NRC000028

PERGAMON

Safety Science 41 (2003) 641–680

SAFETY SCIENCE

www.elsevier.com/locate/ssci

Safety climate, safety management practice and safety performance in offshore environments

Kathryn Mearns*, Sean M. Whitaker, Rhona Flin

Industrial Psychology Group, Department of Psychology, University of Aberdeen, Aberdeen, Scotland AB24 2UB, UK

Abstract

Safety climate surveys were conducted on 13 offshore oil and gas installations in separate years ($N=682$ and 806, respectively), with nine installations common to both years. In addition, data on safety management practices were collected by questionnaire from senior management on eight installations in each year. The associations between management practices and climate scores with official accident statistics and self-reported accident involvement were tested via a series of hypotheses. Associations were found between certain safety climate scales and official accident statistics and also the proportion of respondents reporting an accident in the previous 12 months. Proficiency in some safety management practices was associated with lower official accident rates and fewer respondents reporting accidents.

Keywords: Offshore industry; Safety climate; Health & Safety management; Safety performance

1. Introduction

In recent years there has been a realization that the reliability of complex work systems in achieving operational goals safely depends on social structures as well as technical arrangements. A string of high profile disasters over the past two decades has indicated the role that social and organisational issues played in the etiology of these accidents (Sheen, 1987; Cullen, 1990; OECD Nuclear Agency, 1987; Vaughn, 1996). An understanding of the socio-technical processes behind these accidents has led to investigations moving away from a focus on proximal circumstances operating at the individual level, to investigating potentially more distal weaknesses in the organisation as a whole. As a result, theories of accident process have broadened

* Corresponding author. Tel.: +44-1224-27-3217; fax: +44-1224-27-3211.
E-mail address: k.mearns@abdn.ac.uk (K. Mearns).

0925-7535/03/$ - see front matter
doi:10.1016/S0925-7535(02)00011-5

to include organisational processes and the psycho-social domain (Turner and Pidgeon, 1997). As yet there is little evidence to link weaknesses in safety at the organisational level with *individual accidents*, however, with the value of hindsight, case studies of major disasters have linked weaknesses in so-called 'safety culture' with organisational accidents (Reason, 1997).

The concept of 'safety culture' has largely developed since the OECD Nuclear Agency (1987) observed that the errors and violations of operating procedures occurring prior to the Chernobyl disaster were evidence of a poor safety culture at the plant and within the former Soviet nuclear industry in general (Pidgeon and O'Leary, 2000). Safety culture has been defined as "that assembly of characteristics and attitudes in organisations and individuals, which establishes that, as an overriding priority, plant safety issues receive the attention warranted by their significance" (IAEA, 1986). Safety culture is important because it forms the context within which individual safety attitudes develop and persist and safety behaviours are promoted (Zohar, 1980). Most definitions of safety culture invoke shared norms or attitudes so that the level of aggregation is considered to be the group. Some authors contend that safety culture is only being assessed when the attitude object is the organisation (Cabrera and Isla, 1998). It is interesting to note that the concept of safety culture developed in response to major organisational accidents, however, it is now being more widely applied to explain accidents at the *individual level*. The validity of the safety culture concept with regard to individual accidents has yet to be ascertained.

Safety climate is regarded as a manifestation of safety culture in the behaviour and expressed attitude of employees (Cox and Flin, 1998). As well as rescuing safety culture from an increasingly limitless level of abstraction, operationalizing safety in this way has led to a burgeoning of scales, each purporting to measure safety climate—one observable manifestation of safety culture. The number of dimensions of safety climate remains disputed, although recurring themes across safety climate surveys include management commitment, supervisor competence, priority of safety over production, and time pressure (Flin et al., 2000). Elements of safety climate emerge as predictors of unsafe behaviour or accidents in numerous structural models (Brown et al., 2000; Cheyne et al., 1999; Thompson et al., 1998; Tomas et al., 1999) and non-linear models (Guastello, 1989; Guastello et al., 1999), and it is becoming accepted that a favorable safety climate is essential for safe operation. What is less clear are which antecedent factors promote a favorable climate. The issue is important because of the implications for intervention strategies. Research has focused on supervisors as role models for instilling safety awareness and supporting safe behaviour (Fleming et al., 1996; Mattila et al., 1994). Involvement of the workforce in safety decision-making has also received attention (Simard and Marchand, 1994). Both of these concepts naturally lead to a consideration of the safety philosophy of upper management and the safety management system of the organisation. Hofmann et al., (1995) label the individual attitudes and behaviours discernible in safety climate as the *micro*-elements of an organisation, which themselves are determined by *macro*-elements of the safety management system and practices. In this sense management attitudes and behaviour toward safety permeate down through the organisation to the workforce.

Safety management relates to the *actual* practices, roles and functions associated with remaining safe (Kirwan, 1998). It is therefore *more* than a 'paper system' of policies and procedures. An audit of the official safety management system may begin and end with an analysis of what is contained in the paperwork but it therefore says little about how the system is being enacted in the field. Such an analysis identifies what an organisation *should be doing* to protect its workers, the public and the environment from harm but it does not reveal what is *actually happening at the worksite* and whether or not people and the environment are being protected and adverse events are not occurring.

There have been numerous attempts to isolate specific safety management practices that predict safety performance (i.e. accidents and incidents). Some of the earliest studies identified common features of companies with high safety performance, but failed to include controls with low performance. Cohen (1977) reviewed four such studies, and in at least three cases the following factors were common to the sample: safety officers held high rank; management showed personal involvement in safety activities; training was superior for new employees and conducted at regular intervals for existing employees; specially designed posters were used to identify potential hazards; there were well defined procedures for promotion and job placement; daily communication between workers and supervisors about health and safety was the norm and site inspections were frequent.

In contrast, Shafai-Sahrai (1971) examined 11 *matched* pairs of companies conducting on-site interviews and site inspections at each. Organizations with lower accident rates were characterized by: the presence of upper managers who were personally involved in safety activities; prioritization of safety in meetings, and in decisions concerning work practice; and thorough investigation of incidents.

Cohen et al. (1975) and Smith et al. (1975) examined 42 matched pairs of companies. Those with lower accident rates were characterized by: the presence of safety officers with high rank; the presence of upper managers who were personally involved in safety activities; training for new employees, with frequent retraining for existing employees; and more pervasive lines of informal communication between higher management and workers, e.g. daily communication between supervisors and their teams. Shannon et al. (1996) conducted a postal survey of over 400 manufacturing companies, each having at least 50 employees. The defining features of organisations with lower rates of lost time injury included: managers who perceived more participation in decision-making by the workforce and more harmonious management-worker relations; encouragement of long-term career commitment; provision of long and short term disability plans; definition of health and safety responsibilities in every manager's job description; performance appraisals with topics related to health and safety, and more frequent attendance of senior managers at health and safety meetings. Finally, Shannon et al. (1997) reviewed 10 studies each including at least 20 separate organizations and using injury rates as an outcome variable. Forty eight variables representing areas of management practices were examined. Shannon et al. listed the practices consistently associated with performance, i.e. the association was significant in one direction in at least two thirds of studies in which it appeared, *and* the direction of the relationship was consistent for all studies.

Joint health and safety committee: Health and safety professional on the committee; longer duration of training of committee members.
Managerial style and culture: Direct channels of communication and information; empowerment of the workforce; encouragement of long-term commitment of the workforce; good relations between management and workers.
Organizational philosophy on health and safety: Delegation of safety activities; active role of top management in safety; more thorough safety audits; lengthier duration of safety training for employees; safety training on regular basis; employee health screening.

These studies, together with accounts of successful safety initiatives (DePasquale and Geller, 1999; Griffiths, 1985; Harper et al., 1997; Hine et al., 1999) and more discursive treatise (Hofmann et al., 1995) are in some level of agreement about the ideal safety management practices. The general themes that emerge may be listed:

- Genuine and consistent *management commitment to safety*, including: prioritization of safety over production; maintaining a high profile for safety in meetings, personal attendance of managers at safety meetings and in walkabouts; face-to-face meetings with employees that feature safety as a topic; and job descriptions that include safety contracts.
- *Communication about safety issues*, including: pervasive channels of formal and informal communication and regular communication between management, supervisors and the workforce.
- *Involvement of employees*, including empowerment, delegation of responsibility for safety, and encouraging commitment to the organisation.

Conceptual confusion can arise in differentiating the concept of safety management system from safety culture and climate. Kennedy and Kirwan (1998) assert that "safety climate and the safety management are at lower levels of abstraction (although not necessarily at the same lower level) and are considered to be a manifestation of the overall safety culture" (p. 251). In this sense the safety culture is reflected in the strength of the safety management system *and* the safety climate. However, there is a preference in the present study for viewing safety climate as the more accurate indicator of safety culture within the workforce as a whole, and a preference to view safety management practice as an indicator of the safety culture of upper management. More favorable safety management practices are expected to result in improved safety climate of the general work force, and vice versa.

The typically large number of accidents due to safety management failings (Kawka and Kirchsteiger, 1999; Reason, 1998) justifies the development of audit tools for ensuring effective safety management practices (Hurst et al., 1996; Hudson et al., 1994; Mitchison and Papadakis, 1999). Examination of safety management practices should be considered an adjunct to the assessment of safety climate within an organisation. In hazardous environments, such as offshore oil and gas production installations, it is essential to audit safety climate of the workforce and management practices. The offshore oil and gas industry is unique because of the convergence of several hazardous factors, among these the potential for fire, explosion, transit accidents and blow-outs, the work stress that can result from these threats, the attendant priority of high reliability operation, and the relative isolation of installations. There is the continual risk of fatal accidents and organisational accidents resulting from unanticipated actions of employees on offshore installations (Wright, 1994).

A limited amount of research has identified best management practice in the offshore industry. Sykes et al. (1997), for example, applied health and safety benchmarking to operations of British Petroleum, Conoco, and the Royal/Dutch Shell Group. Prescribed practices included:

- *Top HSE policy document*: top management commits to HSE goals; the policy is 'strong, concise and visionary' (p. 1); the policy refers to striving toward zero accidents; performance is monitored and made public.
- *Assurance of policy compliance*: annual self assessments and reports.
- *Operation and governance*: one managing director has Board level responsibility for health and safety; a corporate health and safety advisor recommends policy and chairs a committee comprising senior business managers.
- *Joint venture/subsidiary policy*: the parent company health and safety policy applies in joint ventures under the parent company; external health and safety reports are made for joint ventures.
- *Linkage of health and safety into the business*: health and safety is a core value and part of company culture; risks are assessed; targets set and performance monitored.

