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Leading and lagging: Process safety climate–incident relationships at one year

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A B S T R A C T

In order to evaluate the leading and lagging effects of process safety climate on incidents, we correlated safety climate survey data with organizational safety records from before and after the survey time period. We obtained data from a large, multinational organization with manufacturing operations involving a number of complex processes, chemicals, and hazardous substances. A total of 7728 employees from 62 sites responded to a safety climate survey in 2007. Individual responses were aggregated to the site-level and matched to site-level organizational records of process safety incidents 1 year before and 1 year after survey administration. Employees' perceptions of good routine housekeeping were significantly related to environmental impact incidents as both a leading and a lagging indicator, as well as fires/explosions and property damage outcomes. Employees' perceptions of systems to prevent backlogs and the extent to which health and safety problems are promptly corrected were also related to environmental releases and fires/explosions. Implications for process safety climate research, organizational survey strategies, and organizational climate change are discussed.

1. Introduction

Workplace accidents and incidents cost approximately $142.2 billion each year in the US alone (Bureau of Labor Statistics, 2006; National Safety Council, 2005). Historically, efforts to understand workplace accidents focused on engineering-related contributors, human factors design issues, and individual propensities such as risk-taking and clumsiness to explain why accidents occurred (Forcier, Walters, Brasher, & Jones, 2001; Gordon, Flin, & Mearns, 2005; Neal & Griffin, 2004; Paul & Maiti, 2007; Wilkinson, 1998). Recently, researchers have turned their focus to organizational influences on workplace safety and, in particular, to safety climate, which has been shown to relate to safe behavior and accidents in the workplace (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006; Zohar, 2003). Our study investigates the leading and lagging effects of process safety climate with a large sample of workers in the chemical processing industry. In doing so, we briefly review the concept of safety climate and theorize why safety climate should be both a leading and a lagging indicator of process safety incidents.

1.1. Process safety climate[1]

Organizational climate is defined as employees' perceptions of workplace events and the expectations that the organization has of workplace behaviors, attitudes, and norms (Ostroff, Kinicki, & Tamkins, 2003). Fundamentally, climate occurs as individual employee's perceptions, but in the aggregate they represent the generalized expectations of the types of safety behaviors that are rewarded, supported, and expected in a workgroup (O'Reilly, 1989; Reichers & Schneider, 1990; Schneider, Bowen, Ehrhart, & Holcombe, 2000). Consistent with this view, Zohar (2003) defined safety climate as employee perceptions of the policies, procedures, and practices concerning safety. Policies describe organizational goals and means for goal attainment, whereas procedures provide tactical guidelines for actions related to these goals. Both of these are created and maintained by top management teams. Practices are the implementation of policies and procedures by managers within each workgroup; thus, practices can vary across workgroups (Zohar & Luria, 2005).

Of paramount interest in the chemical processing industry is process safety, or safety in the activities that use, store,

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[1] We use the term "climate" to be consistent with the literature in organizational psychology and management. Our use of the term "climate" is consistent with the usual understanding of the term "culture" in the broader safety literature; however, distinctions between these terms are made in the organizational literature (e.g., Denison, 1996).

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manufacture, handle, or move on-site highly hazardous chemicals. Zohar's (2003) safety climate definition can be adapted to define *process safety climate* as employee perceptions of the policies, procedures, and practices concerning process safety.

1.2. Leading versus lagging

When current climate is linked to later outcomes, it is a *leading* indicator of safety, whereas when current climate is linked to prior events, it is a *lagging* indicator. There is no conflict between being a leading and a lagging indicator of incidents. Safety climate can, and should, be both (Payne, Bergman, Beus, Rodriguez, & Henning, 2009).

