST, NSAI, NIOSHTIC and NIOSHTIC-2, RILOSH, RoSPA, UK Legislation, Emerald, Springerlink, individual safety journal index searches (eg *Safety Science*, *Reliability Engineering & System Safety*, *Journal of Risk Research*).

The use of this strategy and the follow-up of references listed in the bibliographies of the most relevant papers produced a list of 301 references for further scrutiny. Since the scope of the review paper was focused on the management of rules for 'frontline' operations controlling risks directly, 28 references, which dealt with rule-making at the level of the regulator wishing to control the behaviour of organisations, were eliminated. A small number of very good reviews of parts of the literature were found that had extensive references. Using these papers as meta-references enabled us to reduce the attention needed to a number of their primary source papers. This reduced the number of papers to be read in detail by a further 46. Of the remaining 229 papers, a further 49 were found to be of marginal or no value for understanding the rule management process, leaving 180 papers which were studied in detail.

In arriving at this figure, we paid attention not only to the very small number of papers evaluating the effectiveness of rules in terms of their quantitative effect in reducing accidents and incidents, but also studied papers giving theoretical approaches to the field and papers using much more qualitative methods to review the processes of rule-making, the attitudes of users to rules and the problems arising in rule compliance.

An early version of the review paper formed the basis for a presentation and discussion at the International Conference of the Working on Safety Network in Røros, Norway, in September 2010. A later version was presented at the New Technology and Work Network Workshop in Sorèze, near Toulouse, France. This workshop discussed the limits of proceduralisation in safety. Discussions of our paper and those of the other participants added richness to the paper, which was revised in the light of new insights.

Notes of guidance

On 29 March 2011, a workshop attended by senior practitioners in the safety field was held in Derby, UK to discuss the findings of the review. Nineteen people signed up for the workshop, but only 17 were present on the day, supplemented by the researchers and six colleagues from HASTAM acting as discussion leaders and rapporteurs. The practitioners, who were invited personally from the contact network of HASTAM and the researchers, represented a range of industries, including energy, water, transport, hospitals, manufacturing, universities and aerospace. The review paper and a précis of it were circulated in advance and participants were asked to come along with questions and their experiences of the pitfalls and solutions for managing safety rules.

The workshop was organised into three rounds of discussion, preceded by presentations focusing on different aspects of the rule management process and questions arising from it. The discussion sessions were recorded and summarised by a rapporteur. The sessions provided an essential input into the development of the 'Notes of guidance'.

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* The terms marked with an asterisk denote root words on which searches were based. Thus, 'adapt*' indicates that searches were also carried out for 'adapts', 'adapting', 'adapted', 'adaptation' and so on.

The 'Notes of guidance' take the structure of the management process of modifying, improving and implementing rules, and indicate a number of good practices under the headings of each step. The structure was derived from work done for the European railways in the SAMRAIL project, adapted and enriched by the critical review and the workshop. The description of the rule management process is preceded by a set of principles governing the development and use of rules. The 'Notes of guidance' are intended to be useable on their own without having to read the full literature review.

The draft 'Notes of guidance' were sent out to all of the participants in the workshop and a few other senior practitioners for information, as feedback for them on the workshop, and for comment and suggestions for improvement. These were incorporated in the final version and are contained in the 'Notes of guidance'.

Intervention plan

The final deliverable is a skeleton intervention plan setting out the steps which might be pursued in helping an organisation or a site to review its current management of safety rules and procedures in a critical way, to consider the lessons from the review of literature and the 'Notes of guidance', and to improve the way it deals with rules and procedures. This intervention plan can be used by consultants as a basis to assist such a critical review or benchmarking. It has been appended to the 'Notes of guidance'.

3 Review of the literature: working to rule, or working safely?

Introduction

Throughout this literature review, we use the term 'safety rules and procedures' to mean any rule or procedure that impinges on safety, directly or indirectly. Some rules are almost exclusively directed at safety (eg those rules requiring the use of personal protective equipment), but many have other primary or subsidiary objectives related to quality, productivity, health, environmental control, sustainability, as well as safety. With the focus of the review on safety, we do not wish to imply that there should be a separate set of safety rules, either physically or conceptually, isolated from the rules for conducting all other actions necessary to achieve an organisation's multiple objectives. The experience of many organisations[1] has shown that integration of all the rules directed at all of the objectives of a given activity, in other words a rule set matched to the organisation's processes, results in a rule set that is far smaller and more efficient than one divided by objective. Hence, in what follows, the reader should always have this broad canvas in their mind's eye.

The Janus faces of rules

Safety rules and procedures are presented in many publications on safety management as one of the cornerstones of the risk control system. They are seen as the translation into specific detail of the top management commitment set out in the safety policy. So obvious is their importance felt to be that they sometimes receive only a passing mention as something uncontroversial. Procedures form part of the written documentation required under OHSAS 18001. In the OHSAS 18002:2008 guidance to the 18001 Standard for Occupational Health and Safety Management Systems,[2] 'procedure' is defined as a 'specified way to carry out an activity or process'. The guidance uses the word 'procedures' frequently to talk both about directing and controlling the safety of the primary processes of the organisation and to specify the activities of the safety management system (SMS) itself (hazard identification, risk assessment, communication, participation, monitoring/auditing, emergency response and so on). SMSs such as ISRS,[3] TRIPOD,[4] ARAMIS[5] and Hearts and Minds[6] identify the management of procedures, or their failure, as one of their principal elements. Procedures are seen to be essential[6] because jobs are too complex for people to remember the steps, or to work them out in time, especially in emergency situations, because transparency of behaviour is needed to monitor and check it, to standardise tasks involving several actors, and to provide organisational memory of the way processes work.

The literature on safety climate and culture also identifies rules and procedures, and the workforce's attitudes to them, as key elements of safety climate/culture and perceptions.[7–16] Some studies, such as that by O'Dea & Flin[17] among offshore installations managers in the British North Sea, show the 'failure to follow rules' as the third most important perceived cause of accidents, after 'not thinking the job through' and 'carelessness'. The plethora of legal rules and procedures surrounding health and safety, either in the form of high-level objectives, procedural requirements or detailed action rules,[18] is seen as further proof of the need to define and document the way in which safety, and compliance with these regulatory rules, is to be achieved.

Reports of accidents such as Challenger[19] point to the normalisation of deviance from rules as a primary cause of such accidents, while the enquiry into the *Deepwater Horizon* disaster[20] castigates the company and the regulator for not having explicit procedures to govern changes to the well-drilling, -capping and -testing methods used in that case. A Dutch study[21] analysing incidents of loss of containment in the chemical process industry found that 50 per cent of cases related to procedures – 10 per cent where there were no or unclear procedures; 12 per cent where the procedure was wrong; and 28 per cent where the correct procedure was not followed.

In this view, rules and procedures are seen as largely desirable and certainly unavoidable to allocate responsibility (and later to apportion blame in many cultures and organisations), and to define and guide behaviour in complex and often conflicting environments and processes.

Behind this logical, rational obviousness, however, there lies another 'truth' about the reality of safety rules and their use. In his seminal study of safety rules in the Dutch railways, Elling[22] showed that only 3 per cent of workers surveyed used the rules often, and almost 50 per cent never. Moreover, 47 per cent of workers found rules to be not always realistic; 29 per cent thought they were used only to point the finger of blame; 95 per cent thought that, if you kept to the rules, the work could never be

completed in time; 79 per cent that there were too many rules; 70 per cent that they were too complicated; and 77 per cent that they were sometimes contradictory. Studies by DuPont for British Rail[23] showed similar problems in the UK. Elling[22] and others[24,25] argue that there are already too many rules in most complex technologies and no more are needed to make them safer.

In a survey by Embrey[26] of 400 operators and managers in the chemical industry, the reasons respondents gave for not using procedures included:

- they were unworkable in practice (40 per cent of respondents)
- if they were followed to the letter, the job could not get done in time (62 per cent)
- they were too restrictive (48 per cent)
- they were too time-consuming (44 per cent).

From the same survey, 57 per cent of respondents thought that people were not aware that there were procedures laid down for the job they did; 70 per cent expressed the view that people assume they know what is included in a procedure; 70 per cent prefer to rely on their own skills and experience; 19 per cent thought that experienced people do not need procedures; while 34 per cent resented being told how to do their job and saw rules as a restriction on their freedom of choice and a slur on their competence.

Similar attitudes have been found in a number of subsequent studies.[27–33] The CIRAS report[33] also indicates that the category 'breaches of rules' seems to be increasing as a proportion of types of confidential report from the rail industry in the UK, with 51 per cent on average being intentional violations of rules (100 per cent of those concerning subcontractors) and 31 per cent ignoring best practice in favour of their own methods. The expansion of rule books and procedural manuals, risk analyses and audits, planning, monitoring and reporting tasks and documents has also been linked to a significant shift of time spent by managers from hands-on leadership to dealing with paperwork, to the detriment of interaction, supervision, adaptation and learning,[34] a shift which the authors see as damaging to safety awareness and performance.

These Janus faces of safety rules led Dekker[35] to postulate that there are two contrasting models of safety rules, what their function is, how they emerge, and how they should be managed. One is a top–down, rational, optimistic view of rules, as outlined above; the other is a constructivist view of how rules operate, which turns the dark side revealed in Elling's study and its later counterparts on its head and proposes a bottom–up, participative approach to rule emergence to avoid such negative attitudes. The second approach sees procedures as supports, not strait jackets, as tools to co-ordinate and structure creativity and innovation, not as controls to limit freedom.

Dekker presents these 'model 1' and 'model 2' approaches as conflicting and seems to imply that we have to choose between them. In this paper we want to explore the support for this dichotomy in the diverse literature on safety rules and procedures and their management, and assess whether they are indeed alternatives, perhaps even two steps in a progression to maturity of the rule management system, or whether there is a compromise to be struck between them which draws the positive aspects from both models and can lead us towards the definition of more generic best practice on the management of safety rules and procedures. However, before we present the two models in detail, we wish to introduce two notions which we will draw on in the paper. The first, based on the ideas of Rasmussen,[36] clarifies the role of safety rules in a dynamic system; the second offers a hierarchical classification of (safety) rules[18] based on how generic their formulation is.

Safe envelope of operations: the objective of rules

Rasmussen[36] introduced the valuable (if abstract) notion of a 'drift to danger', whereby an SMS establishes a safe zone of operation, guarded by risk controls. However, the operation of the activity is subject to pressures from competition, the market and regulation, individual and group/organisational motivations for less effort and so on, which push it towards the boundaries of 'the safe zone' and may push it over into the uncharted waters outside it, which bring it closer to 'the edge', where damage and injury begin to occur (see also Snook[37]). Reason *et al.*,[38] Leplat,[39] Amalberti *et al.*[40] and Howell *et al.*[41] used the concept to describe the objective of safety rules, acting as beacons that define the boundary of the safe zone. Hale *et al.*[42] and van der Top[43] developed the notion more explicitly at an operational level to describe the task of railway staff (especially drivers and train controllers). They explicitly distinguished a relatively narrow zone, defined by the organisation (either in combination with the workforce or imposed by management) as being the required safe operating zone (SOZ), usually defined by rules and well within the viable boundary, outside of which damage

begins (giving a safety margin to operations). Between the two lies a 'controllability' boundary, within which the system controller being modelled can still recover and return the system within the SOZ. Between the controllability boundary and the viable boundary, only interventions from other actors (if warned in a timely way), or chance, can prevent the system going over the viable boundary and producing harm. These zones also define the types and functions of rules – for defining the control measures to be taken to navigate within the boundaries, to avoid going over the boundary (itself defined by rules), and to recover under emergency conditions from a position outside the boundaries. These categories also define the frequency with which, and the time pressures under which, the rules will be used. Also, Schelling[44] talks of devising graded rules, so that a breach of one warns of approach to the boundary, but does not involve crossing it.

Making the boundary of safe operations visible is desirable in theory but is problematic in practice. The 'rule of three'[45] is one example from the offshore oil and gas industry where the boundary of safe operations becomes visible through enhancing decision-makers' situation awareness of a range of work environment and other factors that could push the system across the boundary and into disaster. The 'rule of three'[45] refers to three threshold zones (denoted by a traffic light model – red, amber and green) that denote how close the operation may be to the edge of safety. Each threshold zone has a number of critical dimensions (eg weather) and sub-dimensions (eg rain, wind and lighting). If all of the critical dimensions are green, then operations can proceed normally. However, if only one critical dimension is red, then operations cease. For cases judged to be in the amber zone, the decision to halt operations escalates as the number of critical dimensions judged as amber increases from one to three. In this case, three ambers may also be enough to halt operations. Similarly, some coal mines in Australia use 'trigger action response plans' to help delineate the boundary of safe operations, again in relation to work and environmental factors that could push the system over the edge.[46] Other industries have focused on developing the requisite mental skills to recognise when practice may be operating close to the edge. One example relates to patient safety in the UK healthcare system, where work is underway to develop 'error wisdom' in nurses and junior doctors.[47,48] In the construction industry, a method has been proposed that allows workers to know what zone (safe, hazard, loss of control) they are working in and how close to the edge they are working.[41]

In this formulation, rules have two functions: defining the boundaries of the various zones of normal operations, controllability and viability; and supporting the process of manoeuvring to stay inside those boundaries.

Categorisation of rules

Hale & Swuste[18] introduced a useful distinction between different types of rule, which has been taken up by Blakstad[49] (see also Blakstad *et al.*[50]) and Grote *et al.*[51] in their analysis of rule management in railways (see also Energy Institute[6] and Rasmussen[36]). This distinguishes three types, which differ in the amount of freedom they give to the person following the rule to determine their exact behaviour:

- *Performance goals*, which define only what has to be achieved and not how it must be done. These may be in terms of numerical risk targets (eg risk contours around marshalling yards handling dangerous chemicals; target levels of incidents or accidents) or more qualitative ones, such as 'as low as reasonably practicable', 'of sound construction' and so on. Blakstad *et al.*[50] point out that this type of rule is only feasible if there is feedback of the results of actions, so that their achievement can be made visible. In contrast, the two types below are compatible with feed-forward control.
- *Process rules*, which define the process by which the person or organisation should arrive at the way they will operate, but still leaves considerable freedom about what that operation will be. Rules under this heading include requirements of a process to prepare a risk assessment, either generically or at the last minute before starting work; requirements to set up an SMS, and requirements to consult with defined people when an emergency situation arises in order to decide how to handle it. Both performance goals and process rules need time for them to be translated into specific actions – the more competent and experienced the people using the rules, the less time required.
- *Action rules*, which specify, in terms of 'if... then' statements, exactly how people should behave, or how hardware should be designed or tested (eg wearing a seatbelt when in a moving car, checking that various equipment is working before taking off in an aircraft, counting surgical items before closing an incision and so on).

Hale & Swuste[18] point out that every time a person carries out a sequence of behaviour, we should realise that a translation process has gone on at some point from the appropriate performance goals,

through the process rules, to an action rule for that behaviour at that moment in time. Hence, what is interesting to know, and eventually to specify, is not whether a process or action rule has been specified, but when and by whom each translation takes place. Does the organisation trust or allow each individual operator (fitter, surgeon, pilot, machinist and so on) to take the specified (or agreed) performance goals and translate them appropriately into process and action rules for every eventuality they meet; or does the management (or even the regulator) centrally make the translation at a design stage and hand down to the operators binding specific action rules for all situations they can envisage? For example, does an organisation operating on customers' premises instruct its workers simply to operate safely and leave it to their competence to decide on their detailed actions; or does it require them to go through a last-minute risk analysis, either documented or not (a process rule) before starting on any job, or insist that they carry out certain actions, such as the wearing of standard PPE, no matter what the task (an action rule)? The choice of which type of rule to use determines whether the organisation's experts or its field staff will carry out the translation from goal to process to action. Decentralising rule-making requires that translation be done at lower levels in the hierarchy, a process which we can truly call self-regulation. It should and cannot be deregulation, where nobody at the lower level makes the translation.

Grote *et al.*[51] point out that process rules in particular offer a compromise between standardisation and flexibility, which is one of the dilemmas in dealing with diversity and the need for either problem solving to arrive at new ways to meet overarching goals, or adapting more specific action rules to make them fit exceptional circumstances.

This classification has some similarities to that used in the US nuclear industry,[52] where procedures were classified as either 'step-by-step adherence' (action rules) or 'general intent adherence', allowing some deviation at the discretion of the operator, or 'information use', permitting more latitude to achieve the same goal. These and other related categorisations also specified whether active checking of the written rule or reliance on memory was needed, and whether self-checking or checking by an external person was required.

Structure of the paper

We will focus this paper on the use of rules and procedures for those working in the primary processes of hazardous technologies – machine operators, fitters, pilots, surgeons, nurses, anaesthetists and so on. We will only touch on the value and management of rules and procedures at the level of the SMS, or the rules of the regulator imposed on that level. We believe that there may be interesting parallels to draw with these levels and refer the reader to a number of papers listed at the end of this document. The question of writing rules for safety culture was discussed in detail at a workshop run by the New Technology and Work Network in December 2010 (eg Grote,[53] LeCoze & Wiig[54] and Kringen[55]). The consensus there was that regulatory rules for such a subject, which is still so vaguely defined and where there is still not sufficient consensus over good practice, would be premature, except perhaps at the goal level of 'addressing the development and embedding of a culture of safety'.

The paper begins with a section specifying what the two models are, followed by a section on what the support for each model is and what the strengths and weaknesses of rules devised under each model can be. This section draws out a set of underlying issues and influences which need to be dealt with in arriving at a good rule management process. In the final part of the paper, we use a framework devised in an earlier study of rule and procedure management in the chemical and rail industries (Hale *et al.*,[56] Hale & Guldenmund[5] and Larsen *et al.*[57]) to summarise the conclusions which can be drawn about good rule management in general and the relationship between models 1 and 2 in particular.

Contrasting models of (safety) rules*

Dekker[35] was the first to formulate the two models of safety rules in explicit terms, calling them 'model 1' and 'model 2'. However, there is a wide range of earlier literature, which we will analyse, that points to this dichotomy of thinking about rules, deriving from different theoretical traditions and evidence bases. The models Dekker derives are models in the sense of mental representations, ie ways of thinking about rules and explaining how they arrive, or are arrived at; what their function is;

* From this point on, we generally use the words 'rules' and 'procedures' interchangeably to talk generically about the portmanteau of specified goals, procedures and action rules which form the complex of means to specify ways of carrying out activities and processes.

what the drawbacks and problems there are in their use; and what their strengths and limitations are. We draw, in the short sections below, a brief and somewhat stylised sketch of each model before going into the literature that we have used to derive that sketch.