2. Objectives of the current study

The present study reports on a cross-organisational survey designed to benchmark participating offshore installations on their safety climate, and to identify best safety management practices. The project, entitled "Benchmarking offshore safety", ran in collaboration with the Health and Safety Executive and 13 oil and gas companies across two consecutive years, with data collection in each year. Installations were assessed on their safety climate, safety management practice and safety performance. Safety performance was assessed in two ways: first, by official accident and incident rates, and second by the proportion of respondents in the safety climate surveys who reported experiencing an accident in the previous year.

The following hypotheses were advanced:

1. Favorable safety climate at installation level will be associated with lower proportions of employees experiencing an accident.
2. Favorable safety climate at installation level will be associated with lower numbers of official accident reports.

3. Respondents providing favorable safety climate scores at the individual level will be less likely to have experienced an accident.
4. Proficient safety management practice on an installation will be associated with lower proportions of employees experiencing an accident.
5. Proficient safety management practice on an installation will be associated with lower numbers of official accident reports.

Hypothesis 1, 2, 3, 4, 5 may be tested using data aggregated to the installation level (safety climate, safety management practice, safety performance). In contrast, Hypothesis 3 may be tested with data at the individual level (safety climate, safety performance). When operating at the group level or at the individual level there is the risk that accident experience will confound responses on the safety climate survey because those who have experienced an accident may be more likely to rate aspects of safety on the installation negatively (Rundmo, 1994). Therefore, an additional hypothesis precedes Hypothesis 1, 2, 3, 4, 5:

0. True differences between installations in their accident proportions will be reflected in the safety climate scores of accident *and* no-accident groups in a consistent direction.

3. Method

3.1. Safety climate survey

The safety climate survey used the Offshore Safety Questionnaire (OSQ) has been developed from previous research into safety climate in offshore environments (Rundmo, 1994, 1997; Mearns et al., 1997, 1998). The content of the OSQ varied slightly between the two surveys in items and factors (see Appendix A), due to requirements by the sponsoring organisations to target issues of immediate relevance to the offshore industry. In both years there were scales addressing satisfaction with safety activities, workforce involvement in health and safety planning, and communication about health and safety, as well as a set of 19 attitudinal statements about safety and 11 items relating to the frequency of unsafe behaviour. The 19 statements yielded two common factors in exploratory factor analysis, relating to perceived supervisor competence and perceived management commitment to safety. The 11 items pertaining to unsafe behaviour yielded two factors in exploratory factor analysis in each year that addressed unsafe behaviour under incentives, and general unsafe behaviour. These scales are discussed in turn.

3.1.1. Satisfaction with safety activities

Respondents rated on a five-point scale their satisfaction with nine areas of safety management in year one and 13 areas in year two. These areas included quality of safety meetings, emergency response training, support for safety representatives, general housekeeping, involvement of the offshore installation manager

(OIM) in plant activity, and follow-up measures after incidents. Six items were common to both years. The items were adapted from Rundmo (1994). Ratings of satisfaction were made on a five-point scale with anchor points *very satisfied* to *very dissatisfied*. Exploratory factor analysis suggested a one-factor solution in each year.

3.1.2. *Involvement in health and safety*

In year one, four items assessed the extent of workforce involvement in setting health and safety objectives, discussing the effectiveness of the safety management system, discussing procedures for risk control, and auditing health and safety. Responses were made on a three-point scale with anchor points 'not at all' to 'fully'. In year two, there were two items addressing involvement in decision making about work activities and safety issues. Responses were made on a six-point scale with anchor points ranging from complete lack of involvement to complete empowerment.

3.1.3. *Communication about health and safety*

In year one there were five items addressing 'open-door' policy on safety issues, the adequacy of safety information, and praise for working safely. In year two there were eight items addressing the adequacy of communication generally, and between crew changes, during shift handover, and between operator and contractor staff. In both years, exploratory factor analysis suggested one factor.

3.1.4. *Perceived supervisor competence*

Respondents rated on a five-point scale their supervisor's interpersonal skills and approach to safety. There were two items common to each year assessing level of trust in their supervisor and the willingness of their supervisor to accept responsibility for her or his mistakes. There were four items in both surveys. Ratings of agreement with the statements were made on a five-point scale with anchor points ranging from *fully agree* to *fully disagree*.

3.1.5. *Perceived management commitment to safety*

Eight items in year one and six in year two addressed management commitment to safety and the prioritization of safety over production. Two items were common to both surveys. Ratings of agreement with each item were made on a five-point scale with anchor points ranging from *fully agree* to *fully disagree*.

3.1.6. *Frequency of general unsafe behaviour*

This scale was an adaptation of the one used by Rundmo (1997, 2000). Eight items in year one and nine items in year two addressed the frequency with which procedures are disregarded, chances are taken to get the job done, short-cuts are adopted, and safety is ignored. Seven of the items were common to both years. In the first survey a five-point rating scale was used with anchor points *never* to *very often*. In the second survey this was replaced with a three-point scale having anchor points *never* to *often*.

3.1.7. Frequency of unsafe behaviour under incentives

As above, the items from the scale were derived from Rundmo (1997, 2000). Four items in year one and three items in year two addressed the frequency with which management pressure, incentives, and pressure from colleagues result in transgression of procedures. Three items were common to both years. In the first survey a five-point rating scale was used with anchor points *never* to *very often*. In the second survey this was replaced with a three-point scale having anchor points *never* to *often*. This was due to respondents having problems in discriminating the nuances between 'sometimes' and 'occasionally' as expressed in the five-point scale. In addition, respondents never used the 'very often' point on the scale. It was considered less confusing to use the anchor points 'never', 'sometimes' and 'often', particularly as the points 'sometimes' and 'occasionally' and 'often' and 'very often' were collapsed when analyzing the data from year 1.

In addition to these six common themes, year one included scales dedicated to four themes: safety policy knowledge, job satisfaction, written rules and procedures, and willingness to report incidents. Similarly, year two included three scales dedicated to work pressure, perceived competence of the OIM, and written rules and procedures/willingness to report incidents. For both the set of common scales and the scales unique to each year, Cronbach alpha exceeded 0.7.

Finally, there were identical items in both surveys addressing supervisory status, tenure, work roles and whether the respondent had experienced an accident in the previous year. The alterations to the OSQ in year two was a result of continuing refinement based on other related research on the offshore workforce.

3.2. Safety Management Questionnaire (SMQ)

An audit tool, the Safety Management Questionnaire (SMQ) was devised to assess safety management practices on each installation. Leading and lagging performance indicators were included. Leading performance indicators have the advantage of identifying weaknesses in safety management practices before they manifest as accidents. Appropriate indicators have been identified in other industries (Fuller, 1999; Miller and Cox, 1997) and Blackmore (1997) has listed the leading indicators specific to the offshore environment. These studies and those reviewed previously were used to guide the selection of items for the SMQ. In line with HSE (1997), the items were thematically organized. In year one there were six elements:

Health and safety policy: Topics included the corporate statement on health and safety, number and status of dedicated health and safety staff, communication of health and safety policies, and disciplinary procedures.
Organising for health and safety: Topics included: the establishment of health and safety objectives; assigning responsibilities; visits to onshore offices; assessing, recording and meeting training needs; rewarding installation performance.
Management commitment: Topics included managerial safety performance contracts; the number and reasons behind visits by senior onshore personnel; the priority of safety at routine management meetings.

Workforce involvement: Topics included: the percentage of employees receiving formal training in risk assessment; the percentage of staff attending a structured safety meeting every month; the frequency of special training or briefings given to safety representatives; workforce involvement in setting health and safety objectives, discussing procedures for risk control etc.; rewarding of individual safety performance.
Health promotion and surveillance: Topics included: the number of health promotion programmes in place; communication about health issues; extent of any occupational health plan.
Health and safety auditing: Topics included: the percentage of planned health and safety audits achieved; percentage of corrective actions formally closed out; percentage of health and safety goals achieved; percentage of safety inspections targets achieved.

The SMQ in year two contained slightly different items within the same six elements, and an additional category relating to the operator–contractor interfacing:

Operator–contractor interface: Topics included: defining health and safety objectives for shared activities; agreement on an integrated organogram; establishing key accountabilities and responsibilities; routine communication arrangements; identifying health hazards for the shared activity; ensuring competencies of staff involved in the shared project; the number of management visits by the contracting company. Items within this section were taken from guidance published on the UK oil and gas Step Change Initiative website (http://www.oil-gas-safety.org.uk/home2.htm).

The items are listed in Appendix A for both versions of the SMQ. A coding scheme was devised to convert qualitative responses to quantitative data; for brevity, coding schemes are not shown. The relative weighting of importance of each item within each section is difficult to specify in advance. Eq. (1) defines an approach that uses the mean of the unweighted item scores and permits a maximum score of 1 on each element. Inevitably, the omission of weightings for each item compromises the accuracy of the SMQ and introduces some distortion in scores. However, one of the aims was to establish the priority of items in predicting safety performance.

$$\text{Element score} = \sum x_i/u \tag{1}$$

where x_i is the ith item score and u is the number of items within the element.

Safety performance data for the previous year were also collected across installations. These represented the official accident statistics provided by management in response to questions on the SMQ. They included the frequency in the previous year of fatalities, major injuries, lost time injuries of three days or more (LTI$\geqslant$3), visits to the rig medic for first aid, dangerous occurrences, and (in year two only) near miss incidents (see Appendices B and C for definitions of these categories). Rates of occurrence were calculated from the number of personnel on board each installation.

3.3. Participants and background

Safety climate data were collected in consecutive years from thirteen installations operating on the UK Continental Shelf (UKCS). Questionnaires were distributed and returned by post. The installations included fixed production platforms, semi-submersible installations, and floating production, storage and offloading (FPSO) systems. Nine of these installations were common to both years. Safety Management Questionnaires were sent directly to the health and safety manager of each participating company or business unit, or the asset manager for each installation.

4. Results

Response rates and variations across tenure and supervisory status are discussed before addressing each of the hypotheses in turn.

4.1. Offshore Safety Questionnaire (OSQ)

The safety climate survey using the OSQ had a mean response rate across installations of 27% in year one and 38% in year two, representing 682 and 806 respondents, respectively. Installation response rates varied widely, with a minimum of 10% and maximum of 81% (Table 1)[1]. Supervisors represented just under 31% of respondents in year one and just under 29% in year two. The proportion was significantly different across 13 installations in year one [$\chi^2(12)=37.1$; $P<0.001$] and year two [$\chi^2(12)=44.5$; $P<0.001$]. However, each of the nine installations common to both years did not differ in supervisor proportions across surveys, suggesting temporal stability.