1.2.1. Safety climate as a leading indicator

Safety climate clarifies the types of behaviors that are rewarded, supported, and expected. Employee expectations regarding appropriate safety behavior are based both on objective organizational safety goals as well as supervisor and coworker safety practices, which may only partially correspond to stated organizational safety policy (Ostroff et al., 2003). Thus, both written and unwritten guidelines for safety behavior influence workers (Naylor, Pritchard, & Ilgen, 1980; Reichers & Schneider, 1990). Safety climate also reflects the safety conditions of the workplace, including but not limited to (a) the presence and enforcement of safety policies; (b) quality of safety training (and not merely the number of courses offered); (c) the provision and quality of safety equipment; and, (d) maintenance of safe working conditions. These conditions can directly influence workplace safety behavior; they also send messages to workers about how seriously management takes safety as well as expected safety behaviors in the organization. Because safety climate reflects these conditions, it should be a leading indicator and predict future safety incidents in the workplace.

1.2.2. Safety climate as a lagging indicator

Safety climate also reflects employee perceptions of the history of safety in the organization. Past behavior, individual outcomes, and organizational events all contribute to current perceptions of safety. A number of researchers have compared groups of employees who have experienced an accident in the workplace to those employees who have not experienced an accident within the same time frame (e.g., Mearns, Flin, Gordon, & Fleming, 1998). For example, Brown and Holmes (1986) found that employees in the accident-experienced group reported significantly lower levels of management concern and management action (i.e., lower levels of safety climate) than the non-accident group. Brown and Holmes' (1986) study, and others like it, demonstrate how safety climate is a *lagging* indicator of safety incidents.

2. The current study

Although there are clear theoretical and practical reasons for considering safety climate as both a leading and a lagging indicator of workplace safety, very few studies have examined safety climate as a leading indicator. The majority of safety climate research has used retrospective designs (i.e., current safety climate is linked to previous incidents), which examine safety climate as a lagging indicator. This is probably because retrospective designs are easier to conduct because previous incident data are currently available and can usually be obtained for a long time period, whereas future incidents have yet to occur and, if a long time period is of interest, researchers must wait that time before their work can be conducted. Although a recent meta-analysis[2] showed that safety climate is a slightly better lagging than leading indicator of incidents (Beus, Payne, Bergman, & Arthur, in press), the current study makes a neater comparison of leading versus lagging because multiple sites within one organization are examined, assuring the top management team's safety goals and the definitions of incidents are consistent across sites.

Consequently, the current study examines safety climate as both a leading and a lagging indicator of organizational incidents. Site-level survey data were matched to organizational records of each site's incidents both one year before and one year after survey administration. Our research addresses two questions. First, which is stronger—the leading or the lagging relationship? Second, are some components of process safety climate better predictors of incidents?

3. Method

3.1. Participants

For a one-month period in 2007, an online survey was administered at a large international manufacturing organization. Of approximately 16,000 employees invited to participate, 8198 employees from 82 sites responded (51% response rate). The data examined in this study are limited to 7728 employees at 62 sites in which sufficient survey responses and corresponding organizational records could be matched. The analyses reported in the Results section (below) are conducted at the site level.

3.2. Process safety climate measure

We measured employees' perceptions of process safety climate with 12 items that focused on the quality of the implementation of safety procedures (see Table 1). Most items were developed by the participating organization's safety personnel; however, a few were from the safety climate literature (Zohar & Luria, 2005) and the process safety culture survey conducted in 2006 at British Petroleum (BP) U.S. refineries by the Baker independent safety review panel following the 2005 Texas City catastrophe (Baker, 2007). All items were administered on a 5-point agreement scale (1 = strongly disagree, 5 = strongly agree) and coded so that higher numbers reflected better process safety climate.

3.3. Process safety incident measures

Process safety incidents were obtained from a central organizational database. Following organizational policy, incidents were classified into one or more of the following three categories: (1) environmental impact, (2) fire/explosion, and (3) property damage. These categories are not mutually exclusive in that a fire that leads to property damage is coded as both. Environmental impact was defined as a spill, release, or discharge that may or may not meet reportable quantities established by federal, state/provincial, and local agencies. Also, exceedances, excursions, and deviations of regulatory and permit requirements are included in this category. Fire/explosion is relatively self-explanatory. Property damage was defined as damage to property by acts of nature, fire/explosion, or vandalism.