Model 1

This model is rooted in 'scientific management'.[58,59] It is rationalist and prescriptive in its approach, and appeals to engineering concepts and truths. It sees rules, particularly action rules, as the embodiment of the single best way to carry out activities, covering all known contingencies. Rules are devised by experts to guard against the errors and mistakes of fallible human operators at the sharp end, who are more limited than the experts in their competence and experience, and/or in the time necessary, in the heat of operations, to work out the best way to do things. Rules should be derived and devised in advance, based on task and risk analysis. Once devised, they are 'carved in stone', communicated to, and imposed on, the operators or workforce by management (their elders and betters), to be enforced by suitable means to overcome the fallible human tendency to make errors and deviate from the rules, either intentionally or unintentionally. Violations (intentional deviations) and errors (unintentional deviations) are seen as essentially negative actions made with free choice, often by so-called 'elitists' ('who think they know better'), and, at best, as actions to be understood, countered and suppressed. The rules are seen as essentially static, to be worked out as a one-off exercise and only to be modified when the activity changes substantially, which is imagined to be not often. They are to be documented in manuals, or more recently in databases, made available to the workforce, incorporated in training and signed for to signify intent to comply. Their image is essentially top–down, applying to the operational workforce and only relevant to the management in their role as enforcers (though Martin[29] shows that managers are just as fervent violators of rules as the workforce). The dark side of this model is the widespread deviation from rules found in practice and the concern to understand why rules are violated and what can be done to remedy this.

This is the model which is triggered by the media response to major accidents, in which violations of rules which contributed to the accident are identified, and more stringent or more extensive rules are called for to prevent recurrence. It is also the model that powers much of behavioural-based safety (eg Krause *et al.*[60] and Keil Centre[61]) as a set of tools to achieve workforce compliance. The quality management and auditing industry[26,62] fits largely into this model, with its emphasis on the scrutiny of written documentation and detection of non-compliance, as does the work of the regulator checking on legal compliance. Both auditor and regulator emphasise the essentially written nature of safety rules. It is also the dominant view of rules, at least in high-risk organisations, as shown in a study by Bax *et al.*,[28] who found that 72 per cent of a representative sample of Dutch workers in such work settings worked in organisations with (many) formal rules, with half of the organisations having regular or frequent formal controls of those rules.

This is in some ways a caricature of the model, and there have been many attempts to file down its sharper edges, which we shall discuss below. It is also undeniable that this model has led to many improvements in safety, the achievements of behavioural based safety, under it different titles, being among the most significant and best documented (eg Laitinen & Ruohomäki[63]).

Model 2

This model, which has emerged from sociological and ethnographic studies – particularly of high-technology and complex industries, such as aviation and healthcare – sees rules (in the organisational literature, often called 'routines') as patterns of behaviour, socially constructed, emerging from experience with actions and activities by those carrying them out. They are characterised as local and situated in the specific activity, in contrast to the written rules, which are seen as being at a generic level, necessarily abstracted from the detailed situation in order to be able to generalise them across essentially disparate local situations. This view of rules is essentially bottom–up and dynamic. It recognises that rules can never be complete and the written ones are seen as essentially underspecified, requiring a process of translation and adaptation before application to any given, specific situation. This implies that written rules should not be at the detailed, action level but, at most, at the process rule level.

The real experts in this conceptualisation are the operators (pilots, surgeons, maintenance fitters, seamen), whose ability to conduct and navigate this dynamic process of negotiation and construction of rules is seen as an essential part of their skill and identity. There can be a great resistance if attempts are made to impose rules from outside of this operational group, resulting in continued use of the informal, group rules, which are seen as violations by those on the outside, but as skilled adaptations by those on the inside. Rules are seen in model 2 as a support and guidance for the expert, as templates and resources for adaptation, but not something requiring strict compliance and no substitute for

competence. This difference is symbolised by re-labelling them 'guidelines' instead of 'rules' or 'protocols',[59] or reframing rules as 'resources for action'.[64] However, even in this model they may be seen as more binding on the novice. 'Violation' is therefore seen as essential in specific cases where the rule does not match the reality, and is otherwise shunned as a pejorative term to demonise unsuccessful innovation and adaptation. Discovering what the rules are is a process of laying bare explicit knowledge of activity analysis,[59] not task analysis. More recently, Wright & McCarthy[65] have argued, based on their work in commercial aviation, that it is through the processes of the construction of meaning and sense-making in specific situations that operators make procedures work. Therefore, effort needs to be focused on incorporating operators' experience into rule design.

The main support for this model comes from sociological (eg Mascini[66] and Mascini & Bacharias[67]), ethnographic (eg Knudsen[68]) and organisational studies (eg Zoller[69] and McDonald *et al.*[70,71]) of the reality of the use of rules in organisations and the gap between that reality and the rules written to guide and control it.[72] Again, this is somewhat of a caricature of the model, but it is clear that its main thrust is to differentiate the written from the acted rules in much the same way that Argyris & Schön[73] distinguish 'espoused theory' from 'theory-in-use'. It is this gap between rules and reality which is seen as 'causing' or explaining the apparent deviations and violations. In that sense, model 2 starts from the realities of actions and considers (written) rules as inductions and abstractions, while model 1 starts from the written rules and deduces from them that actions are compliances or violations.

We turn now to a summary of the research findings from the two traditions, to identify the strengths and weaknesses of each.

Research evidence

Model 1

Much of the research inspired by model 1 has been aimed at trying to understand, explain and counteract violations from imposed or agreed rules, which are themselves seen as the 'gold standard' of correct behaviour. The large literature on behaviour-based safety (BBS), behavioural monitoring or other similar terms fits classically under this heading and dates from pioneering work by Komaki *et al.*[74] We do not have the space to review it in detail here, besides which there are excellent reviews available (eg McAfee & Winn,[75] Geller,[76] Krause *et al.*,[60] De Pasquale & Geller,[77] Boyce & Geller,[78] Keil Centre[61] and DeJoy[79]). However, its findings are very clear. If simple and observable safety rules or critical behaviours are defined, schedules of observation set up and feedback given about the percentage compliance against targets which have been set, there is usually a very significant rise in compliance with the rules over time, typically ranging from 26 per cent to 69 per cent[60] over one to five years. Compliance declines again if feedback is reduced or discontinued. Feedback is more influential than simple training[80] and is enhanced if there is direct dialogue between the observer and the observed about the feedback.[81] This approach has its roots in classical behaviourism, which associates learning and change with feedback and reward or punishment of behaviour. Its success as an approach has unequivocally been demonstrated by the literature, though it is possible to question how it needs to be adapted to fit different national, regional or professional cultures with different views of hierarchy.

Rigid rules defined either centrally, or with discussion with those subject to them, are therefore still very popular. For example, Shell, which has pioneered many new approaches to safety culture and management – such as TRIPOD[4] and 'Hearts and Minds'[82] – has recently developed a set of 12 'life-saving rules' at the action rules level that are strictly enforced[83] (see also Energy Institute[6]). A breach of a rule results in a default decision of dismissal, unless convincing mitigating conditions can be marshalled in defence of the violation. The rules apply both to the workforce and (importantly) to managers, and have resulted in the use of those extreme sanctions. The rules are chosen as having as few as possible valid exceptions and cover topics such as smoking, seatbelts, gas tests, work permits, fall protection at height, speed limits and journey management plans. It will be interesting to see if such a policy is successful and does not prompt concealment of breaches of the rules to avoid such seemingly draconian punishments.

Reasons for violations

Reasons for violations of safety rules have been studied in a range of papers.[24,29–32,38,66,84–102] The results can be summarised under the headings used by Alper & Karsh[101] for their review – see Table 1, which also incorporates findings from papers which were not reviewed by Alper & Karsh. The list is phrased to show what is positively correlated with violations.

Most entries are self-explanatory, but a few need clarification. Self-efficacy[96] or powerfulness[92] refers to the feeling that a person has the skill to violate rules without reaping the consequences that a less

competent or expert person would incur. It matches the similarly worded factor under organisation climate, where that has become a group norm. Hudson *et al.*[92] also make a classification of those feeling comfortable with violation as 'wolves', and those not as 'sheep' and relates this to the actual violations in a study in the offshore oil industry. They found that:

- 22 per cent of the workforce were not inclined to violate and had not done so (sheep in sheep's clothing)
- 30 per cent were inclined to and had already done so (wolves in wolves' clothing)
- 14 per cent were not inclined to but had (in their eyes exceptionally) done so (sheep in wolves' clothing)
- 34 per cent were comfortable with violation but had not (yet) had occasion to (wolves in sheep's clothing).

Hudson *et al.*[92] advocate (see also Energy Institute[6]) keeping the wolves at bay by involving them in planning and communication and the rewriting of procedures they are tempted to violate, and measures to provide explicit authorisation to deviate that keeps management and supervisors in the loop. For the sheep, who tend to follow rules even unthinkingly, they advocate a high quality of procedure, so that this unthinkingness does not lead them into error.

Alper & Karsh[101] indicate that violation becomes necessary if the rule in existence does not cover the situation facing the person, or would result in harm if followed. However, they remark that, in all 13 empirical studies they reviewed in detail, and the 30 additional ones they comment on more superficially, violations were seen as exclusively negative. They also report that, in driving tasks, there is a correlation between reported violations and accident involvement,[103] confirming the negative view of violations. However, there is no proof of a similar relationship for work-related violations.

Individual factors	Organisational or safety climate factors
• Attitude to and habits of non-compliance • Intention to comply/violate • Previous accident involvement • Low level of knowledge/training/ experience • Sees way to make short cuts • High value on macho, exciting, quick, money- or energy-saving way to work • Self-image and status among peers favours risk and violation • Tiredness • Perceived low risk/threat/consequence • High self-efficacy/powerfulness • Does things on the fly/lack of planning ○ Sex (males in driving, not in other arenas) ○ Age (young in driving, not in other arenas) * Exposure time * Communication	• Management turns a blind eye or is inconsistent in sanctioning • Poor supervisor–worker co-operation • Non-participative style of supervision • Poor (work) group cohesion • Not checking procedures • Site organisation failures • Conflicts between trades • Norm that: 'A skilled person can violate this way with impunity' • Time pressure • Conflicting demands, especially in relation to productivity • Subjective group norm to violate • Lack of trust ○ Workload and work pressure ○ Management commitment ○ Supervisory position * Participation in safety programme * Incentive pay vs. fixed hour rate
Hardware/activity factors	**Rule-related factors**
• Unfamiliarity with design • Complicated, difficult or changed design • Design/layout makes violation necessary to achieve objectives • Use of incorrect materials • Compensate for poor equipment	• Difficult to understand • Difficult to comply/work with • Violation needed to get job done • Outdated rule • Conflicting rules, no priorities given • Rule seen as not appropriate for the organisation/activity (rule-maker has no knowledge of reality of activity) • Too many rules

Table 1
Factors tested for their relationship to the tendency to violate

• = factors that were correlated; ○ = factors that were tested but found to be unrelated; * = conflicting findings from different studies.

The four topics found to be relevant can be summarised as follows:

1 Individual characteristics are often relatively stable personality traits. These are linked to issues of (over-)confidence, risk perception, poor planning, and the effect of a risk-taking culture.
2 Organisational factors refer to a laissez-faire attitude in an organisation, coupled with a lack of monitoring or indeed an active acceptance of rule breaches. This may be accompanied by conflicting goals and a non-participative style of culture and leadership.
3 Hardware factors centring on poor ergonomic design.
4 Rule-related factors centring on poorly designed, outdated and conflicting rules.

A commonly used classification system for violations is that based on Reason's[104] work, further developed by the work of Free[105] (see also HFRG[88]). This classifies violations into four categories and implies different causal patterns for each, picking up some of the factors mentioned in Table 1:

1 Routine violations, which have become normal and accepted ways of behaving by the person's peer group (and often their supervisors), linked to rules perceived as overly restrictive or outdated, and where (management) monitoring or discipline is lacking.
2 Situational violations, in response to specific situations where the rule does not appear to work or be relevant, 'winked at' by supervisors in the name of production.
3 Exceptional violations often to situations never before encountered, where the consequences of the violation may not be thought through and may be very serious. These appear to be a special category of type 2.
4 Optimising violations, done to solve trade-offs of safety with other objectives (boredom, production pressure, effort and so on), or to explore the boundaries of system operation and find new solutions to these trade-offs.

While this adds some useful notions to model 1, particularly in distinguishing routine violations from the other three categories, it does not incorporate or clarify all of the issues addressed in Table 1.

Organisational complicity

Mascini[66] charts the self-perpetuating cycle of violation characterised by the existence of rules which are hard to follow if production is to be achieved and are seen as simply covering the backs of management in case something goes wrong; this engenders, at worst, the enticement by supervisors of workers to breach the rules to achieve production, or at least turning a blind eye to violations (see also HFRG[88]), often accompanied by a breach by the supervisors themselves of the same rules if the enticement fails, which, in turn contributes to the reluctance by those supervisors to report or discipline violations by others of rules they also violate. The upshot is a conspiratorial silence about poor rules. Iszatt-White[96] calls such double binds the 'gambits of compliance'.

In an interview-based study of mining, Peters[85] shows that supervisors and their attitudes are a key stumbling block in disciplining violators. They were very reluctant to report to higher levels of management those miners who violated the rule not to venture under unsupported roofs in the mine, at least the first time it happened (86 per cent would confine their action to a verbal warning and 'bawling out at their level', a reaction firmly agreed by the miners). For a second offence in a short time, 83 per cent of supervisors said they would report the offender to higher management for sanctions; 70 per cent of miners agreed, but only 53 per cent of miners believed the supervisor would actually do so. The reasons given by the majority of the supervisors for not wanting to report violators were remarkably similar to some of the factors in Table 1: too busy with production, breaking the rule themselves (and therefore having a double standard), considering the danger slight, or being afraid of a hostile reaction from the miner or the trades union. A minority also pointed to a lack of higher management support, miners who do not take any notice of reprimands, and a feeling that it was not their job to enforce rules but the individual miner's responsibility. These double standards of supervisors, and also of teachers in a study of rule violation in school sport,[106] point to the pervasive 'conspiracy' of violation throughout a culture. On the other side of the coin, Simard & Marchand[107] show, in a modelling study looking at the macro- and micro-organisational correlates of compliance with rules, that a high quality of worker–supervisor co-operation is the biggest predictor of rule compliance (see also Hofmann & Morgeson[108]), followed by the use of a participative style of supervision and high group cohesion. They enter the caveat that this positive relationship will only be found provided that the pervasive norms in the organisation favour safety; otherwise, those good leader–group member relations can just as effectively convey the message that violation is accepted.

Behavioural economics

Another research tradition which fits with model 1 is that of behavioural economics (eg Battmann & Klumb[86]). This sees the violation of rules as a cost–benefit trade-off for the worker (or manager), which handles many of the factors in Table 1 and optimises them with safety as a trade-off of behavioural efficiency that is learned over a number of experiences or trials. They see the formulation of desired behaviours as rules that provide a forcing function which introduces added cost for their violation *per se* (punishment, loss of face and so on), over and above the injury cost in the percentage of cases where that does follow breach of the rule, and so tries to tip the balance towards safe behaviour. Based on this theory they advocate scrapping all rules where violation costs are low. They also warn against the skewed trade-off of short-term productivity gain for long-term safety loss (see also Polet *et al.*[109] in relation to rules about designed barriers on machinery & Iszatt-White[96] on road maintenance teams). This implies that long-term costs such as injuries are discounted at a high rate compared to short-term gains. Åberg[89] also adopts a cost–benefit approach and sees the definition and enforcement of rules as adding costs of non-compliance to the already present benefits safety of the rules he assesses (seatbelt use, speed limits and prohibition of drunk driving). His figures show the major improvement to compliance when the legal rules are backed by well-organised, conspicuous police enforcement. He too advocates only keeping rules which are enforceable. In addition, he points to anomalies in the subjective acceptance of rules, eg speeding reduction would objectively have far more effect on safety than further reductions in alcohol in blood levels, yet public acceptance of tightening of the two types of rule would favour tighter alcohol limits.

The work of Drach-Zahavy & Somech[102] revealed the qualitative trade-offs people made in deciding whether to comply with safety procedures. These included their need to demonstrate care and concern for their patients, causing them not to want to wear PPE against infections for fear of the patients sensing revulsion, and a neglect of their own safety when it clashed with that of their patients, or the speed they needed to show in responding to patient emergencies. Other factors weighing against their own safety were a desire not to disturb colleagues in their work to come and help, eg to lift a heavy patient. There were also effects of the recency of particular accident types, or publicised exposures, weighting the nurses in favour of the relevant safety procedures. Finally, the presence of a head nurse (supervisor) or trainee nurse (triggering an extra sense of responsibility) increased the likelihood of following safety rules. Such studies link to the extensive literature exploring the theory of planned behaviour.[110]

Conclusion on model 1

Hopkins[111] seems to advocate model 1 when he argues that frontline workers, particularly in tightly coupled technologies, should comply as strictly as possible with (good) rules to prevent them from indulging in casual non-compliance or risk-taking. He seems to consider that risk assessment is not for them to indulge in. If they meet a rule that cannot be complied with, they should appeal to management to authorise a work-around rather than devising one themselves (see also Bourrier[112]). He does recognise that rules can never be complete and compliance should never be blind, but sees the solution in a modification to model 1, not its scrapping.

We could see this multitude of factors leading to violation as either a set of potentially correctable problems with the details of model 1, or as indications that there is a paradigm shift necessary (in this case to model 2), because model 1 cannot be amended to cope with this weight of problems. In terms of the gap between rules and reality,[35] model 1 sees the solution in modifying reality to match the rules, while model 2 advocates changing the rules and their definition fundamentally to match reality. We look first at the papers making this fundamental shift towards model 2, and then discuss the other research traditions which have produced model 2. In the final part of the paper we return to the question of 'repairing or replacing' model 1.

Contrasting model 1 with model 2

In a study of 898 workers from manufacturing firms drawn from different technologies, hazard ratings and accident rates, Marchand *et al.*,[113] working from a social psychological paradigm of model building, demonstrated that it was not only the score on the scales measuring compliance with rules that was predictive of the accident rate. There was also a strong correlation with a scale measuring worker initiatives in safety. This led them to postulate a bi-dimensional relationship in which workers were not simply seen as dumb robots forced to comply with rules imposed on them, but were also playing an active part in formulating and changing those rules, reporting hazards and being involved in problem solving to remove them (see also Clarke[114]). This is already a step towards model 2.

Iszatt-White,[96] reporting an ethnographic study of road maintenance gangs, pointed to the limitation of imposed rules as ways of controlling two types of risk in particular. The first was related to rules controlling long-term health risks, such as noise and vibration. These could be analysed using model 1. It fits the trade-off of the short-term costs of wearing personal protective equipment (PPE), combined with the short-term benefits of getting the job done, against the long-term and often unclear or unacknowledged risks of deafness and vibration-induced white finger. However, the second type – those from motorists crashing into the cordoned-off work area or knocking down workers crossing lanes of traffic to put up warning signs, which were also supposed to be governed by written rules – could not be realistically controlled in that way, because the road maintenance company had no real control over the main causal factor, ie the motorists' behaviour. These risks were coped with by what she called 'increased heedfulness' (a term analogous to Weick's 'mindfulness' and even with the term 'safety consciousness', common in the 1970s) – a state of enhanced attention to the risk and local innovation or adaptation to avoid the danger. This leads us further towards model 2.