One-way ANOVAs revealed that supervisors provided more favorable scores than other respondents on eight of the 11 scales in year one: policy knowledge [$F(1,650)=65.9$; $P<0.001$]; involvement in health and safety [$F(1,661)=140.3$; $P<0.001$]; communication about health and safety [$F(1,661)=9.4$; $P<0.01$]; job satisfaction [$F(1,652)=60.6$; $P<0.001$]; satisfaction with safety activities [$F(1,652)=6.9$; $P<0.01$]; perceived management commitment to safety [$F(1,650)=26.3$; $P<0.001$]; perceived supervisor competence [$F(1,653)=9.88$; $P<0.01$]; and willingness to report incidents [$F(1,666)=13.4$; $P<0.001$].

Supervisors provided more favorable scores than other respondents on all ten scales in year two: involvement in health and safety [$F(1,777)=112.9$; $P<0.001$]; satisfaction with safety activities [$F(1,722)=25.9$; $P<0.001$]; work pressure [$F(1,767)=42.8$; $P<0.001$]; perceived OIM competence [$F(1,770)=35.8$; $P<0.001$]; perceived management commitment [$F(1,757)=51.7$; $P<0.001$]; perceived supervisor competence [$F(1,759)=29.4$; $P<0.001$]; willingness to report/rule adequacy [$F(1,771)=8.3$; $P<0.01$]; general unsafe behaviour [$F(1,750)=18.3$; $P<0.001$];

[1] In the following sections codes are used consistently to maintain anonymity.

Table 1
Response rates across installations

Installation	Year 1		Year 2	
	N	Response rate (%)	*N*	Response rate (%)
A	60	21.4	–	–
B	87	20.7	79	19.8
C	48	34.3	26	16.0
D	82	41.0	53	26.5
E	73	28.1	130	46.4
F	72	36.0	105	52.5
G	54	24.5	73	81.1
H	32	22.9	38	27.1
I	–	–	56	46.7
J	51	47.2	–	–
K	25	10.4	58	19.3
L	48	32.0	62	28.2
M	–	–	83	41.9
Q	–	–	23	47.9
R	–	–	20	38.5
Y	30	12.5	–	–
Z	20	15.0	–	–
Total	682	26.6	806	37.8

unsafe behaviour under incentives [$F(1,772) = 5.5$; $P < 0.05$]; and communication about health and safety [$F(1,727) = 24.5$; $P < 0.001$].

Overall, the distribution of tenure was comparable across surveys. In year one, to the nearest percent, 23% had been on the installation for less than a year, 39% for 1–5 years, 23% for 6–10 years, and 16% for more than 10 years. This compares with 22, 40, 20 and 17% in the second survey. There were statistical differences in the distribution among tenure categories across installations in year one [$\chi^2(36) = 172.8$; $P < 0.001$] and year two [$\chi^2(36) = 255.4$; $P < 0.001$]. However, only one of the nine installations common to both years differed across surveys with respect to tenure: installation G provided significantly more respondents with 6–10 years experience in the second survey [$\chi^2(3) = 23.8$; $P < 0.001$].

In year one, groups of employees defined by their level of tenure did not differ significantly in their scores on 10 of the 11 scales in analysis of variance. The exception was the involvement in health and safety scale [$F(3,667) = 8.99$; $P < 0.01$]. Tukey's HSD test indicated that those with a tenure of less than a year reported lower involvement than did those with tenures of 6 or more years, and those with a tenure of 5 years or fewer reported less involvement than did those with 10 or more years. In year two, three scales showed statistically significant differences among the four categories of tenure in one way analyses of variance. These scales were perceived OIM competence [$F(3,782) = 7.8$; $P < 0.001$], willingness to report/rules satisfaction [$F(3,783) = 2.8$; $P < 0.05$], and communication about health and safety [$F(3,739) = 3.42$; $P < 0.05$]. Tukey's HSD test indicated that:

- *OIM competence in health and safety*: Workers with 1–5 years experience had more favorable perceptions of their OIM than did those with 6–10 years or more than 10 years experience.
- *Willingness to report incidents/rule adequacy*: None of the possible pairs of groups differed significantly, although the largest difference was between those with less than one year's experience and those with 1–5 years experience, the latter having more favorable scores.
- *Communication about health and safety*: Workers with 1–5 years experience provided significantly more favorable scores than did those with 6–10 years or over 10 years experience.

Installations provided significantly different scores in year one across all scales (Table 2). In the second survey, installations differed on 8 of 10 scales (Table 3). A benchmarking approach could be adopted at this point to determine relative weaknesses for any particular installation. Such an analysis is outside the scope of this paper, but provides a means of guiding organisational intervention with respect to safety culture (Mearns et al., 2001).

4.2. Safety management questionnaires

Respondents in 13 business units/installations were sent the SMQ in year one. Ten completed questionnaires were returned, representing a response rate of 77% in the first instance. Of these 10, eight could be linked to respective installations operating on the UKCS that also provided safety performance data relevant to that installation. In year two, 13 questionnaires were distributed and 10 were returned, representing a response rate of 62% in the first instance. Of these 10, eight could be matched directly to installations operating on the UKCS that also provided safety performance data specific to the installation. Mean scores on each element of the SMQ and rates of performance indicators are given in Tables 4 and 5. Rates for

Table 2
Differences between installations in year one

Scale	F[a]
Safety policy knowledge	4.8
Involvement in health and safety	4.6
Communication about health and safety	7.3
Job satisfaction	3.6
Satisfaction with safety activities	10.0
Perceived management commitment	7.0
Perceived supervisor competence	3.3
Written rules and procedures	5.6
Willingness to report incidents	4.7
General safety behaviour	3.5
Safety behaviour under incentives	4.7

[a] All F values significant at $P < 0.001$.

Table 3
Differences between installations in year two

Scale	F
Involvement in health and safety	3.6***
Satisfaction with safety activities	6.8***
Work pressure	3.7***
Perceived OIM competence	6.6***
Perceived management commitment	2.6**
Perceived supervisor competence	5.3***
Willingness to report incidents/ and rule adequacy	1.8*
General unsafe behaviour	1.6
Unsafe behaviour under incentives	1.3
Communication about safety issues	7.9***

* $P<0.05$.
** $P<0.01$.
*** $P<0.001$.

fatalities and major injuries in each year are not presented because frequencies were low, although the RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences) rate does make use of both measures. Missing data (–) precluded the calculation of four lagging indicators in year one and one in year two.

4.2.1. Hypothesis 0

Proportions of respondents reporting an accident on each installation were generally low, ranging from zero to just under 15%. These accident proportions permit an examination of Hypothesis zero: True differences between installations in their accident proportions will be reflected in the safety climate scores of accident *and* no-accident groups in a consistent direction. In each year, installations were divided into two groups based on their accident proportions. The seven installations with the lowest proportions were referred to as *low accident* and the remaining six installations as *high accident*. This was one dichotomous factor in a two-way analysis of variance that included self-reported accidents as the second dichotomous factor. The dependent variable for each analysis was the score on each scale. Assuming that both the accident group and the no-accident group provide accurate assessments, we would not expect a significant interaction term within any analysis.

In year one, there was an absence of significant interaction terms. Two main effects were observed: scores on involvement in health and safety were significantly more favorable on low accident installations [$F(1,671)=4.2$; $P<0.05$], and scores for satisfaction with safety activities were significantly more favorable on low accident installations [$F(1,662)=4.2$; $P<0.05$]. In year two, there were main effects for four of the 10 scales:

Involvement in health and safety: Scores were *less* favorable on installations with lower accident rates [$F(1,785)=4.0$; $P<0.05$]. Respondents who reported an accident had less favorable scores [$F(1,785)=6.9$; $P<0.01$].

Table 4
SMQ element mean scores and installation safety performance in year one

Installation	H&S policy	Organising for H&S	Management commitment	Workforce involvment	Health survellance/ promotion	H&S auditing	Total	LTI $\geqslant$ 3 day	Dangerous occurrences	Near miss	Visits to rig medic	RIDDOR
A	0.70	0.60	0.35	0.84	0.58	0.93	4.01	0.0071	0.0107	–	1.48	0.0226
B	0.59	0.74	0.77	0.47	0.23	0.94	3.74	0.0214	0.0214	0.5238	6.02	0.0451
C	0.56	0.44	0.75	0.85	0.63	0.93	4.16	0.0143	0.0071	0.0643	2.66	0.0226
D	0.65	0.55	0.59	0.86	0.67	0.69	4.01	0.0050	0.1300	0.1600	–	0.1421
E	0.48	0.50	0.47	0.42	0.23	0.35	2.45	0.0385	0.0538	0.1115	4.82	0.0972
F	0.46	0.75	0.29	0.87	0.17	0.91	3.46	0.0400	0.0500	0.0800	1.16	0.0947
G	0.42	0.53	0.44	0.65	0.08	0.64	2.75	0.0364	0.0500	–	0.27	0.1340
N	0.25	0.76	0.53	0.70	0.37	0.88	3.49	0.0046	0.0093	0.0417	3.77	0.0146
X	0.60	0.43	0.13	0.44	0.17	0.79	2.55	0.0250	0.0222	0.4556	–	0.0585

Table 5
SMQ element mean scores and installation safety performance in year two

Installation	H&S policy	Organising for H&S	Managing commitment	Workforce involvement	Health surveillance/ promotion	H&S auditing	Operator/ contractor interface	Total	LTI $\geqslant$3 day	Dangerous occurrence	Visit to rig medic	RIDDOR
A	0.43	0.75	0.69	0.86	0.83	0.99	0.97	5.52	0.0067	0.0100	0.19	0.0175
B	0.46	0.78	0.88	0.98	0.59	0.81	0.50	4.98	0.0222	0.0333	0.96	0.0585
C	0.68	0.76	0.72	0.90	0.86	0.95	0.97	5.84	0.0000	0.0600	0.02	0.0632
D	0.62	0.51	0.78	0.79	0.75	0.91	1.00	5.36	0.0150	0.1050	0.53	0.1289
E	0.13	0.81	0.45	0.86	0.66	0.55	0.81	4.27	0.0000	0.0000	–	0.0000
G	0.41	0.51	0.67	0.73	0.63	0.76	0.72	4.44	0.0091	0.0227	0.07	0.0335
L	0.35	0.63	0.50	0.88	0.60	0.83	1.00	4.79	0.0062	0.0309	0.09	0.0455
O	0.40	0.80	0.38	0.87	0.67	1.00	0.91	5.01	0.0214	0.0143	0.52	0.0451

Satisfaction with safety activities: Scores were more favorable on installations with lower accident rates [$F(1{,}731) = 6.3$; $P < 0.05$].
Work pressure: Respondents who reported an accident had less favorable scores [$F(1{,}777) = 5.9$; $P < 0.05$].
General behaviour: Respondents who reported an accident had less favorable scores [$F(1{,}761) = 4.6$; $P < 0.05$].

