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Safety management systems and safety culture in aircraft maintenance organisations☆

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Abstract

A self-regulatory model was proposed to examine how different organisations manage safety, with particular emphasis on the human and organisational aspects. The relationships of different aspects of safety culture and safety management systems were explored through the deployment of different research measures and methods. Studies of four aircraft maintenance organisations included analysis of documentation and qualitative interviews, surveys of safety climate and attitudes, expected response to incidents and compliance with task procedures. The model was effective in analysing the salient features of each organisation' s safety management system, though it underestimated the roles of planning and change. The data from management interviews, the incidents survey and safety climate survey exhibited a large measure of agreement in differentiating between the different safety management systems and safety climate of the four organisations. The measures of compliance with task procedures and safety attitudes did not differentiate between the four organisations (though one organisation did differ from the others in safety attitudes). This suggests a strong, relatively homogeneous professional sub-culture of aircraft technicians spanning the different organisations. Differences in safety attitudes and climate were found between occupational groups, though in the case of climate the differences between occupational groups were a function of the organisation, suggesting a differentiated notion of safety culture. The professional sub-culture of technicians is likely to mediate between the organisation' s safety management system and safety outcomes.

Keywords: Safety management systems; Safety culture; Aircraft maintenance organisations

1. Introduction

To understand the human contribution to major accidents and disasters, organisational and management factors have to be taken into account. However, the nature of

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these factors is not clear: neither is there a generally accepted model of the organisational aspects of safety, nor is there much literature linking particular organisational forms and accident occurrence or accident types. Until there is such a model, it is difficult to see how systematic links between organisational forms and accident occurrence could be established. Organisations are highly complex dynamic entities and safety is just one aspect of their functioning. This raises the question: what is the most appropriate level at which to analyse the safety aspects of an organisation? This paper is concerned with three concepts which have a central role in explaining the organisational role in safety. These are the notions of safety management system, safety climate and safety culture.

Few attempts have been made in the research literature to produce a comprehensive model of safety management systems. Much of the research is fragmentary and studies have widely different objectives. In a recent paper, Hale et al. (1998) have developed a theoretical model of an ideal maintenance management system incorporating safety. This focuses on three levels of management activity: policy; planning and procedures; and execution and feedback. Secondary analysis of maintenance accidents from a variety of industries indicated a relatively high involvement of the planning and procedures level relative to execution and feedback. Use of the model as an auditing tool and as a questionnaire-based self-assessment demonstrated that it could be used to differentiate between different companies' safety management systems, and to highlight deficiencies in those systems.

The research reported here had, as its first objective, the operationalisation of a model of safety management that could both effectively describe the safety management system of different companies and differentiate between them.

Analyses, which have started from the point of view of individual cognition and attitudes, have developed the theoretical notion of safety climate in order to explain the organisational factors which underlie a predisposition towards safety failures. Brown and Holmes (1986) indicated three major dimensions of safety climate: perceptions of management concern about employee well-being, management action to cope with this concern, and employees' physical risk. More recently Diaz Cabrera and Isla (1997) have developed scales of safety attitudes and safety climate which have been able to differentiate mean levels of these dimensions between different companies and different levels in the organisation. This raises the question: what is the relationship between the social–cognitive variables of attitudes and climate and the safety management system?

While climate concerns a perception of the organisation, safety culture is a more global concept. Pidgeon and O'Leary (1994) define safety culture as "the set of beliefs, norms, attitudes, roles and social and technical practices within an organisation which are concerned with minimising the exposure of individuals both within and outside an organisation to conditions which are considered to be dangerous" (p. 32). In this analysis the characteristics of a good safety culture are proposed as: location of responsibility for safety at strategic management level; distributed attitudes of care and concern throughout an organisation; appropriate norms and rules for handling hazards; and on-going reflection on safety practice.

1.1. Relationship between safety management systems and safety culture

In order to begin to explore the relationship between a safety management system and safety culture, a preliminary hybrid model was developed drawing both from the analysis of safety culture of Pidgeon and O'Leary (1994), and also from the rather more pragmatic and managerial focus of the Health and Safety Executive's 'Successful Health and Safety Management' (HSE, 1991). The HSE analysis focuses on five organisational functions, which are essential to effective safety management. These are:

1. policy: its development and implementation;
2. organisation: the development of the organisation to sustain effective communications, the promotion of competence at all levels and leadership to maintain a common culture supportive of health and safety;
3. planning to minimise risks and setting performance standards;
4. measuring performance; and
5. auditing and reviewing performance: all aspects of the organisational safety system are subject to audit and auditing and review activities provide feedback to all levels of the system.

A danger in this analysis arises from broad theoretical definitions. Pidgeon and O'Leary's (1994) definition of culture is in terms of 'systems of meaning'. This leads them to emphasise that one major drawback to their characterisation of safety culture is that a clear link to risk management practice does not become immediately visible. On the other hand, they also state that some understanding of existing cultures must be gained before risk management efforts, such as new training, reporting systems, procedural frameworks and resource management programmes, are designed and initiated. In drawing these conclusions, Pidgeon and O'Leary (1994) are making a distinction between 'safety culture', on the one hand, and 'risk management practices' on the other, although 'social and technical practices' are explicitly included in their definition of safety culture. This raises some of the issues concerning the definitions and boundaries of culture discussed by Martin (1992). If there is an apparent conflict here, part of the problem may be due to a vagueness in the definition of culture and part may reflect different measures and methods for studying cultural phenomena. On the face of it there appears to be considerable overlap between the two approaches although the language and theoretical background are divergent. This overlap encouraged us to propose a composite model which sought to encompass the main elements of both.

Pidgeon and O'Leary's (1994) emphasis on location of responsibility for safety at strategic management level suggested that a strong emphasis should be put on how safety features in the strategic priorities of senior management and how this priority is manifest in policy. We were also concerned to establish how such policy priorities are implemented in practice (including planning and organising) and in particular, where it would be possible to identify standards against which the successful implementation of policy could be judged.

Pidgeon and O'Leary's (1994) focus on appropriate norms and rules for handling hazards suggested that it would be important to seek to record or measure important aspects of behaviour, what happens in practice, and to compare this with the rules and prescriptive norms of work. This concern was particularly motivated by the evidence implicating failure to follow procedures as contributory factors in incident and accident occurrence and measures of the normative level of procedure violations (e.g. in aviation maintenance: McDonald et al., 1997a; Kanki et al., 1998; Wooton, 1998; in other areas of aviation: Lautman and Gallimore, 1988; McDonald et al., 1994; in the nuclear industry: Marsden, 1996; Bourrier, 1997; in the petrochemical industry: Embrey, 1998; in the rail transport industry: Lawton, 1998).

