 DOI: 10.1111/risa.12583

Failing to Fix What is Found: Risk Accommodation in the Oil and Gas Industry

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The present program of research synthesizes the findings from three studies in line with two goals. First, the present research explores how the oil and gas industry is performing at risk mitigation in terms of finding and fixing errors when they occur. Second, the present research explores what factors in the work environment relate to a risk-accommodating environment. Study 1 presents a descriptive evaluation of high-consequence incidents at 34 oil and gas companies over a 12-month period ($N = 873$), especially in terms of those companies' effectiveness at investigating and fixing errors. The analysis found that most investigations were fair in terms of quality (mean = 75.50%), with a smaller proportion that were weak (mean = 11.40%) or strong (mean = 13.24%). Furthermore, most companies took at least one corrective action for high-consequence incidents, but few of these corrective actions were confirmed as having been completed (mean = 13.77%). In fact, most corrective actions were secondary interim administrative controls (e.g., having a safety meeting) rather than fair or strong controls (e.g., training, engineering elimination). Study 2a found that several environmental factors explain the 56.41% variance in safety, including management's disengagement from safety concerns, finding and fixing errors, safety management system effectiveness, training, employee safety, procedures, and a production-over-safety culture. Qualitative results from Study 2b suggest that a compliance-based culture of adhering to liability concerns, out-group blame, and a production-over-safety orientation may all impede safety effectiveness.

KEY WORDS: Incidents; mixed method; qualitative; risk mitigation; safety climate; safety culture

1. INTRODUCTION

An effective accident investigation should have two main aims: (a) finding the cause of accident, and (b) making recommendations to prevent similar accidents in the future.[(1–3)] These aims, however, are often implied, rather than explicitly stated in the literature, because many accident investigation models satisfy these goals,[(4)] and because of the emphasis in the literature on the importance of learning from negative events.[(4,5)] However, although there are a number of complex theories of accident causation,[(6–8)] what may be more important for improving safety in organizations is learning the appropriate lessons from incidents by applying corrective actions. An organization that investigates incidents and applies corrective actions is demonstrating that it is willing to learn from past events to ameliorate risk and adopt a culture of risk mitigation.

Nevertheless, there has been a dearth of research on *how well* organizations learn from incidents, a gap addressed in the present research. Much of the extant research focuses on identifying the best accident investigation methods (e.g., the

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 0272-4332/16/0100-0001$22.00/1

causal tree method, integrated safety investigation methodology, TRIPOD, etc.),[2,4,9,10–13] debates over the best models for understanding errors (e.g., high reliability, natural accident, Swiss cheese theory),[6] or theories about how organizations can learn from errors.[14] However, no research has explored the extent of companies' *investigations* into the causes of adverse events, and the extent to which they attempt *remediation* approaches. The purpose of the present research is to investigate the extent of oil and gas companies' risk-mitigation orientation in terms of investigating incidents and fixing errors by taking corrective actions.

It is also important to understand what cultural artifacts may lead to a *risk-accommodating* work environment, defined as a workplace that consistently fails to find and fix errors. As such, this research explores the factors associated with a culture of risk accommodation. Much of the research to date has explored safety culture in a range of industries[15–19] and accepts that a positive safety culture is fundamental for safety performance. However, past research has focused on the operationalization of the concept of safety climate,[20] how it differs from safety culture,[21] what the dimensions of safety climate and culture are,[22] and how to measure safety climate.[22–24] There has been less research on what a derailed safety climate or culture may look like, including situations in which environmental barriers to safety may make a company more risk accommodating. The present study uses quantitative and qualitative methods to explore an oil companies' climate and culture in order to better understand what may encourage risk accommodation.[3]

2. STUDY 1

2.1. Incident Investigations and Corrective Actions

This study explores the following question: *How are oil and gas companies performing at finding and fixing errors in order to prevent future events?* In answering this question, we present a descriptive analysis of oil and gas companies' incidents over a 12-month period, and the corrective actions they took. Study 1 has two aims: exploring the quality of incident investigations, and determining the efficacy of corrective actions in the oil and gas industry. In line with the first aim, we explore whether investigations explain the sequence of events that caused an incident.[14] The purpose of such investigations is to determine why the accident occurred in order to facilitate learning by introducing remediation attempts to lower the probability of a similar event in the future,[2,3] especially if the event could be high consequence (e.g., resulting in fatalities or substantial property damage).[25–27] Nevertheless, it is unclear to what extent companies investigate to determine the causes of high-consequence events. Although one study[12] did assess the quality of companies' investigation processes, to our knowledge, no research has studied the extent to which companies investigate errors, and whether those investigations meet quality standards by identifying the cause of the event.

In line with the second aim, we explore a second crucial stage in ameliorating the risk of future incidents: implementing controls to prevent similar accidents from occurring in the future (i.e., applying corrective actions). It has long been recognized that finding the cause of an accident matters only if corrective actions are implemented.[1] However, remediation approaches have received little empirical attention. (see Ref. 11 for an exception.) The key is not just to study events, but to learn from them and implement change.[12] Instead, much of the existing research on accident investigations seeks to understand why they occur, but does not necessarily lead to remediation attempts to rectify causes.[e.g., 28–30; see also 31] A focus on finding the cause of an incident, rather than remediation, is highlighted in the findings of research by Lundberg, Rollenhager, and Hollnagel.[12] Their study analyzed eight accident investigation manuals, and found that the manuals emphasize investigation, data collection, and analysis, but provide little detail on recommendations to fix the errors. They also report that when recommendations do appear in the manuals, they are often generic, such as "set meetings with the affected parties."[12, p. 1308] In addition, research findings indicate that accident investigators spend more time conducting investigations than generating solutions, lending additional support to the argument that investigation is emphasized over remediation.[31] This is especially concerning because, in some cases, safety awards and safety certification structures are not provided for following

[3]There has been a longstanding debate as to the operationalization of these terms, leading some researchers to use them interchangeably. In the present research we distinguish between these terms and view safety climate as employee perceptions of the characteristics of their organization that reduce or eliminate risk,[24] with an emphasis on day-to-day aspects of the work environment.[21,22] Conversely, we view safety culture as an in-depth assessment of beliefs, values, and patterns of behavior.[20,22]

through on implementing corrective actions and remediating errors; rather, they are awarded "points" for an audit checklist for the number of general controls or performance elements (e.g., number of training classes, number of procedures), what Albersmeier, Schulze, Jahn, and Spiller[32] call "checklist governance." Ultimately, it is unclear whether companies take corrective action to ameliorate errors after investing significant time investigating errors. We contribute to this body of work by exploring the frequency with which companies fail to implement at least one corrective action for every high-consequence incident. We further contribute in that we explore the quality of implemented corrective actions for high-consequence incidents in terms of eliminating the probability of the event reoccurring.