In year two, only the analysis involving safety behaviour under incentives revealed a significant interaction of accident proportion and accident experience [$F(1{,}783) = 5.6$; $P < 0.05$]. In this case, Tukey's HSD showed that respondents who had not experienced an accident provided significantly *less* favorable scores on installations with low accident proportions. Additionally, respondents who had experienced an accident provided significantly *less* favorable scores on installations with high accident proportions (Fig. 1).

In summary, Hypothesis 0 was generally supported: differences between installations in their accident rates were reflected in differences in safety climate scores for both accident and non-accident groups. Only one interaction term was significant, but this was not disconfirmatory of Hypothesis 0. Additionally, in all but one case, the significant main effects that did emerge suggested that favorable safety climate scores were associated with installations that had a lower proportion of respondents reporting accident. The exception was workforce involvement in health and safety in year two.

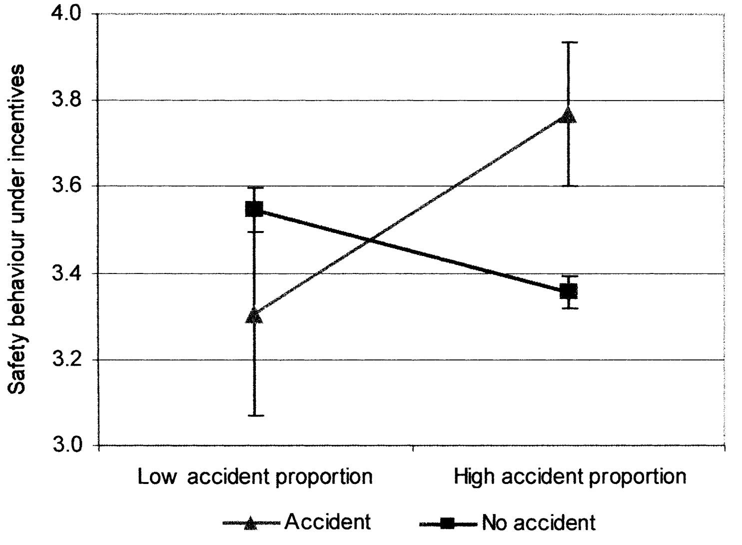

Fig. 1. Scores on unsafe behaviour under incentives, with individual accident experience and installation accident proportion as factors. High scores indicate higher frequency of unsafe behaviours. Error bars denote standard error of the mean.

4.2.2. Hypothesis 1

Hypothesis 1 asserts that favorable safety climate scores at the installation level will be associated with lower proportions of employees claiming to have had an accident during the previous year. To test the hypothesis, Pearson product–moment correlation coefficients were calculated between the means of the 11 scales in year one and the proportion of respondents reporting an accident on the installation. The analysis was repeated in year two with 10 scales.

In year one (Table 6) the only significant coefficient involved scores on communication about health and safety ($r_{13} = -0.56$; $P < 0.05$). In year two (also Table 6), none of the coefficients reached significance. Because statistical power is compromised with only 13 data points in each of the analyses, a second approach assesses the number of coefficients the sign of which is consistent with favorable safety climate scores predicting lower proportions of respondents experiencing an accident. In year one, a significant 10 of 11 coefficients were in the expected direction [$\chi^2(1) = 7.4$; $P < 0.01$]; in year two, only 4 of 10 coefficients were in the expected direction. An alternative approach to testing Hypothesis one is to use safety climate scores in year one as independent variables in predicting accident proportions in year two so that safety climate scores more strictly meet the criteria for leading indicators of safety performance. In this case none of the coefficients reached significance, although 10 of 11 coefficients were in a direction consistent with the hypothesis [$\chi^2(1) = 7.4$; $P < 0.01$].

On this basis, Hypothesis one receives only partial support.

4.2.3. Hypothesis 2

Hypothesis 2 asserts that a favorable safety climate at the installation level will be associated with lower official accident statistics for the installation in both years. To test the hypothesis, Pearson product–moment correlation coefficients were calculated between the means of the 11 scales in year one and five safety performance indicators provided by management in year one. The same process was repeated in year two with 10 scales and four safety performance indicators. The safety performance indicators were rates of LTI $\geqslant 3$, dangerous occurrences, visits to rig medic for first aid, RIDDOR (see Appendix D) and (in year one only) near-misses.

Only one significant coefficient emerged in year one (Table 7): involvement in health and safety was negatively associated with the rate of LTI $\geqslant 3$ [$r_7 = -0.83$]. Overall 35 of 55 coefficients were consistent with the hypothesis, a significantly high proportion [$\chi^2(1) = 4.09$; $P < 0.05$]. Nine of the 11 coefficients involving RIDDOR rate were similarly consistent, a significantly high proportion [$\chi^2(1) = 4.46$; $P < 0.05$]. In year two (Table 8), three significant coefficients emerged: involvement in health and safety was negatively associated with RIDDOR rate [$r_6 = -0.88$; $P < 0.05$]; and communication about health and safety was negatively associated with both the rate of dangerous occurrences [$r_6 = -0.92$; $P < 0.05$] and with RIDDOR [$r_6 = -0.82$; $P < 0.05$]. Overall in year two, only 21 of 40 coefficients were consistent with hypothesis two, although all 10 coefficients that involved RIDDOR rate were consistent.

Hypothesis 2 therefore receives partial support. In year one there was an overall trend consistent with the hypothesis, although this did not emerge in the second

Table 6
Pearson correlation coefficients between safety climate scores and self-reported accident proportions in year one and year two

Scale in year 1	Accident proportion in year 1	Accident proportion in year 2	Scale in year 2	Accident proportion in year 2
Involvement	−0.41	−0.62	Involvement	−0.06
Communication	−0.56*	−0.52	Communication	0.18
Satisfaction with safety	−0.51	−0.39	Satisfaction with safety activities	0.09
Perceived management commitment	−0.30	−0.26	Perceived management commitment	0.36
Perceived supervisor competence	0.13	0.37	Perceived supervisor competence	0.41
General safety behaviour	0.42	0.37	General behaviour	−0.24
Safety behaviour under incentive	0.36	0.16	Safety behaviour under incentives	−0.36
Job satisfaction	−0.37	−0.38	Work pressure	−0.12
Rules and implementation of safety measures	−0.30	−0.17	Perceived OIM competence	0.01
Propensity to report incidents/accidents	−0.06	−0.09	Willingness to report and rule adequacy	0.43
Policy knowledge	−0.36	−0.57		

* $P < 0.05$.

Table 7
Pearson correlation coefficients between safety climate scores for each installation in year one and rates of incident types in year one [$N=55$(rs)]

Year one	LTI ⩾ 3	Dangerous occurrences	Visits to rig medic	Near misses	RIDDOR
Involvement	−0.83*	−0.24	0.08	−0.26	−0.65
Communication	−0.30	−0.03	0.45	−0.68	−0.41
Satisfaction with safety	−0.42	−0.08	0.60	−0.14	−0.49
Perceived management commitment	−0.15	−0.18	0.38	−0.67	−0.44
Perceived supervisor competence	0.65	−0.24	−0.33	−0.50	0.04
General safety behaviour	−0.05	−0.09	−0.60	0.48	0.11
Safety behaviour under incentive	−0.39	0.08	−0.33	0.68	0.10
Job satisfaction	0.09	−0.31	0.68	−0.20	−0.46
Rules and implementation of safety measures	0.02	0.37	0.61	−0.38	0.11
Propensity to report incidents/accidents	0.39	−0.29	0.66	−0.18	−0.33
HS policy	−0.59	−0.21	0.09	−0.41	−0.56

* $P<0.05$ (note that 2–3 values would be expected to be significant by chance at 0.05 level).

Table 8
Pearson correlation coefficients between safety climate scores for each installation in year two and rates of incident types in year two [$N=40$(rs)]

Year 2	LTI ⩾ 3	Dangerous occurrences	Visits to rig medic	RIDDOR
Involvement	−0.28	−0.80	−0.40	−0.88*
Communication	0.31	−0.92**	0.17	−0.82
Satisfaction with safety activities	0.28	−0.79	0.06	−0.67
Perceived management commitment	0.26	−0.65	0.23	−0.57
Perceived supervisor competence	0.20	−0.74	0.24	−0.69
General behaviour	−0.24	0.50	−0.16	0.39
Safety behaviour under incentives	−0.21	0.79	−0.15	0.75
Work pressure	−0.23	0.60	−0.11	0.49
Perceived OIM competence	0.34	−0.75	0.07	−0.61
Willingness to report and rule adequacy	0.75	−0.63	0.62	−0.40

* $P<0.05$ (note that two values would be expected to be significant by chance at 0.05).
** $P<0.01$.

year. In both years the significant majority of scales were associated with RIDDOR rate in a direction consistent with Hypothesis 2.

4.2.4. Hypothesis 3

Hypothesis 3 asserts that respondents providing favorable safety climate scores at the individual level are less likely to have been involved in an accident. Self-reported accident involvement is a binary dependent variable unsuited to traditional regression techniques. Discriminant function analysis (DFA) is more appropriate in this case. DFA is a technique by which a mathematical function, i.e. the discriminant function, is used to classify cases between groups defined by categorical variables.

The discriminant function is derived by assigning coefficients to each of the independent variables in such a way that predicted and actual group membership overlap is optimized. When one or more independent variables result in a significant discriminant function, classification may be considered superior to chance.

In year one, there were 581 cases that provided scores on all scales. The Mahalanobis distance for each case was used to check for multivariate outliers and the data found to be acceptable without exception. The eleven scales were entered as independent variables simultaneously. The discriminant function reached significance [$\chi^2(11)=26.9$; $P<0.01$], correctly predicting 68.5% of cases. Significant differences existed between accident and no-accident groups with respect to safety satisfaction [$F(1,579)=5.39$; $P<0.05$], perceived management commitment [$F(1,579)=6.77$; $P<0.01$], willingness to report incidents and accidents [$F(1,579)=7.9$; $P<0.01$], and general unsafe behaviour [$F(1, 579)=5.14$; $P<0.01$]. In all cases respondents who had not experienced an accident displayed more favorable safety climate scores. The inclusion of only these four scales in DFA still provided a significant discriminant function [$\chi^2(11)=9.9$; $P<0.05$] accounting for 59.4% correct classification.

In year two, DFA was initially applied to the 613 cases for which all scale scores were available and accident category was known. Three multivariate outliers were excluded. The discriminant function reached significance [$\chi^2(10)=27.8$; $P<0.01$] accounting for 68.6% of cases. Significant differences between accident groups existed for general unsafe behaviour [$F(1,608)=8.1$; $P<0.01$], involvement in health and safety [$F(1,608)=5.1$; $P<0.05$], and work pressure [$F(1,608)=4.6$; $P<0.05$]. In all three cases, those reporting an accident provided less favorable scores. When only these scales were included in DFA, the function remained significant [$\chi^2(10)=10.5$; $P<0.05$], accounting for 62.5% of correct classifications.