Both Pidgeon and O'Leary (1994) and the HSE (1991) model prioritised, in different terms, processes of monitoring, review and reflection. Therefore, monitoring and feedback were included as components of the model. Such monitoring activities could include auditing, quality reporting and incident investigation, in effect, all activities which reflect the current status of the system. Finally, Pidgeon and O'Leary's (1994) criterion of distributed attitudes of care and concern throughout an organisation was thought to be best represented in measures of attitudes to safety at all appropriate levels of the organisation. Thus, it is not distinguished as a separate component of the model. In summary, the model proposed at the initiation of this research consisted of five fundamental elements: strategy and policy; implementation of policy and setting standards; operational norms; monitoring; and feedback. This is outlined in Fig. 1.

1.2. Human factors and safety in aircraft maintenance and the present study

Aircraft maintenance is a critical component of the overall system for ensuring safety in aviation. Twelve per cent of major aviation accidents have been attributed to maintenance and inspection deficiencies (Marx and Graeber, 1994). It has also been reported that the number of maintenance-related accidents is on the increase and that over the preceding 10 years, whilst the number of flights had increased by 55%, the number of 'maintenance concern' accidents had increased by 100% (King, 1998).

The human factor is the critical component of these accidents. Extensive analysis of recent aircraft accidents and incidents has shown that these were not simply a consequence of direct technical failure or operator tasks which were carried out incorrectly. The underlying causes were deeply rooted in organisational and management factors. For example, the critical importance of internal processes of communication, decision making, implementation and evaluation have been highlighted by the accident at Gottrora (SHK, 1993) and the Daventry incident (AAIB, 1996). The BAC1-11 (AAIB, 1992) and Daventry incidents have also highlighted the critical importance of adequate manpower, an effective system for monitoring, and efficient regulation.

Aviation maintenance is therefore an appropriate domain in which to evaluate the proposed model. The overall goal of this study is to further develop a conceptual model of a generic, integrated safety management system, focusing particularly on the human factor aspects of safety. The purpose is not to provide a comprehensive description of

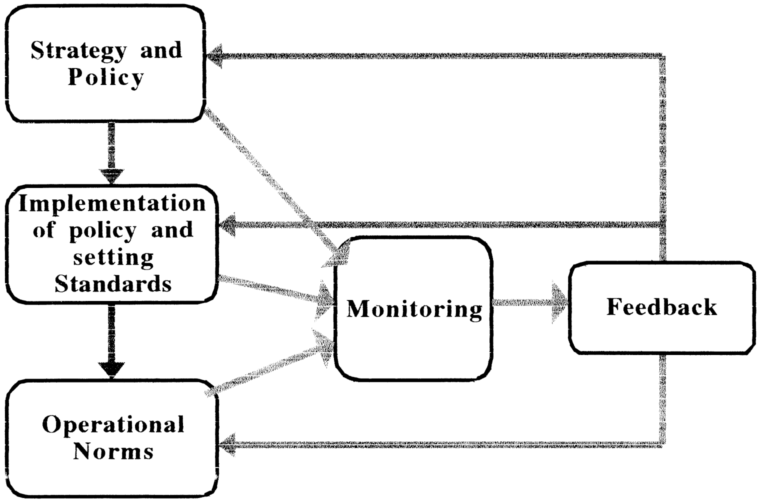

Fig. 1. Safety management system model overview.

all management and organisational activity directed towards safety, but to provide an outline description of the main features of the system, which would enable us to prioritise the organisational aspects of safety, rather than the technical aspects.

The objectives of this paper are:

1. to evaluate the model outlined above in accounting for the organisational aspects of safety in four aircraft maintenance organisationsations; and
2. to explore the relationship of different organisational aspects of safety, through the deployment of different research measures and methods.

2. Methodology

Bearing in mind the diversity of the notion of organisational culture, we decided to adopt a variety of methodologies to reflect different aspects of the organisation, including the formal aspects of the management system, attitudes, expectations, and behavioural norms. The methodologies used were: analysis of documentation, interviews and two surveys using different samples of maintenance personnel. (The results reported here were first published in an internal report, McDonald et al., 1997b, except where otherwise stated.)

2.1. Documentation

The researchers had access to the 'Maintenance Exposition Document' in each of the organisations. The Maintenance Exposition Document is compiled in compliance with the regulations of the European Joint Aviation Authorities governing maintenance organisations (JAR 145).The document contains the company's formal information on Maintenance Management (i.e. roles, responsibilities, accountabilities), Maintenance Procedures (Line, Light and Base), and Quality Systems Procedures. This information allowed the researchers to obtain a formal overview of each of the organisations and to plan the management interviews and administration of questionnaires. Incident and accident reports were also examined. Those involved in processing and responding to selected incident reports were identified. Brief interviews with those who were available were subsequently carried out.

2.2. Interviews

A total of 33 individual semi-structured management interviews (lasting between 1 and 1.5 h) were conducted with managers responsible for maintenance and safety across the four maintenance organisations. The sample interviewed included Chief Executives, production and middle management, quality management, quality investigators/auditors and training personnel. The management interviews focused on the different elements outlined in the model.

A broad based qualitative survey was also undertaken to identify the range of Human Factors issues in maintenance organisations which could be impediments to safe and effective production (Biemans, 1997). A total of 23 interviews were conducted (lasting between 1.5 and 3 h). The sample interviewed included representatives from planning and quality departments, shift managers and a sample of aircraft technicians both from line and base maintenance. This paper only reports on a selection of findings from this particular study.

2.3. Attitude, climate and incident survey

2.3.1. Survey design

The questionnaire used in this study comprised scales of safety attitudes and climate together with an incidents survey. The safety attitudes and climate scales were adapted from scales developed by Diaz Cabrera and Isla (1997) for use in airport ground handling companies. Items for the adapted scale were selected using a two-step process. Firstly, a Factor Analysis (via principal components analysis with varimax rotation of factors) was conducted in order to establish the factor structure of the scales. Secondly, the number of items in each factor was reduced. This was carried out by eliminating items which showed one or more of the following characteristics:

1. were not applicable to the maintenance environment
2. had a high number of missing values
3. produced particularly skewed or homogeneous responses
4. had a low loading on the factor
5. had considerable semantic overlap with other items in a factor

In total, 36 items from the original 69 items on the survey were retained: 16 safety attitude items and 20 safety climate items.

The incidents survey was developed specifically for this study. Participants were required to read four brief incident summaries (taken from actual incidents that had resulted in investigation). The incident summaries were checked by a number of aircraft engineers for their applicability and technical accuracy prior to their inclusion in the survey.

There were two versions of the incident scenarios. In one version the scenarios led to a reported flight incident which could have led to the loss of the aircraft or the death of those on board; in the other version they did not lead to a flight incident. The respondents were asked to indicate, if these incidents occurred in their company, what would happen to the technician(s) involved and how they might hear about the incidents. Both these versions were equally distributed throughout the samples in each of the organisations.