2.2. Method

2.2.1. Sample and Data Collection

One hundred and thirty-seven pipeline organizations that have an incident investigation/safety management program were contacted to participate in this study, of which 34 agreed to participate (a 24.82% response rate). Twelve (35.29%) are supply/service companies, nine (26.47%) are construction companies, seven (20.59%) are midstream pipeline companies, and six (17.65%) are engineering/consulting companies. The companies were small to medium-sized (mean exposure hours = 487,275.73 per year; $SD = 449{,}287.37$).

2.2.2. Data Procurement and Quality

The documentation was collected as follows. First, we gathered documents detailing all incident investigations over a 12-month period from the 34 companies in the sample, including recordable accidents, near misses, and identified hazards. The documentation included the date of the incident, the incident classification or type (i.e., injury incidents resulting in fatalities or requiring medical aid or first aid; property damage; near misses/hits, hazards identified, noncompliance investigations), and details on the corrective action or remediation approach. Second, we compiled a complete list of job task hazard assessments. Third, we collected a complete list of each company's policies and procedures. The job task hazard assessments and policies and procedures were often included as part of the company's safety manual. Fourth, we made a list of all safety-related training courses delivered to employees (including internal mandatory classes, such as orientations, and external mandatory classes requiring accreditation by a third party).

To ensure that we received complete data, we gathered core information from the safety management system. This included formal hazard assessments also known as job task assessments or job safety assessments; operational procedures/practices; safety training matrix; and information on all investigations (including corrective actions taken for each investigation). We gathered this information by using the following checks and balances. First, we sent a checklist to participating companies (see Appendix A). Second, we reviewed the submitted materials for correctness, completeness, and anomalies (e.g., no near-miss reports or property damage investigations or missing corrective actions from what one would naturally expect). Third, we followed up with participant companies by email, with on-site meetings, or by phone, to double check that the right information was provided and was not miscommunicated. For example, we often received field-level hazard assessments instead of formal hazard assessments. We also wanted to ensure that all investigation data were provided, especially because participants were conditioned to focus only on "recordable incidents," and we required information on all investigations, including near-miss and property-damage events. Together, these checks and balances ensured that we had the most complete high-quality data possible.

2.2.3. Evaluation Framework

2.2.3.1. Overview. The general research method for this study was an analysis of each company's high-consequence accident investigation and remediation programs on a set of evaluation criteria. Every incident investigation in a 12-month period from all 34 companies was evaluated. Because each company had numerous incidents, a percentage score of adherence to the evaluation criteria was provided to summarize across all incidents (i.e., the degree to which employees report incidents, and the degree to which those incidents are investigated and remediation actions are put in place).

Incident classification system. We first classified events based on their potential consequences. Researchers have recognized the need to focus on events that have high consequences, yet may occur relatively infrequently, because such events can result in serious injury or fatality to one or more employees, and can cost the organization financially with significant property damage (the low-probability/high-consequence approach).[31–37] However, it is complex and challenging to model low-probability/high-consequence events.[26] It may be more important to consider the consequences of events from an incident-mitigation perspective.[33,34] Given that the consequences of events are "generally measured in terms that directly affect people and their environment such as the loss of life or injury and economic losses,"[35, p. 176; 36] we classified incidents based on (a) their impact on *people*, either employees or members the general public, and (b) *property damage*, both in terms financial loss and environmental impact that resulted in a high-consequence injury and a classification as property damage.

Criteria for evaluating investigation quality. For the present study, we adapted Benner's[9] incident rating scheme, which provides three possible incident quality scores (0, 1, or 2) depending on the degree to which the incident quality criteria are met. We used this classification system to determine whether the incident investigation system was too minimal to allow for extrapolation as to the cause or sequence of events, whether the information provided enough data to reasonably extrapolate the cause of the incident, and whether the information satisfied all the criteria of a quality investigation. Rather than using Benner's[9] numbered classification system, we labeled each of these categories weak, fair, or strong, respectively, to allow for ease of understanding. An overall percentage score was then given to each company based on the extent to which its incidents were determined to be weak, fair, or strong.

The incident quality criteria we used for classifying incidents into each stage were based on Katsakiori and colleagues'[4] recommendations for what should be considered a quality investigation. As such, our results include a descriptive evaluation of quality investigations. Katsakiori and colleagues[4] state that quality investigations should (a) describe the event and circumstances under which the event happened, (b) determine at least one possible cause of the event (e.g., what task the person was performing when the event occurred), and (c) allow for recommendations to be made (what are referred to as a descriptive requirement, revealing requirement, and consequential requirement[4]). An incident was classified as strong if the descriptive requirement and revealing requirement were satisfied (but not the consequential requirement, given that this may fall into the corrective action part of incident remediation). An incident was classified as fair if we could reasonably extrapolate from missing information at least the descriptive requirement (i.e., the circumstances of the event were described). An incident was classified as weak if there was not enough information to understand either the circumstances of the event or the event's cause (i.e., it failed to be a quality investigation based on Katsakiori and colleagues[4]).

Criteria for evaluating corrective actions. Corrective action presence was determined based on whether each company met the standard of at least one corrective action per incident. We used two steps to validate whether corrective actions were present or not (consistent with the data-gathering information outlined in Section 2.2.2.). When the research team noted that corrective action data were missing or of low quality, the participant would be contacted by phone to confirm the completeness of the data set submitted. In addition, after the data were analyzed we generated a report for the participating firm (specifically the safety department). This allowed the participant firm to point out any flaws or missing data. At this time, all participants confirmed that we had been provided with all the documentation that they had. It is possible that in some cases, corrective actions were taken and completed, but that no one could specifically state that this was indeed the case or provide any proof of it. Nonetheless, we were confident that to the best of our ability, we had captured whether or not a corrective had been applied.

For each company, a number was given for each incident that had failed to result in at least one corrective action. This was a binary rating based on whether or not something was written to attempt to ameliorate the event. Then, the percentage ratio of the number of incidents to the *failure* to take at least one corrective action was computed for each company (0% representing perfect follow-through on corrective actions, 100% representing complete failure to meet this standard).