In summary, Hypothesis 3 was partially supported. In both years, respondents reporting an accident provided significantly less favorable scores on certain scales. In year one, these scales were safety satisfaction, perceived management commitment to safety, willingness to report incidents, and general unsafe behaviour. In year two, these scales were general unsafe behaviour, involvement in health and safety, and work pressure.

4.2.5. Hypothesis 4

Hypothesis 4 predicts that proficient safety management practice will be associated with lower proportions of employees self-reporting an accident in the previous year. To test this hypothesis, Spearman rank correlation coefficients were calculated between the proportion of respondents reporting an accident on each installation and scores on the SMQ elements within the same year.

In year one, all coefficients were in a direction consistent with the hypothesis (Table 9). Two coefficients proved significant: the proportion of respondents reporting an accident was negatively associated with SMQ scores on management commitment ($rho_8=-0.79$; $P<0.05$) and health promotion and surveillance ($rho_8=-0.81$; $P<0.05$). In year two (also Table 9), none of the coefficients reached significance although all were in a direction consistent with the hypothesis.

Table 9
Spearman correlation coefficients (rho) between SMQ scores and the proportion of respondents that reported experiencing an accident in the preceding year

SMQ element	Accident proportion in year 1	SMQ element	Accident proportion in year 2
Policies for health and safety	−0.52	Policies for health and safety	−0.49
Organising for health and safety	−0.31	Organising for health and safety	−0.14
Management commitment	−0.79*	Management commitment	−0.26
Involvement	−0.19	Involvement	−0.77
Health promotion and surveillance	−0.81*	Health promotion and surveillance	−0.14
Health and safety auditing	−0.56	Health and safety auditing	−0.77
		Operator–contractor interface	−0.38
Total SMQ score	−0.67	Total SMQ score	−0.71

* $P<0.05$.

Hypothesis 4 receives support in both years. Management commitment emerges as a key predictor of accident proportion in year one, and in both years the direction of association is suggestive of favorable SMQ element scores having favorable effects on accident proportions.

4.2.6. *Hypothesis 5*

Finally, Hypothesis 5 predicts that proficient safety management practice will be associated with lower official accident reports. To test this hypothesis, Spearman correlation coefficients were calculated between each of the SMQ element scores and the SMQ safety performance measures.

In year one there were four negative and significant coefficients (Table 10): health promotion and surveillance with the rate of lost time injuries [$rho_9=-0.76$; $P<0.05$]; health and safety auditing with rate of dangerous occurrence [$rho_9=-0.71$; $P<0.05$] and RIDDOR rate [$rho_9=-0.68$; $P<0.05$]; and total SMQ score with rate of lost time injuries [$rho_9=-0.67$; $P<0.05$]. In total 24 of 35 coefficients were in a direction consistent with the hypothesis, a statistically significant proportion [$\chi^2(1)=4.8$; $P<0.05$]. Six of the seven coefficients that involved RIDDOR rate were similarly consistent, a proportion just failing to reach significance.

In year two, there were four significant coefficients (Table 11): management commitment and rate of dangerous occurrences [$rho_8=0.81$; $P<0.05$]; operator–contractor interfacing and rates of visits to the rig medic [$rho_7=-0.95$; $P<0.01$]; health and safety auditing and rate of lost time injuries [$rho_8=-0.85$; $P<0.01$]; and total SMQ score and rate of lost time injuries [$rho_8=-0.75$; $P<0.05$]. In total 24 of 32 coefficients were in a direction consistent with the hypothesis, a statistically significant proportion [$\chi^2(1)=8.0$; $P<0.01$]. Five of the eight coefficients involving RIDDOR rate were consistent—a non-significant proportion.

In summary, Hypothesis 5 is supported in both years. Note that only the coefficient between management commitment and rate of dangerous occurrences was significantly positive, and therefore contradictory to the hypothesis.

Table 10
Spearman correlation coefficients (rho) between SMQ element scores in year one and safety performance rates in year one [$N=35$(rhos)]

SMQ element in year 1	LTI ⩾3	Dangerous occurrence	Rate of visits to medic	Near misses	RIDDOR
Policies for health and safety	−0.27	0.08	0.29	0.75	0.07
Organising for health and safety	−0.25	−0.12	0.04	−0.36	−0.28
Management commitment	−0.45	−0.22	0.75	0.07	−0.14
Involvement	−0.23	−0.06	−0.57	−0.36	−0.01
Health promotion and surveillance	−0.76*	−0.23	0.34	−0.29	−0.26
Health and safety auditing	−0.28	−0.71*	0.23	0.00	−0.68*
Total SMQ score	−0.67*	−0.43	0.11	−0.14	−0.32

* $P<0.05$ (note that two values would be expected to be significant by chance at 0.05).

Table 11
Spearman correlation coefficients (rho) between SMQ element scores in year two and safety performance rates in year two [$N=32$(rhos)]

SMQ element in year 2	LTI	Dangerous occurrences	Rate of visits to medic	RIDDOR
Policies for health and safety	−0.43	0.55	−0.32	0.52
Organising for health and safety	0.10	−0.45	0.39	−0.33
Management commitment	−0.07	0.81*	−0.11	0.79
Involvement	−0.11	0.10	−0.04	0.05
Health promotion and surveillance	−0.61	−0.36	−0.39	−0.31
Health and safety auditing	−0.85**	−0.48	−0.57	−0.55
Operator—tractor interface	−0.62	−0.19	−0.95**	−0.30
Total SMQ score	−0.75*	−0.05	−0.46	−0.10

* $P<0.05$ (note that1–2 values would be expected to be significant by chance at 0.05).
** $P<0.01$.

4.3. Summary of hypotheses and their support

Table 12 summarises findings across the two years. Generally there was at least partial support for all hypotheses when trends in the data are examined.

4.4. Specific management practices and safety performance

Table 13 shows the SMQ items that were significantly associated with one or more of the safety performance measures provided by management in year one; Table 14 shows results for year two. Measures of association were based on the Spearman coefficient of rank correlation. In year one, practices associated with improved

Table 12
Summary of hypotheses and findings

Hypothesis	Year 1	Year 2
0: True differences between installations in their self-report accident proportions will be reflected in the safety climate scores of accident and no-accident groups in a consistent direction.	Supported	Supported
1: Favorable safety climate at installation level will be associated with lower proportions of employees experiencing an accident	Communication significantly associated with accident proportion. Trend in coefficients supportive.	No scales significantly associated with accident proportion. Trend in coefficients not supportive.
2: Favorable safety climate at installation level will be associated with lower official accident reports	Involvement—LTI $\geqslant 3$ – – Trend in coefficients supportive overall. Trend in coefficients with RIDDOR supportive.	Involvement—RIDDOR Communication—dangerous occurrences Communication—RIDDOR Trend in coefficients not supportive overall. Trend in coefficients with RIDDOR supportive.
3: Favorable safety climate at individual level will be associated with a lower likelihood of accident involvement.	DFA confirms hypothesis Best predictors: • satisfaction with safety activities • perceived management commitment • willingness to report incidents • general unsafe behaviour.	DFA confirms hypothesis Best predictors: • work pressure • involvement in health and safety • general unsafe behaviour
4: Proficient safety management practice at installation level will be associated with lower proportions of employees experiencing an accident	Accident proportion associated with management commitment and health promotion/surveillance. All coefficients in predicted direction	Accident proportion fails to associate with any SMQ element All coefficients in predicted direction

(*Table continued on next page*)

Table 12 (*continued*)

Hypothesis	Year 1	Year 2
5: Proficient safety management practice at installation level will be associated with lower official accident rates	• Health promotion/surveillance—LTI$\geqslant$3	• Management commitment—dangerous occurrences (NB. But direction of coefficient disconfirmatory of hypothesis)
	• H&S auditing—dangerous occurrences	• H&S auditing—LTI$\geqslant$3
	• H&S auditing—RIDDOR	• Operator/contractor interfacing—visits to rig medic for first aid
	• Total SMQ score—LTI$\geqslant$3 Trend in coefficients supportive	• Total SMQ score—LTI$\geqslant$3 Trend in coefficients supportive

Table 13
The set of items sharing significant ($P<0.05$) Spearman correlation coefficients with at least one safety outcome in year one

LTI>3	RIDDOR	Near miss	Dangerous occurrence	Item of the Safety Management Questionnaire
	–		–	Do you have a system by which you can test employees knowledge of what is in the statement? If yes how is this done?
			+	Offshore position of HSE advisor
				In general what was the purpose of the visits of these personnel and did these safety tours involve face to face discussions with members of the workforce? (refers to visits to the installation by senior on-shore figures)
–				Managing director
–				Business unit/asset manager
				How frequently during 1997 did the senior onshore managers attend safety committees on this installation?
			–	Business unit/asset manager
		–		What percentage of staff on this installation attend a properly structured safety meeting once a month?
–				What health promotion programmes have you in place?
–	–	–		Did you have an occupational health plan for 1998? If yes, what percentage of your occupational health plan was completed?
	–		–	What percentage of corrective actions have been formally closed out against an agreed time scale for this installation in the last year?

+ denotes practices associated with unfavorable performance; – denotes practices associated with favorable performance.

safety performance included: the testing of policy knowledge; visits and tours by onshore personnel; attendance at monthly safety meetings; occupational health plans and programmes; and a high percentage of corrective actions closed out.

In year two, there were many more contra-indicated items. However, practices associated with favorable performance in year two included: formal and regular assessment of training needs; routine health surveillance; achievement of health and safety goals; fully endorsed statement of health and safety commitment between operating and contracting companies; defined health and safety goals for shared activities between operating and contracting companies; and methods to ensure that staff have requisite skills in these shared activities.

5. Discussion and summary

This paper has reported selected results of a project that addressed concurrent perceptions and attitudes of the workforce on 13 offshore installations, management practices on a subset of these installations, and accident data derived from workforce self-report and management records. These data permitted an examination of

Table 14
The set of items sharing significant ($P < 0.05$) Spearman correlation coefficients with at least one safety outcome in year two

LTI > 3	RIDDOR	Visits to the rig medic for first aid	Dangerous occurrences	Item of the Safety Management Questionnaire
–		–		Does the corporate statement on H&S appear in your company annual report?
	+		+	Do you prepare a separate annual safety report?
	+		+	Number of dedicated and fulltime H&S personnel offshore
		+		Do you have a system by which you can test employees knowledge of what is in the statement? If yes how is this done?
			–	How regularly during the period June 98 to July 99 did you assess and record H&S training needs for the installation? How was this assessment carried out?
				How frequently during the year did senior onshore managers conduct health and safety tours on this installation?
	+		+	Platform manager
				In general what was the purpose of the visits of these personnel? Did these visits involve face to face discussions with the workforce?
		+		Business unit/asset manager
	+		+	In what ways are employees encouraged to raise safety matters with their managers?
		–		What provision is there for routine health surveillance of workers?
–				Did you set H&S goals for this installation in the last year? If yes what percentage of H&S goals was achieved during the last year?
		–		Is there a fully endorsed joint statement of health and safety commitment for the shared activity on the target installation?
–		–		Have health and safety goals and objectives for the shared activity been defined?
–		–		Is there a system to confirm that all personnel involved in a shared activity have the necessary competencies to fulfil the requirements of their jobs?