2.3.2. Survey participants

The survey was administered across the four organisations and amongst four main groups of personnel: operational personnel (apprentices, aircraft technicians, certifying technicians), management with direct responsibility for production (from shift manager to the Chief Executive level), quality personnel (auditors, inspectors, investigators, quality managers) and planning functions (planning, technical support). A total of 800 questionnaires were distributed across the four maintenance organisations and 622 surveys were completed and returned (a response rate of 77.8%).

Table 1 outlines the total number surveyed and a breakdown of job categories across the four organisations. Comparability of job categories across organisations was not always self-evident; therefore, it was not always possible to pre-plan filling job categories with equal numbers.

2.4. Survey of compliance with task procedures

2.4.1. Survey design

The purpose of this survey was to gather data on the role and use of maintenance manual procedures. The questionnaire asked the technicians whether they had consulted the official maintenance manual procedure, whether they had followed it, and if not, why not. The questionnaire was developed from preliminary observation studies and

Table 1
Breakdown of respondents to the survey by occupation and company

	Total count	A	B	C	D
Unqualified operators	29	2	9	0	18
Aircraft technicians	336	94	90	17	135
Licensed technicians	120	68	12	33	7
Quality personnel/inspectors	29	3	12	5	9
Graduate engineers/management	29	12	2	7	8
Shift/crew management	34	9	14	0	11
Planning	28	9	0	5	14
Support	17	3	0	0	14
Total	622	200	139	67	216

checked by a number of aircraft engineers for its applicability and technical accuracy (McDonald et al., 1997a).

2.4.2. Survey participants

The questionnaires were administered and collected over the course of week-long visits to each of the aircraft maintenance organisations (except in one company where a number of 1-day visits were carried out). The researchers administered the surveys to aircraft technicians as they completed a task (either returning from the aircraft after push back or as they returned a task card to the rack). A total of 286 questionnaires were completed across the four organisations. This paper only reports on a selection of findings from this particular study.

3. Results

The research aims outlined in the Introduction are considered in five sub-sections: (1) Summary of analysis of management interviews and Human factor 'bottleneck' survey; (2) Safety climate survey; (3) Safety attitude survey; (4) Incident survey; and (5) some selected findings from the Task procedures survey. For reasons of confidentiality the companies are de-identified and are referred to throughout this paper as Companies A–D.

3.1. Management interviews and company documentation

The primary company documentation outlining the main management structures in the organisations was the Exposition Document drawn up under Joint Aviation Regulations (JAR) 145. This was supplemented by other documents and organisational charts outlining, amongst other things, the quality system, disciplinary policy and reporting procedures. It was not always possible to identify all the relevant aspects of the safety management system from the documentation (on occasions the situation had changed since the documentation was drawn up). However, where information was lacking, this was discussed in the interviews. From the documentation and the descriptive statements of the interviewees, an exposition of each organisation's safety management system was developed according to the main dimensions of the model (McDonald et al., 1997b). This was circulated for review and comment and was accepted as being accurate in all important essentials by the company representatives participating in the project.

Table 2 summarises very briefly the main distinguishing features of the four companies' safety management systems along the relevant dimensions. Table 2 and the following comments can only be seen as a very general characterisation of what are complex situations and processes.

3.1.1. Policy and standards

The management interviews looked at two primary issues with regard to safety strategy and policy: (1) how important is safety in relation to other company goals?

Table 2
Summary of elements of safety management systems in the four organisations

Model elements	A	B	C	D
Policy (expressed commitment to safety)	Safety seen to be 'built in'. Explicit policy on human factors (HF)	Safety has to be made compatible with commercial survival. Compliance with JAR 145 a major commitment of effort	Safety — 'sine qua non' of the success of the company. No explicit HF policy but human concerns built in	Safety contrasted with other goals. Inconsistent message at different levels
Standards	Exceed technical requirements. Monitor trends	Reference to compliance with JAR 145 as safety standard	Internal safety standard built into management system	Reference to compliance with JAR 145 as safety standard
Organisation and planning of work				
Methods and documentation	Major initiative on process reengineering. Goal of 'fully engineered task' not realised	Industrial relations (IR) seen as a major constraint on planning, but have achieved improvements with reorganisation. Recent investment in IT with customer focus	Strong commitment to the planning and organisation of work. Has invested heavily in IT to support this function	Demarcations and IR seen to inhibit effective planning, organisation and communication
Personnel training	Extensive management training not always rated effective	Inconsistent management training	Comprehensive and effective management training	Training in management skills not seen to be relevant
Monitoring				
Audits	Main focus on documentation rather than actual work	Auditing of documentation. Informal awareness of actual work standards	Substantial system and process audits	Main focus on documentation rather than actual work
Quality discrepancy reporting	Reporting much used but huge backlog	Quality reporting system recently implemented	Computer-based system recently introduced	Reporting system used but difficulties achieving systematic follow through

(continued on next page)

Table 2 (*continued*)

Model elements	A	B	C	D
Incident/accident investigation	Well-developed HF-based investigation	HF investigation method not used by all investigators	Serious incidents or recurring incidents investigated by multi-disciplinary team	No explicit HF method for incident/accident investigation
Feedback	Publication of safety issues especially HF	Verbal briefings only	Feedback through company bulletins and company wide IT network	Accident/incident information not openly distributed
Human/organisational change	Difficulty in translating HF-based information into change	Routine 'retraining session' after incident involvement	Systematic change following recent incidents	No systematic mechanism for managing non-technical change

and (2) what is the driving force of safety policy within each of the organisations? Expressed commitment by senior executives to safety ranged from safety being seen as core to commercial success to being in tension with commercial survival. Compliance with the requirements of JAR 145 is a major factor driving safety policy and strategy in all of the organisations. Company C differed from the other companies in the self-regulatory model of their safety system. This is designed to express the internal goals and standards of the organisation, which should equal or exceed those set by external regulators.

3.1.2. Organisation and planning of work

In looking at the implementing of policy across the organisations, four issues emerged as impacting the effectiveness of planning and the organisation of work: organisational change, co-ordination between departments, the role of technology, and industrial relations. A major process re-engineering initiative appeared to be more effective at the level of integrating departments and fleets than in delivering its goals of a ‘fully engineered task’. Horizontal integration and co-ordination between departments was well developed in one organisation. Investment in information technology plays a critical role in facilitating this horizontal integration. In other organisations, industrial relations were seen both as a major constraint on effective planning and management.

In two companies, training in management skills (particularly skills in managing people) was systematic and extensive, but only in one was it consistently rated positively by all managers interviewed. In the other companies many managers had not received such management training, and, where they had, it was often not rated highly.