Loukopoulou[100] contrasts the procedure book's picture of pilots taking off (which is pure model 1, with its apparently linear, predictable, controllable task sequence set out in the training manual), with the reality of a set of tasks that have to be time-shared, displaced, compressed, overlapped or interleaved because of interruptions and delays. Reality is much more diverse than rules give credit for, and all of these changes to the idealised model 1 picture give more opportunities for error and deviation, and make some violations necessary. The inevitability of violations, indeed their positive necessity, in contrast with the negative image of them in model 1, is also emphasised by Besnard & Greathead.[93] They claim, based on an analysis of two major accidents (the Sioux City plane crash in the USA and the Tokai-mura nuclear criticality incident in Japan), that violation coupled with a good mental model is acceptable, if not actually essential, for safety, as shown by the violations which allowed the pilots to land the plane at Sioux City despite a complete loss of hydraulics and the tail engine. Only if violation is coupled with an incorrect mental model, as in Tokai-mura, is it bad for safety. Dekker[35] points out that the negative image linking violations and major accidents is based on fallacious reasoning, which takes no account of the thousands of occasions when violations led to positive outcomes (and were relabelled 'innovations' or 'expertise') rather than to accidents. He also reminds us that a number of very safe, but very complex activities – such as aircraft carrier operation at sea – are not proceduralised in any detail, relying instead on training and competence and highly sophisticated social control, while other major accidents such as Mann Gulch and *Piper Alpha* have shown that it can be those who violate rules who survive such emergencies, while those who obey die.

Polet *et al.*[94] also consider violations to be endemic and trace the way in which rules and procedures devised by designers of machinery (in their case a printing press) become informally modified or deviated from in the process of installation of the equipment and its use, as these circumstances gradually drift away from what the designer envisaged them to be (see also Rasmussen[36] and Hale *et al.*[42] for consideration of this concept of a safe envelope of operation, and Fleury[115] for a treatment of rules across the designer–user interface in road infrastructure design). These include the cleaning of running machinery, the removal of designed physical barriers, and operating outside the defined manning, competence or maintenance regimes. Polet *et al.* label these violations 'borderline tolerated conditions of use', since they are tolerated by supervisors as ways of getting production done more efficiently and quickly, often without negative consequences because of the defence-in-depth from other barriers. They criticise the mental models designers have of operators as inadequate, and hence the rules they define to control that behaviour as also inadequate and optimistic about the rationality of actual operations (see also Perrin[52] and Energy Institute[6]). This point is confirmed by Dien,[116] who found in the nuclear industry that designers saw operators in emergency situations as mechanistic and static in their response, like robots needing to be fed, and to follow step-by-step rules (model 1) without recourse to significant skills or competence in order to control an essentially sequential process of operation or recovery (cf. Loukopoulou[100]). This contrasts with the much more uncertain and chaotic nature of reality. Norros[24] found a similar perceptual and knowledge gap between work planners and those carrying out maintenance work.

The inevitability of violations to get the work done (routine violations in the terms of Reason *et al.*[38]) and the gradual drift this engenders leads to the normalisation of deviance,[19] as all concerned accept the violations informally as normal and permissible, yet without any modification of the formal rules system to reflect and legitimise that drift (see also Snook[37]).

Parker *et al.*,[82] in their formulation of the development of procedures and attitudes to them in Hudson's 'Hearts and Minds' scale of development of the SMS, capture some of the shift from model

1 to model 2. They see procedures in the pathological organisation as devised merely to avoid lawsuits and harm to assets; in the reactive organisation as written to prevent the last accident, without considering the consequences of having to work to them; in the calculative firm as a proliferation of behavioural barriers linked to training; and in the proactive organisation as a vehicle to spread good practice, but with the acknowledgement that a competent workforce can see them as occasionally inconvenient and that limited non-compliance is seen as acceptable. The generative organisation is almost pure model 2, trusting expert operators to challenge procedures where necessary and to refine them for efficiency, using the appropriate channels.

In Table 1 we included the finding from a number of studies that most organisations had too many (safety) rules. This is also repeated in studies derived from the traditions of model 2. The sheer volume of rules in the rule books of complex technologies, such as nuclear and railways, have been shown to be a barrier to their use.[22,–24] Amalberti,[25] in a paper discussing the improvement of technologies that are already ultra-safe, warns of the danger of increasing regulations and procedures beyond a certain point; more rules simply mean more violations and a stultification and suppression of creativity to be able to operate outside the boundary of the envelope defined by safety procedures. Similarly, Katz-Navon *et al.*,[117] in a study of treatment errors in the Israel healthcare industry, found that an increase in procedures was associated with lower safety performance. Fucks & Dien[118] point out that, in the energy generation sector, it is simply impossible to have procedures which deal with anything except average conditions. The range of non-nominal conditions that can occur is so great that thick volumes of procedures would be needed to cover them (and indeed these are sometimes written), making the use of the procedure system impossible.

Weick[119] gives a cogent analysis of the behaviour of fire-fighters in the Mann Gulch and South Canyon fires, which both saw loss of life when the fire-fighters stuck to their rules instead of dropping their tools to aid their escape. He uses this metaphor of 'dropping the tools' to argue for the adaptations and flexibility needed in such conditions to survive, when defined rules are counter-productive. We might take this as a call, as he intends, to consider whether we should drop the tool of model 1 when considering the subject of safety rules and escape to model 2. We return to that in the final part of the paper. However, such an escape is not likely to be easy. In a number of cases, the papers also document the strength of the defences built in to model 1 in resisting such a change.[35,43,49,50,120] Vested interests and the influence of a culture derived ultimately from notions of hierarchical (military) command (in the case of railways and fire-fighting) can frustrate the open discussion of rules and violations. In a similar vein, Wright *et al.*,[64] in discussing the role of procedures on the flight deck, argue that different communities of practice attach different meanings to the role of procedures. For example, where pilots may regard procedures as 'resources for action', regulators may regard them as 'artefacts' of accountability to be wielded after an accident to demonstrate what should have been done. The double-binds mentioned earlier also inhibit those who breach rules, however nonsensical they may privately consider them to be from admitting openly to that, for fear of legal or managerial censure and punishment, particularly when rules are wielded as the aforementioned artefacts of accountability. Without a clear signal that model 1 type rules are not working, there is no pressure to shift paradigms.

Underpinning model 2

A much more detailed critique of model 1 as a basis for defining rules is given in a series of papers dealing with healthcare,[70,71,97–99,121,122] seamanship in the maritime world,[68] aviation (maintenance fitters,[123,124] pilots,[35,125,126] and both groups plus ambulance dispatchers[59]), railways,[49–51,127,128] nuclear power and its emergency procedures,[24,116,129] fire-fighters,[119,120,130] energy companies[67] and other cases.[131–134] These studies have been undertaken partly as a response to the external 'wisdom' that managers from outside/above were planning to impose or had imposed, namely that these activities (particularly healthcare and seamanship) should become more proceduralised[71] and partly in recognition that the current high level of proceduralisation has flaws (aviation – pilots and maintenance fitters) or is hiding a different reality. The papers uniformly advocate a shift from the situation described in model 1 to that in model 2, especially in placing centrally the competence, experience and ability to adapt to diverse situations of those at the sharp end, rather than relying on imposed rules. DEGAS[126] summarises the viewpoint succinctly by saying that 'rules should be the expression of the concentrated experience of the professionals', by which they mean the pilots, and that the responsibility for deciding on behaviour should be laid as close as possible to the task execution level. Also relevant to model 2 are papers derived from the traditions of 'organisational routines'[51,135–140] and, to a lesser extent, papers on mindfulness[119,130] and trust.[141–144] We also see links to the work of Karasek[145] and others on the 'job demand and control model', which relates occupational stress to the balance between job demands and the degree of control or decision latitude that the worker has over the pressures and the way work is done.

Coping with the diversity of reality

The message coming from these studies is that model 1 does not remotely describe the way in which these activities are done in practice. It may describe how novices operate and what support is needed for them. However, moving from being novice to become an expert – a process which Mascini & Bacharias[67] compare to the traditional steps of apprenticeship enshrined in the guild system for reaching mastery (see also Dreyfus & Dreyfus,[146] cited in Knudsen[68]) – the beginner follows a path which leaves generic rules behind. This is a move from the sequential, analytical, rule-driven and context- and outcome-independent performance of tasks to an increasing concern for the consequences of actions and the need for the prioritisation of approaches and solutions at the stage of the advanced learner. This is succeeded, in the competent practitioner, by a level of pattern recognition, intuition and situational experience, and in the final expert stage, by a holistic, completely situated competence that arrives at decisions not on a rationally analysable and queryable basis (based on problem decomposition and solution), but on a far more automatic and richly contextualised linking of situation to response. This parallels the development through Rasmussen's K- and R-levels, to the S-level of operation, interpreted by Reason[104] as the way in which tacit knowledge is built up and used in highly skilled performance. At the final expert level, rules imposed from outside are seen as an attack on the treasured identity of the experts, a sign of mistrust of them and lack of respect towards them, and an attempt to limit their autonomy. It is also seen as being in danger of stifling innovation. Instead of generic, formal company rules, the studies find that experts have their own personal sets of information, heuristics and reminders, often kept in 'little black books',[26,35,52,59] or shared by the socially enacted culture of what is 'acceptable behaviour'. Only this tacit knowledge is seen as able to cope with the diversity of different individual patients, contingencies such as equipment failures or the competences of different team members (in operating theatres), or flights, weather conditions and equipment operation (in aviation), and the equivalents in the other activity spheres. To avoid this imposition of alien rules, the papers recommend that rules should be formulated as support for the expertise and not as replacements for it, and that those using them at the operations level should be trained in how to adapt the rules and when. Bourrier[112] describes the latter solution to rule modification working in a French nuclear station (model 2), and contrasts it with an alternative solution in a US nuclear station, where an expert was always on tap to modify and agree any rule that could not be carried out by the operators as it stood (model 1). She portrays these as alternative solutions adapted to the local cultures, without giving any preference, implying that the most important consideration is to match the solution to the culture.

The 'rules' or 'routines' which experts have devised through this apprenticeship and accumulation of experience are depicted as situated, locally adapted, explained and justified, present as largely tacit knowledge, and which copes well with local diversity by translating, expanding and finding alternatives to imposed rules and protocols. However, there is always a balancing act between failing to adapt when the signs were there (certainly in hindsight) that the 'normal' (generic) procedure was not appropriate and trying to adapt without the necessary complete overview and expertise and still failing to cope with the actual situation.[35,51,129] This double bind is made worse the stricter the imposed procedures become. The papers also document another self-perpetuating cycle, namely that experts would have to reveal that they were having to violate the imposed rules and risk punishment for that in a blame culture, in order to highlight the fact that the rule system needs changing.[35,68]

Expert routines

In the healthcare sphere,[70,71,121,122] it is doctors, particularly surgeons, who are most negative about rules/protocols and most positive about the need for violations. Nurses and midwives hold views diametrically opposed to doctors, equating the use of protocols with professionalism and being in favour of compliance, considering that deviations should be reported even if they produce good consequences. They see the views of doctors as 'cavalier' and elitist. Hospital managers, too, fit model 1 much more than model 2 and see the protocols as evidence of an evidence-based approach. In summary, managers see surgery as a science, but surgeons see it more as an art, where rules do not belong. Grote *et al.*[51] find similar differences between shunters (model 1) and signalmen (model 2) in their willingness to use discretion, and attribute it to differences in skill level, with signalmen being more willing to use discretion. Rayner[147] captured the differing attitudes to radiation hazards and rules held by different occupational groups in hospitals using a 'grid/group' matrix, showing that hospital specialists (doctors, ie low grid, low group) aimed to rely on individual competence and expert judgments, not on formal rules, while technicians and administrators in the opposite quadrant of the matrix (high grid, high group) relied bureaucratically on rules to reassure themselves that the risk was low. Taking a different perspective, Otsuka *et al.*[148] studied creative mental sets and their relationship to rule violations among Japanese nurses. They argue that top–down (model 1) approaches to rule design may cause workers with strong creative mental sets to find ways to violate the rules to reduce

the workload imposed by the rule. Conversely, bottom–up approaches to rule design (model 2), incorporating a more flexible approach to safety rules, would allow creative mental sets to be directed toward adapting and improving the rules, suppressing the need to violate. Drach-Zahavy & Somech[102] studied nurses and the way they decided on which safety procedures and rules to apply and which to breach, and found a set of meta-rules or routines over-riding specific action rules, such as putting their patient's safety above their own.

Implicit, or explicit in many of the studies, including those discussed above (eg Brady,[149] McDonald *et al.*,[70,71] Knudsen,[68] Decker,[35] Polet *et al.*,[94] Peters[85] and Gherardi & Nicolini[134]), is the notion that rules are a tool in the game of power and control of one group by another. Leplat,[39] among others (see above), points to the danger that management devise rules under model 1 in order to cover its back and to hide behind and shift blame in the event of an accident onto the 'violating' operators.

In a study of an energy company, Mascini & Bacharias[67] devised a questionnaire to try to translate insights from sociological/ethnographic/organisational studies into a measuring instrument. They defined three scales of what they call 'craftsmanship':

1 The value of discretion: de-emphasising formal rules, because the rule-maker cannot foresee all risk situations and is not in the best position, even for risk that can be foreseen, to know what is the best way to control them.
2 Tacit knowledge: learned by exposure, interaction with experts (often with hard-handed correction, banter, testing with near misses or other indicators of mettle and trustworthiness) and situated experience, to a greater extent than by formal training.
3 Personal responsibility: the attribution of accidents as a shameful proof of lack of personal professionalism.

These scales also demonstrate the ethical and social correlates of model 2. Mascini & Bacharias[67] found the first two craftsmanship scales, coupled with a scale measuring attitudes to the formal safety policy of the company, to be predictive of safe behaviour and low involvement in accidents and incidents.

Organisational routines

There is a research tradition from organisational studies which relates closely to model 2. This is the study of so-called 'organisational routines' (eg Reynaud,[135,136] Becker,[137,138] Becker *et al.*,[150] Levinthal & Rerup,[139] Nathanael & Marmaras,[151] Bruns[140] and Grote *et al.*[51]). The field has flourished over the past 50 years since Gouldner[152] proposed routines as alternative means of organisational control to direct supervision. March & Simon[153] saw them as essential building blocks for control, to be adapted to diverse situations by judging their appropriateness. However, Becker[137] indicates that, in that long period, the field has been characterised by a lack of clarity over the definition of 'routines'. He distinguishes the enacted, recurring patterns of behaviour at an organisational (not an individual) level (called in his tradition 'routines'), from representations of those routines in written rules. This parallels the distinction between imposed rules and emerging expert enactments of coping behaviour as described in model 2. Becker makes the point that it is not possible, from knowing the written rule, to deduce what behaviour will be shown in practice, nor to induce the written rule from the enacted behaviour. They are related, but the relationship is not simple; it requires a trigger to activate the routine, which may be, but is not always, the rule (cf. the theory of planned behaviour).[110] Becker also emphasises the need for rules to be embedded in context and therefore interpreted to a greater or lesser degree in local situations (see also Bruns[140]). He considers law and safety as contexts for little discretion in interpretation, something which contrasts with the papers directly concerning safety rules, which we have discussed under model 2 above. These papers consider operational safety rules much more as the guidelines, heuristics and building blocks, which Becker sees at the high discretion end of his spectrum. This formulation comes close to the idea that these tacit rules and the motivations which lie behind their use or violation form the structure of an organisational culture ('the unwritten rules of the game' as Scott-Morgan[154] calls them). We do not pursue this line here, as a review of culture would take this report into a vast additional area.

Becker sees routines as emerging from experience and repetition in a social context in a way that is essentially informal and not written down. They form, in this analysis, the repository of organisational memory, and as such are necessarily subject to change as learning takes place. He also discusses the pressures leading to the routinisation of activities, namely the saving in cognitive resources, facilitation of learning across 'similar situations', coping in a harmonised way with diversity and variety, and promoting co-ordination across different actors in a group. It is the process

of abstraction of the enacted routines to form generic written rules which is problematised by this direction of analysis.

Reynaud,[136] making the same distinction, sees formal written rules as complete, but only in an abstract, generic sense, while routines are necessarily incomplete as they have to be adapted to cope with unpredictable diversity. She sees the routines as organisational sense-making tools, located, context-bound and tacit, often as heuristics leading towards solutions (cf. the process rules advocated by Hale & Swuste[18]), while the written 'standard operating procedures' are explicit, finite, but generic instructions, leading in a guaranteed way in defined situations to reproducible solutions, but not able to cope with diversity unless interpreted. This equates also to the distinction by Argyris & Schön[73] between espoused theory and theory in use.

Grote *et al.*[51] combine the literature on organisational routines with that on the management of uncertainty to tackle the compromise needed between the standardisation and flexibility of rules in railways. They contrast high uncertainty activities, which need a high flexibility of rules and coping mechanisms, with low uncertainty activities, which are best achieved and coped with by the standardisation of rules. However, high risk also goes with the need for standardisation to shut out severe consequences, leaving the dilemma of combining high risk and high uncertainty in complex, high-tech activities. This creates the need for some form of compromise between standardisation and flexibility (see Adler *et al.*[142] for a treatment of this dilemma in relation to product design). Grote *et al.* use the notion of 'flexible routines'[155] to arrive at a compromise and a loose coupling to be able to cope with the two extremes. These flexible routines are adapted and enacted translations of generic rules. In particular they point to the process rules of Hale & Swuste[18] as flexible guidance on how to arrive at the specific behaviour to meet any possibly unique situation and see them as potential tools for bridging the gap between detailed rules and diverse reality. In a study of railways, they point to some shift in more modern rule sets towards these process rules, but still catalogue far more rules specifying concrete actions, many with complex exceptions. Nathanael & Marmaras[151,156] tackle the same issue of combining prescription (the written rules) with practice (the enacted diversity). They distinguish three mechanisms in practice: 'repetition of action', from which emerges the distinction between different (normal vs. abnormal) enactments. The latter lead to 'reflection on action' (often in the form of stories about notable exceptions) and alteration or expansion of the repertoire of actions. A linked activity of 'description' of these linked processes leads to institutionalisation of the rules in either formal or informal format. Nathanael & Marmaras[151,156] go on to argue that top–down formalisations – which deny work communities the ability to form their own descriptions – not only render the community impotent in adapting to novel situations, but inhibit organisational flexibility and learning. However, if work communities secretly reject top–down formalisations and develop their own descriptions based on day-to-day realities, then this may lead to a breakdown in organisational cohesion and even the erosion of safety defences.

Sense-making and trust

The tradition of research on organisational routines has clear links to the research of Weick[119,130] on mindfulness and sense-making. Once we accept that rules cannot cover all eventualities and that all rules have exceptions, it becomes essential that operators, or others somewhere in the system but in close contact with those at the 'sharp end', use their deep competence and tacit knowledge to exercise discretion in applying any rules that are defined, so that they are able to come up with adaptations, improvisations and extensions of them to cope with the unexpected and unforeseen situations. This requires mindfulness to be alert to the need to modify procedures and devise new coping strategies, and expert sense-making to make those innovations or adaptations. At this point the burgeoning literature from Weick and his colleagues becomes relevant, as does that on resilience (eg Hollnagel *et al.*[157]). It is beyond the scope of this paper to review the bulk of that literature in detail here, since it lies, by definition, beyond the point where written rules and procedures play a central role, however abstractly they are formulated.