Corrective action quality was established based on a company implementing (not just proposing) a corrective action and confirming that the corrective action was completed. Therefore, a percentage score was given to each company based on the number of incidents that (a) completed a corrective action implementation, and (b) confirmed the corrective action was completed. That is, a 0% rating corresponded to a company's incidents resulting in zero corrective actions that were completed and confirmed as complete, and a 100% rating corresponded to all of a company's incidents resulting in corrective actions, and confirmed as complete.

Corrective actions control types, in terms of the corrective actions' ability to eliminate risk by eliminating, controlling, and preventing health and safety hazards in the work environment, were evaluated based on the hierarchy-of-controls approach.[37–39] This approach categorizes corrective actions into three types: engineering controls, administrative controls, and personal protective equipment (PPE) controls.[38–40] Similarly, we classified each corrective action into one of three categories. We outline the operationalization of these categories below.

Engineering controls (a) the direct source of the hazard and (b) the transmission of that hazard onto the worker.[38,39] Engineering controls include changing the work environment itself, such as the manner in which work is performed, equipment, and the tools used.[38] As such, engineering controls are the most desirable control type as they are believed to eliminate or control hazards in the workplace. Engineering controls have been further categorized in the industrial hygiene literature as *fully eliminating* the hazard or *controlling* the hazard.[41,42] Replacing a toxic substance with a nontoxic substance would be a better control compared to improving ventilation of the toxic substance, for instance.[42,43] As such, we further classified engineering controls into engineering elimination (a hazard engineering control that eliminates the risk without the need for further controls) and engineering control (an engineering control that reduces risk exposure from the hazard to the employee).

Administrative controls refer to those that focus only on controlling the transmission of the hazard onto the worker or worker exposure to the hazard, rather than the direct source of the hazard, as is the case with an engineering control.[38] As such, they are considered less ideal than engineering controls.[39] Administrative controls are often management-dictated administrative procedures and work practices,[39] and may include training programs, policies and procedures, and scheduling of work. However, certain administrative controls may be better than others. We therefore further categorized administrative controls into *administrative-primary controls* (defined as administrative solutions that are more permanent at reducing exposure to hazards) and *administrative-secondary controls* (defined as administrative controls that are interim in nature at reducing exposure to risk). Examples of administrative-primary controls include things such as job task analysis, policies and procedures, competencies, training, and learning validation. Examples of administrative-secondary controls include meetings, inspections, safe work observations, or pretask assessments, all of which result in an interim reduction of an employee's risk of hazards.

PPE controls refer to equipment such as hard hats, safety shoes, hearing protection, and eye protection. They are considered the least desirable type of control,[39] although they are easier to implement than engineering controls.[44]

Each company was given a percentage score based on the extent to which its overall investigations fell into each of these categories. Then, these categories were further divided into weak controls (PPE and administrative-secondary controls), fair controls (administrative-primary controls), and strong controls (engineering control and elimination). A fair to strong percentage score was given to each company. Then, an overall score was given for those corrective actions that were fair to strong *and* were completed.

2.3. Results

2.3.1. Descriptives

Of the incident events reported at the 34 corporations over a 12-month period ($N = 2{,}552$; mean per company = 77.6, $SD = 16.22$), 207 did not have enough data to be classified based on type of incident or seriousness of the consequences, and were therefore excluded from subsequent analysis (165 unknown incidents, 29 unknown near misses, and 13 unknown hazard identification events). Of the remaining sample, 37.23% ($N = 873$) were high-consequence incidents resulting in serious injuries, fatalities, or severe property damage. Of the low-consequence incidents ($n = 1{,}254$), 85.19% were reactive ($n = 1{,}254$), 1.22% were near misses ($n = 18$), and 13.59% ($n = 200$) were from proactive hazard identification reports. Of the high-consequence incidents ($n = 873$), 43.18% were reactive ($n = 377$), 48.68% were near-miss ($n = 425$), and 8.13%

Table I. High-Consequence Investigation Quality per Company

Company Pseudonym	Weak	Fair	Strong
A	14.30%	53.60%	32.10%
B	0.00%	100.00%	0.00%
C	9.10%	54.50%	36.40%
D	7.40%	77.80%	22.20%
E	6.70%	78.30%	20.00%
F	61.90%	38.10%	0.00%
G	0.00%	61.90%	38.10%
H	20.00%	80.00%	0.00%
I	0.00%	69.60%	30.40%
J	6.00%	70.10%	23.90%
K	8.30%	83.30%	8.30%
L			
M	0.00%	100.00%	0.00%
O	26.50%	70.60%	2.90%
N	0.00%	80.00%	20.00%
P	0.00%	54.50%	45.50%
Q	18.20%	72.70%	9.10%
R	17.70%	81.00%	1.30%
S	0.00%	100.00%	0.00%
T	0.00%	78.30%	21.70%
U	13.00%	85.40%	1.60%
V	6.30%	87.50%	6.30%
W	0.00%	100.00%	0.00%
X	0.00%	72.70%	27.30%
Y	6.70%	91.10%	2.20%
Z	0.00%	100.00%	0.00%
AA	7.70%	84.60%	0.00%
BB	12.10%	80.30%	7.60%
CC	20.60%	79.40%	0.00%
DD	27.30%	68.20%	4.50%
EE	12.70%	71.40%	15.90%
FF	7.10%	50.00%	42.90%
GG	50.00%	50.00%	0.00%
HH	16.70%	66.70%	16.70%
Mean	11.40%	75.50%	13.24%
SD	14.14%	16.06%	14.36%

(n = 71) were from proactive hazard identification reports. Of the high-consequence incidents, 55.11% were attributed to the job task or equipment used, 15.80% to the work environment or facilities, 12.01% to a failure in safety awareness, 7.91% to maintenance issues, 7.47% to unknown causes, 1.35% to human factors, and 0.75% to workplace violence or harassment.

2.3.2. *Evaluation of Results*

The results of the incident quality evaluation are presented in Table I. As can be seen, most investigations fell into the "fair" category. Of note is that an average of only 13.24% of high-consequence incidents satisfied all three criteria (a "strong" rating), and that an average of 11.40% of cases failed to meet any of the criteria (a "weak" rating), although it should also be noted that there is high variability between companies regarding their investigation quality. Company F, Company GG, Company CC, and Company DD have especially poor quality investigations compared to the rest of the sample, whereas Company P and Company FF both have higher-quality investigations compared to the rest of the sample. A subsequent evaluation of low and high incident investigation quality showed that across the organizations' low- and high-consequence events, 11.72% of investigations, on average, were rated as "strong."

