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Extending the empirical evidence for process safety climate

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A R T I C L E I N F O

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A B S T R A C T

Numerous incidents in the oil and gas and chemical processing industry have been attributed in part to a "poor safety culture". Whereas previous research has largely focused on evaluating a *general* safety climate/culture with a greater emphasis on *personal* safety, this study examines the relationship between *process* safety climate and process safety incidents, after controlling for general safety climate. Survey data gathered in 2018 from over 700 employees in an oil and gas company in the Middle East were combined with organisational records of 275 personal and 940 process safety events at the department level across 12 calendar years (2009–2020). Despite general safety climate scores showing relationships within the survey consistent with previous research, general safety climate was not significantly related to organisational records of personal and process safety events at the department level. Positive relationships between process safety climate measured in 2018 and process safety events in three years before 2018 (2010, 2011, and 2013) substantiate previous findings that process safety climate can be a lagging indicator of workplace safety and evidence of organisational improvements made in between.

1. Introduction

Safety climate, employees' shared perceptions of safety policies, procedures, and practices, is an integral part of an organisation's safety culture (Zohar, 2011). The collective values, beliefs, and assumptions that comprise a strong safety culture are translated into various organisational rules (policies, procedures, and practices). Employees' perception of the enforcement of those rules (safety climate) influence decisions employees make about how and when to engage in safe behaviour which in turn greatly impacts the overall safety performance of the organisation. The importance of safety culture to organisational safety has been supported by numerous incidents in history, such as the Bhopal disaster (1984), the Texas City Refinery explosion (2005), and the Deepwater Horizon oil spill (2010), which were attributed in part to poor safety culture within the organisations.

The terms "safety culture" and "safety climate" are sometimes used interchangeably. However, the distinction between them parallels the distinction between "organisational culture" and "organisational climate" in organisational psychology research literature. *Organisational culture*, as defined by Schein (1992), refers to the shared fundamental assumptions and beliefs of a group. On the other hand, *organisational climate*, as defined by Schneider and Reichers (1983), refers to the shared perceptions of employees regarding organisational policies, procedures, and practices. The organisational climate conveys and facilitates an understanding of behaviours that are incentivized, supported, and expected in the workplace and is considered a part of the broader organisational culture (Ostroff et al., 2003). Similarly, *safety culture* represents the shared values and beliefs related to safety within an organisation, whereas *safety climate* represents shared employee perceptions of safety policies and practices. Although the term "safety culture" is commonly used in practice, it is widely accepted among psychologists that safety climate is what is being measured in safety culture questionnaires and has a stronger relationship with behaviour than safety culture or the general organizational climate (Neal et al., 2000). Correspondingly, we refer to process safety climate in our study.

Historically, psychologists theorise that organisational climate is an antecedent of behaviour and outcomes and depict it this way in static models of the role of climate on organisational behaviour. Specifically, a favourable (i.e., safer) organisational climate is expected to positively predict favourable organisational outcomes. However, theoretical models also include feedback loops showing that behaviour and outcomes influence subsequent climate. In fact, in a meta-analysis of 53

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safety climate-injury studies, Beus et al. (2010) reported the most common study design is cross-sectional; however, any reports of behaviours or incidents has to be prior to the assessment making the data reflect a postdictive design. In other words, most studies relate safety climate measured at one point in time with reports of behaviours or injuries that occurred in the past (e.g., Griffin and Neal, 2000), which would suggest that safety climate is a lagging indicator of workplace injuries. Nevertheless, studies employing a predictive design also support that safety climate is a leading indicator of safety behaviours as noted in multiple meta-analyses (Christian et al., 2009; Nahrgang et al., 2011), and injuries as well (Beus et al., 2010).

1.1. Process vs. personal safety

The distinction between process and personal safety lies in the nature of the hazards (e.g., toxic gases within confined spaces vs. rotating equipment), safety processes (e.g., lockout-tagout vs. holding a handrail), and outcomes (e.g., chemical explosion vs. broken bones) involved. According to Occupational and Safety Health Administration (OSHA), process safety involves the implementation of measures to avoid the catastrophic release of hazardous chemicals, such as toxic, reactive, flammable, or explosive substances (Occupational Safety and Health Administration, n.d.). In The Health and Safety (2006) Executive published a step-by-step guide for developing process safety indicators by encouraging organisations to contemplate process safety incident scenarios in which they brainstorm all the things that can go wrong within each scenario.