The literature on trust in organisations points to some of the same factors being important in combining standardisation and flexibility, namely the importance of trusting the operators as experts in defining and writing routines and rules, rather than imposing rules made by experts on operators perceived as recalcitrants (eg Adler *et al.*[142] and Jeffcott *et al.*[143]). The latter paper, describing research in train operating companies, also points to the negative, iterative link possible between an increased culture of proceduralisation (trust in rules) and a high-blame culture. In this, compliance is used as a means of self-preservation, leading to a prescriptive, inflexible, compliance culture. They point to a shift from a 'job for life' culture to one with many new non-rail staff being recruited, leading to more reliance on procedural rules to fill the gaps in tacit knowledge left by the abandonment of long

apprenticeships and to replace the trust of known colleagues based on long histories of mutual interaction (see also Maidment[23] and Larsen *et al.*[57]). The knowledge to vary and adapt the procedures is no longer present, so much more is done 'by the book'. Borys[72,158] also pointed to the trust felt in immediate supervisors to adapt rules as important factors in rule compliance on Australian construction sites.

Conchie & Donald[144] and Schöbel[159] point to the need to balance trust in rules with mistrust, leading to a critical view of rules and their applicability, and a culture that will support the checking and monitoring of the behaviour of others (institutionalised mistrust), manifest in turn as the challenging of violations. Too much trust leads to unquestioning rule following when it is not appropriate; too much mistrust of rules leads to needless violations of them.

Job demand and control

In his model of the balance between job demands and the control that the worker has over the work methods used, the timing and the work pressure, Karasek[145] associates low control and high demand with occupational stress, and high control and high demand with learning (see also van der Doef & Maes[160]). This would predict that more involvement in the making of safety procedures would lead to more feelings of ownership and control and hence lower stress, which Snyder *et al.*[161] seems to find, although Torp & Grøgaard[162] fail to find more than a marginal correlation between job demands and procedure compliance, far less than the correlation of the latter with high management or social support. The job demand and control model would, however, fit with the proposals from other studies[26,72] that procedures are needed most, as tools of control, for complex, high-risk and infrequent tasks, all of which have high task demands. However, taking account of the earlier studies referred to earlier in this section, one can question whether these situations require action rules, or whether it would be more appropriate to rely on ability, based on deep tacit knowledge, to adapt generic rules at the process rule or goal levels to this challenging diversity.

Summary

We summarise the main strengths and weaknesses of models 1 and 2 in Table 2, before moving on to consider whether the strengths of the two approaches can be combined in the management of an organisation's rules. The picture in Table 2 is painted deliberately rather black and white to make the contrast greater.

Model 1	Model 2
Strengths • Makes rule-making explicit and easy to audit • Makes consequences of rule violation explicit • Emphasises competence in rule-making and role of subject experts • Logical, rational, engineering approach • Works well for novices • Proven effectiveness for simple, 'golden rules' (behavioural-based safety) • Emphasises the role of organisational complicity in rule violation	**Strengths** • Recognises operators as experts central to rule-making • Recognises social processes as key to rule use • Sees rule-making as a continuous, dynamic process • Links rules to the crystallised competence of organisational memory • Recognises the importance of managing exceptions and their link to violations • Recognises the centrality of experience
Weaknesses • Sees operators as robots, lacking competence and social motivation, and needing imposed rules • Encourages a blame culture and negative view of rules and violations • Sees rule-making as a one-off, static process, until accidents trigger rule modification • Fails to deal adequately with exceptions except as triggers for rule book growth • Tendency to bureaucracy, and gap between rules and reality	**Weaknesses** • Rule-making and modification process lacks transparency for auditing and for novices learning the skills • Undervalues the need for the organisation to explicitly manage rule development and use • Hides differences of interpretation and competence

Table 2
Summary of the main strengths and weaknesses of models 1 and 2

Management of rules

The review of the two models of rules and their development and use has resulted in the definition of a broad set of concerns and dilemmas. The picture that emerges is of a gap between the reality of work and its routines, and the abstraction of the (often written) rules that are supposed to govern it and guide behaviour to carry out that work safely (see also Borys[72]). We have described two contrasting perceptions of violations of those written rules, either as deviations to be stamped out, or as inevitable and sometimes necessary adaptations to local circumstances to be used and reinforced. We have contrasted also the bottom–up development, through social interaction, of domain expert rules embodied in tacit knowledge, with the top–down imposition of rules devised by external experts on operators perceived as fallible and relatively unskilled. We reconcile these two views by making the monitoring and improvement of rules an explicit and central process in the rule management process. We also stress the need for involvement of 'sharp-end' experts (operators, supervisors) in these processes, so that monitoring can lead in appropriate cases to changes in existing rules, and not just to reinforcement and discipline.

Central to any system of management of rules is how to cope with diversity and exceptions to whatever rule is formulated. Central also is the need to see rule sets as dynamic and to place the focus of their management on the processes around monitoring and change (flexibility), rather than purely on development and communication. We draw these aspects from model 2 together with the need for the rules which are formulated to be calibrated to the competence, motivation and trustworthiness of the rule users. From model 1 we draw the need for transparency in rule-making, so that it is clear to both rule users and supervisors, and to auditors, what the current, agreed set of rules is. We also draw from there the need to clarify whether there is a subset of 'golden rules' which are so universally applicable that any violation can be seen as a *prima facie* case for discipline. From both models we draw the general principle that explicit written rules and procedures should not be seen as the first means of control to be proposed for hazards. Design and layout to reduce the need to interact with hazards takes precedence, and training to implant rules in the heads of users, plus social control to keep them central to practice, is an alternative to written rules to be used on line.* These characteristics define the gap between procedures and practice; Dekker[35] urges us to monitor the gap and try and understand why it occurs, while Knudsen[68] urges us to 'stop bitching' about the fact that the gap exists and set about closing it. What follows tries to do both. As such, it tends to modify a number of steps in rule management from essentially model 1, top–down steps towards model 2, bottom–up steps.

We turn now to the implications of all of this for the management of safety rules in organisations faced with reconciling these apparent conflicts and dilemmas. Are we able to arrive at a compromise between models 1 and 2 in devising and using rules, or is it a case of following model 1 for some tasks and activities (notably simple, routine, low risk) and model 2 for others (notably complex, uncertain and high risk)? Do we need to distinguish written rules from operational rules and see the latter as translations of the former, to be done by competent operators trained to modify them to match the diversity of reality? Should the former, then, be formulated as generic sets of goals and process rules with default translations to action rules, to be adapted by those competent operators?

The framework

We will structure this section of the paper by using the earlier work of Hale and colleagues[5,57,163] to act as a framework for grouping the insights provided by the literature reviewed. We present this framework as essentially neutral between model 1 and model 2, both of which it can encompass. This framework, set out in Figure 1, is a prescriptive categorisation of the steps logically necessary for the development, promulgation, use, monitoring, modification or enforcement of rules – see also Schulman[164]). We use the framework to assess whether rule management in practice follows this pattern, and whether the recommendations from literature are compatible with it, and flesh it out with good practice. This framework embodies a view of what Bax *et al.*[28] call 'the regulatory regime'.

The framework is also informed by those offered by the Labour Inspectorate[21], the Energy Institute[6] and Embrey.[26] In his CARMAN (Consensus-based Approach to Risk MANagement) method, Embrey draws on active involvement of experienced operators in carrying out risk evaluation, drawing out best practices based on their experience, using a facilitator and translating this into training for competence and job aids as support. It also mirrors the steps proposed by Sundström-Frisk[27] for work method

* The term 'on line' indicates direct engagement in carrying out a task (sometimes called 'hands-on'). Its corollary, 'off line', denotes preparing for a task or reflecting on it, but not directly engaging in it.

change, starting with the profiling of actual behaviour, its feedback to the work group to identify obstacles to safe behaviour and propose safety measures to eliminate or circumvent them, and propose them to management for decision-making. The 'Notes of guidance' describe the framework and utilise it for grouping the findings of the literature review into good practice.

The framework applied

The framework in Figure 1 has a cyclical structure, emphasising the fact that rule management is a dynamic process of adapting rules to the changing realities of the activity and its environment (model 2). This has the structure of Deming's 'plan-do-check-adjust' cycle and places the emphasis on the monitoring and learning part of the loop. Larsen *et al.*[57] is an example of the use of this framework to assess the quality of rule management in European railways, in order to come up with proposals for good practice. Bax *et al.*[28] argue that this sort of analysis of the 'regulatory regime' is essential to understand how workers assess the legitimacy of rules. They found in their sample of Dutch workers in high-risk work that legitimacy was related to the degree of control by management of the rules and the amount of information provided by supervisors about the working of the rules.

Monitoring and feedback

This, together with the subsequent steps in the learning and change part of the rule management cycle (2, 3 and 5), forms a crucial set of steps which distinguish models 1 and 2, which is one reason why we begin with it, the other being that it is for most organisations where they will start, rather than with a blank sheet and a new activity. Model 1 plays down these steps apart from enforcement, while model 2 sees this as the powerhouse of rule use and flexibility. Leplat,[39] Dekker,[35] Bax *et al.*[28] and Antonsen *et al.*[165] emphasise the need to monitor continually the gap between procedures and reality and the continuing need to adapt procedures to local conditions. However, studies such as Larsen *et al.*[57] show that, in the railway systems studied, no formal monitoring was taking place, pointing to a model 1 approach.

Behaviour-based safety operates at this level. The classic model of it developed by Komaki *et al.*[74,80,166] emphasised the feedback process as a powerful influence on compliance and this has been amply

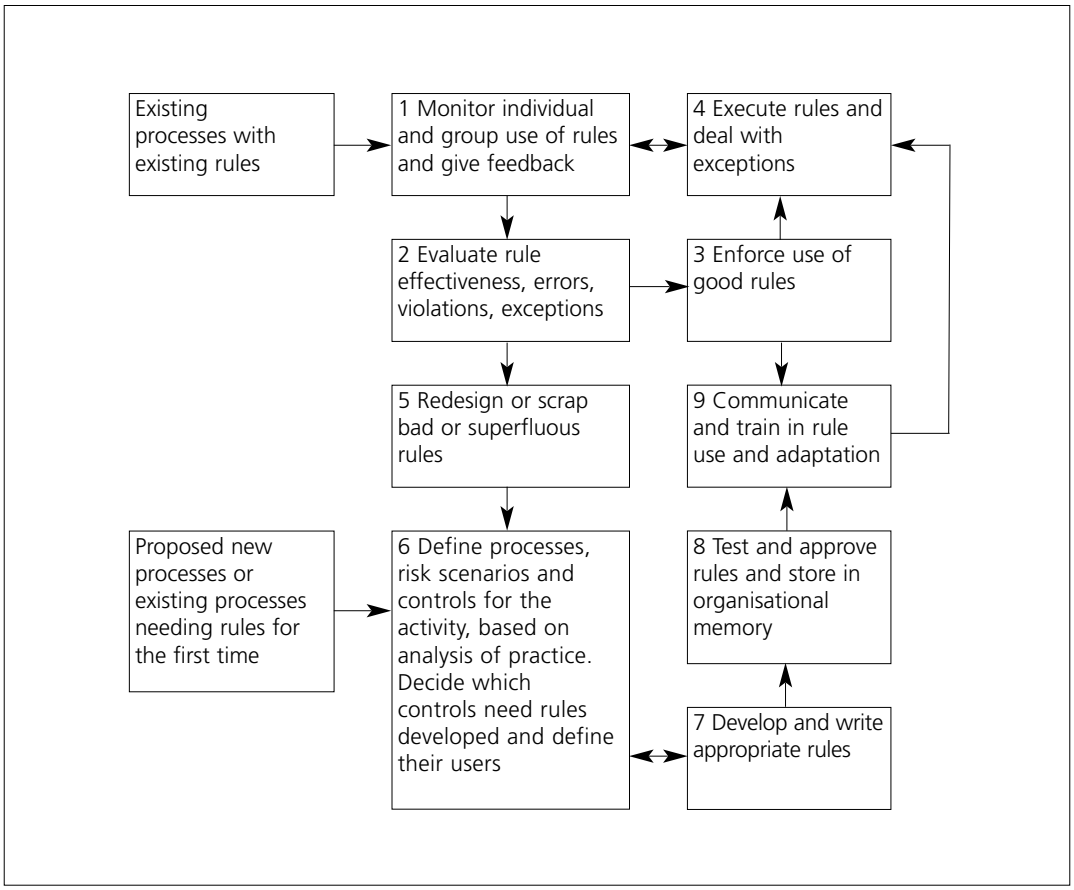

Figure 1 Framework of rule management (adapted from Larsen *et al.*[57]

proven (eg Krause *et al.*[60]). Related initiatives have placed more emphasis on adding a discussion or dialogue to the feedback, on an individual basis, rather than a group one. This was more successful than just posting the figures as group feedback in evaluations conducted by Hale *et al.*,[167] although whether this was a reflection of the difference in national culture and social control between the Netherlands and the USA is an interesting, but unresolved, question. The successful interventions evaluated did show the organisations concerned moving from model 1 cultures towards model 2, by setting up mechanisms of dialogue about working rules and safety. Behavioural observation and dialogue also give the rule-makers or managers an opportunity to see the diversity of practice and assess whether their safety rule is indeed operable in that variety. The step from simple feedback, aimed at compliance, to dialogue, aimed at understanding reality and being open to the need for the rules to change to match its diversity, is a clear shift from model 1 to model 2. Hudson *et al.*[92] also emphasise the need for encouraging the reporting of violations, coaching by supervisors when they are reported, rather than policing and punishing, leading to optimisation of the procedures through dialogue. Model 2 suggests that, if people routinely violate procedures, it is more likely that the procedures need to change than that violations should be suppressed.

Monitoring requires not just observation by second or third parties (eg behavioural monitoring, 'line operations safety audits' in aviation[168]), but also self-monitoring and -reporting of deviations. The latter process is claimed to be relatively complete,[126] but is always subject to conflict in a blame culture. It stands or falls with the perception potential reporters have of what constitutes a deviation or surprise (see, for example, Parker & Lawton[121] and McDonald *et al.*[70,71] for contrasting views on this held by doctors and nurses). Hardware to monitor rule compliance includes the black box in aircraft and its equivalents in lorries, which can provide extensive data.[88,169] Davies *et al.*[170] suggest that it is now technically feasible to equip much more equipment using mobile sensors to record use and so rule compliance. This epitomises top–down model 1 control and as such generates anger, fear and mistrust (eg the spy in the cab). To cope with this it has to be surrounded by agreements about data analysis and retention, and the use of individual analysis. However, it has clear potential, if these problems of mistrust can be overcome, as an ingredient in the discussion of the feasibility of rules.

Schelling,[44] in a thought-provoking (albeit unreferenced) paper on ways of enforcing rules on oneself, places great emphasis on making deviations from rules transparent and visible, and of enlisting the aid of others (social control) to monitor behaviour.

Evaluate rule effectiveness

The majority of model 2 papers make this process of assessing the adequacy of routines and written rules central to their analysis, which is not a position it enjoys in many organisations,[52] where the updating of design specifications, drawings and process documentation is often way behind the real changes. Model 2 papers see the process as going on implicitly as a part of the use of tacit knowledge, hence the failure of the documentation to keep up. Better management of this process is one of the main contributions that model 2 could make to model 1, but assessment does require that the tacit knowledge be made explicit, either for peer review or more top–down evaluation.

The need for an organisational memory and for its updating is emphasised by other writers covered in this review (eg Gherardi & Nicolini[134] and Holmqvist[171]) and is worked out in detail by Koornneef.[172] This can preserve information about what the rules are and why they are formulated as they are, in order to function as an 'instruction book' for the system.

The evaluation of the existing safety rules needs to take into consideration the principles set out in the later steps (6 to 9) described below as criteria for deciding if the rules are good: good choice of rule as the barrier, or barrier element, good design and formulation, good training and communication. If the rules are found to be essentially appropriate and useful, we move to steps 3 and 4, which enforce them and execute them. If not, we move to step 5 to make changes or scrap them.

Enforce the use of good rules

Åberg[89] has convincing proof of the value of police enforcement to encourage drivers to use seatbelts, avoid drunk driving and keep to speed limits. He points to the need for a critical mass of enforcement leading to a perception of a high chance of detection. This echoes Peters'[85] call for a clear policy on the enforcement of rules in mining, but one, in his case, developed in collaboration with supervisors and miners. Glazner *et al.*[173] showed that the use of disciplinary action on a construction site in all cases of violation was associated with lower injury rates for contractors on that site in the USA. The question one must ask, however, is whether this action resulted in fewer accidents or in less reporting of them. The ultimate aim is to create a climate in which the rules that are in place are seen to be sensible, and that the workgroup uses social control to 'enforce' them.

Execute rules and deal with exceptions

The accessibility of the procedures for reference when required is a point mentioned by Leplat[39] and by Antonsen *et al.*,[165] once we have decided that the written rules are appropriate and needed. This applies particularly to emergency procedures.

In this step we arrive at a core of the difference between model 1 and model 2. Model 1 tries to minimise exceptions and may require the workforce to stop work when they come across one, waiting until management provides a new or adapted rule to follow in this exceptional situation, as Bourrier[112] describes in her study of maintenance work in a US nuclear station (see also Dien,[116] Harms-Ringdahl[174] and Hopkins[111]). Model 2 trains the fitters and their supervisor to make the adaptations, as Bourrier found in the French station she studied, where only significant changes were reported up to management. The message from Bourrier's study is that the rule management system must provide a mechanism, matched to the culture, for coping with exceptions, since the many studies reviewed under model 2 indicate that they are inevitable (eg Brady,[149] Besnard & Greathead[93] and Loukopoulou[100]). Fucks & Dien[118] point out that management must define whether procedures should be followed to the letter or discretion should be used by operators, but management should accept responsibility in either case if the behaviour leads to negative consequences. Even the Shell[83] project of 12 'life-saving rules' admits that there are rare exceptions to the rules specified and there needs to be provision for the violators to be able to present mitigating arguments before applying the heavy sanctions the project wields. Some exceptions and rules for coping with them can be 'pre-authorised',[44] but others can only be dealt with when they occur.

Iszatt-White[96] points to the need in road maintenance to combine rule-following related to some hazards that the individual and organisation has control over, with a heightened attention (which she calls 'heedfulness', but Weick would call 'mindfulness') paid to unpredictable hazards which they have no control over, such as motorists invading cordoned-off areas. If these times of heightened attention are limited to short periods, such as crossing carriageways to set up warning signs, this switch of attention is sustainable; but heedfulness is not something that can be kept 'switched on' permanently.