Table II presents the types of events investigated across the sampled organizations, with the overall percentage of firms that failed to take at least one corrective action per incident. As the table shows, most high-consequence incidents in our sample were associated with property damage (77.45% of 377 accidents), and about 10% of these incident types were not associated with a corrective action. Furthermore, results showed that lost-time incidents, modified-work incidents, and fatalities met a minimum standard of at least one corrective action per event, but that first aid and medical aid incidents had the greatest average failure to result in the implementation of at least one corrective action per event.

Broken down by company, the results showed that most companies failed to create a minimum standard of at least one corrective action for every high-consequence incident overall (see Table III). An average of 14.05% (SD = 18.02) of serious injuries or cases of property damage failed to result in at least one corrective action. Furthermore, an average of 24.88% (SD = 33.78%) of fatalities or cases of catastrophic property damage failed to meet a minimum standard of at least one corrective action for every high-consequence incident. The same pattern was found for near-miss serious versus catastrophic corrective actions; a higher proportion of catastrophic events failed to have at least one corrective action. Specifically, out of the companies that reported high-consequence, near-miss incidents (n = 23 companies), a mean of 10% (SD = 16.35%) of serious injuries or property damage incidents failed to result in at least one corrective action, and an average of 23.51% (SD = 2.17%) of fatalities or cases of catastrophic property damage failed to result in at least one corrective action. Furthermore, though few companies reported hazards (n = 11 companies), of those that did, most took a

Table II. Type of Incidents by Corrective Action Failure

Event Classification	Incident # by Type	# Failure to Have at Least One Corrective Action	Fail % Ratio Incidents to Corrective Actions
Property damage only	292	33	11.30%
First aid	49	13	26.53%
Medical aid	19	3	15.79%
Modified work	3	0	0.00%
Lost time	12	0	0.00%
Fatality	2	0	0.00%
Near miss	425	58	13.65%
Risk identification	71	9	12.67%

corrective action (a mean of 4.64% did not result in an associated corrective action).

2.3.3. Corrective Action Quality and Completeness

Results of the quality evaluation show the following: a mean of only 45.23% were assigned to an individual to complete, a mean of only 38.54% had a due date, a mean of only 32.26% were completed, and a mean of only 13.77% were confirmed as completed. However, there was substantial variability between companies on the extent to which they completed the implementation of corrective action ($SD = 36.51\%$), and substantial variability on the extent to which they confirmed that a corrective action implementation was completed ($SD = 32.17\%$). For example, two companies (Company G and Company W) completed the implementation of all their corrective actions. They also confirmed all of their corrective actions as complete. On the whole, however, most companies failed to implement (complete) their proposed corrective actions: 26 (76.47%) failed to implement their proposed corrective actions more than 50% of the time. Company A, for instance, completed implementation of corrective actions in only 2.63% of its overall incidents.

2.3.4 Corrective Action Control Type

The results of the high-consequence control type evaluation are presented in Table IV. As the table shows, a large proportion of controls (mean = 46.19%) were indeterminate. This means the specified corrective action was not a corrective action by definition—as per evaluation criteria described above, it did not specify a call to action to ameliorate the problem, such as a simple statement that no one was hurt—or that the corrective action had no relation to the underlying problem and was more a facet of the investigation phase (e.g., need to interview witnesses). Of the controls that could be classified as controls, the majority were administrative (in particular, secondary administrative). A low number of controls are fair to strong controls, including administrative-primary, engineering controls, and engineering elimination (mean = 9.15%, $SD = 9.12\%$).

2.4. Study 1 Summary

Study 1 presented a descriptive evaluation of pipeline companies' investigation quality, as well as the quality and implementation of corrective actions they took to mitigate future risk. The results showed that, although most companies have fair quality investigations, the corrective actions are of lower quality for nearly a third of the sample. The results also showed that many high-consequence incidents did not have at least one corrective action, and that many corrective actions were not confirmed as implemented. Ultimately, the results support the contention that the sampled oil and gas companies fail to sufficiently find and fix errors once they occur, and, with a few notable exceptions, fail to consistently and efficiently ameliorate the risk of incidents reoccurring. However, Study 1 is limited in that it does not investigate the cultural artifacts or factors of the operational work environment that may lead to a corporate culture being risk accommodating in not applying corrective actions to mitigate risk. This was the purpose of Study 2.

3. STUDY 2

Study 2 extends the findings of Study 1 by investigating the operational work factors and cultural artifacts that may relate to a deleterious

Table III. Total Incidents and Corrective Actions for High-Consequence Events per Company

	Serious Injuries or Major Property Damage			Fatality or Catastrophic Property Damage		
Company Pseudonym	Incident Number by Type	# With no Corrective Action	% Failure to Have at Least One Corrective Action	Incident Number by Type	# With no Corrective Action	% Failure to Have at Least One Corrective Action
A	9	1	11.11%	7	0	0.00%
B	4	0	0.00%	2	0	0.00%
C	4	0	0.00%	2	0	0.00%
D	5	0	0.00%	2	0	0.00%
E	8	1	12.50%	1	1	100.00%
F	2	0	0.00%	4	1	25.00%
G	9	0	0.00%	1	0	0.00%
H	4	0	0.00%	1	0	0.00%
I	21	5	23.81%	0	0	—
J	38	15	39.47%	7	4	57.14%
K	5	1	20.00%	1	1	100.00%
L	76	8	10.53%	8	4	50.00%
M	2	0	0.00%	1	0	0.00%
N	13	1	7.69%	3	1	33.33%
O	3	0	0.00%	0	0	—
P	8	1	12.50%	2	0	0.00%
Q	8	4	50.00%	2	0	0.00%
R	21	0	0.00%	8	0	0.00%
S	0	0		0	0	—
T	7	0	0.00%	0	0	—
U	7	0	0.00%	12	0	0.00%
V	3	0	0.00%	0	0	—
W	2	0	0.00%	0	0	—
X	2	1	50.00%	0	0	—
Y	10	5	50.00%	2	1	50.00%
Z	4	0	0.00%	0	0	—
AA	8	2	25.00%	1	0	0.00%
BB	10	0	0.00%	2	0	0.00%
CC	1	0	0.00%	1	0	0.00%
DD	12	5	41.67%	5	3	60.00%
EE	28	12	42.86%	7	5	71.43%
FF	9	0	0.00%	0	0	—
GG	3	2	66.67%	1	1	100.00%
HH	3	0	0.00%	1	0	0.00%
Mean	10.26	1.88	14.05%	2.47	0.65	24.88%
SD	14.45	3.65	18.02%	3.08	1.36	33.78%