Also following organizational policy, process safety incidents were further categorized by severity as a learning event, near miss,

[2] A meta-analysis is a statistical procedure whereby the results of multiple studies are aggregated. Meta-analysis is considered to provide a more accurate estimate of a relationship than any single study can provide, because any given sample is not a perfect representation of the population due to sampling error and each study suffers from statistical artifacts (e.g., unreliable measurement) that can be corrected for in a meta-analysis.

Table 1
Site-level process safety climate item descriptive statistics.

	M	*SD*
Operators are empowered to take corrective action as soon as possible (including shutting down when appropriate) if health and safety-related devices fail or become unavailable during operation. (BP)	4.2	0.6
Site management focuses on process safety in audits, self-assessments, and inspections. (ZL)	4.2	0.6
In my work area, we always take time to stop and assess the safety hazards before doing a job.	4.2	0.3
I believe systems and processes are in place at my site that prevent: large backlogs	3.5	0.6
I believe systems and processes are in place at my site that prevent: non-conformance with standards	4.0	0.3
I believe systems and processes are in place at my site that prevent: improper bypassing practices	3.7	0.6
I believe systems and processes are in place at my site that prevent: out of date drawings	3.4	0.6
I believe systems and processes are in place at my site that prevent: tolerance of repeat findings	3.7	0.3
Every health and safety-related incident at this site is taken seriously and investigated.	4.4	0.2
Adequate monitoring of performance and pursuit of improvement exists for: PSM leading indicators	3.8	0.5
We do a good job of routine housekeeping at this site.	4.0	0.4
Health and safety issues or problems are promptly corrected in my work area. (BP)	4.0	0.4

Note. *M* represents the site-level mean for each item, *SD* represents the site-level standard deviation for each item. BP indicates an item borrowed from the BP survey. ZL indicates an item adapted from Zohar and Luria (2005). Items were responded to on a 5-point agreement scale (1 = strongly disagree, 5 = strongly agree).

Level 1, Level 2, or Level 3. A learning event is a significant event that has specific relevance to making improvements in the organization's capabilities and/or has the potential to be an incident. A near miss is also a significant event that has specific relevance to making improvements in the organization's capabilities and/or has Process Safety Management implications and often leads to some corrective action items. A Level 1 environmental impact incident would be a planned or unplanned release to the environment or a discovery of historical contamination that does not trigger an agency reporting requirement but may involve a courtesy call. A Level 1 fire/explosion involves a flame, less than $10,000 damage, little impact to the environment and/or safety/health, and an agency inspection without findings. Level 2 property damage involves damage between $10,000 and $150,000. Fortunately for the focal organization, Level 3 incidents (e.g., property damage exceeding $150,000) were so rare that it was impossible to analyze them; thus, they were excluded from the analysis.

4. Results

Table 1 contains the means and standard deviations for each item at the site level. As can be seen, seven of the 12 item means in Table 1 are in the agree-strongly agree range (i.e., above 4 on a 1–5 scale) whereas the remaining five means are in the neutral-agree range (i.e., between 3 and 4 on a 1–5 scale). Thus, in general, the 62 sites included in this study have a positive view of these safety indicators. Further, standard deviations ranged from 0.2 to 0.6 which is a relatively small range. Higher standard deviation values indicate greater variability across sites for an item.

Tables 2–4 present means and standard deviations for the process safety incidents as well as correlations[3] (r) between the process safety climate survey items and the various process safety incidents one year before and one year after the survey administration. In calculating these correlations we matched the survey data from each site ($N = 62$) with the corresponding incident data from that site. Because it is better to have fewer incidents, negative correlations are desirable because they demonstrate that the more employees agreed with a given survey item, the less frequently the corresponding incident occurred. Therefore, negative correlations between process safety climate items and incident data show that the process safety climate item is a meaningful leading or lagging indicator within a one-year time frame of the process safety climate survey. In the following, we describe some of the more interesting and impactful findings of our research.[4]