At the use stage, many of the factors identified in Table 1 come to bear, as do the insights from the cost–benefit analysis of behavioural economics.[86]

Rule execution needs support not only with training, but with good tools and information which make written procedures easily available when needed (eg DEGAS[126] and Hale & Guldenmund[5]). Maidment[23] analyses critically the periodic examination of rule knowledge in UK railways as requiring only rote learning, while undervaluing comprehension and the understanding of the context for application. The prevailing training at that time, therefore, emphasised the 'what' and 'how' of rules, but not the 'why' and 'where'.

Redesign or scrap bad or superfluous rules

Since we place rule adaptation central to our framework in order to cope with diversity and exceptions, it is important that there is an explicit mechanism to capture any change, legitimise it and incorporate it into the organisation's memory, its master rule book. Schulz[132] looked empirically at the growth and change in rules in a bank and a university (not related to safety, but to personnel and policy, but interesting nevertheless for its theoretical insights). He tested whether rules were static (permanent) or dynamic (impermanent) and introduced the notion of 'life-span' of a rule from birth through revisions to suspension. He showed that the rules in his organisations grew over time: 10-fold in the university over 18 years and four-fold in the bank over 21 years (see also Labour Inspectorate[21] and Hale[175]). He identified the search for reliability, legitimacy and efficiency, together with processes of institutionalisation as forces to keep rules unmodified, but pointed also to the growth of unofficial work-arounds, coupled with a tolerance for obsolescence as relieving pressure on revision. Forces encouraging revision were the need to learn and update the organisational memory. He pointed to the lack of central monitoring of rules as the reason that their obsolescence was not seen or was tolerated awaiting a major revamping. The implication of this is that we need a 'rule-destruction' process to counter the tendency for rules to expand. Baram[176] also emphasises the life-span of rules, in his case at the regulatory level, calling for all such rules to have a defined and limited life. At the end of that time they should automatically lapse unless extended, or renewed with modification. These are often called 'sunset provisions'. We do not advocate that safety rules should automatically lapse, as this would send out the wrong signal about their importance, merely that they should automatically be reviewed to see if they need modification, or even replacement with more

fundamental design or layout changes to make them superfluous. Such an automatic requirement for reappraisal can and does work well at management and workplace level, with a fixed schedule for reassessment. This can also help to guard against excessive routinisation of the old familiar routines and the consequent drop in mindfulness. This mechanism of regular reappraisal and eventual scrapping of rules can also help with the tendency that rules and rulebooks have of growing almost autonomously, driven by accident and incident investigations, court cases, study findings and plugging the gaps found in practice.[25,126]

This issue leads us to the steps of design and redesign of rules (6 to 9), which are also the point of entry for an organisation which is starting up a new activity, or subjecting one for the first time to explicit (written) safety rules.

Task and risk analysis and choice of risk controls

The cycle begins with an analysis of the processes, risk scenarios and potential risk control measures for the activity, being aware of the potential gap between processes as designed (and described in the manuals) and those (needing to be) carried out in practice.[6] Blakstad *et al.*[50] set out to assess whether the process of rule change she studied in Norwegian railways would contain an explicit risk assessment step, something model 1 would require. Despite plans for that to occur, it did not materialise, and railway knowledge from experts (tacit knowledge) was used to decide which rules to modify and introduce, ie a reliance on model 2. The existence of old prescriptive action rules based on tacit knowledge and experience inhibited rule-makers from going back to the first principles to decide on which rules should be made and to set up high-level performance goals. The rule-makers defaulted to a more bottom–up approach of 'reverse invention', taking the trusted tacit rules based on long experience as the basis, making the tacit basis explicit and then modifying it for the new circumstances, in parallel inducing the higher-level process and performance output rules. Risk analyses were found to be time-consuming and were often only conducted in parallel with the rule formulation, even in some cases being used as feedback and validation of the modified action rules. Risk analysis was not trusted as much as the long experience with prescriptive rules. Similar findings were made in Larsen *et al.*'s[57] study of other European railways. It would appear that the rational approach set out in our model only has a good chance of being used in totally new novel activities, or perhaps in industries less suffused with tradition.

Häller & Stoelwinder[177] found that 'crew resource management' (CRM) training in hospitals created the space and opportunity for the whole operation theatre team to discuss risks and control procedures in such a way that a common view of them and their priority emerged, including what needed to be written down explicitly, rather than being left to this consensus to inform social control.

Other industries subject to safety case regimes, such as nuclear and chemical processes, have developed explicit, rational, model 1 style models to link the scenarios they identify to decisions about the risk controls which can best be used (see, for example, Bellamy *et al.*,[178,179] Hale *et al.*[42] and Hale & Guldenmund[5]). Derivation from past accidents or from risk catalogues is an option even for low technology activities, such as home accidents (eg Peterson & Schick[180]). However, many of the studies we have analysed under model 2 point to the limits of this step and the need for alertness to unexpected risks, which can only be coped with by the use of deep tacit knowledge to cope when they occur.

Many texts, including the guidance on OHSAS 18002, advise that the use of rules as risk controls should not necessarily be a first choice, since hardware controls can eliminate hazards and reduce the reliance on behavioural conformity or problem solving.[39] However, almost all risk controls, even if exclusively hardware, need to be put in place and suitably maintained, and all others need to be used by people in a suitable way so that they do protect against injury and damage. It is therefore axiomatic that behaviour covering all of these activities needs to be defined and executed, in order to achieve these objectives of the risk controls. The remaining questions are: who defines it (the expert, as per model 1, the operator, as per model 2, or a combination of both)?; and is it committed to paper in a formal way (model 1) or does it remain in the informal sphere (model 2)?

We also have to ask here who the customers for the rules are. The regulator and the auditor flourish at the moment on written rules, since these provide a quick and easy basis for checking compliance (but see, for example, Power[62] for a criticism of this 'death by audit'). The safety manager may have the same instinct to require rules to be explicit, so that they can be interrogated and improved, and so that they can form the organisational memory (or instruction book) for the SMS and its risk controls.[133,134,171] The larger the organisation and the more it seeks to harmonise across its different

processes or sites, the more the need for these written rules.[21] Similarly, the trainer charged with putting the behaviour into the heads and limbs of those who must execute it needs an explicit training objective and plan,[24] unless the organisation is going to rely entirely on the informal methods of apprenticeship, known in the past as 'sitting by Nellie' and identified with model 2. We regard these requirements for, and uses of, written rules as legitimate and needing to be met in the form of what we might call the 'instruction book' for the system, which is very different from procedures for frontline operators.

Therefore, the main question remains whether the operator needs explicit (written) rules, or whether the rules should be self-generated, and/or internalised. The sheer volume of rules in rule books in complex technologies have been shown to be a barrier to use.[22–24] Reason[104] (and Reason *et al.*[38]) strongly advocates not relying too heavily on the 'administrative controls' of written formal rules, but of using also Hopwood's[181] other categories:

- Social control (rules internalised and monitored by the group) such as CRM (Häller & Stoelwinder[177] and Pélegrin[182]) developed in aviation, but now widely used in other sectors to encourage explicit communication and mutual control in work groups. Checklists, when used jointly, were also found to produce similar effects.[122]
- Self-control (rules internalised by the individual to become competence and skill).

Others (eg Labour Inspectorate[21]) argue even more strongly that procedures should be seen as a last resort when other equipment and work design and layout measures are not feasible. We also approach here the limits of the use of rules, in the sense that proactively made rules can never cover all eventualities, even in relatively simple tasks. At that point the only defence against the unpredictable (or unpredicted) is deep professional competence through experience, training and the sharing of expertise.[35,40,126,157]

Embrey[26] argues that operators need a completely different set of on-line job aids than the detailed procedure manuals produced for off-line training and audit. These could resemble the 'little black books' beloved of fitters, with reminders, settings, routines for coping with disturbances, infrequently used procedures and so on. He summarises the need for detailed written (or even step-by-step) procedures, often at the process rule level, as limited to high consequence, low frequency and high-complexity tasks. The plea of workers and supervisors to confine detailed written procedures to high-risk and out-of-the-ordinary, infrequent activities was also found in Borys' study of Australian construction sites,[72,158] coupled with the recognition of young, inexperienced workers as another set of users of detailed, prescriptive action rules. The same study also found differences between operators, supervisors and managers in the purposes they saw for written procedures – operators were concerned with them as behaviour guides; supervisors saw them also as ways of limiting personal liability in the case of accident and hence (possibly) worth the greatly expanded paperwork burden; while site and project managers cited also their role in planning as well as risk control, and as tools for monitoring behaviour.

Fucks & Dien[118] emphasise that it should be clearly defined and taught to the appropriate rule users (but also to their colleagues and supervisors) what role procedures have in a system and how much discretion people have in following them (see also Elling[22]). We indicated earlier in this section that a number of studies have found unrealistic assumptions among designers, planners and procedure writers about the capabilities of, and constraints on, operators.[6,24,94,116] These studies advocate the involvement of operators in designing and developing rules (this step and the next), in order to bridge this gap and resolve the misconceptions.

Develop appropriate rules

This is a step which has attracted much of the reviewed literature. The notion of the categorisation into goals, process rules and action rules[18] provides a means of specifying how detailed the rules should be,[51,68] although it was not followed at all by the rule-makers in Blakstad's[49] study. Much of the literature[35,39,51,116] emphasises that the level of competence of the rule users needs to be taken into account in choosing at which level to write the rules – the higher the competence, the less action rules are appropriate and the more process rules will be sufficient,[51] since they can be phrased in terms of guidance, which is an essential element of model 2, rather than as rigid forcing functions. Dekker[35] and Dien[116] argue against over-specifying rules situations that are too narrow, preferring to leave room for adaptation, rather than inciting violation.

The notion of the safe envelope set out earlier in the paper provides another language for talking about the place within the safe envelope picture that is taken by the rule. Is the safe operating zone (SOZ)

defined very narrowly, with the risk that violations will be encouraged to occur in the name of productivity, and the operators will come into uncharted territory for them, where they cannot 'feel the edge' (the controllability or viable boundary)?[38,39,41] Are rules needed for strict optimisation within the SOZ, or can navigation in this area be safely left to the competence of the operators? How can rules for operation outside the SOZ (abnormal or emergency procedures) best be formulated, given that they will (or should) be less frequently used and so will be less practised. These and other categorisations of rule functions (eg Schelling,[44] Hale[175] and Elling[22]) can provide the basis for discussion with rule users about what types of rules are useful. Studies such as those for British Rail[23] point to the pressure from some regulators and from legal cases to use prescriptive rules, because of their unambiguity, rather than giving discretion to operators and using process rules or performance goals.

Related to the last point is the question of the status of a given rule: is it an absolute requirement or specification, or is it a piece of guidance from which an expert operator can deviate by using an action that is equivalent or better in the level of safety achieved?[22] As indicated earlier in the paper, formulating the rule as guidance has been show to work well for experts in complex technologies. There are often only a few 'golden rules' that have (almost) no exceptions and can be promulgated as true specifications.

Vital for the success of rules, according to the literature, whether from the criticisms of model 1 or the advocates of model 2, is the participation of rule users in formulating the rules. This is endorsed by almost all of the studies reviewed (eg Leplat,[39] McCarthy *et al.*,[59] Dien,[116] Embrey,[26] Dekker,[35] Antonsen[165] and Polesie[183]). However, authors from the organisational disciplines (eg Perrin[52] and Hofstede[184]) warn that introducing such participation in rule-making in organisational cultures which value hierarchy and have a high power-distance score, is not an easy task. Bax *et al.*[28] found that workers in high-risk jobs believed that rules were more legitimate if they were consulted regularly about them, but not if they were involved in writing them, which directs us to think carefully about what participation should entail. Model 2 gives the domain expert user the central role by definition, given its bottom–up orientation. However, it is not difficult to adapt the top–down approach of model 1 to incorporate their participation, displacing the subject expert to a supporting, organising, writing and polishing role (see also Hale *et al.*[175]), instead of being seen as the fountain of all wisdom, despite their lack of hands-on experience and of awareness of practical constraint.[26] Borys[72,158] found that the workers on construction sites did not see it as their job to write the safe work method statement (SWMS), which usually came down from higher levels in the hierarchy, but did value the opportunity in toolbox meetings and informally to have their say in adapting them. Above all, this process of producing procedures needs to be seen as an important and high status one, not drudgery inferior to the interesting activity of technical design and development.[52]

At a more basic level, this step is concerned with the more mundane criteria for appropriate rules set out, for example, by Wagenaar,[185] Elling[22,186,187] Labour Inspectorate,[21] HFRG,[88] Leplat[39] or Energy Institute.[6] An important question is how much explanation of the rule needs to be given within it (or as commentary/training on it) about why it is formulated as it is, and to which situations it does and does not apply, with what preconditions before it is valid, and with what prerequisites for the use of safety equipment, competence, (additional) manpower and so on (see also Hale,[175] Iszatt-White[96] and Fucks & Dien[118]). Too little explanation favours violations out of ignorance and does not equip the user to adapt the rule if meeting situations outside the definition; too much makes the rules complex and impenetrable. In complex systems, a failure to write down the reason for the rule and how it fits with prevention principles can lead to the organisation forgetting why some of the rules were made as they were (eg Larsen *et al.*[57] and Blakstad[49]). This makes them very vulnerable to change, since those making the change cannot easily go back to the principles defining the role of the rule.

Decisions also need to be made about whether to keep safety rules integrated with work rules so that they do not get treated as separate and second class, or separate so that they are emphasised and prioritised. Waszink *et al.*[1] emphatically favour the former on the basis of their research, as this allows for a significant reduction in the bulk of rules and improvement in their relevance to each person's specific activity. This requires aligning the rules with the organisation's primary processes, to emphasise for each user the whole set of rules governing their specific activity. This has great advantages for the rule user, but makes the rule set less transparent for the safety auditor only interested in rules about risk control.

Leplat,[39] Elling[22,186,187] and Wagenaar[185] all emphasise the importance of completeness, specificity, readability and understandability in formulating rules. Maidment[23] cites an internal British Rail study which found that the reading age required to understand its rules was 16 to 18, whereas the average

measured reading ability of the staff needing to apply the rules was eight. Readability and understandability are subsumed by Embrey[26] under the heading of 'accessibility', which he offers alongside 'accuracy', 'practicality', 'optimisation', 'presentation', 'policy' and 'usage' as headings for optimising the content and presentation of procedures. Embrey emphasises that 'best practice' consists of two elements, that the procedures work and that they are acceptable to those using them. Without either one they will not be used. Elling[22,186,187] warns that improvements to rules too often concentrate on surface characteristics such as readability, rather than on the content, its clarity, specificity, comprehensibility and appropriateness. He also advocates the ordering of the procedures by task, to assist the operator in finding them, rather than by the system functions they deal with. Wagenaar[185] points to the need to have checkpoints to monitor (both by self and outsiders) if the procedure is progressing correctly, and also to check the mutual compatibility of procedures. He also requires explicit instructions on how to cope with unforeseen situations, specification of the discretion allowed to the procedure users, and the priority to be given where any conflict with objectives other than safety are to be met. These are all worthy requirements, but implementing them can make procedures extremely complex and unusable.

Antonsen *et al.*[165] carried out a study in offshore supply bases to try to close the gap between work as imagined and work as done. The main changes they made were to reduce the number of procedures and to simplify and clarify their language, using workers as informants. They also prioritised procedures on importance and implemented a weekly discussion of procedures at health, safety and environment meetings. The workers felt that there had been an improvement in safety, but this was not borne out by the number of accidents, and 44 per cent still felt the procedures were being violated after the changes. Borys[72,158] studied the use of written SWMSs* in two Australian construction sites and found a rather small (perceived) gap between the SWMSs and the real procedures, which seems to be explained by the relatively informal methods of supervisors on the spot allowing modifications of standard SWMSs, prepared in advance, to cope with local situations. These modifications were often not made to the formal issued SWMSs, but only incorporated later (if at all) as modifications for future use. These sites seemed not to be typical of Australian sites in that respect, according to the findings of a WorkCover[189] study.

Trials with and approval of the rules

A trial use of any proposed rules is always desirable.[6] To evaluate this, there needs to be a set of criteria for accepting rules and giving them a formal status (see the 'Notes of guidance', which accompanies this document). Model 2 suggests that this 'approval' resides in the consensus of the group of domain experts using the routines and sees it as an essentially informal process. Model 1 sees it as needing to be formalised. Larsen *et al.*[57] found that the railways studied did not have such criteria and relied, as with so many other issues, on the expertise of the rule writers and checkers. Leplat[39] provides a number of attributes (see previous section) and warns that, as rule sets get larger, the danger of internal inconsistencies becomes greater and these need to be deliberately checked for. McCarthy *et al.*[59] come up with a longer list for hospital guidance protocols: validity (evidence based), cost-effectiveness, reproducibility, reliability, developed with all interests (including patients), clinical applicability and flexibility, identification of exceptions, clarity, meticulous documentation and wording and presentation as guidance and learning resource and not as imposed control. Antonsen *et al.*[165] focus on comprehensibility, accessibility and accuracy.

Communication and training in rule use

Training has to produce the balance between internalisation of the rules as tacit knowledge and the remaining reliance on consulting written rules or checklists; the balance lying towards internalisation for normal operations, but more to consultation of paperwork in emergency situations (provided time is available) or other unexpected situations. The training step is also the point at which any of the individual factors identified in Table 1, earlier in the paper, can be identified and attempts made to counter them, particularly in relation to underestimates of risk and poor knowledge about the reasons for specific rules and the consequences of violating them (model 1). The importance of good mental models of what rules are trying to achieve is emphasised by Besnard & Greathead,[93] while vivid and convincing demonstration of the risks is underlined in Bell & Fogler's[190] suggestion for using accident simulations, and the emotive training using victims of injury in the evaluation study in Hale *et al.*[191] In pursuit of model 2, this is the step which could provide the knowledge and understanding to be able to adapt rules to the diversity of situations to be faced,[35,125] especially complex ones involving multiple

* These are required by law as written statements for dangerous activities, setting out the hazards identified and the risk control measures to reduce the risks to acceptable levels.

failures of hardware or of other operators, which can produce unpredicted interactions. The studies reviewed emphasised that this learning takes place over a long time of experience and of meeting different situations, but formal training and refresher retraining can structure this learning and alert people to the need for it, and also make explicit the processes by which it occurs and monitor its progress.

When rules are changed, prompt information to users is vital to avoid them violating the new rule by continuing to use the old one. Larsen *et al.*[57] found problems here in many railways. However, Drach-Zahavy & Somech[102] in their study of nurses cite studies showing only minor effects of training and enforced compliance on accident rates, because these interventions were not translated into practical implementation.

In summary, we can indicate the various options under this set of steps as follows, drawing particularly on the summaries of HFRG[88] and the Energy Institute:[6]

- monitor and analyse violations to understand them
- audit violation potential
- redesign the job or equipment to remove the need for procedures or violations, or to support procedure use
- rewrite procedures with a well-designed process and to adequate criteria
- involve/consult/inform the workforce during the rewriting
- train and retrain in risk perception, the procedure and its use and adaptation
- anticipate the need for, and provide a system for, varying procedures
- promote a learning and sharing culture around compliance
- enforce where the procedure is the best way of proceeding.