Table IV. Overall High-Consequence Corrective Action Control Types

		Weak Controls		Fair Control	Strong Control	
	Indeterminate	PPE	Admin. secondary	Admin. primary	Engineering control	Engineering elimination
Mean	46.19%	1.00%	40.63%	5.40%	3.40%	0.35%
SD	23.23%	3.06%	20.66%	5.62%	6.63%	2.02%

risk-accommodating culture. Study 2 explores the following research question: *What factors of the operational work environment act as safety barriers?* In answering this question, we present a quantitative and qualitative evaluation of a case organization's cultural barriers related to a failure to find and fix errors. The case organization was a medium-sized oil pipeline company operating in North America. To protect the company's identity we will refer to it using the pseudonym Mullen Oil.

Table V. Factor Loadings

	Factor						
	F1	F2	F3	F4	F5	F6	F7
Management is slow to correct problems	**0.743**	0.070	−0.181	−0.050	−0.023	−0.012	0.056
If you voice concerns, management doesn't care/ listen	**0.650**	−0.153	0.010	0.007	0.079	−0.001	0.058
Management does not care about safety problems/ risks	**0.588**	−0.245	−0.148	0.060	0.279	−0.114	0.204
Corrective action is taken when management is told	−0.**537**	0.009	0.282	0.233	−0.228	0.281	−0.157
Management is committed to safety	−0.**525**	0.124	0.262	0.228	−0.100	0.268	0.103
Incident investigations should tell you what caused the incident	−0.083	**0.918**	0.053	−0.021	−0.075	−0.038	−0.055
A near-miss needs to be investigated to find out the causes and ensure that preventative measures are established	−0.072	**0.749**	0.063	−0.002	0.131	0.239	−0.140
High-consequence corrective actions should have a call to action that does something to fix the cause of the incident	−0.032	**0.665**	−0.036	0.042	0.185	0.224	0.173
The safety management system is effective in preventing harm/loss	−0.183	−0.057	**0.927**	0.136	−0.040	0.034	0.074
The safety management is effective in preventing errors	−0.159	0.107	**0.792**	0.142	−0.063	−0.091	−0.087
Safety procedures are carefully followed	−0.280	−0.050	**0.468**	0.256	−0.294	0.169	0.154
Training for proper equipment use ensures competency	−0.029	−0.102	0.106	**0.983**	0.024	0.101	0.010
Training for the safety program ensures competency	−0.124	0.079	0.231	**0.621**	−0.016	−0.104	−0.064
Employees engage in unsafe behaviors	0.115	0.133	−0.041	0.038	**0.706**	−0.230	−0.092
Other employees ignore safety	0.224	0.136	−0.235	0.009	**0.684**	0.046	0.230
I don't follow safety policy and procedures	0.221	−0.196	0.026	0.013	**0.406**	−0.385	0.308
There needs to be more buy-in from employees regarding safety	−0.086	0.303	0.024	−0.114	**0.320**	−0.025	−0.139
In my unit, disregarding safety procedures is rare	−0.007	0.079	−0.021	−0.032	−0.003	**0.669**	−0.089
Generally, I follow policy and procedures	−0.178	0.405	−0.075	0.038	0.012	**0.441**	0.010
It is the safety department's responsibility to do what needs to be done regarding safety problems	0.063	−0.067	−0.027	−0.001	0.158	−0.**327**	−0.023
Here production is more important than safety	0.512	0.163	−0.244	−0.136	0.002	−0.216	**0.686**

Note: Rotation converged in eight iterations. Bolded items reflect the highest loading items onto the factor. F1 = management safety disengagement; F2 = finding and fixing errors; F3 = safety management system effectiveness; F4 = training effectiveness; F5 = employee safety; F6 = procedures; F7 = productive over safety climate.

3.1. Study 2a

3.1.1. Overview

Prior to answering our research questions, we conducted a descriptive functional incident assessment of Mullen Oil (see Study 1 for the procedures) in order to better understand the company's investigation and the quality of its corrective actions. Then, we implemented a comprehensive safety climate measure designed to tap into the most commonly assessed safety climate metrics[22] for employee participants working on oil rigs or performing associated duties (i.e., not administrative assistants working in the head office). This 30-item questionnaire was based on other safety climate measures established in the literature,[19,45] and an item revised from the Singer PSCI survey,[46] to read "breaches of safety occur to save time" (see Appendix B). The company had 625 employees at the time of the survey, of which approximately 150 worked on or near the oil rig and were recruited to complete the survey. Responses were received from 90 employees, for a total response rate of approximately 60% (14 surveys were completed by drillers; 29 by roughnecks, derrickhands, and floorhands; four by safety personnel; 26 by rig managers, managers, field supervisors, or test supervisors; and 17 by others, such as testers or those in unknown positions). Questionnaires were completed on paper.

3.1.2. Evaluation Results

Mullen Oil recorded 101 incidents over a 12-month period and 1,081,117 exposure hours. Of these, 53.47% (N = 54) were high-consequence events, such as injuries, fatalities, or severe property damage. The incident types were as follows: property damage (37.04%; $n = 20$), near-miss serious injuries (22.22%; $n = 12$), cases of proactive high-consequence risk identification (18.52%; $n = 10$), modified work (11.11%; $n = 6$), first aid (5.56%; $n = 3$), lost-time injuries (3.70%, $n = 2$), and medical aid (1.85%; $n = 1$).

The results of the incident quality evaluation showed that most investigations fell into the weak category (50%; $n = 27$), while a smaller proportion fell into the strong (12.96%; $n = 7$) or fair categories (37.04%; $n = 20$). This indicates a large proportion of Mullen Oil's investigations did not determine the event cause or the circumstances surrounding the incident.