3.1.3. Monitoring

All the companies are subject to an annual audit under the European Joint Aviation Authorities regulations. However, within this there are a number of differences between the companies in the manner in which auditing and inspection are carried out. It appears that the primary focus of auditing in Companies A and D is on all the relevant documentation and site visits to audit the physical resources and infrastructure. However, it does not include observation or sampling of the work actually being carried out. It was reported in Company B that a quality audit would focus primarily on auditing all the documentation supplemented by a visual inspection of the various sections of the aircraft. In addition, each week a particular zone on an aircraft is audited. This involves, for example, auditing adequacy of inspection, standards of workmanship, cleanliness and the general state of the zone. Company C has a substantial auditing department who carry out system and process audits. The former concern the organisation and infrastructure; the latter follow a particular work process from initiation to completion. This can involve observation of the work being carried out.

While all of the organisations have some form of quality discrepancy reporting system, which enables aircraft technicians to report problems and deficiencies in the production system, these systems are at various stages of development in the companies. The most developed generates many more reports than it can deal with expeditiously and there is a problem in getting departmental managers to accept responsibility for the problems identified. The systems in the other companies are either early in their development, not well known or not extensively used.

Arrangements for incident and accident investigation also vary between the companies, with two having a well-developed investigation system addressing human factors, one taking some steps in that direction and the other not. The disciplinary code is very influential in the reporting of incidents and governs the manner in which companies respond to incidents, so it is appropriate to discuss this aspect of company policy here. In Company A, there is a corporate 'no blame' safety policy, which exists alongside with the disciplinary code. It is the latter framework that governs the manner in which individual involvement in incidents is managed. The development of better investigation practices has led to a proposal to integrate these two policies in a coherent way in order to remove the contradictions between them. In Company B there is an informal policy described by managers as seeking not to blame individuals involved in incidents where serious negligence was not involved. However, at the same time, the policy is routinely to suspend the license of those involved in incidents and to put them through a half-day training programme, which can be seen as being a 'blame and train' policy. In Company C the issue of discipline was not seen to be problematic. A strong preference was expressed for dealing with issues by discussion rather than punitively; in the case of serious incidents the issue of suspension of approval may arise but nothing would be decided without consultation with the union. There is a dedicated multidisciplinary team for investigating incidents. In Company D there was a strong emphasis on the importance of discipline and the enforcing of disciplinary standards from senior management. A disciplinary response to involvement in incidents, which could be interpreted as indicating negligence, appeared to be normal.

3.1.4. Feedback and change

There were great differences between the companies in the way they handled information from incident investigations and quality reports. These differences then are reflected in how the companies address the possibility of change as a response to the incidents and reports. Company A disseminates much information from incident and quality reports in two internal company magazines. The scope and depth of the 'human centred' investigations raise issues which are difficult for managers to deal with because of their organisational implications. In Company B, incident reports are highly confidential. Managers get a verbal briefing which they are meant to 'cascade down' to their subordinates in a sequence of briefings at increasingly junior levels. There is a strong reluctance to discuss details of incidents within the company. In Company C the investigation reports are normally available on demand throughout the organisation. In this company it was possible to trace serious efforts to address human and organisational deficiencies which had been implicated in incidents. In Company D managers are given reports of incidents including the level of detail deemed appropriate to their role and seniority (full investigation reports are treated as highly confidential). The response to recent incidents has been to emphasise the importance of discipline.

Feedback from the various quality reporting systems also differs between the organisations. In both Companies A and C, quality systems appear to be clogged with too many reports leading to long delays in dealing with the reports and providing feedback to the originator. In Company A, part of the problem appears to be difficulty in getting management to take responsibility for the problem, rather than passing it on to someone else. In Company D, the low level of spontaneous reporting may be due in part to the disciplinary climate — people feel that they will get blamed for raising problems. Managers whose department is the subject of discrepancy reports feel that the finger of blame is pointing at them, which can lead to a tendency to a somewhat defensive attitude.

3.2. Human factors 'bottlenecks' survey

An interview survey of human factors 'bottlenecks' identified a clear difference of job perception between company management and the technicians. Some of the maintenance technicians reported that they sign off for the airworthiness of the aircraft instead of for following prescribed task procedures. Management believe that the role of technicians is to follow the task and organisational procedures explicitly, though they often acknowledge that if every one followed procedures to the letter, production would be hugely delayed.

3.3. Safety climate survey

Fig. 2 shows the mean safety climate scores and standard deviation for each organisation. The safety climate scale ranges from 1 (an entirely negative safety climate) to 2 (an entirely positive safety climate). The overall level of safety climate for all organisations was 1.494, almost exactly on the mid-point of the scale.

One-way analysis of variance (ANOVA) results indicate that safety climate is significantly different between the organisations ($F\,(3, 662) = 30.55$, $P < 0.001$). Tukey's post hoc comparisons showed each of the organisations differed significantly from each other in safety climate ($P < 0.05$).

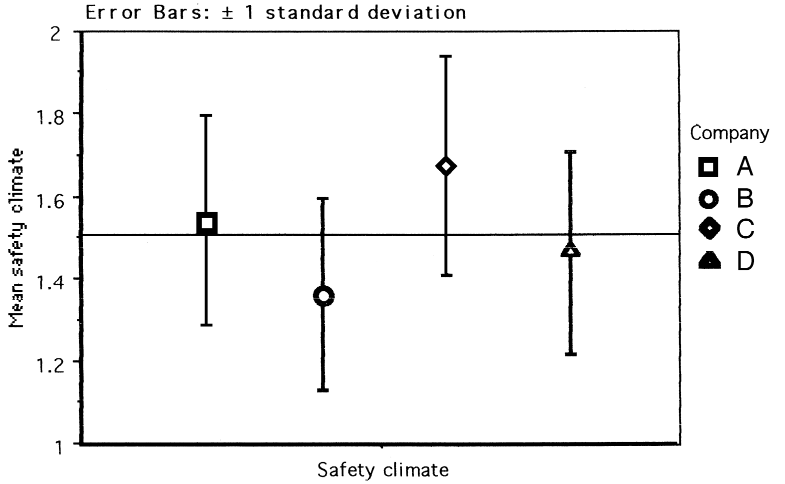

Fig. 2. Mean safety climate score and standard deviations for each organisation.

Safety climate also varied significantly across job types (F (7, 612) = 7.28, P < 0.001). Fig. 3 shows the levels for all the job types. However, Tukey's post hoc comparisons showed few differences in paired comparisons. The differences that did emerge were that aircraft technicians showed significantly lower safety climate than quality personnel/inspectors, graduate engineers/management, and planning personnel (P < 0.05).

Aircraft technicians formed the biggest group (n = 334). Differences between other groups, e.g. between unqualified operators (n = 29) and quality personnel/inspectors (n = 29) may not have emerged due to smaller sample size.

It was not possible to conduct a factorial ANOVA on job type and company because some of the cells have too few data points. However, separate one-way ANOVAs were carried out for company within each job. The climate of licensed and other technicians differed significantly across companies (P < 0.01). This is not surprising since these are by far the largest two groups, and contribute most to the overall differences in climate between companies, outlined above. More interesting are significant differences which emerged among quality personnel (P < 0.05), support personnel (P < 0.05) and graduate engineers/management (P < 0.01).