Personal safety hazards concern exposure and activities that can harm an individual and impact their health and well-being, but are not necessarily linked to processing activities. These hazards may lead to falls, trips, crushings, electrocutions, and vehicle accidents (Hopkins, 2009). Personal safety in the workplace encompasses the measures taken to protect workers from both process-related and personal safety hazards. Not all safety researchers differentiate between personal and process safety, raising the empirical question, is *process safety climate* different from the more general safety climate and does it capture meaningful variance when predicting process safety events and outcomes?

1.2. Process safety culture

The process industry has been concerned about safety culture for quite some time and used the phrase "process safety culture" on occasion to emphasise the importance of process safety when discussing safety culture in this industry. In 2003, the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AIChE) defined *process safety culture* as "the combination of group values and behaviours that determine the manner in which process safety is managed." CCPS identified process safety culture as an element in their Risk-Based Process Safety model, identifying four specific actions for managing process safety including committing to process safety, understanding hazards and risks, managing risk, and learning from experience (Frank, 2007). For this study, we adopt the definition of process safety climate offered by Payne et al. (2010) which is modelled after Zohar's (2003) definition of safety climate: employee perceptions of the policies, procedures and practices concerning process safety.

Following the March 2005 explosion at the BP Texas City refinery, an independent safety review panel was formed and headed by James A. Baker, III. The Baker Panel conducted interviews, visited refineries, administered a survey, and reviewed relevant documents as a part of their investigation. One of the key findings in this investigation was an overreliance on a lack of personal safety injuries as evidence of good organisational safety. The investigation team highlighted the importance of process safety throughout the report making multiple recommendations about process safety. Whereas process safety is defined in the report as the prevention of unintentional releases of chemicals or energy and lots of examples of how to manage process safety are also mentioned (e.g., preventing leaks, maintaining equipment, etc.), to the best of our knowledge, *process safety culture* is never formally defined in the report. Nevertheless, the "Process Safety Culture Survey" that was administered to BP employees appears in the appendix of the BP Baker Report (2007) and thus is publicly available for organisations to benchmark themselves against other organisations. It is important to note that process safety culture is measured with individual employee ratings of survey items organised into one of six categories: (1) process safety reporting, (2) safety values/commitment to process safety, (3) supervisor involvement and support, (4) procedures and equipment, (5) worker professionalism/empowerment, and (6) process safety training. Many of the items refer specifically to process safety (e.g., "Interlocks, alarms, and other process safety-related devices are regularly tested.").

Over the years, various articles about the importance of process safety culture have been published primarily in the *Process Safety Progress* journal on the importance of safety culture to an effective process safety management program (Hendershot, 2012), how to nurture process safety culture in chemical engineers (Mckay & Lacoursiere, 2010; Olewski et al., 2016) and in organisations (Kadri and Jones, 2006), and how to possibly measure it (e.g., with root cause analysis by Sutton, 2008; with surveys by Forest, 2012; with social network analysis by Hunter & Wolf, 2016; and with interviews by Behari, 2016). Despite the proliferation of safety culture and climate measures in the research literature, most of the measures are largely focused on personal safety rather than process safety.

Multiple studies of safety climate and culture have been conducted in the process industries (e.g., Bensonch et al., 2022; Dahl and Kongsvik, 2018; Donald and Canter, 1994; Gao et al., 2019; Vinodkumar and Bhasi, 2009) and some have even claimed to measure process safety culture (e.g., Siuta et al., 2022); however, upon close review, in all of these studies, researchers have primarily or only measured general safety climate, not process safety climate explicitly. The only known empirical examination and peer-reviewed publication of a study measuring process safety culture that we could locate was conducted by Payne and colleagues in 2010. In their study, over 7700 employees from 62 sites of a global chemical processing company completed a process safety culture survey in 2007. Survey data were linked to process safety events one year before and after the survey administration. They found evidence that process safety culture was both a leading and lagging indicator, supporting previous speculation (Payne et al., 2009) and empirical evidence about general safety climate (Beus et al., 2010). Payne et al. (2010) concluded, "although there were several [process] safety climate items that were unrelated to incident data, it is premature to conclude that these components are unimportant" (p. 810). Additionally, Payne et al. (2010) did not report a comparison of the predictive validity of process safety climate to general safety climate, which we test in this study.