+ denotes practices associated with unfavorable performance; – denotes practices associated with favorable performance.

associations between safety climate and safety performance, and between safety management practices and safety performance.

In addressing these issues there was heavy reliance on correlation coefficients, these being calculated in all cases with limited data. Therefore, as well as restrictions on causal interpretations, there was diminished statistical power because data points ranged in number from 9 to 13 when data were aggregated at installation level. In an attempt to overcome the problem, the trend across correlation coefficients was examined as well as their absolute values.

A second issue concerns the aggregation of individual perceptions and attitudes under the assumption that the resulting mean scores are representative of the installation, i.e. that the attitude-object may legitimately be considered the installation. As Guldenmund (2000) has suggested, this issue has not received the attention that it warrants. Researchers have tended to word their scale items so that the organisation is the group attitude (Cabrera and Isla, 1998; Ostrom et al., 1993). In contrast, questions in the OSQ were generally worded to be specific to the respondents' experience; for example, questions asked about the respondent's supervisor and not supervisors in general within the company. An advantage of this approach is that respondents are not forced to make generalizations but respond based on their personal experiences.

A final methodological issue concerns the measures used to assess safety performance. In this study official accident and incident rates (in the case of the SMQ) or proportions of respondents reporting an accident in the previous year (in the case of the OSQ) were used as the measure of safety performance rather than safety behaviours. There are undoubtedly advantages to using safety behaviour (Brown et al., 2000), but ultimately valid models and theories of the accident process must include actual events for reasons of validity.

5.1. Safety climate scores and safety performance

There was partial support for the idea that installation safety climate predicts the proportion of respondents reporting an accident on each installation. This support was confined to year one: scores on the OSQ communication scale were significantly correlated with self-reported accident proportions, and all eleven scales were associated with accident proportions in the expected direction. Communication was also significantly correlated with the rate of dangerous occurrences and the RIDDOR rate provided by the official installation figures. Communication of health and safety issues to the workforce has been viewed as a key stage of organisational learning that proceeds from accident/near miss investigations, safety audits or changes to procedures. It is a key aspect in the PRIMA safety management tool of Hurst et al. (1996), as well as the HSE safety climate survey tool. Lee (1998) lists communication in his nine characteristics of low accident plants, and it emerges as an important factor in the success of safety programs (Harper et al., 1997; Tan-Wilhelm et al., 2000).

The OSQ scale addressing involvement in health and safety decision-making was significantly associated with LTI$\geqslant$3 in year one and RIDDOR in year two. A sense of involvement may be fostered by immediate supervisors during day to day tasks as well as the specific design of safety programs but in both cases evidence suggests that high involvement promotes safer working practice (Simard and Marchand, 1994; DePasquale and Geller, 1999). The OSQ scale in year one was more general in its scope, covering involvement in the formulation of health and safety objectives, discussing the effectiveness of the safety management system, discussing procedures for risk control, and auditing health and safety. In year two the emphasis was on decision making and work planning. In both cases involvement in health and safety emphasises personal responsibility, and perceptions by the workforce that safety interventions are based on pragmatic concerns and a ‘welfare before profit’ philosophy within the company.

The safety climate scores were also considered at the individual level as predictors of self-reported accidents. When all scales were included in each year, the proportion of correct classifications exceeded 68%. However, this value is not high and there was little consistency in the set of best predictors; only general unsafe behavior featured in both sets. In all cases, unfavorable scores on the OSQ scales predicted an increased likelihood of reporting an accident. The causal direction to this relationship is questionable because experience of an accident may bias perceptions and attitudes toward safety. However, respondents who experienced an accident and those who did not provided similar scores across installations with high and low accident proportions. This suggests that accident experience does not necessarily bias ratings to any large degree.

5.2. Safety management practices and safety performance

Safety management practice displayed wide variation across installations. In year one, lower self-reported accident proportions were observed on installations with favorable SMQ scores for management commitment, and health promotion and surveillance. In both years all coefficients were in the correct direction. In both years, favorable total SMQ scores were associated with lower rates of lost time injuries. Health and safety auditing was implicated in both years.

Contrary to the hypothesis, management commitment was positively associated with the rate of dangerous occurrences in year one. It may be the case that high rates of dangerous occurrences the previous year motivated a higher level of management commitment and that changes in management commitment were reactive rather than proactive.

5.3. Specific management practices

The area labelled ‘health promotion and surveillance’ has received limited attention in the past but showed associations with safety performance in year one. There is some evidence to suggest that health screening may reduce personal injury rate and lost work days (Shannon et al., 1997). Integrating safety awareness outside the immediate professional environment has also been connected with lower accident rates in at least one study (Shannon et al., 1997). Benefits of health promotions and occupational health programmes may be realised through at least one of two processes:

1. Investment by the company in these areas fosters perceptions of company commitment and builds worker loyalty in areas such as safety behaviour;

2. Health plans and health programmes improve worker health directly and 'immunise' against work-related injury.

Both processes are presented speculatively. Indeed, it is important not to get ahead of ourselves because data presented here are correlational and relatively limited. However, there is a growing awareness within the health and safety community that extra-professional health and safety measures introduced by the company may promote a mindful approach to safety at home *and* at work.

The second section with strong links to safety outcomes in year one was health and safety auditing. Health and safety auditing is clearly a broad area. The SMQ addressed inspection targets achieved and corrective actions formally closed out. Two further items addressed general health and safety goal setting and achievement. Effective health and safety auditing can be viewed as a first line defence in preventing injury. Griffiths (1985), among many others, includes auditing as a key requirement in any effective safety management system, and the theme of auditing emerges in safety diagnostic tools, not least among these the Process Safety Management System (Hurst et al., 1996). Shannon et al. (1997) in their review identified five studies that included a measure of auditing proficiency, and four of these studies associated proficient auditing with lower injury rates.

Results of year two were more ambiguous because they included many significant positive coefficients that contra-indicate certain practices presumed favourable. However, there is again an emphasis on aspects of health promotion and surveillance, and health and safety auditing. Additionally, operator–contractor co-ordination in the area of health and safety emerged as a key area associated with lower incident rates.

Recommendations for management strategy based on these findings include:

- Ambitious auditing goals and their achievement in the area of health and safety need to be emphasised within the safety management system.
- The approach to safety management should include areas of health and worker well-being that extend outside the workplace. Employee occupational health plans and health programmes fall within this category.
- Finally, there is evidence, albeit limited, that commitment by senior onshore personnel taking the form of regular visits offsite to discuss safety and talk with workers may improve safety performance.

Acknowledgements

The project entitled "Benchmarking Offshore Safety", from which this paper derives, is an ongoing study based at the Department of Psychology, Aberdeen University, Aberdeen, UK. The views presented are those of the authors and should not be taken to represent the position of the HSE or the companies involved. The study was supported by the Offshore Division of the Health and Safety Executive, UK, in collaboration with the following oil and gas companies: Agip UK Ltd.; AMEC Process and Energy Ltd.; BP Amoco; Coflex Stena Offshore Ltd.; Conoco

UK Ltd.; Elf Exploration UK plc.; Halliburton Brown and Root; Kerr-McGee North Sea Ltd.; Salamis/SGB Ltd.; Transocean Sedco Forex; Shell Expro UK Ltd.; Texaco North Sea UK Ltd.; and Total Fina.

We would also like to thank two anonymous referees for their helpful comments, which led to the improvement of the paper.

Appendix A. Items in the Offshore Safety Questionnaire in each year

OSQ year 1

Involvement in health and safety

Setting health and safety objectives and/or improvement plans

Discussing the effectiveness of the health and safety management system

When decisions are being made about safety issues which may affect you, how involved do you feel?

Discussing procedures and instructions for risk control

Health and safety auditing

Communication about safety

Management operates an open door policy on safety issues

My line manager/supervisor does not always inform me of current concerns and issues

Safety information is always brought to my attention by my line management/supervisor

There is good communication about safety issues which affect me

I don't get praise for working safely

Satisfaction with safety activities

*Follow-up measures taken after injuries and accidents have taken place

*OIM/Master 'walkabouts'

*The quality of safety meetings

*The support safety reps get in order to do their job properly

*Housekeeping at the workplace

*Emergency response training

Safety instructions/training

Information from the safety department

OSQ year 2

Involvement in health and safety

In planning and decision making about your work activities, how involved do you feel?

Communication about safety

I am satisfied with way I am being kept informed about what takes place at work

There is poor communication between operator and contractor staff

My supervisor gives me clear instructions

I get praised for working safely

There is poor communication between crew changes

There is poor communication about health issues that may affect me

There is good communication at shift hand over

There is poor communication about safety issues that may affect me

Satisfaction with safety activities

*Follow up measures after injuries and accidents have taken place

*OIM 'walkabouts'

*The quality of safety meetings

*The support given to safety reps in order to do their jobs properly

*Housekeeping at the workplace

*Emergency response training

Safety audits/inspections

Supervisor 'walkabouts'

Control and inspection routines for safety	The Permit to Work system Social and team building activities Toolbox talks Competency of personnel for multi-skilling activities Risk assessment
Perceived supervisor competence	**Perceived supervisor competence**
*My supervisor is reluctant to take the blame for his/her errors	*My supervisor is reluctant to take the blame for his/her errors
*I trust my supervisor	*I trust my supervisor
My supervisor is sensitive to the personal problems of members of the work group	My supervisor has good 'people skills'
My supervisor cares about safety more than the average worker	My supervisor would approve of me taking shortcuts to get a job done quickly
Management commitment to safety	**Management commitment to safety**
*My company's procedures are only there to cover the management's backs	*The company's procedures are only there to cover management's backs
*If you say too much about safety they might fire you	*If you say too much about safety they might fire you
*Minor accidents cause so much hassle they are quite often ignored	*Minor accidents cause so much hassle they are quite often ignored
*My company will stop work due to safety concerns, even if it means they are going to lose money	*The company would stop us working due to safety concerns, even if it meant losing money
My management does not act on safety concerns	My supervisor would approve of me taking shortcuts to get a job done quickly
Senior management show a lack of commitment to health and safety	
The rules are too strict and I can work better without them	
My company only records accidents because it has to	
Senior management are genuinely concerned about the health and safety of their employees	
General unsafe behaviour	**General unsafe behaviour**
*I ignore safety regulations to get the job done	*I ignore safety regulations to get the job done
*I break work procedures	*I break work procedures
*I take chances to get the job done	*I take chances to get the job done
*I bend the rules to achieve a target	*I bend the rules to achieve a target
*I get the job done better by ignoring some rules	*I get the job done better by ignoring some rules
*Conditions at the workplace stop me working to the rules	*Conditions at the workplace stop me working to the rules
*I take shortcuts which involve little or no risk	*I take shortcuts which involve little or no risk
I carry out activities which are forbidden	I do not adhere to codes of practice when under pressure
	I break rules due to management pressure
Unsafe behaviour under incentives	**Unsafe behaviour under incentives**
*Incentives encourage me to break the rules	*Incentives encourage me to break the rules
*I break rules due to management pressure	*I break rules due to management pressure