Conclusion

The rule management framework can accommodate the vast majority of the insights provided by both model 1 and model 2, but it does not help us to decide between the models *per se*. It simply highlights where in detail the models differ. Our review has also shown that the two models have their own strengths and weaknesses. Model 1 is more transparent and explicit than the tacit knowledge and emerging set of routines characterised by model 2. This makes it more scrutable for trainers, assessors and improvers, but often at the cost of creating the gap between work as imagined in the rule set, which has to written to achieve that scrutability, and work as carried out in practice. The quality management and auditing industry favour written procedures for these reasons and create major incentives for organisations to write weighty procedure manuals, but are then blind to the gap with reality which a paperwork-based system audit does not pick up.
The stages of developing appropriate rules, their use, including dealing with exceptions, and their monitoring and adaptation, are steps where there are conflicting recommendations from the two models, implying that choices have to be made, or at the very least that work has to be done to arrive at a compromise which encompasses both standardisation and flexibility. Rules may be imposed from above, but they must be at least modified from below to meet the diversity of reality. As DEGAS[126] says, 'a rule is fit for purpose because it works, not because it is written'. Model 1 fits best with routine work with few exceptions, conducted by lowly skilled people (the classic machine bureaucracy of Mintzberg[192] – see also Häller & Stoelwinder[177]), but even there the rule management system can benefit from their greater participation based on trusting them as domain experts in defining rules and tempering the top–down nature of model 1.

This view coincides with the 'telling and directing' leadership style of Hersey *et al.*,[193] which they characterise as appropriate for workers with low competence and commitment. The 'participating and supporting' and particularly the 'delegating and observing' leadership styles are suitable for a workforce with high competence and variable or high commitment, such as pilots, surgeons, and possibly seamen and fitters working in a professional bureaucracy. Detailed written procedures are also appropriate for learners, for high-risk situations and for infrequently conducted tasks, provided that these risks can be and have been predicted. If not, their resolution requires the opposite approach of deep tacit knowledge and the ability to improvise. Here lies on of the biggest question marks of rule use, since these two approaches appear to contradict each other. Model 2 fits best with complex, high-uncertainty, high-risk domains with great variety and the need for improvisation.

The work on the proceduralisation of healthcare, aviation and other candidates for this grouping does, however, show that there is scope for making guidance and protocols more explicit, usable and used, by specifying them as process rules rather than as action rules. Models 1 and 2 also fit together better if we

see 1 as the producer of written rules and 2 as the producer of enacted routines. The task then is to how to articulate the two and derive one from the other. It would appear that it is very often more productive to start with the enacted routines and derive the rules from them and not vice versa. The literature does point clearly to the advantage in this respect, if not the necessity of greater participation in rule-making and modification by the rule-users, and the need for monitoring and change to be a central plank in rule management. These can be easily grafted onto model 1 to take away some of its elitist image.

We would hypothesise that model 1 is probably still the dominant model in the majority of industry, at least among top managers and safety advisers, and certainly among regulators and auditors. Model 2 is somewhat hidden from their view, either deliberately by the work-floor to retain their autonomy, or because management, supervisors and the workforce turn a blind eye to it. As indicated above, there is room for mixing some of the best features of each model, but we believe that there is still a need for a significant culture shift, perspective change or paradigm shift for many of those individuals and organisations operating under a pure model 1, to accommodate the ideas of the flexibility implied in model 2.

As we have shown, the framework in Figure 1 can be used to structure both model 1 and model 2 approaches and to offer valuable compromises or combinations between the models to use their strengths and repair their weaknesses. In order to move the emphasis in rule management from rule-making to rule monitoring, adaptation and modification, the cultural assumptions of top managers, supervisors and regulators need to be explicitly challenged. In particular, the dead hand of the last group needs to be faced. The more rule sets come under the scrutiny of legal or quality management and auditing processes examining compliance to detailed provisions, the less likely is it that organisations can preserve the flexibility of their own sets of rules to deal with the diversity of work as actually performed.

The discussion of the papers reviewed has also emphasised that all situations, all rules and all users are not alike. Detailed rules written by head-office experts may be appropriate for a novice group with low levels of training working on complex, high-risk technology or coping with emergencies. On the other hand, experts with long experience and deep knowledge may only need advisory protocols for off-line browsing to refresh their minds about complex skills and procedures that may have become too automatic to be monitored and reviewed. This ‘horses for courses’ approach needs to be worked out in detail in future research (see also Rosness[194] and Schulman[164] for some first attempts at defining dimensions).

Coda

Interesting questions arising from our review, but not articulated here, include the following, which we recommend to other reviewers:

1 Does this analysis of rule-following and rule management at the level of the work floor or primary process have anything to offer for the analysis of regulations imposed by regulators on organisations, or by organisations on their managers, as part of the SMS, where violation is just as prevalent? This question is addressed in a recent paper by Hale *et al.*[195]
2 If evaluation and improvement, and the demands of an organisational memory, require rules to be made explicit, how can we do this without going to the expense and trouble of making all rules formal and written down? How can we reliably interrogate and audit tacit knowledge and implicit rules? What does this have to say about the knowledge and domain competence of auditors, but also of the top managers of organisations?
3 What is the role of national culture and its influence on the image and use of rules in explaining the differences found in the literature reviewed?

References

1 Waszink A C, Meyer F O and van der Pelt A C W. Integratie van zorgsystemen ('Integration of management systems'). *Sigma* 1995; 1: 4–7.
2 British Standards Institution. *OHSAS 18002:2008. Occupational health and safety management systems. Guidelines for the implementation of OHSAS 18001:2007*. London: BSI, 2008.
3 International Loss Control Institute. *International Safety Rating System (ISRS)*. Loganville, Georgia: ILCI, 1990.
4 Groeneweg J. *Controlling the controllable: the management of safety*. 4th edition. Leiden: DSWO Press, 1998.
5 Hale A R and Guldenmund F G. *ARAMIS audit manual*. Version 1.3. Delft: Safety Science Group, Delft University of Technology, 2004.
6 Energy Institute. *Managing rule breaking: the toolkit*. 2008 www.eimicrosites.org/heartsandminds. Viewed 29 August 2012.
7 Pidgeon N. Safety culture and risk management in organizations. *Journal of Cross-cultural Psychology* 1991; 22 (1): 129–140.
8 Diaz-Cabrera D, Hernandez-Fernaud E and Isla-Diaz R. An evaluation of a new instrument to measure organisational safety culture values and practices. *Accident Analysis and Prevention* 2007; 39 (6): 1202–1211.
9 Flin R, Mearns K, O'Connor P and Bryden R. Measuring safety climate: identifying the common features. *Safety Science* 2000; 34 (1–3): 177–192.
10 Guldenmund F. The nature of safety culture: a review of theory and research. *Safety Science* 2000; 34 (1–3): 215–257.
11 O'Toole M. The relationship between employees' perceptions of safety and organizational culture. *Journal of Safety Research* 2001; 33 (2): 231–243.
12 Farrington-Darby T, Pickup L and Wilson J. Safety culture in railway maintenance. *Safety Science* 2005; 43 (1): 39–60.
13 Mohamed S. Safety climate in construction site environments. *Journal of Construction Engineering and Management* 2002; 128 (5): 375–384.
14 Mohamed S. Scorecard approach to benchmarking organizational safety culture in construction. *Journal of Construction Engineering and Management* 2003; 129 (1): 80–88.
15 Prussia G E, Brown K A and Willis P. Mental models of safety: do managers and employees see eye to eye? *Journal of Safety Research* 2003; 34: 143–156.
16 Törner M and Pousette A. Safety in construction – a comprehensive description of the characteristics of high safety standards in construction work, from the combined perspective of supervisors and experienced workers. *Journal of Safety Research* 2009; 40: 399–409.
17 O'Dea A and Flin R. Site managers and safety leadership in the offshore oil and gas industry. *Safety Science* 2001; 37 (1): 39–57.
18 Hale A and Swuste P. Safety rules: procedural freedom or action constraint. *Safety Science* 1998; 29 (3): 163–177.
19 Vaughan D. *The Challenger launch decision: risk technology, culture and deviance at NASA*. Chicago: University of Chicago Press, 1996.
20 National Commission. *Deepwater: the Gulf oil disaster and the future of offshore drilling*. Washington: National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011.
21 Labour Inspectorate. *Procedures in the process industry: examples and proposals concerning development, introduction and control of procedures in the process industry*. Voorburg, NL: Directorate-General of Labour, Ministry of Social Affairs and Employment, 1989.
22 Elling M G M. *Veiligheidsvoorschriften in de industrie* ('Safety rules in industry'). PhD thesis. Publication WMW No.8. Netherlands: University of Twente, Faculty of Philosophy and Social Sciences, 1991.
23 Maidment D. *A changing safety culture on British Rail*. Paper to the 11th New Technology and Work Workshop on 'The use of rules to achieve safety'. Bad Homburg, 1993.
24 Norros L. *Procedural factors in individual and organisational performance*. Paper to the 11th New Technology and Work Workshop on 'The use of rules to achieve safety'. Bad Homburg, 1993.
25 Amalberti R. The paradoxes of almost totally safe transportation systems. *Safety Science* 2001; 37 (2–3): 109–126.
26 Embrey D. *Preventing human error: developing a best practice safety culture*. Paper to the Berkeley Conference International Conference 'Achieving a step change in safety performance'. London, Barbican Centre, February 1999.

27 Sundström-Frisk C. Understanding human behaviour: a necessity in improving safety and health performance. *Journal of Occupational Health & Safety – Australia and New Zealand* 1998; 15 (1) 37–45.
28 Bax E H, Stejn B J and De Witte M C. Risk management at the shop floor: the perception of formal rules in high-risk work situations. *Journal of Contingencies and Crisis Management* 1998; 6: 177–188.
29 Martin L. Bending the rules or fudging the paperwork? Documenting learning in SMEs. *Journal of Workplace Learning* 2001; 13 (5): 189–197.
30 Parker D and Malone C. *Influencing driver attitudes and behaviour.* SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, 29–31 March 2004.
31 Laurence D. Safety rules and regulations on mine sites – The problem and a solution. *Journal of Safety Research* 2005; 36 (1): 39–50.
32 Shaw A, Blewett V, Stiller L, Cox S, Ferguson S, Frick K and Aickin C. *Digging deeper.* Mount Egerton, Victoria, Australia: Shaw Idea, 2007.
33 Confidential Incident Reporting & Analysis System. Are rules really made to be broken? *The Reporter* 2007; 12: 1. London: CIRAS, Rail Safety & Standards Board.
34 Lamvik G M, Naesje P C, Skarholt K and Torvatn H. Paperwork, management and safety: towards a bureaucratization of working life and a lack of hands-on supervision. In: Martorell S, Guedes Soares C and Barnett J. *Safety, reliability and risk analysis: theory, methods and applications.* London: Taylor and Francis, 2009.
35 Dekker S W A. *Ten questions about human error: a new view of human factors and system safety.* New Jersey: Lawrence Erlbaum, 2005.
36 Rasmussen J. Risk management in a dynamic society: a modelling problem. *Safety Science* 1997; 27 (2/3): 183–213.
37 Snook S A. *Friendly fire: the accidental shoot-down of US Black Hawks over Northern Iraq.* Princeton: Princeton University Press, 2002.
38 Reason J, Parker D and Lawton R. Organizational controls and safety: the varieties of rule-related behaviour. *Journal of Occupational and Organizational Psychology* 1998; 71: 289–304.
39 Leplat J. About implementation of safety rules. *Safety Scienc*e 1998; 16 (1): 189–204.
40 Amalberti R, Vincent C, Auroy Y and de Saint Maurice G. Violations and migrations in health care: a framework for understanding and management. *Quality & Safety in Health Care* 2006; 15 (Suppl. 1): i66–i71.
41 Howell G, Ballard G, Abdelhamid T and Mitropoulos P. Working near the edge: a new approach to construction safety. In: *Proceedings of the 10th Annual Conference for Lean Construction.* 6–8 August 2002, Gramado, Brazil: 49–60.
42 Hale A R, Goossens L H J, Ale B J M, Bellamy L A, Post J, Oh J I H and Papazoglou I A. Managing safety barriers and controls at the workplace. In: Spitzer C, Schmocker U and Dang V N (eds). *Probabilistic safety assessment and management.* Berlin: Springer Verlag, 2004: 608–613.
43 Van den Top J. *Modelling risk control measures in railways: analysing how designers and operators organise safe rail traffic.* PhD thesis. Delft University of Technology. Safety Science Group, 2010.
44 Schelling T. Enforcing rules on oneself. *Journal of Law, Economics and Organization* 1985; 1 (2): 357–374.
45 Hudson P, van der Graaf G C and Bryden R. *The rule of three: situation awareness in hazardous situations.* The Hague: Shell. Undated.
46 Hopkins A. *Lessons from Gretley: mindful leadership and the law.* Sydney: CCH Australia, 2007.
47 Reason J. Beyond the organisational accident: the need for 'error wisdom' on the frontline. *Quality and Safety in Health Care* 2004; 13: Suppl. 1: 28–33.
48 Reason J. *The human contribution.* Aldershot: Ashgate, 2008.
49 Blakstad H C. *Revising rules and reviving knowledge: adapting hierarchical and risk-based approaches to safety rule modifications in the Norwegian Railway System.* Unpublished PhD dissertation. Trondheim: Norwegian University of Science and Technology, 2006.
50 Blakstad H C, Hovden J and Rosness R. Reverse invention: an inductive bottom-up strategy for safety rule development: a case study of safety rule modifications in the Norwegian railway system. *Safety Science* 2010; 48 (3): 382–394.
51 Grote G, Weichbrodt J, Gunter H, Zala-Mezo E and Kunzle B. Coordination in high-risk organizations: the need for flexible routines. *Cognition, Technology & Work* 2009; 11 (1): 17–27.
52 Perrin C. *The dynamics of safety: the intersection of technical, cultural and social regulative systems in the operation of high hazard technologies.* Paper to the 11th New Technology and Work Workshop on 'The use of rules to achieve safety'. Bad Homburg, 1993.

53 Grote G. *Why regulators should stay away from safety culture and stick to rules.* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.

54 LeCoze J-C and Wiig S. *Beyond procedures: can 'safety culture' be regulated?* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.

55 Kringen J. *Proceduralization and regulation of culture: experiments on the frontiers of risk regulation.* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.

56 Hale A, Heijer T and Koornneef F. Management of safety rules: the case of railways. *Safety Science Monitor* 2003; 7 (1): Article III-2 (electronic version).

57 Larsen L D, Petersen K, Hale A R, Heijer H, Parker D and Lawrie D. *A framework for safety rule management.* Lyngby: Danish Traffic Institute, 2004.

58 Taylor F W. *The principles of scientific management.* New York: Harper & Brothers, 1911.

59 McCarthy J, Wright P, Monk A and Watts L. Concerns at work: designing useful procedures. *Human–Computer Interaction* 1998; 13 (4): 433–457.

60 Krause T R, Seymour K J and Sloat K C M. Long-term evaluation of a behavior-based method for improving safety performance: a meta-analysis of 73 interrupted time-series replications. *Safety Science* 1999; 32 (1): 1–18

61 Keil Centre. *Strategies to promote safe behaviour as a part of a health and safety management system.* CRR 430/2002. Sudbury: HSE Books, 2002.

62 Power M. *The audit society: rituals of verification.* Oxford: Oxford University Press, 1997.

63 Laitinen H and Ruohomäki I. The effects of feedback and goal setting on safety performance at two construction sites. *Safety Science* 1996; 24 (1): 64–73.

64 Wright P, Pocock S and Fields R E. The prescription and practice of work on the flight deck. In: Green T R G, Bannon L, Warren C P and Buckley J (eds). *Cognition and cooperation: proceedings of the 9th European Conference on Cognitive Ergonomics (ECCE9).* Paris: EACE Press, 1988: 37–42.

65 Wright P and McCarthy J. Analysis of procedure following as concerned work. In: Hollnagel E (ed). *Handbook of cognitive task design.* Mahwah, NJ: Lawrence Erlbaum Associates, 2003: 679–700.

66 Mascini P. The blameworthiness of health and safety rule violations. *Law & Policy* 2005; 27 (3): 472–490.

67 Mascini P and Bacharias Y. Formal and informal risk handling strategies: the importance of ethnographic research for safety surveys. In: *Proceedings of the 4th International Working on Safety Network Conference.* Crete, 2008.

68 Knudsen F. Paperwork at the service of safety? Workers' reluctance against written procedures exemplified by the concept of 'seamanship'. *Safety Science* 2009; 47 (2): 285–303.

69 Zoller H. Health on the line: identity and disciplinary control in employee occupational health and safety discourse. *Journal of Applied Communication Research* 2003; 31 (2): 118–139.

70 McDonald R, Waring J, Harrison S, Walshe K and Boaden R. Rules and guidelines in clinical practice: a qualitative study in operating theatres of doctors' and nurses' views. *Quality and Safety in Health Care* 2005; 14: 290–294.

71 McDonald R, Waring J and Harrison S. Rules, safety and the narrativisation of identity: a hospital operating theatre case study. *Sociology of Health & Illness* 2006; 28 (2): 178–202.

72 Borys D. *Exploring risk awareness as a cultural approach to safety: an ethnographic study of a contract maintenance environment.* PhD thesis. University of Ballarat. School of Science & Engineering, 2007.

73 Argyris C and Schön D. *Organizational learning: a theory of action perspective.* Reading, Massachusetts: Addison Wesley, 1978.

74 Komaki J, Barwick K and Scott L. A behavioral approach to occupational safety: pinpointing and reinforcing safe performance in a food manufacturing plant. *Journal of Applied Psychology* 1978; 63 (4): 434–445.

75 McAfee R B and Win A R. The use of incentives/feedback to enhance workplace safety: a critique of the literature. *Journal of Safety Research* 1989; 20: 7–19.

76 Geller E S. *Understanding behaviour-based safety: step by step methods to improve your workplace.* 2nd edition. Neenah, Wisconsin: J J Keller & Associates, 1998.

77 De Pasquale J P and Geller E S. Critical success factors for behavior-based safety: a Study of twenty industry-wide applications. *Journal of Safety Research* 1999; 30 (4): 237–249.

78 Boyce T E and Geller E S. Applied behavior analysis and occupational safety: The challenge of response maintenance. *Journal of Organizational Behavior Management* 2001; 21 (1): 31–60.