1.3. Industry-specific safety climate

One way to conceptualise process safety climate is to describe it as an industry-specific assessment of safety climate. The safety climate literature is filled with measures incorporating industry-specific terms to capture unique hazards (e.g., needles) and rules (e.g., no cell phone use when driving) for being safe in the corresponding industry. In fact, Dov Zohar (sometimes referred to as the Father of Safety Climate as he published the first article on this concept in 1980), advocates for including industry-specific items in safety climate inventories (Zohar, 2014). Some studies have found value in including industry-specific items when predicting safety-related outcomes (e.g., Huang et al., 2013).

Relatively few studies have explicitly compared general (or sometimes called universal) measures of safety climate to industry-specific assessments. In one of the only studies explicitly doing so with the same sample, Keiser and Payne (2018) found gains in prediction of safety knowledge, behaviours, and events with industry-specific items over general safety climate items especially in less safety salient contexts. Meta-analytic research has found industry-specific safety climate measures predict risk perceptions and safety behaviours better than general safety climate measures, but general safety climate measures predict errors, near misses, and other safety events better than industry-specific safety climate measures (Jiang et al., 2018).

This research study extends the empirical evidence for process safety climate by testing the relationships between general safety climate, process safety climate, and safety events using survey data and organisational records from an oil and gas company. Analyses are guided by the following research questions (1) How related are general safety climate and process safety climate? (2) Compared to general safety climate, how strongly does process safety climate relate to safety events? (3) Does process safety climate predict above and beyond general safety climate in safety events?

2. Method

2.1. Survey administration

To maximise survey participation, a task force comprised of employees from multiple departments within the organisation, including Marketing, Information Technology (IT), Human Resources (HR), and Health, Safety and Environment (HSE) was established. The marketing team was responsible for promoting the project and raising company-wide awareness through the creation of a logo and promotional materials, such as desktop wallpapers, digital screen boards, and posters in elevators. The IT and HR departments helped with the electronic deployment of the survey, while the HSE team provided feedback on the survey questions, addressed language issues, and conducted a pilot study to determine the time required to complete the survey. Management frequently communicated the importance of the survey and why the company was conducting it, adding to the sense of significance created by the marketing team's promotional materials.

During the survey period, department heads reported the number of employees who completed the survey from their respective departments, which was then reported to higher management on a weekly basis. This tracking of response rates fostered competition among departments and promoted survey participation. Employees and contractors were invited to reserve a 30-minute time slot to go to a meeting room fitted with multiple computers to complete the anonymous survey programmed in Qualtrics (all questions were optional). Task force members were available in the room to answer questions about the survey.

2.2. Participants

The survey was administered between October 22, 2018 and January 31, 2019 to approximately 1000 employees and contractors in one of four geographical locations and employed by a multinational oil and gas company located in the Middle East. A total of 748 employees from 36 different departments responded to the survey (74% response rate). A majority (641; 85.5%) of the participants identified as male. Participants ranged in age from 21 to 67 with an average age of 42.61 ($SD = 9.61$) years. A considerable percentage (44.3%) of the participants had a Bachelor's degree, 32.4% had less than this, and 13.1% reported having a graduate degree (19% did not answer this question). Over half of the sample (57%) reported having more than 10 years of experience working at the focal organization, 42.6% reported working 3–10 years, 20.4% reported working 1–3 years, and 6.5% reported working less than a year (55 did not indicate).

2.3. Survey data

General Safety Climate was assessed with a 31-item measure showing strong internal consistency (Coefficient alpha =0.97). Thirty of the items came from the previously validated measure published by Beus et al. (2019). An example item read "My supervisor strictly enforces the safe working procedures in my workgroup." Items were rated on a 5-point agreement scale with higher scores indicating a safer work environment. One additional item was added by HSE: "My supervisor clearly explains the hazards associated with my work." Survey items are averaged together for an overall general safety climate score for each respondent.