First, we examined environmental impact incidents (Table 2). Employees' beliefs about systems and processes to prevent large backlogs ($r = -.3$, $p < .05$) was a lagging indicator of Level 2 environmental impact incidents. Additionally, good routine housekeeping was a relatively consistent leading and lagging indicator of environmental releases; routine housekeeping at the site was related to both Level 1 and Level 2 environmental impact incidents as both a lagging ($r = -.3$, $p < .05$ and $r = -.3$, $p < .05$, respectively) and a leading ($r = -.3$, $p < .05$ and $r = -.4$, $p < .05$, respectively) indicator. Finally, employees' perceptions that health and safety problems are promptly corrected were significantly associated with Level 2 environmental releases both before ($r = -.3$, $p < .05$) and after ($r = -.3$, $p < .05$) the survey, showing that this is also a meaningful leading and lagging indicator of environmental releases.

Beyond the process safety climate items that were statistically significant, items regarding employee beliefs about systems and processes in place to prevent non-conformance with standards, out of date drawings, and tolerance of repeat findings each had sizable negative correlations with Level 1 and Level 2 environmental impact incidents. Further, employee perceptions that every health and safety-related incident is taken seriously and investigated also related negatively to Level 1 environmental releases.

Second, we examined incidents involving fires/explosions (Table 3). Two process safety climate items were significantly associated with fires/explosions. The item concerning employees' perceptions of good housekeeping was a leading ($r = -.4$, $p < .05$) and a lagging ($r = -.4$, $p < .05$) indicator of Level 1 fires/explosions as well as

[3] Mathematically, correlations range from −1.0 to +1.0 and contain two pieces of information. The first, strength, is indicated by the coefficient's absolute value. Correlations with absolute values close to zero are weak and indicate that there is little to no relationship. As correlations approach 1.0, the relationship between the two variables is stronger. Typically, correlations above .20 (absolute value) are considered of interest. The second piece of information, direction, is indicated by the sign of the correlation. A negative sign means that the relationship is inverse (i.e., as one variable increases, the other decreases), whereas a positive sign means that the relationship is direct (i.e., as one variable increases or decreases, the other does the same).

[4] We highlight both statistically significant results as well as some trends in the data that did not reach statistical significance. Correlations (r) are considered statistically significant—and thus representing meaningful relationships—if the probability of obtaining the correlation was less than 5% when the relationship did not actually exist (written as $p < .05$). This level of 5% is a standard in psychology and represents a very low likelihood that this correlation could be found simply by chance. Failure to reach statistical significance can often be traced to statistical power (i.e., the ability to detect effects when they do exist), which is low when there is a small sample size. Here, the sample size is 62 sites, which is relatively small.

Table 2
Item level correlations between process safety climate items and environmental impact incidents.

Process safety climate items	Environmental impact incidents							
	LE-Lg	LE-Ld	NM-Lg	NM-Ld	L1-Lg	L1-Ld	L2-Lg	L2-Ld
M	3.0	6.3	7.1	9.0	4.7	5.2	1.5	1.3
SD	11.5	24.7	36.7	46.2	14.1	14.4	3.4	3.0
Operators are empowered to take corrective action as soon as possible (including shutting down when appropriate) if health and safety-related devices fail or become unavailable during operation.	−.05	−.06	.02	.02	.03	.03	.06	.06
Site management focuses on process safety in audits, self-assessments, and inspections.	−.03	−.02	−.03	−.02	−.00	−.01	−.05	−.04
In my work area, we always take time to stop and assess the safety hazards before doing a job.	−.02	.04	.02	.03	−.02	−.03	−.01	−.01
I believe systems and processes are in place at my site that prevent: large backlogs	.00	−.04	−.11	−.09	−.11	−.14	**−.29***	−.25
I believe systems and processes are in place at my site that prevent: non-conformance with standards	.03	.03	−.08	−.07	−.13	−.14	−.15	−.18
I believe systems and processes are in place at my site that prevent: improper bypassing practices	.02	.04	.03	.03	.04	.04	.04	−.02
I believe systems and processes are in place at my site that prevent: out of date drawings	−.00	−.02	−.09	−.08	−.10	−.12	−.19	−.21
I believe systems and processes are in place at my site that prevent: tolerance of repeat findings	−.02	−.02	−.12	−.11	−.16	−.17	−.21	−.23
Every health and safety-related incident at this site is taken seriously and investigated.	.03	−.00	−.14	−.14	−.14	−.17	−.13	−.05
Adequate monitoring of performance and pursuit of improvement exists for: PSM leading indicators	−.02	−.01	−.01	−.00	.00	.01	−.03	−.02
We do a good job of routine housekeeping at this site.	−.10	−.11	−.10	−.10	**−.26***	**−.28***	**−.28***	**−.42****
Health and safety issues or problems are promptly corrected in my work area.	−.08	−.07	−.13	−.13	−.21	−.23	**−.27***	**−.29***