79 DeJoy D M. Behavior change versus culture change: divergent approaches to managing workplace safety. *Safety Science* 2005; 43 (2): 105–129.
80 Komaki J, Heinzmann A and Lawson L. Effect of training and feedback: component analysis of a behavioral safety program. *Journal of Applied Psychology* 1980; 65 (3): 261–270.
81 Hale A R, Guldenmund F W, van Loenhout P L C H and Oh J I H. Evaluating safety management and culture interventions to improve safety: effective intervention strategies. *Safety Science* 2010; 48 (8): 1026–1035.
82 Parker D, Lawrie M and Hudson P. A framework for understanding the development of organisational safety culture. *Safety Science* 2006; 44: 551–562.
83 Shell. *Guidance for employee and (sub) contractor front-line staff*. Version 2. The Hague: Shell, 2009: 12. Life-saving rules.
84 Baker E. Predicting response to hurricane warnings: a reanalysis of data from four studies. *Mass Emergencies* 1979; 4: 9–24.
85 Peters R. *The challenge of enforcing safety rules in remote hazardous work areas*. Paper presented at Work, Stress, and Health '99: Organization of Work in a Global Economy Conference, Baltimore, 13 March 1999.
86 Battmann W and Klumb P. Behavioural economics and compliance with safety regulations. *Safety Science* 1993; 16 (1): 35–46.
87 Zeitlin L R. Failure to follow safety instructions: faulty communication or risky decision? *Human Factors* 1994; 36 (1): 172–181.
88 HFRG. *Improving compliance with safety procedures: reducing industrial violations*. Human Factors in Reliability Group. London: HMSO London, 1995.
89 Åberg L. Traffic rules and traffic safety. *Safety Science* 1998; 16 (1): 205–216.
90 Lawton R. Not working to rule: understanding procedural violations at work. *Safety Science* 1998; 28 (2): 77–96.
91 Ng I and Dastmalchian A. Organizational flexibility in Canada: a study of control and safeguard rules. *The International Journal of Human Resource Management* 1998; 9 (3): 445–456.
92 Hudson P, Parker D, Lawton R and van der Graaf G. *Bending the rules: managing violation in the workplace*. International Conference of the Society of Petroleum Engineers 2000. www.energyinst.org.uk/heartsandminds/docs/bending.pdf. Viewed 29 August 2012.
93 Besnard D and Greathead D. A cognitive approach to safe violations. *Cognition, Technology and Work* 2003; 5 (4): 272–282.
94 Polet P, Vanderhaegen F and Amalberti R. Modelling borderline tolerated conditions of use (BTCU) and associated risks. *Safety Science* 2003; 41 (2–3): 111–136.
95 Wilson N A. *Improving compliance with permanent attachment safety procedures in the overhead transmission industry: reducing the potential for violations*. MSc thesis in Risk Management & Safety Technology, University of Aston in Birmingham, 2004.
96 Iszatt-White M. Catching them at it: an ethnography of rule violation. *Ethnography* 2007; 8 (4): 445–465.
97 Alper S J, Holden R J, Scanlon M C, Kaushal R, Shalaby T M and Karsh B. Using the Technology Acceptance Model to predict violations in the medication use process. In: *Proceedings of the Human Factors & Ergonomics Society Annual Meeting* 2007; 51 (11): 745–749.
98 Alper S J, Holden R J, Scanlon M C, Patel N, Murkowski K, Shalaby T M and Karsh B. Violation prevalence after introduction of a bar-coded medication administration system. In: *Proceedings of the 2nd International Conference on Healthcare System Ergonomics and Patient Safety*. Strasbourg, 2008.
99 Alper S J, Scanlon M C, Murkowski K, Patel N, Kaushal R and Karsh B. Routine and situational violations during medication administration. In: Sznelwar L, Mascia F and Montedo U (eds). *Human Factors in Organizational Design and Management IX, 2008*. Santa Monica, California: IEA Press, 2008.
100 Loukopoulou L. Pilot error: even skilled experts make mistakes. In: *Proceedings of the 4th International Working on Safety Network Conference*. Crete, 2008.
101 Alper S and Karsh B-T. A systematic review of safety violations in industry. *Accident Analysis and Prevention* 2009; 41 (4): 739–754.
102 Drach-Zahavy A and Somech A. Implicit as compared with explicit safety procedures: the experience of Israeli nurses. *Qualitative Health Research* 2010; 20 (10): 1406–1417.
103 Parker D, Reason J T, Manstead A S R and Stradley S G. Driving errors, driving violations and accident involvement. *Ergonomics* 1995; 38 (5): 1036–1048.
104 Reason J T. *Human error*. Cambridge: Cambridge University Press, 1990.
105 Free R. *The role of procedural violations in railway accidents*. PhD thesis. University of Manchester, 1994.

106 Theodoulides A. 'I would never personally tell anyone to break the rules, but you can bend them': teaching moral values through team games. *European Journal of Physical Education* 2003; 8 (2): 141–159.
107 Simard M and Marchand A. Workgroup's propensity to comply with safety rules: the influence of micro-macro organisational factors. *Ergonomics* 1997; 40 (2): 172–188.
108 Hofmann D and Morgeson F. Safety-related behavior as a social exchange: the role of perceived organizational support and leader-member exchange. *Journal of Applied Psychology* 1999; 84 (2): 286–296.
109 Polet P, Vanderhaegen F and Wieringa P. Theory of safety-related violations of system barriers. *Cognition, Technology & Work* 2002; 4: 171–179.
110 Fishbein M and Ajzen I. *Belief, attitude, intention and behavior: an introduction to theory and research*. Reading, Massachusetts: Addison-Wesley, 1975.
111 Hopkins A. *Risk management and rule compliance decision making in hazardous industries*. Working Paper 72. Canberra: National Research Centre for OHS Regulation, 2010.
112 Bourrier M. Organizing maintenance work at two American nuclear power plants. *Journal of Contingencies and Crisis Management* 1996; 4 (2): 104–112.
113 Marchand A, Simard M, Carpentier-Roy M-C and Ouellet F. From a unidimensional to a bidimensional concept and measurement of workers' safety behaviour. *Scandinavian Journal of Work, Environment and Health* 1998; 24 (4): 293–299.
114 Clarke S. The relationship between safety climate and safety performance: a meta-analytic review. *Journal of Occupational Health Psychology* 2006; 11 (4): 315–327.
115 Fleury D. Reinforcing the rules or integrating behavioural responses into road planning. *Safety Science* 1998; 16 (1): 217–228.
116 Dien Y. Safety and application of procedures, or 'how do 'they' have to use operating procedures in nuclear power plants?' *Safety Science* 1998; 29 (3): 179–188.
117 Katz-Navon T, Naveh E and Stern Z. Safety climate in health care organizations: a multidimensional approach. *Academy of Management Journal* 2005; 84 (6): 1075–1089.
118 Fucks I and Dien Y. *'No rule, no use'? The effects of overproceduralization*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
119 Weick K E. Drop your tools: an allegory for organizational studies. *Administrative Science Quarterly* 1996; 41: 301–313.
120 Thackaberry J. 'Discursive opening' and closing in organizational self-study: culture as trap and tool in wildland firefighting safety. *Management Communication Quarterly* 2004; 17 (3): 319–359.
121 Parker D and Lawton R. Judging the use of clinical protocols by fellow professionals. *Social Science & Medicine* 2000; 51 (5): 669–677.
122 Høyland S, Aase K, Hollund J G and Haugen A. *What is it about checklists? Exploring safe work practices in surgical teams*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
123 McDonald N, Corrigan S, Daly C and Cromie S. Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science* 2000; 34 (1–3): 151–176.
124 Corrigan S. *Comparative analysis of safety management systems and safety culture in aircraft maintenance*. PhD thesis. Trinity College, Dublin, 2002.
125 Dekker S W A. Failure to adapt or adaptations that fail: contrasting models on procedures and safety. *Applied Ergonomics* 2003; 34 (3): 233–238.
126 DEGAS. Regels als gestolde ervaring ('Rules as concentrated (solidified) experience'). Dutch Expert Group Aviation Safety. Advice 2010-053. 2010. www.adviescollege-degas.nl/linked/rage_-_degas-advies_2010-053.pdf. Viewed 29 August 2012.
127 Ranney J and Nelson C. Impacts of participatory safety rules revision in US railroad industry. *Transportation Research Record: Journal of the Transportation Research Board* 2004; 1899: 156–163.
128 Grote G. *Rules management as source for loose coupling in high-risk systems*. Paper presented at the 2nd Symposium on Resilience Engineering, Juan-les-Pins, France, 8–10 November 2006.
129 Woods D D and Shattuck L G. Distant supervision – local action given the potential for surprise. *Cognition, Technology & Work* 2000; 2: 242–245.
130 Weick K E. The collapse of sense-making in organizations: the Mann Gulch disaster. *Administrative Science Quarterly* 1993; 38: 628–652.
131 Reason J T. *Managing the risks of organisational accidents*. Aldershot: Ashgate, 1997.
132 Schulz M. Impermanent institutionalization: the duration dependence of organizational rule changes. *Industrial and Corporate Change* 2003; 12 (5): 1077–1098.

133 Schulz M and Beck N. *Iron laws of bureaucracy – comparing incremental and radical change of organizational rules in the US and Germany.* Unpublished manuscript. Sauder School of Business, University of British Columbia, 2000.
134 Gherardi S and Nicolini D. To transfer is to transform: the circulation of safety knowledge. *Organization* 2000; 7 (2): 329–348.
135 Reynaud B. Types of rules, interpretation and collective dynamics: Reflections on the introduction of a salary rule in a maintenance workshop. *Industrial and Corporate Change* 1996; 5 (3): 699–721.
136 Reynaud B. Void at the heart of rules: routines in the context of rule-following. The case of the Paris Metro Workshop. *Industrial and Corporate Change* 2005; 14 (5): 847–871.
137 Becker M. The concept of routines: some clarifications. *Cambridge Journal of Economics* 2005; 29 (2): 249–262.
138 Becker M. A framework for applying organizational routines in empirical research: linking antecedents, characteristics and performance outcomes of recurrent interaction patterns. *Industrial and Corporate Change* 2005; 14 (5): 817–846.
139 Levinthal D and Rerup C. Crossing an apparent chasm: bridging mindful and less-mindful perspectives on organizational learning. *Organization Science* 2006; 17 (4): 502–513.
140 Bruns H. Leveraging functionality in safety routines: examining the divergence of rules and performance. *Human Relations* 2009; 62 (9): 1399–1426.
141 Kramer R. Trust and distrust in organizations: emerging perspectives, enduring questions. *Annual Review of Psychology* 1999; 50: 569–598.
142 Adler P, Goldoftas B and Levine D. Flexibility versus efficiency? A case study of model changeovers in the Toyota production system. *Organization Science* 1999; 10 (1): 43–68.
143 Jeffcott S, Pidgeon N, Weyman A and Walls J. Risk, trust, and safety culture in UK train operating companies. *Risk Analysis* 2006; 26 (5): 1105–1121.
144 Conchie S and Donald I. The functions and development of safety-specific trust and distrust. *Safety Science* 2008; 46 (1): 92–103.
145 Karasek R A. Job demands, job decision latitude, and mental strain: implications for job redesign. *Administrative Science Quarterly* 1979; 24: 285–308.
146 Dreyfus H and Dreyfus F. *Mind over machine: the power of human intuition and expertise in the era of the computer.* Oxford: Blackwell, 1989.
147 Rayner S. Management of radiation hazards in hospitals: plural rationalities in a single institution. *Social Studies of Science* 1986; 16: 573–591.
148 Otsuka Y, Misawa R, Noguchi H and Yamaguchi H. A consideration for using workers' heuristics to improve safety rules based on relationships between creative mental sets and rule-violating actions. *Safety Science* 2010; 48: 878–884.
149 Brady F. Rules for making exceptions to rules. *Academy of Management Review* 1987; 12 (3): 436–444.
150 Becker M, Lazaric N, Nelson R and Winter S. Applying organizational routines in understanding organizational change. *Industrial and Corporate Change* 2005; 14 (5): 775–791.
151 Nathanael D and Marmaras N. *The interplay between work practices and prescription: a key issue for organizational resilience.* In: Hollnagel E and Rigaud E (eds). *Proceedings of the 2nd Symposium on Resilience Engineering*. Paris: Press de MINES, 2006: 229–237.
152 Gouldner A W. *Patterns of industrial bureaucracy.* New York: Free Press, 1954.
153 March J and Simon H. *Organizations*. New York: John Wiley and Sons, 1958.
154 Scott-Morgan P. *The unwritten rules of the game.* New York: McGraw-Hill, 1994.
155 Feldman M and Pentland B. Reconceptualizing organizational routines as a source of flexibility and change. *Administrative Science Quarterly* 2003; 48: 94–118.
156 Nathanael D and Marmaras N. On the development of work practices: a constructivist model. *Theoretical Issues in Ergonomics Science* 2008; 9 (5): 359–382.
157 Hollnagel E, Woods D D and Leveson N (eds). *Resilience engineering: concepts and precepts.* Aldershot: Ashgate, 2006.
158 Borys D. The role of safe work method statements in the Australian construction industry. *Safety Science* 2012; 50 (2): 210–220.
159 Schöbel M. Trust in high-reliability organizations. *Social Science Information* 2009; 48 (2): 315–333.
160 van der Doef M and Maes S. The job-demand-control (-support) model and psychological well-being: a review of 20 years of empirical research. *Work and Stress* 1999; 13: 87–114.
161 Snyder L A, Krauss A D, Chen P Y, Finlinson S and Huang Y-H. Occupational safety: application of the job demand-control-support model. *Accident Analysis and Prevention* 2008; 40: 1713–1723.
162 Torp S and Grøgaard J B. The influence of individual and contextual work factors on workers' compliance with health and safety routines. *Applied Ergonomics* 2009; 40, 185–193.

163 Larsen L and Hale A R. Safety rule management in railways. In: *Proceedings of the European Transport Conference*. Strasbourg, 4–6 October 2004.
164 Schulman P. *Procedural paradoxes and the management of safety.* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
165 Antonsen S, Almklov P and Fenstad J. Reducing the gap between procedures and practice – Lessons from a successful safety intervention. *Safety Science Monitor* 2008; 12 (1): Article 2 (electronic version).
166 Komaki J, Collins R and Penn P. The role of performance antecedents and consequences in work motivation. *Journal of Applied Psychology* 1982; 67 (3): 334–340.
167 Hale A R, Guldenmund F W, van Loenhout P L C H and Oh J I H. Evaluating safety management and culture interventions to improve safety: effective intervention strategies. *Safety Science* 2010; 48 (8): 1026–1035.
168 Klinect J R. *Line operation safety audit: a cockpit observation methodology for monitoring commercial airline safety performance*. Doctoral Dissertation. University of Texas, 2005.
169 Roelen A L C. *Causal risk models of air transport: comparison of user needs and model capabilities*. PhD thesis. Delft: Delft University of Technology, Safety Science Group, 2008.
170 Davies N, Efstratiou C, Finney J, Hooper R, Kortuem G and Lowton M. Sensing danger – Challenges in supporting health and safety compliance in the field. In: *Proceedings of the Eighth IEEE Workshop on Mobile Computing Systems and Applications*. Washington DC: IEEE Computer Society, 2007: 34–38.
171 Holmqvist M. Intra- and inter-organisational learning processes: an empirical comparison. *Scandinavian Journal of Management* 2003; 19 (4): 443–466.
172 Koornneef F. *Learning from small-scale incidents*. PhD thesis. Safety Science Group. Delft: Delft University of Technology, 2000.
173 Glazner J E, Borgerding J, Bondy J, Lowery J T, Lezotte D C and Kreiss K. Contractor safety practices and injury rates in construction of Denver International Airport. *American Journal of Industrial Medicine* 1999; 35: 175–185
174 Harms-Ringdahl L. *Swedish case study – safety rule management in railways*. Stockholm, Sweden: Institute for Risk Management and Safety Analysis, 2004.
175 Hale A R. Safety rules OK? Possibilities and limitations in behavioural safety strategies. *Journal of Occupational Accidents* 1990; 12: 3–20.
176 Baram M. *The use of rules to achieve safety: introductory remarks*. Paper to the 11th New Technology and Work Workshop on 'The use of rules to achieve safety'. Bad Homburg, 1993.
177 Häller G and Stoelwinder J. *Teamwork management by the 'crew resource management' method used in civil aviation: an alternative to procedure-based strategies to improve patient safety in hospitals?* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
178 Bellamy L J, Papazoglou I A, Hale A R, Aneziris O N, Ale B J M, Morris M I and Oh J I H. *I-risk: development of an integrated technical and management risk control and monitoring methodology for managing and quantifying on-site and off-site risks*. Contract ENVA-CT96-0243. Den Haag: Report to European Union. Ministry of Social Affairs and Employment, 1999.
179 Bellamy L J, Ale B J M, Geyer T A W, Goossens L H J, Hale A R, Oh J I H, Mud M, Bloemhoff A, Papazoglou I A and Whiston J Y. Storybuilder: a tool for the analysis of accident reports. *Reliability Engineering & System Safety* 2006; 92 (6): 735–744.
180 Peterson L and Schick B. Empirically derived injury prevention rules. *Journal of Applied Behavior Analysis* 1993; 26 (4): 451–460.
181 Hopwood A G. *Accounting systems and managerial behaviour*. London: Paul Chapman, 1974.
182 Pélegrin C. *The story of proceduralization in aviation*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
183 Polesie P. V*aluing freedom and standardization when working at the construction site*. Building and Real Estate Workshop paper. Hong Kong: The Hong Kong Polytechnic University, 2009.
184 Hofstede G R. Werken aan de organisatiecultuur ('Working on the organisational culture'). *Bedrijfskunde* 1986; 58 (2): 102–106.
185 Wagenaar W A. Checklist voor de evaluatie van geschreven procedures ('Checklist for the evaluation of written procedures'). Soesterberg, NL: TNO Instituut voor Zintuigfysiologie, 1982.
186 Elling M G M. Veilig werken volgens geschreven procedures: illusies en werkelijkheid ('Safe work according to written procedures: illusion and reality'). *Toegepaste Taalwetenshap* 1987; 2: 133–143.

187 Elling M G M. Duidelijkheid, bruikbaarheid en effectiviteit van werk- en veiligheidsinstructies ('Clarity, usefulness and effectiveness of work and safety instructions'). *Tijdschrift voor Taalbeheersing* 1988; 10: 1–13.
188 Hale A R. Safety rules OK? Possibilities and limitations in behavioural safety strategies. *Journal of Occupational Accidents* 1990; 12: 3–20.
189 WorkCover New South Wales. *Priority issues for construction reform: safe building New South Wales*. Report summary. Sydney: WorkCover NSW, 2001.
190 Bell J and Fogler H. Virtual laboratory accidents designed to increase safety awareness. In: *Proceedings of the 1999 American Society for Engineering Education Annual Meeting*. Charlotte, North Carolina, 1999: Session 3613.
191 Hale A R, Jacobs J and Oor M. Safety culture change in two companies. In: *Proceedings of the International Conference on Probabilistic Safety Assessment & Management*. Seattle, Washington, 7– 11 June 2010.
192 Mintzberg H. *Structures in five: designing effective organisations*. Englewood Cliffs, New Jersey: Simon & Schuster, 1983.
193 Hersey P, Blanchard K H and Johnson D E. *Management of organizational behavior: leading human resources*. 9th Edition. New Jersey: Prentice Hall, 2007.
194 Rosness R. *The proceduralisation of traffic safety and safety management in the Norwegian Rail Administration: a comparative case study.* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
195 Hale A R, Borys D and Adams M. *Regulatory overload: a behavioral analysis of regulatory compliance*. Working paper no. 11-47. Arlington, Virginia: Mercatus Center, George Mason University, 2011.