Process Safety Climate was assessed with a 14-item scale. Nine items were primarily inspired by items used in the Baker investigation following the BP Texas City accident. These same nine items were used in Payne et al.'s (2010) study. Five additional items (#4, 5, 12, 13, 14 depicted in Table 1) were recommended by HSE management. Coefficient alpha was.80, supporting the aggregation of items to an overall construct score.

In addition to the safety climate constructs, respondents were also asked the following two questions about injuries in the workplace: (1) "In the last 6 months, how many times have you or members of your workgroup been injured while working on the job and reported these injuries to management?" and (2) "In the last 6 months, how many times have you or members of your workgroup been injured while working on the job and NOT reported these injuries to management?" Response options were: 0, 1–2, 3–4, 5 + .

2.4. Organisational records: safety events

Safety events were compiled by the organisation in their incident database over the course of 12 years (2009–2020). A wide range of events were recorded by personnel. For most events, the following information was recorded in the database: the date of the event, the department it was associated with, a brief description of the event, and the severity of it. Severity was categorised on a 6-point scale with higher numbers indicating greater severity: 1 = near miss, 2 = high potential near miss, 3 = notable, 4 = important, 5 = significant, 6 = high potential. Events were not classified as personal or process safety in the database. This was done by the researchers.

The safety events database contained a total of 1834 events. Unfortunately, 2 events did not have a description of the event and an additional 387 events did not have department information inhibiting the linkage of these events to climate survey data. This reduced the safety events to 1447. Another 206 events had to be removed as there was insufficient information to classify the event (e.g., "XXX liquid sulphur

Table 1
Process Safety Climate Survey Items.

Please mark the response that indicates the extent to which you agree with each statement. (1 = strongly disagree, 5 = strongly agree)
Operators are empowered to take corrective action as soon as feasible.
Site management focuses on process safety in audits, self-assessments, and inspections.
We always take time to stop and assess the safety hazards before doing a job.
Tool Box Talks are conducted prior to starting work.
Tool Box Talks effectively address hazards associated with my work.
Large backlogs due to preventive maintenance are prevented at my site.
Improper bypassing practices are tolerated at my site. (R)
We have out-of-date drawings (for example, P&I diagrams). (R)
Repeat findings in investigations, audits, and inspections (due to failure to correct) are tolerated at my site. (R)
Every safety-related incident at this site is taken seriously and investigated.
We do a good job of housekeeping at this site.
Investigations conducted following incidents identify their real causes.
The causes of incidents as determined by investigations are communicated and discussed in a timely manner with the workforce.
Corrective Action Management effectively addresses the findings from audits, investigations, etc.

Note. Items 4, 5, 12, 13, and 14 were added by the focal organization's HSE personnel. Remaining items were borrowed from the BP survey.

transfer pump" and "Sulphur export line YYY during heavy rain") or they were security events rather than personal or process safety events (e.g., "fishing boat encroachment"). The uncodable events were relatively evenly distributed across the years with the fewest (8) in 2018 and the most (23) in 2009, as well as 2016. About 30% of the uncodable events were associated with the operations support department and another 22% took place at the offshore facility. Safety event data was further reduced to 1217 events as three departments did not contribute any survey data.

Each of the 1217 safety event descriptions was read and carefully classified as either personal or process safety by the first and third authors, independently. Consistent with the definitions mentioned in the Introduction section, process safety events primarily consist of a loss of containment including leaks, spills, equipment failure or malfunction, trips, and fires. Personal safety involved a range of injuries or illnesses to workers (employee or contractor) and sometimes referenced personal protective equipment. As many events were not actual incidents, the possibility of injury to personnel also needed to be contemplated (e.g., a heavy tool falling a height). All discrepancies were resolved through discussion and consultation with the second author. Initial discrepancies primarily concerned how to classify fires (process) and road traffic accidents (personal). Upon agreeing on this, there were very few discrepancies.