*I am under pressure from my work mates to break rules	*I am under pressure from my workmates to break rules
Conditions at the workplace stop me working to the rules	

Unmatched scales

Safety policy knowledge	**Work pressure**
Have you read the company's policy on health and safety?	If I didn't take risks the job wouldn't get done
Do you understand what the policy means?	Sometimes it is necessary to ignore safety regulations to keep production going
Do you understand what the policy requires you to do?	Low manning levels sometimes result in rules being broken to get the job done
Are you involved in updating, revising or reviewing the policy?	Whenever I see safety regulations being broken I point it out on the spot
	There is never any pressure to put production before safety on this installation
Job satisfaction	**Perceived OIM competence**
Sometimes I feel I'm not paid to think	I trust my OIM
My work is boring and repetitive	My OIM is genuinely concerned about the health and safety of people are this installation
I do my job only for money	
My OIM acts promptly on safety concerns	
There is plenty of scope for satisfaction in my job	
I feel I have good future job prospects with the company I'm working for	
On the whole, good work is rewarded	
A 'pat on the back' for making a good job of things is usual around here	
Written rules and procedures	**Written rules and procedures and willingness to report incidents**
The written safety rules and instructions are easy for people to follow	People are willing to report near-misses
The rules always describe the safest way of working	The written safety rules and instructions are easy for people to understand and implement
Safety improvements are implemented within a reasonable period of time	People are willing to report accidents
My management care about the negative effect that job uncertainty has on safety	The rules always describe the safest way of working
Willingness to report incidents	
People are willing to report near misses	
People are willing to report accidents	

*Item appears in both years.

Appendix B. Issues addressed in the SMQ in year one

A. Health and safety policies

1. Corporate statement on health and safety
2. Dedicated and fulltime H&S personnel **offshore**
3. Onshore position of HSE advisor
4. Offshore position of HSE advisor
5. Does the corporate statement on H&S appear in your company annual report?
6. Does the corporate or the installation statement appear in any other reports you produce?
7. Do you prepare a separate annual safety report?
8. How is the health and safety policy communicated within the corporate organisation?
9. How is the health and safety policy communicated on this installation?
10. Do you have a system by which you can test employees knowledge of what is in the statement? If yes, how is this done?
11. Do you have disciplinary procedures in place for dealing with infringements of safety rules and regulations? If yes, under what circumstances?
12. Have disciplinary procedures been invoked on this installation during 1997?

B. Organizing for health and safety

1. How are health and safety objectives established for this installation?
2. How do you communicate and assign safety responsibilities for the installation?
3. How often during 1997 did the OIM visit the head office or the office of the onshore supervisor/manager?
4. How often during 1997 did the dept heads from the installation visit the head office or the office of the onshore supervisor/manager?
5. How often during the same period were reviews of health and safety performance on the installation carried out?
6. How regularly during 1997 did you assess and record H&S training needs for the installation?
7. What percentage of targeted H&S training was completed during 1997?
8. Is the installation H&S performance rewarded? If yes, how is it appraised and rewarded?

C. Management commitment

1. With respect to Step Change Initiative have you identified all managers who should have a Personal Safety Performance Contract?
2. If yes what percentage of qualifying managers has a Personal Safety Performance Contract?

3. How frequently during the year did senior onshore managers conduct health and safety tours on this installation? Managing director; Platform manager; Business unit/Asset manager.
4. In general what was the purpose of the visits of these personnel? Did these safety tours involve face to face discussions with members of the workforce? Managing director; Platform manager; Business unit/asset manager
5. How frequently during 1997 did the senior onshore managers attend safety committees on this installation? Managing director; Platform manager; Business unit/asset manager
6. Are health and safety issues on the agenda at all routine management meetings on this installation and if so where do they come on the agenda?

D. Workforce involvement

1. What percentage of the total workforce on this installation have received formal training in risk assessment?
2. What percentage of staff on this installation attend a properly structured safety meeting once a month?
3. What percentage of constituencies are currently filled by trained reps?
4. How frequently during the year were safety reps on this installation given special training and briefings?
5. Are offshore employees actively involved in the following? Please describe how they are involved.
   - Carrying out risk assessments
   - Setting installation H&S objectives and or improvement plans?
   - Discussing the effectiveness of the H&S management system?
   - Discussing procedures and instructions for risk control
   - Proactive health and safety auditing
6. Is the H&S performance of individuals working on the installation rewarded? If yes, how is it appraised and rewarded?
7. Do you have a system in place for resolving the situation when problems disputes and conflicts arise about health and safety issues? If yes how do you resolve the situation?

E. Health promotion and surveillance

1. What health promotion programmes have you in place?
2. How do you communicate to the workforce about health issues which may affect them?
3. Did you have an occupational health plan for 1997? If yes, what percentage of your occupational health plan was completed?

F. Health and safety auditing

1. What percentage of H&S audits have been achieved against the audit review plan for this installation in the last year?
2. What percentage of corrective actions have been formally closed out against an agreed time scale for this installation in the last year?
3. Did you set H&S goals for this installation in the last year? If yes what percentage of H&S goals was achieved during the last year?
4. Did you set safety inspection targets for this installation in the last year? If yes, what percentage of targeted safety inspections was completed in the last year?
5. How many contracting company management visits were there to this installation during the period of last year?

Appendix C. Issues addressed in the SMQ in year two

A. Health and safety policies

1. Corporate statement on health and safety
2. Dedicated and fulltime H&S personnel **offshore**
3. Dedicated and fulltime H&S personnel **onshore**
4. Does the corporate statement on H&S appear in your company annual report?
5. Do you prepare a separate annual safety report?
6. How is the health and safety policy communicated on this installation?
7. Do you have a system by which you can test employees knowledge of what is in the statement? If yes how is this done?

B. Organizing for health and safety

1. How are health and safety objectives established for this installation?
2. How do you communicate and assign safety responsibilities for the installation?
3. How often during July 98 to June 99 did the OIM visit the head office or the office of the onshore supervisor/manager?
4. How often during July 98 to June 99 did the dept heads from the installation visit the head office or the office of the onshore supervisor/manager?
5. How often during the same period were reviews of health and safety performance on the installation carried out?
6. How regularly during the period June 98 to July 99 did you assess and record H&S training needs for the installation?
7. What percentage of targeted H&S training was completed during the period June 98 to July 99?

8. Is the installation H&S performance rewarded? If yes, how is it appraised and rewarded?
9. Is the HSE included in job descriptions?
10. Are safety critical competencies included in job specs, recruitment selection criteria and performance appraisals?
11. Do you have a NVQ programme or equivalent in place on this installation? If yes what percentage of the programme was achieved in the period June 98 to June 99?

C. Management commitment

1. How frequently during the year did senior onshore managers conduct health and safety tours on this installation? Managing director; Platform manager; Business unit/asset manager.
2. In general what was the purpose of the visits of these personnel? Did these safety tours involve face to face discussions with members of the workforce? Managing director; Platform manager; Business unit/asset manager
3. Have line managers been told specifically that when there may be a conflict between safety and production a decision to err on the side of safety will be supported by senior management?
4. How are managers held accountable for their health and safety performance?

E. Workforce involvement

1. What percentage of the total workforce on this installation have received formal training in risk assessment?
2. What percentage of staff on this installation attend a properly structured safety meeting once a month?
3. What percentage of constituencies are currently filled by trained reps?
4. How frequently during the year were safety reps on this installation given special training and briefings?
5. Are offshore employees actively involved in the following? Please describe how they are involved.
   - Carrying out risk assessments
   - Discussing procedures and instructions for risk control
   - Health and safety inspections
   - Planning and making decisions about their work activities
   - Making decisions about safety issues
   - Investigating accidents
   - Getting feedback about lessons learned from accidents
6. In what ways are employees encouraged to raise safety matters with their managers?
7. What evidence is there to suggest that employees are raising safety matters with their managers?

8. Is the H&S performance of individuals working on the installation rewarded? If yes, how is it appraised and rewarded?
9. Do you have an employee safety suggestion scheme in place on the installation? If yes how many suggestions were received last year? How many of these suggestions were taken up and acted upon?

E. Health promotion and surveillance

1. What health promotion programmes have you in place?
2. How do you communicate to the workforce about health issues which may affect them?
3. Did you have an occupational health plan for 1998? If yes, what percentage of your occupational health plan was completed?
4. What provision is there for routine health surveillance of workers?
5. Are there facilities for health review on return to work after sickness?
6. Is counselling, support and professional advice made available during periods of ill health or stress?
7. Are there mechanisms for identifying and helping individuals with alcohol or drug related problems?

F. Health and safety auditing

1. What percentage of H&S audits have been achieved against the audit review plan for this installation in the last year?
2. What percentage of corrective actions have been formally closed out against an agreed time scale for this installation in the last year?
3. Did you set H&S goals for this installation in the last year? If yes what percentage of H&S goals was achieved during the last year?
4. Did you set safety inspection targets for this installation in the last year? If yes, what percentage of targeted safety inspections was completed in the last year?

G. Operator contractor interfacing

1. Is there a fully endorsed joint statement of health and safety commitment for the shared activity on the target installation?
2. Have health and safety goals and objectives for the shared activity been defined?
3. Is there an agreed integrated organogram? If yes have key accountabilities and responsibilities been assigned and defined for all personnel on the organogram?
4. Have routine communication arrangements covering relevant areas of work execution been agreed?
5. Have the parties agreed a process for identifying and assessing health and safety hazards that may arise from shared activity?

6. Is there a system to confirm that all personnel involved in a shared activity have the necessary competencies to fulfil the requirements of their jobs?
7. How many contracting company management visits were there to this installation during the period of last year?

Appendix D. Definitions of accident categories

Fatalities: A death as a result of an accident arising out of or in connection with work.