Quality personnel in Companies A and C have a very positive safety climate (about 1.9), while those in Companies B and D have significantly lower climate scores about the mid-range (1.53 and 1.56, respectively). Support personnel were sampled only in Companies A and D, but their scores are higher in Company A (1.88) than Company D (1.43) (t (15) = 2.34, P < 0.05). Graduate engineers/managers have climate scores that are high in Company C (1.81), moderate in Company A (1.62) and low in Company D (1.43), differences between these three groups being significant (P < 0.05). Company B had only two of this job type in the sample, making statistical tests unfeasible.

3.4. Safety attitude survey

The mean safety attitude score for all companies was 3.697; on a five-point scale this represents a positive safety attitude score (3 being the mid-point). Fig. 4 shows the mean safety attitude scores and standard deviations for each organisation.

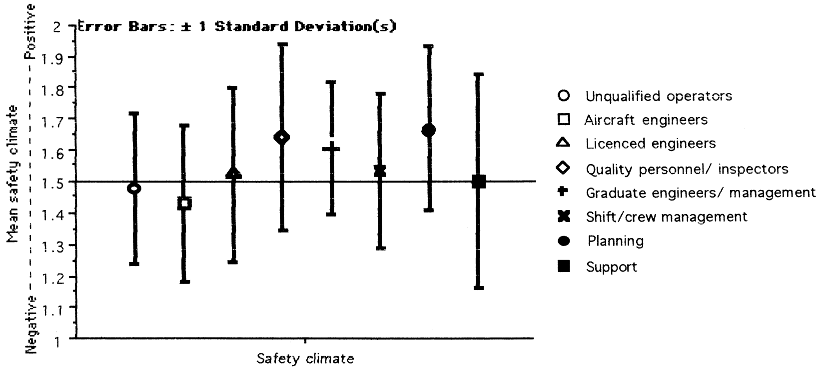

Fig. 3. Mean safety climate scores and standard deviations for each job type.

There was a significant difference in the overall pattern of safety attitudes across the organisations (F (3, 664) = 7.38, $P < 0.001$). Tukey's post hoc comparisons showed that one of the companies (Company D) differed significantly from the other three in having a more negative level of safety attitudes ($P < 0.05$).

Significant differences were also found across job types on safety attitudes (F(7, 613) = 2.09, $P < 0.05$). Tukey's post hoc comparisons showed one significant paired comparison: quality personnel differed from unqualified operators in having more positive scores on the attitude scale (Fig. 5).

It was not possible to conduct a factorial ANOVA on job type and company because some cells have too few data points. However, one-way ANOVAs were carried out for company within each job. Significant differences were found for the aircraft technicians between Companies D and A ($P < 0.05$) and between Companies

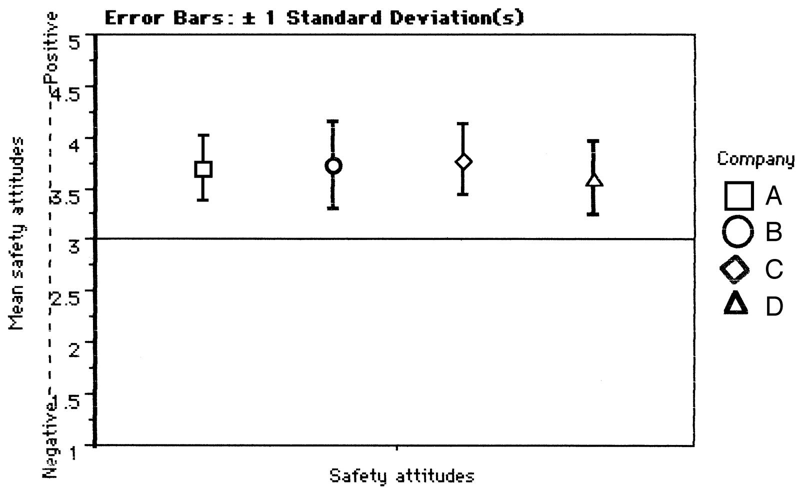

Fig. 4. Mean safety attitude scores and standard deviations for each organisation.

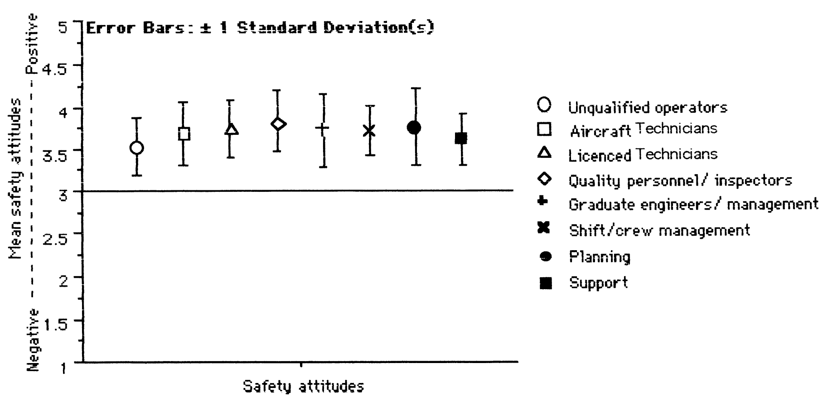

Fig. 5. Mean safety attitudes by job type.

D and B ($P<0.001$), with the technicians in Company D showing a lower level of safety attitudes than in the other two companies. No other significant differences were found.

3.5. Incident survey

When asked what they would expect to happen if any of the incident scenarios occurred in their company, the most common response was impartial investigation to find out what factors gave rise to the incident (42.7%). 36.6% felt a disciplinary hearing would ensue and 35.3% reported that they would expect the technician(s) involved to have the incident discussed with them so that they could learn from their mistakes.

Respondents were more likely to indicate a "loss of licence" as a consequence of a scenario which led to a flight incident than of one that did not ($\chi^2=5.112$, $P<0.05$). Similarly the "suspension of job" was perceived as a more likely consequence if the scenario led to a flight incident condition ($\chi^2=9.563$, $P<0.01$).

There were significant differences between organisations in the consequences of the scenarios regardless of whether they led to an incident or not (Fig. 6).