2.5. Data aggregation

Following the classification of each event as process or personal safety events, these data needed to be aggregated to the department levels ($N = 36$) based on calendar year. A sum of process and personal events for each year were tallied. Individual survey data for general and process safety climate scores also needed to be aggregated (averaged) to the department level. Then department level survey data were merged with department-level event data.

3. Results

Table 2 depicts descriptive statistics for process and personal safety events for each calendar year they were available (2009–2020). In any given year, the number of safety events that occurred ranged from 76 to 142 ($M = 101.42$, $SD = 23.57$) in 5–13 ($M = 10$, $SD = 2.39$) unique departments. The number of process safety events ranged from 48 to 129 ($M = 78.33$, $SD = 20.67$) and the number of personal safety events ranged from 7 to 49 ($M = 22.92$, $SD = 14.74$). The severity of the process safety events (on a 6-point scale) ranged from 2.80 to 3.08 ($M = 2.96$, $SD = 0.14$) and the severity of personal safety events ranged from 2.72 to 3.29 ($M = 2.90$, $SD = 0.28$). Overall, across the 12-year time span, a total of 940 process safety events and 275 personal safety events were recorded.

3.1. Relationship between general safety climate and process safety climate

To examine the relationship between personal and process safety climate, we simply correlated the respective construct scores together. We can do this at the individual employee level ($N = 742$) or at the department level ($N = 36$). At the individual level, the correlation was very strong ($r = 0.77$, $p < .05$), indicating that employees who perceived a favourable general safety climate also tended to report a favourable process safety climate. At the department level, the correlation was also very strong, but just a little bit weaker ($r = 0.73$, $p < .05$).

3.2. Relationship between process safety climate and process safety events

Next, we examined the relationship between process safety climate

Table 3
Correlations between Personal and Process Safety Climate with *Process Safety Events*.

	Process Safety Climate 2018	Personal Safety Climate 2018
Process Safety Events 2009	0.30	0.18
Process Safety Events 2010	0.38 *	0.24
Process Safety Events 2011	0.36 *	0.21
Process Safety Events 2012	0.30	0.17
Process Safety Events 2013	0.33 *	0.17
Process Safety Events 2014	0.24	0.16
Process Safety Events 2015	0.18	0.14
Process Safety Events 2016	0.18	0.13
Process Safety Events 2017	0.17	0.12
Process Safety Events 2018	0.18	0.13
Process Safety Events 2019	0.20	0.14
Process Safety Events 2020	0.15	0.11

Note. $N = 36$; * $p < .05$

Table 2
Descriptive Statistics and Intercorrelations Among Personal and Process Safety Events.

Year	Number of events	Number of departments having events	Number of process events	Severity of process events *M* (*SD*)	Number of personal events	Severity of personal events *M* (*SD*)
2009	109	12	64	2.80 (1.27)	45	2.73 (0.78)
2010	100	13	63	3.08 (1.10)	37	2.92 (0.80)
2011	139	13	90	3.00 (1.12)	49	2.84 (0.75)
2012	116	12	83	2.98 (0.92)	33	2.64 (0.78)
2013	80	12	64	3.01 (0.93)	16	3.01 (0.93)
2014	85	11	78	3.06 (0.61)	7	3.00 (0.58)
2015	66	7	48	2.98 (0.86)	18	2.72 (1.02)
2016	103	11	76	3.21 (1.29)	26	2.96 (1.29)
2017	92	5	80	2.93 (0.95)	12	2.33 (0.98)
2018	142	11	129	2.82 (1.31)	13	3.31 (1.97)
2019	109	10	96	2.67 (0.90)	12	3.08 (1.88)
2020	76	10	69	3.04 (0.86)	7	3.29 (0.76)
Sum	1217		940		275	
Mean	101.42	10.58	78.33	2.96	22.92	2.90
SD	23.57	2.39	20.67	0.14	14.74	0.28

Note. $N = 36$.

and both personal and process safety events by year. As depicted in Table 3 and somewhat surprisingly, process safety climate measured in 2018 correlated *positively* with process safety events in all years. These correlations were not statistically significant for most years, but they were for three out of twelve years (2010, 2011, and 2013), indicating that higher numbers of process safety events during those years were associated with a more favourable process safety climate in 2018. Initially, this may sound troubling as higher, more favourable climate scores should be negatively related to safety events. However, it is important to consider the time lag between the survey and the events. A positive correlation between process safety events and subsequent process safety climate could be indicative of changes and improvements in process safety made by management following the events. As depicted in Table 4, process safety climate was not significantly related to any of the personal safety events.