Additional references

The following references are handled extensively in review articles which we have referenced in the paper, so they are not included in the above bibliography. However, their importance as original sources chosen from the preceding literature means that it is useful to include them in this supplementary list.

Andriessen J H T H. Safe behaviour and safety motivation. *Journal of Occupational Accidents* 1978; 1: 368–376.
van Avermaete J A G and Hakkeling–Mesland M Y. *Maintenance human factors from a European research perspective: results from the ADAMS project and related research initiatives.* Amsterdam: National Aerospace Laboratory, 2001.
Baiche B, Walliman N and Ogden R. Compliance with building regulations in England and Wales. *Structural Survey* 2006; 24 (4): 279–299.
Beatty P C W and Beatty S F. Anaesthetists intentions to violate safety guidelines. *Anaesthesia* 2004; 59: 528–540.
Beekmann S E and Henderson D K. Protection of health care workers from blood borne pathogens. *Current Opinion in Infectious Diseases* 2005; 18: 331–336.
Berg M. *Rationalizing medical work: decision support techniques and medical practice.* Cambridge, Mass: MIT Press, 1997.
Bisset L. Can alcohol hand rubs increase compliance with hand hygiene? *British Journal of Nursing* 2002; 11 (16): 1072–1077.
Blau P. *The dynamics of bureaucracy.* Chicago: Chicago University Press, 1955.
Brody J G. Responses to collective risk: appraisal and coping among workers exposed to occupational safety hazards. *American Journal of Community Psychology* 1988; 16: 645–663.
Cabana M D, Ebel B E, Cooper-Patrick L, Powe N R, Rubin H R and Rand C S. Barriers pediatricians face when using asthma practice guidelines. *Archives of Pediatrics and Adolescent Medicine* 2000; 154: 685–693.
Conner M, Lawton R, Parker D, Chorlton K, Manstead A S R and Stradling S. Application of the theory of planned behaviour to the prediction of objectively assessed breaking of posted speed limits. *British Journal of Psychology* 2007; 98: 429–453.
Cutter J and Jordan S. Uptake of guidelines to avoid and report exposure to blood and body fluids. *Journal of Advanced Nursing* 2004; 46 (4): 441–452.
Eccles M, Clapp Z, Grimshaw J, Adams P C, Higgins B, Purves I and Russell I. North of England evidence-based guidelines development project: methods of guideline development. *British Medical Journal* 1996; 312: 760–762.
Espin S, Lingard L, Baker G R and Regehr G. Persistence of unsafe practices in everyday work: an exploration of organizational and psychological factors constraining safety in the operating room. *Quality and Safety in Health Care* 2006; 15: 165–170.
Gabbay J and Le May A. Evidence-based guidelines or collectively constructed 'mindlines'? Ethnographic study of knowledge management in primary care. *British Medical Journal* 2004; 329: 1013–1017.
Grilli R and Lomas J. Evaluating the message: the relationship between the compliance rate and the subject of a practice guideline. *Medical Care* 1994; 32: 202–213.
Grimshaw J and Russell I T. Achieving health gain through clinical guidelines. 1. Developing scientifically valid guidelines. *Quality in Health Care* 1993; 2: 243–248.
Grimshaw J and Russell I T. Effect of clinical guidelines on medical practice: a systematic review of rigorous evaluations. *Lancet* 1993; 342: 1317–1323.
Grimshaw J and Russell I T. Achieving health gain through clinical guidelines. 2. Ensuring guidelines change clinical practice. *Quality in Health Care* 1994; 3: 45–52.
Hobbs A and Williamson A. Unsafe acts and unsafe outcomes in aircraft maintenance. *Ergonomics* 2002; 45 (12): 866–882.
Horning L A and Smith P W. Infection control violations. *Infection Control and Hospital Epidemiology* 2001; 12: 672–675.
Koppel R, Wetterneck T B, Telles J L and Karsh B T. Workarounds to barcode medication administration systems: their occurrence, causes and threats to patient safety. *Journal of the American Medical Informatics Association* 2008; 15 (4): 408–423.
March J. *Decisions and organisations.* Oxford: Basil Blackwell, 1988.
March J, Schulz M and Zhou X. *The dynamics of rules: change in written organizational codes.* Stanford: Stanford University Press, 2000.
Maskerine C and Loeb M. Improving adherence to hand hygiene among health care workers. *Journal of Continuing Education in the Health Professions* 2006; 26: 244–251.

McCarthy J, Wright P, Healey P, Dearden A and Harrison M D. Locating the scene: the particular and the general in contexts for ambulance control. In: *Proceedings of the Group '97 International Conference on Supporting Group Work*. New York: ACM, 1997: 101–110.
McDonald N, Corrigan S and Ward M. *Well-intentioned people in dysfunctional systems*. 5th Workshop on Human Error, Safety and Systems Development. Newcastle, Australia, 2002.
McDonald R and Harrison S. The micropolitics of clinical guidelines: an empirical study. *Policy and Politics* 2004; 32 (2): 223–229.
McKeon C M, Fogarty G J and Hegney D G. Organizational factors: impact on administration violations in rural nursing. *Nursing and Healthcare Management and Policy* 2006; 55 (1): 115–123.
Moore D, Gamage B, Bryce E, Copes R and Yassi A. Protecting health care workers from SARS and other respiratory pathogens: organizational and individual factors that affect adherence to infection control guidelines. *American Journal of Infection Control* 2005; 33 (2): 88–96.
Parker D and Lawton R. Psychological contribution to the understanding of adverse events in health care. *Quality and Safety in Healthcare* 2003; 12: 453–457.
Patterson E S, Rogers M L, Chapman R J and Render M L. Compliance with intended use of barcode medication administration in acute and long term care. *Human Factors* 2006; 48: (1) 15–22.
Peters R. Strategies for encouraging self-protective behaviour. *Journal of Safety Research* 1991; 22: 53–70.
Rebok G W, Qiang Y, Baker S P, McCarthy M I and Li G. Age, flight experience and violation risk in mature commuter and air taxi pilots. *International Journal of Aviation Psychology* 1998; 15 (4): 363–374.
Russell I T Y and Grimshaw J. The effectiveness of referral guidelines: a review of the methods and findings of published evaluations. In: Roland M O and Coulter A (eds). *Hospital referrals*. Oxford: Oxford University Press, 1992.
Schulz M. Limits to bureaucratic growth: the density dependence of organizational rule births. *Administrative Science Quarterly* 1998: 43: 845–876.
Shinar D, Schechtman E and Compton R. Self-reports of safe driving behaviour in relationship to sex, age, education and income in US adult driving population. *Accident Analysis and Prevention* 2001; 33: 111–116.
Simard M and Marchand A. The behaviour of first line supervisors and effectiveness in occupational safety. *Safety Science* 1994; 19: 169–184.
Snyder L A, Autumn D, Krauss A D, Peter Y, Chen P Y, Finlinson S and Huang Y-H. Occupational safety: application of the job demand–control-support model. *Accident Analysis and Prevention* 2008; 40: 1713–1723.
Starbuck W H and Milliken F J. Challenger: fine tuning the odds until something breaks. *Journal of Management Studies* 1998; 25 (4): 319–340.
Suchman L A. *Plans and situated actions: the problem of human–machine communication*. Cambridge: Cambridge University Press, 1987.
Taxis K and Barber N. Causes of intravenous medication errors: an ethnographic study. *Quality and Safety in Health Care* 2003; 12 (5): 343–347.
University of Leeds, Faculty of Health Care. Implementing clinical practice guidelines: can guidelines be used to improve clinical practice? *Effective health care* 1994; 8.
Wills A R, Watson B and Biggs H C. Comparing safety climate factors as predictors of work-related driving behaviour. *Journal of Safety Research* 2006; 37: 375–383.
Woods D D, Johannesen L J, Cook R I and Sarter N B. *Behind human error: cognitive systems, computers, complexity and hindsight*. CSERIAC State of the Art Report 94-01. Ohio: Wright-Patterson Air Force Base, 1994.
Zhou X. The dynamics of organizational rules. *American Journal of Sociology* 1993; 98: 1134–1166.
Zhou X. Organizational decision making as rule following. In: Shapira Z (ed). *Organizational decision making*. New York: Cambridge University Press, 1997: 257–281.

References on safety management and regulatory level rules

This is a list of references which were turned up in the search for papers about safety rules. That search and the report we have written on it concentrates on rules at the primary process/workplace level. The following references were concentrated at the safety management system and regulatory levels, which is beyond the scope of this paper. However, we include them here as a start for an eventual further study to compare findings at these different levels.

Bain P. Human resource malpractice: the deregulation of health and safety at work in the USA and Britain. *Industrial Relations Journal* 1997; 28 (3): 176–191.
Chapman J. After the inspector's visit. *The Safety Representative* 5 March 1982.
Deharvengt S. *Regulating airline's safety management systems: when proceduralization of risks meets the risk owners*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Elffers H, van der Heijden P and Hezemans M. Explaining regulatory non-compliance: a survey study of rule transgression for two Dutch instrumental laws, applying the randomized response method. *Journal of Quantitative Criminology* 2003; 19 (4): 409–439.
Fairman R and Yapp C. Enforced self-regulation, prescription, and conceptions of compliance within small businesses: the impact of enforcement. *Law and Policy* 2005; 27 (4): 491–519.
Fowler D. *Proceduralization of safety management: a barrier to rational thinking?* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Grote G. W*hy regulators should stay away from safety culture and stick to rules*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Gun R T. The role of regulations in the prevention of occupational injury. *Safety Science* 1993; 16 (1): 47–66.
Gunningham N and Sinclair D. *Regulation and the role of trust: reflections from the mining industry.* Working Paper 59. Canberra: National Centre for OHS Regulation, Australian National University, 2008.
Gunningham N and Sinclair D. *On the limits of management based regulation.* Working Paper 69. Canberra: National Centre for OHS Regulation, Australian National University, 2009.
Hale A R, Goossens L H J and van der Poel I. Oil and gas industry regulation: from detailed technical inspection to assessment of management systems. In: Kirwan B, Hale A R and Hopkins A (eds). *Changing regulations: controlling risks in society.* Oxford: Pergamon, 2002: 79–108.
Hale A R, de Loor M, van Drimmelen D and Huppes G. *Risk analysis vs. specific rules as approaches to the control of 'normal' hazards*. Paper to the 1st Conference of the European Section of the Society of Risk Analysis, Laxenburg, Austria, 10–11 November 1993.
Kirwan B, Hale A R and Hopkins A. *Changing regulations: controlling risks in society.* Oxford: Pergamon, 2002.
Kringen J. *Proceduralization and regulation of culture: experiments on the frontiers of risk regulation*. Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Langbein L and Kerwin C. Implementation, negotiation and compliance in environmental and safety regulation. *The Journal of Politics* 1985; 47 (3): 854–880.
Lange B. Compliance construction in the context of environmental regulation. *Social and Legal Studies* 1999; 8 (4): 549–567.
LeCoze J-C and Wiig S. *Beyond procedures: can 'safety culture' be regulated?* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Lindoe P H, Baram M and Braut G S. *Risk regulation and proceduralization: an assessment of Norwegian and US risk regulation in offshore oil and gas industry.* Paper to the 27th New Technology and Work Workshop on 'How desirable or avoidable is proceduralization of safety?'. Sorèze, France, 2010.
Majumdar S. Rules versus discretion: the productivity consequences of flexible regulation. *Academy of Management Journal* 2000; 44 (1): 170–179.
May P and Wood R. At the regulatory front lines: inspectors' enforcement styles and regulatory compliance. *Journal of Public Administration Research and Theory* 2003; 13 (2): 117–139.
May P. Compliance motivations: affirmative and negative bases. *Law and Society Review* 2004; 38 (1): 41–68.

Nielsen V. Are regulators responsive? *Law and Policy* 2006; 28 (3): 395–416.
Olson M. Agency rulemaking, political influences, regulation and industry compliance. *The Journal of Law, Economics and Organization* 1999; 15 (3): 573–601.
Scally G and Donaldson L J. Clinical governance and the drive for quality improvement in the new NHS in England. *British Medical Journal* 1998; 31: 61–65.
Walls J, Pidgeon N, Weyman A and Horlick-Jones T. Critical trust: understanding lay perceptions of health and safety risk regulation. *Health, Risk and Society* 2004; 6 (2): 133–150.
Wiig S and Lindoe P. Patient safety in the interface between hospital and risk regulator. *Journal of Risk Research* 2009; 12 (3–4): 411–426.
Winter P and May S. Motivation for compliance with environmental regulations. *Journal of Policy Analysis and Management* 2001; 20 (4): 675–698.

Appendix: Workshop

This appendix gives an abbreviated description of the workshop held to assist in translating the academic findings of the literature review into more practical guidance.

The workshop was held in Derby on 29 March 2011 to present the results of a literature review of safety rules and procedure management to a number of senior safety professionals. The objective was to test theory against practice, in order to see if further nuances needed to be incorporated into the literature review, but principally to derive a set of good practices which could be distilled into guidelines for managing safety rules and procedures, as well as an intervention plan outlining how an organisation could review its own system of management of rules and set about improving it to match good practice.

Thirty-six senior safety practitioners forming part of the professional network of the authors and of HASTAM were sent a personal invitation to attend the workshop, which was announced as a first step in setting up a forum for thought leadership in developing scientifically underpinned good practice. Nineteen accepted, but two were unable to make it on the day. The 17 were supplemented by the two authors and six other safety consultants from HASTAM, who acted as discussion group leaders and rapporteurs.

The workshop was divided into three presentations based on the structure of the literature review. Each presentation was followed by a breakout discussion in three groups to gather comments and suggestions, which were collected and presented by the rapporteurs and discussed at a plenary session before moving onto the next topic. Each breakout session was guided by a set of questions to be discussed. The presentations and breakout sessions were entitled as follows:

1 Presentation: Models 1 and 2 and the safe envelope
2 Breakout: Facing the gap between rules and reality
3 Presentation: The diversity of rules: horses for courses
4 Breakout: Golden rules, guidance notes and other animals: populating a matrix for choice
5 Presentation: A rule-making framework
6 Breakout: Achieving participation and intelligent compliance

The participants were sent the programme of the workshop, a two-page summary of the points made in the literature review and a copy of the review itself. Participants were asked to come with examples of problems and solutions in relation to the different aspects of rule management which they had themselves experienced. They were also invited to make comments about the ideas and frameworks presented.

The sessions were all highly interactive and many examples and suggestions were given. These did not strictly fall under the headings of the breakout sessions, but fell broadly under three themes, gathering together issues over the sessions. The following is an abbreviated sample of points made or questions raised under those three themes as noted by the rapporteurs. These fed into the writing and rewriting of the 'Notes of guidance'.

Theme 1: The gap between rules and reality

We write the rules for the norm, but is the norm reality?

Many examples of rules which could not be followed in particular circumstances: lone worker procedures, loading of transport vehicles, risk assessments, supervision of contractors, excavation in areas where underground services may be, some PTW [permit to work] provisions, electrical isolation, job handovers, PPE [personal protective equipment] in low risk areas, rules for handling aggression.

Also examples of rules which were well obeyed: seatbelts, mobile phone use, PPE where manifest risks present, drink driving, infection control in hospitals, pedestrian routes.

Rules lie on a continuum from 'usually violated' to 'never violated'. They can move from one category to the other depending on circumstances. The position depends on how applicable the rules are, whether supervision is possible, where violations are condoned, if rules are clear, whether

conflicts are resolved and appropriate consequences for breaches, training of risk perception. Rules have a bad press.

Need for approval process for exceptions. Training to interpret rules. Negotiating the forest of rules. Importance of communication and supervision.

Importance of the working culture of the organisation, but also of the professional group (eg electricians). Pressure from customer, supervisor or self to get job done. Perception that rule-following takes time can be countered by videoing and showing gain is minimal.

Need to clarify what rules are for – legal use in court?; to assist working safely?; to show auditors?; learning to work better?

Theme 2: The diversity of rules

Golden rules which can never be broken are a popular idea. They are possible if simple, in predictable and static situations, specific and applicable in high-risk areas where a breach has obvious consequences, but there still needs to be a mechanism to handle the very rare exceptions. Perhaps important that they protect others as well as the perpetrator. The problem comes when they are broken – is the resolve firm to use discipline? What about unintentional breaches? Does labelling of some rules as golden demean and downgrade those not so designated? Great care needed before designating golden rules – are there predictable circumstances where they do not apply?

Examples: earthing tankers when unloading, access to asbestos control area, ignition source in mines/chemical plants, seatbelts, smoking (an important example of a rule that has become golden over the last decade), 'break' a shotgun when carrying it, drinking on duty or when driving. Participants would like many others to be treated as such: PPE, operation of vehicles, fall prevention, use of safety protection devices; if in doubt stop and think before each task.

Hierarchy of rules useful – strategic performance goal, tactics of process rules, operational action rules. Choice is related to time available, competence and knowledge. Guidance for experts, compliance for novices.

Theme 3: Rule-making framework

Generally welcomed as a worked example of the Deming circle or HSG65, but beware that it looks too rational. Version presented at the workshop did not have a clear starting point – norm is that that is monitoring and reappraisal of existing rules. Need to specify when to use it. Rule management needs a facilitator to own the management process, as well as owners of individual rules – the enforcer?

Suggest starting with a default that no rule is necessary, or the rule can be scrapped, unless good arguments given. Get workforce to suggest rules to be scrapped. Need to record rationale for decisions – why rules in place. Some organisations have an arbitrary edict from directors to cut 50 per cent of rules. Rules do need slimming down.

Do not aim for perfect rule. Focus on ease of compliance, not purity of aim. Test rules by comparing them with what people get rewarded for. How do you arrange the monitoring? Day-to-day supervision, post-failure review, audit, behavioural monitoring. Need for trust to allow critical monitoring. Don't forget there is a danger in changing rules.

Writing down the rules is to protect your back in audit or prosecution (danger of legal jargon to formulate them) and to inform training content, not for the rule user – latter need coverage in training and communication, not leave the rules to die in a rule book. Training is also an environment for questioning rules.

Good basis for deciding who does which step and who participates. Who does the writing? Can you use pictures and flow charts instead of words?

Results

The topics arising in the workshop were used to modify the literature review, in particular to modify the order of presentation of the framework for rule management and emphasise that it starts usually with appraisal of an existing rule or situation and only occasionally with a new process needing rule development from scratch.

The main use was to structure the guidelines and intervention plan, and decide which issues to incorporate as good practice. Not all of the discussions and suggestions could be used, as some were clearly controversial and generated critical comment from other participants. A clear lesson to learn from the discussion was that rules and procedures need to be adapted to the circumstances facing a given organisation or site, or even working group. There are very few rules which are universal; even what can be labelled a 'golden rule' may differ according to circumstances.

After the workshop, the guidelines and intervention plan were produced and circulated to all of the participants in the workshop for comment and correction. The few comments received were incorporated to make the final version.

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