Note. LE = learning event, NM = near miss, L1 = Level 1, L2 = Level 2, Lg = lagging (climate measured after the event), Ld = leading (climate measured before the event). *M* represents the site-level mean for each item, *SD* represents the site-level standard deviation for each item.
*$p < .05$; **$p < .01$.

a lagging indicator of Level 2 fires/explosions ($r = -.3$, $p < .05$). The item concerning employees' perceptions regarding the prompt correction of health and safety issues was a lagging indicator of near miss fires/explosions ($r = -.3$, $p < .05$) and a leading indicator of Level 1 fires/explosions ($r = -.4$, $p < .05$). Beyond the statistically significant relationships, employees' perceptions regarding systems and processes to prevent large backlogs, non-conformance with standards, out of date drawings, and tolerance of repeat findings also had sizable negative correlations with fire/explosion incidents.

Third, we analyzed property damage incidents (Table 4). Generally speaking, the correlations for incidents involving property damage tended to be smaller than for the other types of incidents. Only one process safety climate item related significantly to property damage incidents: good routine housekeeping. These perceptions were lagging indicators of near miss ($r = -.3$, $p < .05$) and Level 1 ($r = -.3$, $p < .05$) property damage incidents.

Further, process safety climate items concerning employees' perceptions about efforts to reduce backlogs, non-conformance with standards, improper bypassing practices, out of date drawings, and tolerance of repeat findings exhibited sizable negative correlations with property damage incidents. Additionally, prompt correction of health and safety issues was also negatively related to property damage incidents.

Incidentally, process safety climate items concerning operator empowerment to take corrective actions and site management's focus on process safety during safety audits and inspections were not related to the incidents examined in this study. These items may be useful for predicting other safety-related outcomes (e.g., injuries) that were not included in this study.

5. Discussion

The purpose of this study was to examine safety climate components as both leading and lagging indicators of process-related incidents. We had two overarching goals: to examine whether some components of safety climate were more important than others in predicting incidents and to determine whether these components were better leading or lagging indicators of incidents. In the following, we further discuss the results of our work and provide practical suggestions for how this research can be applied to chemical processing organizations.

Table 3
Item level correlations between process safety climate items and fire/explosion incidents.