The results of the corrective action evaluation showed that 33.33% ($n = 18$) of high-consequence incidents failed to lead to at least one corrective action. However, some incidents had more than one corrective action ($n = 24$; $n = 37$ total corrective actions). Of these corrective actions, most (85%; $n = 54$) were assigned to a person to complete, most had a due date (77.61%; $n = 52$), and a large portion were completed (58.21%, $n = 39$). Furthermore, of these corrective actions, the majority were administrative-secondary (56.72%; $n = 38$; e.g., complete task inspections), followed by administrative-primary (17.91%; $n = 12$; e.g., implement new work procedures), and engineering controls (8.96%; $n = 6$). A smaller proportion of corrective actions involved PPE (2.99%; $n = 2$), engineering-elimination (1.49%; $n = 1.49\%$), and were indeterminate (11.94%; $n = 8$). These results suggest that Mullen Oil's corrective actions were relatively high in quality, though were not applied a third of the time. Together, the results support the findings from Study 1, and suggest that Mullen Oil may have an environment that is risk accommodating, deeming the sample worthy of further study to understand the climate and culture variables that may drive a failure to consistently find and fix errors.

3.1.3. Measure Results

Factor analysis (maximum likelihood with varimax rotation) was used to reduce the items into a small number of explanatory factors.[47] This method is commonly used to determine the dimensions of a safety climate.[48] In our preliminary analysis we used the criterion of unity, and only extracted factors that exceeded one eigenvalue.[49] Eight factors were initially extracted (54.69% variance explained). During several steps, nine items were removed from the item pool due to poor loadings, cross-loading, and communalities that were too high or low.[50] This resulted in a 21-item, seven-factor final solution (see Table V). The final solution accounted for 56.41% variance explained. We labeled the factors based on their highest loading item as follows: management disengagement to safety (Factor 1), finding and fixing errors (Factor 2), safety management system effectiveness (Factor 3), training effectiveness (Factor 4), employee safety (Factor 5), procedure effectiveness (Factor 6), and a climate of production over safety (Factor 7). The explanation of the factors' variance is as follows: management's disengagement of safety = 11.45%, $\lambda = 2.52$; finding and fixing errors = 10.74%, $\lambda = 2.36$; safety management system = 9.70%, $\lambda = 2.13$; training effectiveness = 7.33%, $\lambda = 1.61$; employee safety = 7.08%, $\lambda = 1.56$; procedure effectiveness = 6.28%, $\lambda = 1.38$; and climate of production over safety = 3.82%, $\lambda = 0.84$. The measurement model demonstrated adequate fit (χ^2 [150] = 243.53, $p < 0.0001$; $\chi^2/df = 1.62$; $CFI = 0.836$; $RMSEA = 0.052$; $AIC = 403.527$; $PNFI = 0.492$). Together, these variables explain the safety climate within the oil and gas organization.

3.2. Study 2b

3.2.1. Overview

The variables that were helpful in explaining the safety climate based on the results of the case organization's climate survey were supplemented by a qualitative study designed to explore the factors in the larger macro safety culture that may drive ineffective risk management and support a risk-accommodating culture. Specifically, this study employed a qualitative focus group approach, which is ideal for understanding the shared worldviews and paradigms held among a group of people.[51,52] Specifically, this study extends Study 2a in that it explores the deeper-rooted shared cultural worldviews that may relate to the attitudes found in Study 2a.

3.2.2. Method

Over a two-week period seven nominal focus group interviews were conducted with Mullen Oil employees ($n = 22$ employees; three focus groups), supervisors and managers ($n = 18$; three focus groups), and the upper management team ($n = 5$; one focus group). The focus groups ranged from five to ten employees (total = 45 employees; 1 female), were

Table VI. Summary of the Themes

Theme	Definition	Sample Quotation
Ineffective safety practices	*A general perception that safety practices are ineffective in making people safe.*	You just fill it out [incident paperwork] because you have to fill it out. [Researcher: what happens to it when you fill it out] I don't know. [other person]—it get's shredded (laughs) [other person] The paper goes to the office. [Researcher: Do they fix the problem?] Most of the time I take care of it myself. I have to respond by fixing it, otherwise it won't get done.
1. Compliance-based culture	*Perception that current practices are confined due to industry standards, the presence of the client onsite, and industry competition. Compliance is the emphasis of safety.*	Why we have safety meetings—it's a paper trail, CYA liability. [another company] reported everything .... their TRIF numbers were too high because they reported it, but another company didn't [report everything] so they lost business. Why are we spending time with this online stuff instead of PST. PST is just to cover their [words omitted].
1.1. Reactive versus proactive	*Perception that there is reactive safety management.*	I have even been going through some [safety] stuff with [city] and they know that we are looking at things through a rear view mirror. ... Or, looking through the back *windshield* instead of the rearview mirror! Ha!
1.2. Safety system data	*Perception that the current practice of managing incidents and fixing errors is ineffective.*	Measures do not differentiate [between little incidents and fatalities]. A papercut is the same as death.
2. Production-over-safety culture	*Perception that money and production supersede safety.*	Corporate greed determines how safe we want to be. As soon as money becomes a crunch ... they will say get that d*** oil rig going—just do it—we are stuck in the middle. If I said I want to shut down this then how long will it take until I get a call from upper management to go and get things fixed.
2.1 Maintenance	*Lack of maintenance of equipment.*	You can't preach safety and then have guys slip on oil and say "oh we didn't wash it" ... they were busy
2.2 Training	*Emphasis on "making due" with training and a lack of formal training periods or processes.*	Yes, we need more training ... Ya so ya' gotta just babysit [greenhands]. You're so focused on the green guy doing his job rather than having guys able to do their job. It is bad. It is so bad ... it's horrible.
2.3 Fatigue	*Feelings that people are overworked.*	I worked 14 hour days and had to work, and was falling asleep at work ... after that—I just wanted to get out of there and they would not let us go.
3. Blame-based culture	*Management attitude that employees are complacent, risk taking, unable to perceive risks, and have no commonsense, contrasted with an attitude that management doesn't care about safety.*	*Management*: When we go out they [employees] will change the way they do things because we are there. They show us they know what to do. [they are] like kids—when you are away the kids play .... *Employees*: There is more blaming than there is trying to fix and solve problems and there is no worker appreciation.
3.1 Worker helplessness	*Perception that they have no ability to make their workplace safe—and that no one cares.*	I keep telling them [management] again and again ... nothing is done. Someone could die!

audio recorded with the consent of participants, and lasted between 1.75 to 2.5 hours in length.