The types of consequences which would occur differed significantly between companies on five of the seven items ("incident discussed": $\chi^2=22.625$, $P<0.001$; "impartial investigation": $\chi^2=47.033$, $P<0.001$; "disciplinary hearing": $\chi^2=16.042$, $P<0.01$; "suspension of licence": $\chi^2=80.246$, $P<0.001$; "suspension of job": $\chi^2=16.460$, $P<0.001$). Only the frequencies of "nothing" and "verbal reprimand only" do not differ significantly across companies. It was more likely in Company C,

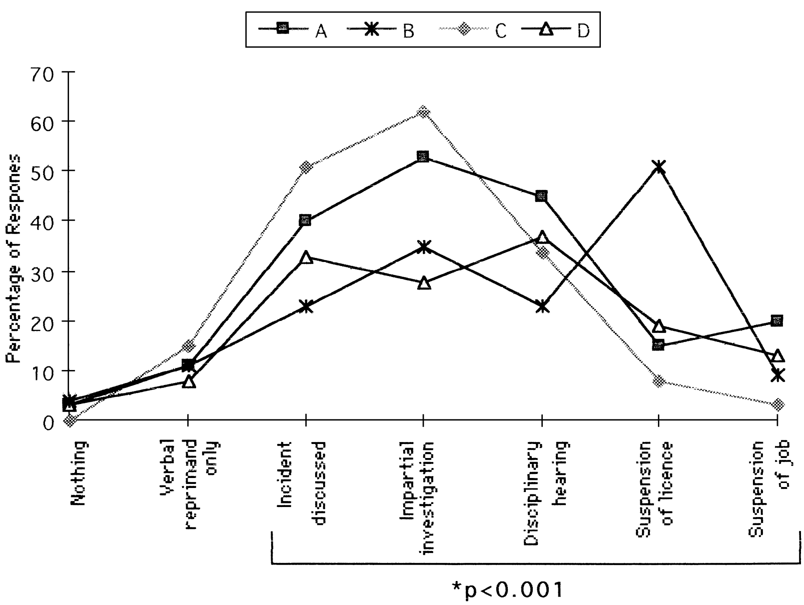

Fig. 6. Consequences of incident scenarios by organisation.

compared to the other companies, that the incident would be discussed with a view to learning from the mistake and that an impartial investigation would be carried out to identify causal factors. Thirty-seven per cent felt that a disciplinary hearing might ensue which was comparable to the average across all companies. However, Company C scored significantly lower than the other companies on licence suspension and job suspension pending disciplinary hearing.

This pattern was reflected to some extent in Company A though it was less marked. Respondents were significantly more likely than Companies B and D to report that the incident would be discussed and that an impartial investigation would be carried out. A disciplinary hearing was reported as significantly more likely than in the other organisations with 15% feeling that this would be associated with licence suspension and 19% feeling it would be associated with suspension from the job.

In Company D, discussion of the incident with a view to the individual learning from their mistake was the third lowest of the companies (33%) and the item "impartial investigation" was the lowest ticked of the four companies suggesting a more 'closed' policy towards incidents. The "disciplinary hearing" consequence was the most ticked consequence for Company D respondents (37%) as well as being the second highest compared to other companies. (Although, as can be seen from Fig. 6, it is comparable to the level in Company C while being significantly lower than that in Company A and significantly higher than that in Company B.)

In contrast, Company B appeared to have a relatively consistent policy of suspension of licence pending disciplinary hearing (51%) which is significantly higher than the other three organisations. Company B also had the lowest reported level of discussion of the incident with the individual and was also significantly lower than Companies C and A on the item "impartial investigation to find out what factors gave rise to the incident".

A number of significant differences were found when the source of information reported was compared across organisations. Fig. 7 shows the percentage of respondents in each company who selected each information source. Word of mouth was a significantly more likely source of information in Companies A and B than in Companies C and D; however, levels were quite high in all organisations studied. Company C was significantly more likely to receive information in a written alert than the other three organisations (72% vs. mean of 46.4%), which may partly explain why word of mouth is less important in that organisation as a source of information.

Companies A and C were significantly more likely to hear about the incidents through notification of a procedure change. Company A were also significantly more likely to hear about incidents through company magazines.

Overall the most common source of information reported in Company C was the written alert (72%). In Companies A, B and D, word of mouth was the most common response with written alert the next most common response.

3.6. Task procedure survey

The analysis of the Survey of Task Procedures showed that overall 34% of respondents reported not following the official procedure for the task. There were

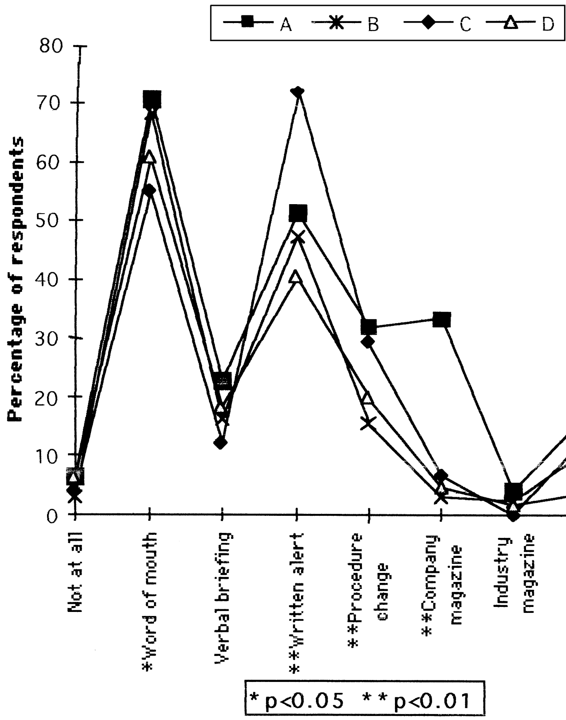

Fig. 7. Percentage of respondents in each organisation who selected each information source.

differences between the companies in these percentages but these differences were not statistically significant (Table 3). The most common reason given was that there was an easier way than the official method (45%), followed by 43% saying there was a quicker way. A number of factors that were related to increased likelihood of non-compliance were identified. Those individuals who consulted the manual but did not follow the official method were significantly more likely to report that:

1. the task card was unclear;
2. the necessary steps to complete the task were unclear;
3. they employed guesswork or trial and error; or
4. the maintenance history was desirable but unavailable.

4. Discussion

In order to provide a framework for discussing the various strands of the results of this study it is useful to differentiate between those aspects which reflect fairly directly the components of the safety management model and those which relate to more general aspects of safety culture. The formal aspects of each organisation's

Table 3
Reported percentage violations of task procedures by organisation

Company	Violations reported (%)
A	30
B	36
C	37
D	47

safety management system as laid out in the company documentation have not been expounded in this paper. While there were differences between the formal structures of each organisation, the safety management system model was designed to be fairly abstract in order to facilitate mapping between these generic organisational processes and the specifics of each organisation. What is included in the results and this discussion is a qualitative overview of the more salient features of the model as represented in each organisation. This discussion will address the following questions:

1. How well does the safety management system model describe the data, particularly from the interviews and from the incidents survey? In what way should the model be developed to better represent these data?
2. How does the model, as revised, differentiate relevant characteristics of the safety management systems of the different organisations?
3. How does normal operational behaviour (as exemplified in the procedures survey) differ between the organisations? How does this relate to other measures of safety culture?
4. Is it possible to characterise the safety culture of the different organisations?
5. Are there aspects of safety culture which are differentiated rather than integrated (Martin, 1992)?