Process safety climate items	Fire/explosion incidents							
	LE-Lg	LE-Ld	NM-Lg	NM-Ld	L1-Lg	L1-Ld	L2-Lg	L2-Ld
M	0.7	2.0	0.9	3.8	1.2	1.5	0.2	0.1
SD	2.6	6.4	2.2	13.7	2.3	2.8	0.5	0.3
Operators are empowered to take corrective action as soon as possible (including shutting down when appropriate) if health and safety-related devices fail or become unavailable during operation.	.03	.03	.03	.06	−.02	−.05	.08	.07
Site management focuses on process safety in audits, self-assessments, and inspections.	.02	.00	−.01	.01	−.02	−.04	.03	.03
In my work area, we always take time to stop and assess the safety hazards before doing a job.	.08	.04	.06	.01	−.05	−.05	−.06	.15
I believe systems and processes are in place at my site that prevent: large backlogs	−.06	−.14	−.15	−.01	−.23	−.17	−.11	−.03
I believe systems and processes are in place at my site that prevent: non-conformance with standards	.07	.04	−.09	.04	−.18	−.14	−.05	.12
I believe systems and processes are in place at my site that prevent: improper bypassing practices	.10	.08	.07	.10	.00	−.02	−.03	.11
I believe systems and processes are in place at my site that prevent: out of date drawings	−.06	−.13	−.12	.04	−.19	−.18	−.16	−.05
I believe systems and processes are in place at my site that prevent: tolerance of repeat findings	−.02	−.06	−.16	.01	−.24	−.23	−.10	.03
Every health and safety-related incident at this site is taken seriously and investigated.	.05	−.02	−.12	−.04	−.09	−.11	.12	.02
Adequate monitoring of performance and pursuit of improvement exists for: PSM leading indicators	.02	.02	−.05	.07	−.02	−.04	−.02	.08
We do a good job of routine housekeeping at this site.	−.11	−.17	−.22	−.08	**−.40****	**−.44****	**−.34****	−.08
Health and safety issues or problems are promptly corrected in my work area.	−.10	−.14	**−.26***	−.09	**−.35****	**−.34****	−.16	−.05

Note. LE = learning event, NM = near miss, L1 = Level 1, L2 = Level 2, Lg = lagging (climate measured after the event), Ld = leading (climate measured before the event). *M* represents the site-level mean for each item, *SD* represents the site-level standard deviation for each item.
*$p < .05$; **$p < .01$.

Table 4
Item level correlations between process safety climate items and property damage incidents.

Process safety climate items	Property damage incidents							
	LE-Lg	LE-Ld	NM-Lg	NM-Ld	L1-Lg	L1-Ld	L2-Lg	L2-Ld
M	2.8	4.4	2.3	8.4	2.1	2.9	0.1	0.2
SD	8.1	13.7	6.0	31.0	3.8	4.9	0.4	0.8
Operators are empowered to take corrective action as soon as possible (including shutting down when appropriate) if health and safety-related devices fail or become unavailable during operation.	−.01	.05	.11	.08	.06	.11	.01	.13
Site management focuses on process safety in audits, self-assessments, and inspections.	.01	.04	.01	.03	.05	.03	.03	.07
In my work area, we always take time to stop and assess the safety hazards before doing a job.	.06	.09	.04	.04	−.02	.01	.05	.10
I believe systems and processes are in place at my site that prevent: large backlogs	.02	−.06	−.15	.00	.00	−.03	−.06	.09
I believe systems and processes are in place at my site that prevent: non-conformance with standards	.09	.10	−.03	.04	−.06	.00	−.05	.17
I believe systems and processes are in place at my site that prevent: improper bypassing practices	.06	.11	.06	.11	.04	.09	.00	.17
I believe systems and processes are in place at my site that prevent: out of date drawings	.01	−.04	−.14	.04	−.04	−.03	−.10	.14
I believe systems and processes are in place at my site that prevent: tolerance of repeat findings	−.00	−.01	−.15	.02	−.12	−.05	−.10	.16
Every health and safety-related incident at this site is taken seriously and investigated.	.12	.09	−.02	.00	.11	.08	.02	.08
Adequate monitoring of performance and pursuit of improvement exists for: PSM leading indicators	−.02	.04	−.01	.06	.04	.05	.03	.16
We do a good job of routine housekeeping at this site.	−.12	−.13	**−.27***	−.04	**−.29***	−.24	−.16	.11
Health and safety issues or problems are promptly corrected in my work area.	−.08	−.09	−.20	−.05	−.17	−.14	−.09	.07

Note. LE = learning event, NM = near miss, L1 = Level 1, L2 = Level 2, Lg = lagging (climate measured after the event), Ld = leading (climate measured before the event). *M* represents the site-level mean for each item, *SD* represents the site-level standard deviation for each item.
*$p < .05$; **$p < .01$.