Consistent with the nominal focus group methodology, at the beginning of the session participants were given a question and asked to brainstorm their responses for a 10-minute period.(53) The question asked was: "If you could change anything about safety in your workplace what would you change?" This was followed up with the clarifying question: "That is, if you had a magic wand and could change anything in your workplace, what would it be?" Following the nominal approach, after writing individual reflections, participants were asked to share their ideas with the group in a round-table fashion.(53,54) The group discussed each idea voiced by a participant; this group discussion approach allowed the group to arrive at a general consensus regarding the organization's safety culture. The nominal focus group ended after all participants had a chance to share each point they brainstormed at the beginning of the session, and after participants indicated they had no further comments to add.

3.2.3. *Analysis*

Transcripts were analyzed using a grounded-theory-like approach(55) to thematic analysis, wherein the transcript was first coded in a line-by-line sentence-level fashion using open coding. At this level, expressions and statements were given a word or words to represent the interpretation of the expression in the right-hand margin of the interview sheet. For example, the statement, "it is with the procedures is more cover your a** and document, so that due diligence is covered when something happens," was given the following codes: procedures, compliance, and paper-based safety. In the second stage of coding, codes were read and reread to develop an interpretivist account of "what was going on" in the data.(55,56) At this phase, the constant comparison method(55,56) was used to contrast similar and different expressions and codes. At this phase, old codes were revised or added to for a preliminary understanding of the themes within the data. The third stage involved an explicit search for patterns in the data. Further questions were asked of the data, such as: "What assumptions are speakers making?" "What is this expression a theme of?" and "What patterns are present in the data?"(56) At the end of this stage, preliminary themes were derived to describe the data. In the final stage, themes were combined into higher-order categories based on answers to questions asked of the preliminary themes, their underlying codes, and their underling expressions, such as the same questions that were used in stage three.

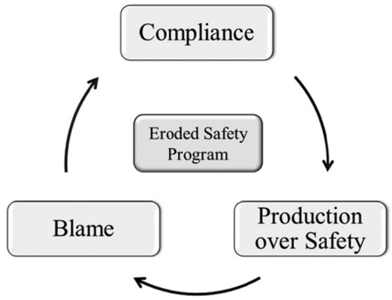

Fig. 1. Qualitative results theme summary.

3.2.4. *Results*

Three macro-level themes emerged from the data, including a compliance-based culture, a production-over-safety culture, or a blame-based culture. (The themes and subthemes are summarized in Table VI.) For example, employees feel that incidents are not followed up on or corrected, which may lead to employee frustration and feelings of helplessness, employees perceiving that safety practices are confined to oil industry standards, and employees feeling that desire for profit takes precedence over their well-being. In addition, blame is operationalized as an out-group attitude, such that management sees employees as accountable for safety lapses, while workers derogate management for allowing them to work in a risky environment. These themes can be viewed through a lens in which these cultural elements reinforce, and are reinforced by, ineffective safety practices and processes (Fig. 1).

4. GENERAL DISCUSSION

The results suggest that companies are diverting the majority of their attention to investigations, without devoting sufficient attention on to remediation, which should be the ultimate goal of incident investigation.(2,3) This finding is consistent with findings from research by Lundberg and colleagues,(12) who, in an analysis of accident investigation manuals, found that there was a greater focus on investigating than on designing and implementing remediation approaches. Our results build on Lundberg and colleagues(12) by showing that emphasis on accident investigations over remediation not only in investigation manuals, but also in terms of finding and fixing actual incidents.

The results also show that the pipeline company featured in the case study faced several barriers to effective safety, with the most variance explained by management's safety disengagement, the ability to find and fix errors, and safety management system effectiveness (Study 2a). Specifically, these issues were elucidated in a qualitative exploration of safety barriers in three macro categories: a blame-oriented culture, a compliance-based safety program, and an emphasis on production over safety.

4.1. Theoretical Contributions

The present research builds on past research in several ways. First, it builds on research that has evaluated *what* the best accident investigation methods may be,[2,4,9–13] theorizes how organizations can learn from past events,[14] and evaluates the effectiveness with which organizations learn from these past events. Findings that show that organizations may not always effectively learn from past events lend support to other research findings that organizational learning often fails to occur due to cultural barriers, such as employee blame, a lack of openness, or leadership challenges.[57–61] It may be that the oil and gas industry has not yet built up a culture that is highly reliable or reliability seeking in which errors are seen as learning opportunities, employees are mindful of safety failure, cultural norms enhance safety, and rewards are consistent with a desired behavior of reporting incidents.[62]

Second, the present study shows the extent to which pipeline companies proactively identify hazards. Past research has shown that health-care companies engage in reactionary practices towards incidents (i.e., fixing problems only after they have occurred),[63] and that companies with reactive safety management practices have greater injury rates.[63] Some companies within the oil and gas industry appear to be no better than the health-care industry at proactively identifying hazards in order to mitigate risk.

Third, and related to the point above, the present research contributes to Cooke and Rohleder's[14] incident learning model in that we show that breaks in the "chain" of the cycle of safety improvements can occur at both the investigation phase and the corrective action phase. That is, just because a company has high-quality "strong" investigations does not necessarily mean that it takes effective corrective actions following such investigations, and vice-versa.

Fourth, the present study contributes to the understanding of what barriers contribute to a reticence on the part of the organization to find and fix errors. There has been a plethora of work that operationalizes the concepts of safety climate and safety culture and what these constructs contain,[65] but less research has focused on what factors of the operational work environment may be responsible for deleterious safety conditions. Our results suggest that safety barriers via safety climate attitudes (e.g., management's disengagement from safety concerns, failure to find and fix errors) may be engendered in the larger macro-culture products of blame, compliance, and a production-over-safety orientation. Together, these artifacts may lead to a risk-accommodating culture that fails to consistently find and fix incidents when they occur.

4.2. Limitations and Future Research Directions

One limitation of the present research is that it summarizes data across a number of oil and gas companies (Study 1), and, as noted in the results section, there was some variability between companies. However, we were interested in capturing a general industry pattern of effectiveness at finding and fixing errors, rather than a comparison of companies. We feel that our method accomplished this goal. Furthermore, the present research is limited by the low response rate of companies that were invited to participate. We contacted as many pipeline companies (Study 1) and employees (Study 2) as possible, and those that responded and participated could have views different from those who declined participation. For this reason, we encourage further research into the findings presented here. Another limitation is that we did not have data on the extent to which employees felt reticent to report incidents; our analysis was limited to an investigation of near-miss incidents based on a set of criteria. Future research would benefit from a survey of employee attitudes towards reporting incidents in the energy sector and how frequently they feel they report incidents (e.g., 25% of the time, 50% of the time, etc.). Such data would provide better insight into energy companies' effectiveness at finding and fixing errors in response to reported incidents.