Major injury: An injury specified in Schedule 1 of RIDDOR '95 including fractures, amputations, certain dislocations, loss of sight, burns, acute illness, hyperthermia/hypothermia, and loss of consciousness requiring hospitalization for at least 24 h.

Lost time incidents of three or more days ($LTI \geqslant 3$): A work-related injury resulting in incapacitation for more than three consecutive days.

Dangerous occurrences: Any one of 83 criteria, including 11 specific to offshore detailed in Schedule 2 of RIDDOR '95 with the potential to cause a major injury. This includes failure of lifting machinery, pressure systems or breathing apparatus, collapse of scaffolding, fires, explosion, and release of flammable substances.

Near-misses: An uncontrollable event or chain of events which, under slightly different circumstances could have resulted in injury, damage or loss.

Reportable diseases: An occupational disease specified in column 1 of Schedule 3 of RIDDOR '95.

Visits to the rig medic for first aid: Number of visits to the rig medic in the course of the previous year.

RIDDOR rate: The *R*eporting of *I*njuries, *D*iseases and *D*angerous *O*ccurrences *R*egulations (1997) provides the relevant equation for calculating a composite index of rates of fatalities, major injuries, lost time injuries and dangerous occurrences within any organisation. This index was used in both years as a lagging safety performance indicator.

References

Blackmore, G.A., 1997. Leading performance indicators. Conference Proceedings of the International Association of Drilling Contractors (IADC), Aberdeen, UK, 15 June 1997.

Brown, K.A., Willis, P.G., Prussia, G.E., 2000. Predicting safe employee behavior in the steel industry: Development and test of a sociotechnical model. Journal of Operations Management 18, 445–465.

Cabrera, D.D., Isla, R., 1998. The role of safety climate in a safety management system. In: Hale, A., Baram, M. (Eds.), Safety Management: The Challenge of Change. Elsevier, Oxford, UK.

Cheyne, A., Tomas, J.M., Cox, S., Oliver, A., 1999. Modelling employee attitudes to safety: a comparison across sectors. European Psychologist 1, 4–10.

Cohen, A., 1977. Factors in successful occupational safety programs. Journal of Safety Research 9, 168–178.

Cohen, A., Smith, M., Cohen, H.H., 1975. Safety Program Practices in High vs. Low Accident Rate Companies—An Interim Report (questionnaire phase): Department of Health, Education and Welfare Publication No. 75-185. National Institute for Occupational Safety and Health, Cincinnati. Cited in Cohen (1977) ibid.

Cox, S., Flin, R., 1998. Safety culture: philosopher's stone or man of straw? Work and Stress 12, 189–201.

Cullen, D., 1990. The Public Inquiry into the Piper Alpha Disaster. Department of Energy. HMSO, London, UK.

DePasquale, J.P., Geller, E., 1999. Critical success factors for behavior-based safety: a study of twenty industry-wide applications. Journal of Safety Research 30, 237–249.

Fleming, M., Flin, R., Mearns, K., Gordon, R. 1996. The offshore supervisor's role in safety management: Law enforcer or risk manager. Conference Proceedings of the Third International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, New Orleans, 9–12 June 1996, SPE 35906.

Flin, R., Mearns, K., O'Connor, P., Bryden, R., 2000. Measuring safety climate: identifying the common features. Safety Science 34, 177–193.

Fuller, C., 1999. Benchmarking health and safety performance through company safety competitions. Benchmarking: An International Journal 6, 325–337.

Griffiths, D.K., 1985. Safety attitudes of management. Ergonomics 28, 61–67.

Guastello, S.J., 1989. Catastrophe modeling of the accident process: evaluation of an accident reduction program using the Occupational Hazards Survey. Accident Analysis and Prevention 21, 61–77.

Guastello, S.J., Gershon, R.R.M., Murphy, L.R., 1999. Catastrophe model for the exposure to blood-borne pathogens and other accidents in health care settings. Accident Analysis and Prevention 31, 739–749.

Guldenmund, F., 2000. The nature of safety culture: a review of theory and research. Safety Science 34, 215–257.

Harper, A.C., Cordery, J.L., de Klerk, N.H., Sevastos, P., Geelhoed, E., Gunson, C., Robinson, L., Sutherland, M., Osborn, D., Colquhoun, J., 1997. Curtin industrial safety trial: managerial behaviour and program effectiveness. Safety Science 24, 173–179.

Hine, D.W, Lewko, J., Blanco, J., 1999. Alignment to workplace safety principles: an application to mining. Journal of Safety Research 30, 173–185.

Hofmann, D.A., Jacobs, R., Landy, F., 1995. High reliability process industries: individual, micro and macro organisational influences on safety performance. Journal of Safety Research 26, 131–149.

HSE, 1997. Successful Health and Safety Management HS(G) 65. HSE Books, Sudbury.

Hudson, P., Reason, J., Wagenaar, W., Bentley, P., Primrose, M., Visser, J., 1994. Tripod-Delta: proactive approach to enhanced safety. Journal of Petroleum Technology 40, 58–62.

Hurst, N.W., Young, S., Donald, I., Gibson, H., Muyselaar, A., 1996. Measures of safety management performance and attitudes to safety at major hazard sites. Journal of Loss Prevention in the Process Industries 9, 161–172.

International Atomic Energy Authority (IAEA), 1986. Summary report on the post accident review meeting on the Chernobyl accident 75-INSAG-1. IAEA, Vienna.

Kawka, N., Kirchsteiger, C., 1999. Technical note on the contribution of sociotechnical factors to accidents notified to MARS. Journal of Loss Prevention in the Process Industries 12, 53–57.

Kennedy, R., Kirwan, B., 1998. Development of a hazard and operability-based method for identifying safety management vulnerabilities in high risk systems. Safety Science 30, 249–274.

Kirwan, B., 1998. Safety management assessment and task analysis—a missing link? In: Hale, A., Baram, M. (Eds.), Safety Management: The Challenge of Change. Elsevier, Oxford, pp. 67–92.

Lee, T., 1998. Assessment of safety culture at a nuclear reprocessing plant. Work and Stress 12, 217–237.

Mattila, M., Hyttinen, M., Rantanen, E., 1994. Effective supervisory behaviour and safety at the building site. International Journal of Industrial Ergonomics 13, 85–93.

Mearns, K., Flin, R., Fleming, M., Gordon, R., 1997. Human and Organisational Factors in Offshore Safety (HSE Report OTH 543). HM Stationary Office, Norwich, UK.

Mearns, K., Flin, R., Gordon, R., Fleming, M., 1998. Measuring safety climate on offshore installations. Work and Stress 12, 238–254.

Mearns, K., Whitaker, S., Flin, R., 2001. Benchmarking safety climate in hazardous environments: a longitudinal, inter-organisational approach. Risk Analysis 21 (4), 771–786.

Miller, I., Cox, S., 1997. Benchmarking for loss control. Journal of the Institute of Occupational Safety and Health 1, 39–47.

Mitchison, N., Papadakis, G.A., 1999. Safety management systems under Seveso II: implementation and assessment. Journal of Loss Prevention in the Process Industries 12, 43–51.

OECD Nuclear Agency, 1987. Chernobyl and the Safety of Nuclear Reactors on OECD Countries. Organization for Economic Co-operation and Development, Paris.

Ostrom, L., Wilhelmsen, C., Kaplan, B., 1993. Assessing safety climate. Nuclear Safety 34, 163–173.

Pidgeon, N., O'Leary, M., 2000. Man-made disasters: why technology and organizations (sometimes) fail. Safety Science 34, 15–30.

Reason, J., 1997. Managing the Risks of Organizational Accidents. Ashgate, Aldershot.

Reason, J., 1998. Achieving a safe culture: theory and practice. Work and Stress 12, 293–306.

Rundmo, T., 1994. Associations between safety and contingency measures and occupational accidents on offshore petroleum platforms. Scandinavian Journal of Work Environment and Health 20, 128–131.

Rundmo, T., 1997. Associations between risk perception and safety. Safety Science 24, 197–209.

Rundmo, T., 2000. Safety climate, attitudes and risk perception in Norsk Hydro. Safety Science 34, 47–59.

Shafai-Sahrai, Y., 1971. An inquiry into factors that might explain differences in occupational accident experience of similar size firms in the same industry. Division of Research, Graduate School of Business Administration, Michigan State University, East Lansing, Michigan. Cited in Cohen, A (1977) ibid.

Shannon, H.S., Mayr, J., Haines, T., 1997. Overview of the relationship between organizational and workplace factors and injury rates. Safety Science 26, 201–217.

Shannon, H.S., Walters, V., Lewchuk, W., Richardson, J., Moran, L.A., Haines, T., Verma, D., 1996. Workplace organizational correlates of lost time accident rates in manufacturing. American Journal of Industrial Medicine 29, 258–268.

Sheen, J., 1987. M.V. Herald of Free Enterprise (Report of Court No. 8074). HMSO, Department of Energy, London, UK.

Simard, M., Marchand, A., 1994. The behaviour of first line supervisors in accident prevention and effectiveness in occupational safety. Safety Science 17, 169–185.

Smith, M.J., Cohen, H.H., Cohen, A., Cleveland, R., 1975. On-site observations of safety practices in plants with differential safety performance. National Safety Congress Transactions 12 Industrial Subject Sessions 97-103 Cited in Cohen (1977) ibid.

Sykes, R.M., Paxman, J.F., Thoem, T.L. 1997. Benchmarking of HSE performance and practice in the worldwide upstream operations of British Petroleum, Conoco and the Royal Dutch/Shell Group. Volume 1—Text and Data. SIEP 97–0585.

Tan-Wilhelm, D., Witte, K., Liu, W.Y., Newman, L.S., Janssen, A., Ellison, C., Yancey, A., Sanderson, W., Henneberger, P.K., 2000. Impact of a worker notification program: assessment of attitudinal and behavioural outcomes. American Journal of Industrial Medicine 37, 205–213.

Thompson, R.C., Hilton, T.F., Witt, L.A., 1998. Where the safety rubber meets the shop floor: a confirmatory model of management influence on workplace safety. Journal of Safety Research 29, 15–24.

Tomas, J.M., Melia, J.L., Oliver, A., 1999. A cross validation of a structural equation model of accidents: organisational and psychological variables as predictors of work safety. Work and Stress 13, 49–58.

Turner, B.A., Pidgeon, N.F., 1997. Man-made Disasters. Oxford: Butterworth Heinemann.

Vaughn, D., 1996. The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA. University of Chicago Press, Chicago.

Wright, C., 1994. A fallible safety system: institutionalised irrationality in the offshore oil and gas industry. Sociological Review 42, 79–103.

Zohar, D., 1980. Safety climate in industrial organisations: theoretical and applied implications. Journal of Applied Psychology 65, 96–102.