4.1. The safety management system model

The model is defined in terms of those explicit organisational processes which have an impact on safety or compliance with safety regulatory obligations. As such it is deliberately wider than those organisational functions explicitly dedicated to safety. The model was also kept conceptually simple in order to facilitate mapping onto diverse organisations. Company documentation was the starting point in outlining the main structural features of each organisation and the roles and responsibilities of key managers and their departments. This was then supplemented by discussion and interview in order to confirm current roles and responsibilities and how these mapped onto the generic organisational processes in the model. While the framework adopted is applicable to all aspects of safety, a particular emphasis was placed on how the human, social and organisational aspects of safety were managed.

In general the model received substantial support from the study in differentiating the organisational aspects of safety across the four organisations. Analysis of the interview results did, however, lead to a slight reformulation of the model in order to emphasise critical features of a self-regulatory safety system.

The critical importance of the planning and organisation of work became apparent as the interview studies progressed. Because it was not an issue which had been highlighted in previous analyses of organisational safety culture (e.g. Pidgeon and O'Leary, 1994), the role of planning and the organisation of work was not one of the focal aspects in the original model. Nevertheless, sufficient material was elicited from the interviews to comment on the planning and organisational process engaged in by the participant organisations. Three issues emerged as important dimensions influencing the way planning and organisation of work was described in the organisations. The first concerned the extent to which the planning and organisation of work was seen to be constrained by the industrial relations system and demarcations based on custom and practice. Secondly, several companies had been actively engaged in, or were considering, systematic 're-engineering' of their operational processes. While some of the focus of this activity concerned the restructuring of organisational departments and their relationships, activity was also directed at systems for the provision of materials, documentation and personnel to fulfil the companies' operational requirements. The third factor that appeared to be influencing the way in which production was organised concerned the use of information technology in the planning process. All of these factors were perceived to have implications for the safety and reliability of the production process. These considerations suggest that a more systematic representation of the planning and organisation of work is needed in the model. The division of resource management into parts, personnel resources, facilities, and methods/documents, suggested by Smit and Slaterus (1992), may provide a good starting point for such an analysis. In the interviews in this study most of the issues addressed concerned methods and documentation and personnel issues. Less attention was given to parts and facilities.

It also became apparent during the study that while the model did address the various feedback mechanisms that should influence all levels of the system, the evidence as to whether change (particularly change in human issues) resulted was not explicitly highlighted in the model. This became particularly clear in the context of the quality reporting systems, which purport to be a major engine of change in the quality and reliability of production systems. In none of the organisations were these systems fully functioning and routinely delivering improvements in the way in which work was organised and performed. Either such systems had not been fully implemented or else they tended to be backlogged. Again, one highly problematic area appeared to be transforming information about specifically human aspects of failures and deficiencies into implemented programmes for change. For this reason it was decided to make an explicit stage in the model.

The elements of a revised model are as follows:

1. Safety policy — how safety is represented as an organisational goal and the organisation's strategy for achieving its safety goals.
2. Safety standards — the global criteria against which the organisation judges its level of safety. This should provide a framework for identifying the specific standards which govern particular areas of operational practice.

3. Planning and organisation of work — the management activities to ensure the provision of resources in the areas of methods/documentation, personnel, parts and facilities, in order to carry out the organisation's functions.
4. Normal operational practice — the normal practice or behaviour in carrying out the organisation' s functions.
5. Monitoring — all the activities of monitoring and review of operations, including auditing, incident investigation, quality reporting, etc.
6. Feedback — transfer of information of the various monitoring functions to potential users at all levels of the system.
7. Change — the use of this information in effecting change in any of the elements in the system. In this context we are particularly interested in change in the human and organisational aspects of the system in response to information that these aspects of the system are not functioning optimally. We are less concerned with the channels for correcting technical deficiencies in aircraft systems, tools, documentation, etc.

Fig. 8 provides a schematic representation of this model. It emphasises the sequential nature of policy, standard setting, planning and execution, and the idea that this entire sequence is subject to review. If such review is to influence the way in which this sequence is carried out then the information from the review processes needs to be fed into organisational activities which will effect change. This is a fairly abstract representation of organisational processes and is not expected to map precisely onto individual organisational functions and boundaries, because these processes involve co-ordination between different parts and roles in the organisation.

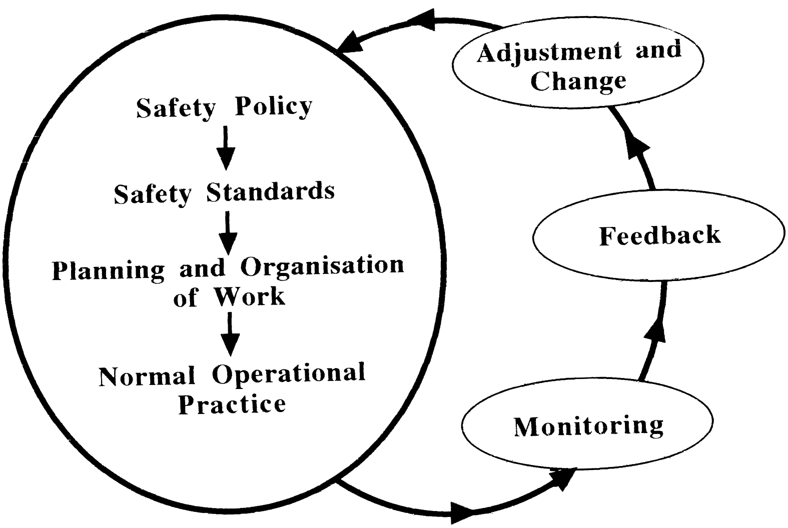

Fig. 8. Revised safety management system model.

4.2. Differentiation of organisational safety systems

Table 2 provides an overview of the different elements of the safety management systems using the revised elements of the model. Discussion of normal operating practice will be deferred to the next section. The following summarises some of the most salient differences.

The way in which safety was expressed as a goal differed between the companies — on the one hand being seen as a core component of the company's success, on the other hand as contrasting with other goals. Only one company had an explicit formulation of an overall internal standard of safety; for others demonstrable compliance with regulations was the effective criterion. In planning and organisation of work one dominant theme concerned a tension between constraints on planning through traditional industrial relations practices and attempts to re-engineer the production process.

The review of auditing practices highlighted the question of what was audited and how. There is a contrast between three types of auditing practices: those which are concerned to ensure that the documentation is complete and in order; the auditing of static facilities; and auditing which is concerned with directly sampling how work is performed. Only one company outlined a systematic approach to all three types of auditing. Incident investigation methods also varied, particularly in relation to the human aspects and the training of investigators. Differences here were also reflected in the degree of expectation of various outcomes in the incidents survey. Impartial investigation and discussion of the incident with those involved were more commonly expected in those organisations using trained investigators with human factors knowledge. Policy on feedback and communication also differed markedly in the organisations particularly with respect to general communication of safety information throughout the company. Again these differences were mirrored in the incidents survey with those organisations with a more open policy on information having higher expectations of hearing about incidents through written alerts, procedure changes or company magazines.