It also would be valuable to explore companies' success in mitigating risk accommodation by improving investigations and taking corrective actions following a cultural intervention. Clark and colleagues[64] found safety improvements at a radiation treatment center after the organization introduced a system of learning from past events. We would predict greater success in finding and fixing errors following a similar intervention in a pipeline company. Moreover, it would be interesting to elucidate whether postintervention successes in finding and fixing errors is due to the initiative itself (i.e., increased attention to finding and fixing errors) or to changes in the corporate culture following the initiative (i.e., a reduction in out-group blame orientation or a change in the emphasis on production over safety). Finally, future research may wish to employ the climate and culture methods used here to explore whether the artifacts found can be generalized across a range of industries (e.g., healthcare, construction, railway).

4.3. Implications and Recommendations for Safety Management Practice

The findings in this article have several implications for safety practice. First, organizations may consider the factors in their operational work environments that contribute to deleterious safety practices and a risk-accommodating culture. Communication that implies that performance is more important than safety, for instance, may encourage risky behaviors among employees. Second, companies should focus more on investigating and correcting high-consequence incidents than on low-severity incidents. It is widely agreed, for example, that an employee papercut is not nearly as important as a near-miss fatality, yet current recordable metrics do not distinguish between the potential consequences of each. It would be beneficial for organizations to adopt a database that allows the organization to record the incident severity in order to focus on the incident learning cycle. Third, companies could ensure that investigations determine incident *causes*, so that they can learn from them. An incident investigation has little value unless learning from it can prevent future errors.[65] In the present research, most companies' incident investigations were fair in quality, meaning that a cause could be reasonably extrapolated despite missing data. It also should not be acceptable that high-consequence incidents that can cause serious injury or death do not result in at least one corrective action. The quality of an investigation is important, but only if the information derived from that investigation is the basis of a corrective action. Organizations should develop corrective actions for high-consequence incidents in order to prevent similar incidents from reoccurring in the future. We hope to provide greater insights into how the oil and gas industry is performing at finding and fixing errors. We further endeavor to provide preliminary explanations of climate and culture factors that may allow a corporate culture to be risk accommodating by ineffectively finding and fixing errors.

ACKNOWLEDGMENTS

This research project was funded in part by the Canadian Energy Pipeline Association. The information and views set out in this report are those of the authors and do not necessarily reflect the official opinions of the Canadian Pipeline Association. An earlier version of this research was presented to the Canadian Pipeline Association.

APPENDIX A: SAFETY DATA CHECKLIST

This evaluation examines aspects of the safety management system over a 12-month period. The information gathering is a simple, easy to follow process.

1. Incident Investigations

This should include all your incident investigations for the last 12 months not just recordable or reportable events and be organized by month. Please note: we do not require names of people and they can be blocked out. Investigation data, at a minimum, should include: (however, please provide all investigation data that you have)

☐ **Date of Incident** ☐ **Incident Description**
☐ **All Incident Types** or classification including:
  ☐ Injury Incidents (Fatalities, Medical Aid, First Aid)
  ☐ Property Damage
  ☐ Near Miss/Hit
  ☐ Hazards identified or noncompliances investigated.
☐ **Corrective Action** details (whatever you gather and could include: description, assigned to, due date, signed off etc.)

2. Exposure hours for the period corresponding to the incidents (enter here)

3. Proactive Measures

☐ **Job task hazard assessments**: Provide a **list of hazard assessments**. Please note: These are not Field Level Risk Assessments, pretask hazard analysis or Stop and Go cards but full occupational analysis if you have them. If it is easier for you and they are all contained there, **please send your safety manual**.
☐ **Job task hazard assessments: Provide examples of** ones that have been completed.
☐ **Safe Practices & Procedures**: Provide a list of practices and procedures. This may be covered off in your manual. I would just need that confirmation and the manual itself.
☐ **Safe Practices & Procedures**: Provide examples of ones that have been completed.
☐ **Training Matrix or List of Training Courses**: This should contain all the courses and orientations that your employees are required to take and can be delivered either internally or by a third party. **We do not require employee training records**.

Note: Before sending requested information, please ensure completeness of the request as per the check boxes above.

APPENDIX B: SAFETY CLIMATE QUESTIONNAIRE

1.	The safety management system is effective in preventing harm/loss
2.	The safety management evaluation system is effective
3.	A reliance on a safety approach that only addresses problems after they occur is wholly inadequate to ensure safety
4.	A near miss needs to be investigated to find out the causes and ensure that preventative measures are established
5.	Incident investigations should tell you what caused the incident
6.	It is acceptable to have high-consequence incidents on the worksite, i.e., that can cause serious injury or death
7.	High-consequence incident investigations should have at least one corrective action
8.	High-consequence corrective actions should have a call to action that does something to fix the cause of the incident
9.	All high-consequence corrective actions should be confirmed as being completed
10.	The training for the safety program is sufficient to ensure competency
11.	Training for proper equipment use is sufficient to ensure competency
12.	Management is committed to safety
13.	If you voice your opinion regarding safety to management, they don't care/ don't listen
14.	Management is slow to correct safety problems
15.	Corrective action is taken when management is told of safety risks or equipment problems
16.	Management does not care about safety problems/risks
17.	There needs to be more buy-in from employees regarding safety
18.	Even though employees understand safety issues, they engage in risky behaviors
19.	It is the safety department's responsibility to do what needs to be done regarding safety problems
20.	Other employees ignore safety procedures
21.	Safety procedures are carefully followed
22.	In my unit, disregarding safety policies and procedures is rare
23.	Generally, I follow policy and procedures
24.	I don't follow safety policy and procedures because I don't have time

25.	Safety procedures are carefully followed
26.	Good communication flows exist up the chain regarding safety issues
27.	It's only a matter of time before there is an accident
28.	Here production is more important than safety
29.	The safety department does not do enough to prevent incidents
30.	There are barriers to communication across the organization regarding safety issues

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