5.1. Importance of specific components of safety climate

With regard to our first goal, our results demonstrated that some of the aspects of safety climate included here were more strongly related to incidents than others. In particular, employees' perceptions of good routine housekeeping were negatively related to all three types of incidents. It is clear that good routine housekeeping is a very important part of process safety climate. Maintaining a clean and tidy work environment reduces the number of hazards present and facilitates the identification of hazards and maintenance issues. Correspondingly, managerial efforts to ensure good housekeeping are likely to facilitate a safer working environment for all workers. Further, it is indicative of organizational investment and attention to detail in the day-to-day maintenance of the environment and employee well-being. However, good routine housekeeping, in and of itself, is not sufficient to maintain high process safety. Although it is an important contributor and a “first line of defense” against incidents, investing *only* in routine housekeeping will not make a workplace safe. Instead, it needs to be part of a broad campaign of workplace investments and routine proactive maintenance in the organization.

Further, employee beliefs about prevention of large backlogs was significantly related to previous Level 2 environmental releases and had a substantial relationship with previous Level 1 fires/explosions. It is well documented that large workloads are stressful for employees (Spector & Jex, 1998) and when employees are stressed their performance is likely to suffer (Spector, Dwyer, & Jex, 1988). Excessive workloads were identified as one of the contributing factors that led to the explosion at BP Texas City (Baker, 2007). Thus, organizations must be sure not to overburden their workers with excessive workloads, as the quality of work and worker safety can be compromised when quantity is emphasized.

A final process safety climate component that was valuable to the prediction of both environmental releases and fires/explosions was employees' perceptions that health and safety issues are promptly corrected in their work areas. Certainly health and safety concerns that are not addressed are likely to lead to incidents, so it is not surprising that prompt correction of such issues would result in fewer incidents. Although we did not directly assess such corrective actions, employees' perceptions that corrective efforts are promptly made likely reflect such efforts. Further, when employees believe that safety concerns and issues will be addressed, they may be more likely to share them with management because they know that their efforts to communicate problems are not futile.

Although there were several safety climate items that were unrelated to incident data, it is premature to conclude that these components are unimportant. They may be important for other types of incidents, such as severe events (e.g., in this organization, Level 3 incidents) or injuries. Additionally, the organization that participated in this study had a very strong safety record and is well-respected in the industry for its empowered management. It may be that because so many workers at so many sites regularly assessed hazards and believed that they had the ability to take corrective action that these items were not predictive, because—statistically—there must be variability across sites for prediction of incidents to occur. This is a fortunate situation for the organization, because it leads to a safer organization, but limits the researcher's ability to determine relationships among safety climate indicators and incidents.

5.2. Is safety climate a stronger leading or lagging indicator?

With regard to our second goal, it appears that safety climate is generally as good of a leading indicator as it is a lagging indicator. In general, leading relationships and lagging relationships are of similar magnitude. At first blush, it would seem that safety climate's function as a leading indicator is more important than its function as a lagging indicator. However, it is just as essential for safety climate to act as a lagging indicator because employees “on the ground” in an organization have the closest view to the action (Payne et al., 2009). Their ability to see what is happening in the organization is a resource that managers should regularly tap into in order to understand what is really happening in the organization day-to-day. To that end, safety climate ideally should be a lagging indicator of incidents because it suggests that the employees are paying attention to what is happening in the organization, remembering the events, and trying to reconcile these events with their experiences, knowledge of the organization, and knowledge of the process.

5.3. Other indicators of process safety

Although this paper has focused on process safety climate, it is important to recognize that safety climate is one of myriad factors that contribute to process safety. As organizational psychologists, we have focused on the area of expertise in which human resources practitioners and scientists within chemical processing organizations can contribute directly to process safety. This is not to suggest that safety climate is the most important contributor to process safety; undoubtedly, good engineering of processes, high mechanical integrity, and the like are the front line of good safety and good business. However, our position is that without good safety climate, workers are less likely to speak up about problems that could be corrected with better engineering, and management is less likely to invest the time and money to implement such changes. It is the safety climate that brings together the workers at all levels in an organization to understand safety policies, practices, and procedures and their paramount role in maintaining the integrity of the chemical process and employee well-being.