Policy on discipline also contrasts the response of the different organisations to incidents. Again, the interviews mirrored the incidents survey, with Company A maintaining its disciplinary procedures alongside its 'no blame' policy and openness on information, while Company B shows a high reliance on suspension of licence, is relatively low on disciplinary hearings and has a routine response of retraining following involvement in incidents. Company C, where impartial investigation is most often expected, has the lowest reliance on suspensions of license or job following incident involvement.

All of the companies are part of a well-developed feedback system involving maintenance companies, airlines, aircraft manufacturers, and regulatory agencies, for correcting technical defects in technical systems, documentation and procedures. This multi-organisational safety system will be addressed in a subsequent paper. While there was no difficulty in getting examples of technical defects or discrepancies eliciting appropriate changes, it was very difficult to elicit examples of systematic or routine procedures for changing the situation in a way that would prevent repetition in response to identified human and organisational defects or failures. Indeed

Company A, where a considerable amount of organisational effort had been expended in collecting such information, appeared to have considerable difficulty in translating this into effective remedial action. On the contrary, there was a strongly expressed belief that the existence of this information exposed the company to criticism from the regulatory authorities. Company B routinely required those involved in incidents to undergo a brief 'retraining' session. In Company C it was possible to assemble an extended case study of change in response to a series of incidents.

4.3. Safety cultures and sub-cultures

The measure of safety climate systematically discriminated between each of the organisations studied and did so in a manner which is quite congruent with the interviews and incidents survey. The differences between the organisations in relation to their expressed commitment to safety, standards, planning and organisation, monitoring, feedback and change are reflected in the differences in safety climate. A more detailed analysis of the safety climate and safety attitude results in these and other organisations will be the subject of a further paper.

On the other hand, the pattern of results in the procedures survey (representative of 'normal operational practice') and the safety attitude survey (another component of safety culture) did not show the same pattern of results. The incidence of non-compliance with task procedures showed no significant differences between the four companies. The safety attitude survey showed a similar pattern with the exception of a small but significant difference between Company D and the other companies. When broken down by job type, it was the aircraft technicians who were significantly different in Company D from those in Companies A and B. Thus, while some aspects of the organisational safety culture (safety management system, safety climate, expectations of response to incidents) are strongly differentiated between organisations, other aspects (the behaviour and attitudes of aircraft technicians) are not. This seems to suggest the existence of a 'professional sub-culture' amongst aircraft maintenance technicians that spans all four companies (with the exception of safety attitudes in Company D which diverge slightly). Some understanding of the nature of this sub-culture comes from some findings of the human factors 'bottlenecks' which indicated that there is a gap in 'job perception' between maintenance technicians and management. Putting it fairly crudely, technicians believe that they are responsible for the overall safety of the aircraft, and that it is their role to exercise their knowledge, skill and professional values to enable them to fulfil that responsibility. Procedures are there to support that goal. Management, on the other hand, believe that the role of technicians is to follow the task and organisational procedures explicitly, though it is often acknowledged that if every one followed procedures to the letter, production would be hugely delayed. This difference in perception means that engineers perform their tasks differently from the way that the company expects.

This analysis suggests that there is a strong professional sub-culture, which is relatively independent of the organisation. One implication of this finding is that this professional sub-culture mediates the effect of the organisational safety system on normal operational practice. This needs to be borne in mind in interpreting the safety management system model in Fig. 8. Arguably, this professional sub-culture provides the flexibility to deal with situations which are not fully anticipated or planned and to make the judgement to do what it takes to get the job done. On the other hand, when this divergence between the management system and subculture becomes routine and institutionalised, then the difference between the 'official' way of doing things and the 'actual' way of doing things becomes impervious to scrutiny. When this happens it becomes very difficult to have an objective standard of safety. This question will be developed in a subsequent paper analysing the procedures survey in more detail. However, one implication is that one should not expect a clear and direct relationship between the organisation's safety management system and safety outcomes (incidents and accidents).

Differences were also found in safety attitudes and safety climate between occupational groups. Thus quality personnel had overall significantly higher safety attitude scores than unqualified technicians. Safety climate appears to depend on both job type and company, though this interaction could not be tested. While, overall, aircraft technicians showed significantly lower levels of safety climate than quality personnel/inspectors, graduate engineers/management and planning personnel, these differences appear specific to particular companies. Broadly, the quality and support personnel and graduate engineers/management were (where represented) significantly higher in safety climate in Companies A and C than B and D. It is tempting to suggest that this is evidence of a differentiated safety culture (in Martin's, 1992, terms), with safety attitudes being conditioned to some extent by occupational role in the production process, climate being even more so; but these occupational differences in climate being heavily influenced by the particular organisation.

5. Summary and conclusion

A model was proposed which sought to integrate the main features of a safety management system, developed as a practical guide for management (HSE, 1991) and the main components of safety culture as outlined by Pidgeon and O'Leary (1994). This model is essentially a self-regulatory, feedback model. It was evaluated as a vehicle for understanding how aircraft maintenance organisations manage safety in their operations, with particular emphasis on the human and organisational aspects of safety which have been highlighted in incident reports. Empirical studies of four aircraft maintenance organisations were undertaken, including analysis of documentation and qualitative interviews, surveys of safety climate, safety attitudes, expected response to incidents and compliance with task procedures. The model proved to be an effective tool for analysing the salient features of each organisation's safety management system, although it was judged to have underestimated the important roles of planning and change. The main elements of a revised model comprise policy, standards, planning and organisation, normal operational practice, monitoring, feedback and change. The data from management interviews, the incidents survey and safety climate survey exhibited a large measure of agreement in differentiating between the different safety management systems and safety climate of the four organisations. The measures of compliance with task procedures and safety attitudes did not differentiate between the four organisations (though one organisation did differ from the others in safety attitudes). This suggests a strong, relatively homogeneous professional sub-culture of aircraft technicians spanning the different organisations. Differences in safety attitudes and climate were found between occupational groups, though in the case of climate the differences between occupational groups were a function of the organisation. This suggests a differentiated notion of safety culture. A professional sub-culture is likely to mediate the effect of the organisation's safety management system on safety outcomes. For this reason it is impossible to infer the implications of these findings for the level of safety in these organisations. Further analyses of the data on compliance with procedures and the attitude and climate surveys will seek to clarify some of the issues involved. The multi-organisational aspects of safety management systems will also be further analysed with respect to relationships with aircraft manufacturers and aviation authorities. This will enable the theoretical and practical implications of these studies (including their implications for safety) to be addressed in a more comprehensive manner.

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