5.4. Study limitations

Although there are a number of strengths to this study, there are also limitations. First, despite the large number of individual respondents, we had data from only 62 sites, limiting our statistical power to detect small effects. Additionally, we studied rare events, which are a well-known statistical prediction problem (Johns, 1998). We also measured near misses which can be hard to define; although the participating organization had a definition for their reporting database, there are always perceptual issues in determining whether a near miss has occurred. We chose to aggregate incident data over one year periods prior to and after the administration of the safety climate survey in order to have sufficient numbers of events to correlate with safety climate, which might have obscured relationships over shorter time periods. Despite the year-long aggregation periods, there were still not enough Level 3 events that could be reliably examined here (fortunately for the organization and its workers).

These latter limitations point to an important issue for both researchers and practitioners: the “shelf life” of safety climate assessments. That is, is there a time at which safety climate assessments no longer predict incidents in the organization? Considering that organizational assessments are costly, yet it is important to have up-to-date information, having a sense of how far into the future a safety climate assessment is predictive would be useful. Similarly, it is also important to consider how today’s incidents will affect future safety climate, and for how long. Here, it must be noted that memory processes are likely to play a role. For example, a notorious event from several years ago—even decades ago—could have greater impact on a safety climate assessment than a near miss from a few months ago. Additionally, notorious events do not necessarily need to be experienced by the current workforce; news media outlets can bring these events to the attention of workers, as can organizational lore and social information processes.

5.5. Potential paths forward

Our results point to several practical issues that every processing organization must take seriously. First, management must invest the time and effort into “low level” maintenance, such as routine housekeeping, in addition to maintenance of mechanical process components. We suspect that the average worker might not know or understand whether all processing components are adequately maintained, but they should all be able to tell with a simple glance whether their worksites are cared for in a routine manner. This routine housekeeping sends a signal to workers about whether their well-being is valued by the company; workers pay organizations back in kind.

Second, management must prevent backlogs. Backlogs mean that problems are not being addressed in a timely manner, which introduces additional threats and hazards to the process. Additionally, backlogs send a message to workers that the organization does not have the time, effort, resources, and/or interest in maintaining the chemical process and/or the workflow. Relatedly, management and supervisors must also promptly correct health and safety issues. When these issues arise, workers need to see that management takes them seriously, because threats to safety are unacceptable.

Underlying our results is a broader issue regarding communication between management and line workers and employee empowerment. Supervisors and management should make every effort to ensure that workers have the opportunity to voice their concerns about safety-related pitfalls. It is essential that employees speak up when such events occur because they may be able to forewarn management about current “low level” problems that, if left unchecked, could develop into serious events. Further, organizations should ensure that employees feel free to voice their concerns without fear of punishment. It is important to recognize that “punishments” are more than the obvious disciplinary actions within an organization. Workers can also be ostracized and retaliated against by their peers and supervisors, subjected to onerous additional responsibilities because of the reports they made, or branded as “troublemakers” if their concerns are found to be unwarranted. For organizations to capitalize on their workforce’s ability to identify safety problems, the barriers to reporting safety problems must be removed. Additionally we advocate for regular safety climate assessments to provide organizational decision-makers consistent feedback regarding employees’ perceptions of extant safety policies and practices. Such feedback can help top management determine whether there is a need to implement changes to more adequately ensure both process and personal safety.

5.6. Conclusions

This study supports process safety climate as both a leading and lagging indicator of process safety incidents that occur within one year before or after safety climate assessment. The results suggest that a handful of process safety climate perceptions (good routine housekeeping, the prevention of backlogs, and prompt correction of health and safety issues) are particularly important indicators of process safety incidents. This is a boon for organizations, because from an occupational health and safety standpoint, the ability to anticipate future unsafe events is crucial to the prevention of injuries and larger scale catastrophes. To the extent that safety personnel can identify sites with poor safety climates in advance, the better they will be able to intervene and attempt to address the problems before something disastrous happens.

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