Consistent with Payne et al. (2010), we also examined individual item-level correlations with the safety events. Interestingly, the item “Tool box talks are conducted prior to starting work” appeared to drive the relationship between process safety climate and process safety incidents in 2010. This item plus two others drove the relationship with process safety events in 2011: “Tool box talks effectively address the hazards associated with my work,” and “Large backlogs due to preventative maintenance are prevented at my site.” Similarly, the two tool box items drove the process safety climate-2013 process safety event relationship.

For comparison purposes, we also present general safety climate correlations with personal and process safety events. Interestingly and contrary to considerable research, general safety climate was not significantly related to personal or process safety events in any year (see Tables 3 and 4). Given this surprising finding, we also examined the relationship between general and process safety climate scores with self-reports in the survey of injuries in the last six months. Consistent with theory and past research, general safety climate was significantly related to unreported injuries ($r = -0.09$, $p < .05$) and interestingly process safety climate was also significantly related to unreported injuries ($r = -0.10$, $p < .05$). In both cases, a more favourable safety climate is associated with less unreported injuries. This implies that individuals who perceive a favourable safety climate are more comfortable reporting injuries (and less likely to not report them).

Table 4
Correlations between Personal and Process Safety Climate with *Personal Safety Events*.

	Process Safety Climate 2018	Personal Safety Climate 2018
Personal Safety Events 2009	0.19	0.11
Personal Safety Events 2010	0.24	0.14
Personal Safety Events 2011	0.10	0.04
Personal Safety Events 2012	0.17	0.05
Personal Safety Events 2013	0.23	0.16
Personal Safety Events 2014	0.04	0.01
Personal Safety Events 2015	0.11	0.10
Personal Safety Events 2016	0.13	0.10
Personal Safety Events 2017	0.09	0.08
Personal Safety Events 2018	0.09	0.07
Personal Safety Events 2019	0.06	0.03
Personal Safety Events 2020	0.18	0.14

Note. $N = 36$.

3.3. *Incremental validity of process safety climate over general safety climate in the prediction of process safety events*

Testing for the incremental validity of process safety climate over general safety climate assumes that general safety climate significantly predicted process safety events in the first place. Contrary to this assumption, general safety climate was not significantly related to process safety events.

4. Discussion

The purpose of this study combining an employee survey with organisational records from a multinational oil and gas company in the Middle East was to test the extent to which process safety climate is a meaningful predictor of process safety events and to compare this predictive validity evidence to general safety climate. Conceptually process safety climate concerns organisational efforts to maintain process safety which primarily means avoiding the release of hazardous materials. Operationally, process safety climate was measured using survey items from the BP Baker report. Overall, the study data revealed a strong positive relationship between general safety climate and process safety climate. This suggests one of two things. On the one hand, it suggests that departments with a favourable general safety climate also have a favourable process safety climate. On the other hand, it may indicate that employees do not differentiate between the two and include process safety efforts when rating general safety climate. Overall, the high correlation raises some doubts about whether unique information is being gathered by administering process safety climate items.

The examination of the relationship between process safety climate and the number of process safety events that occurred within 12 distinct calendar years revealed a somewhat surprising positive significant relationship for one-fourth of these relationships. Specifically, the number of process safety events in 2010, 2011, and 2013 was positively related to process safety climate in 2018. Whereas organisational theory proposes that a favourable climate is positively related to favourable organisational outcomes (Ostroff et al., 2003), it is assumed that the outcomes are measured in the future. When climate is measured after outcomes, it is influenced not only by the previous events but also what the organisation did in response to those events. Ideally, the organisation institutes some changes that improved process safety and in turn improved process safety climate.

Process safety climate survey item-level analyses revealed that items concerning conducting tool box talks and the extent to which they effectively address hazards were driving the relationships with process safety events that did emerge. This is interesting because tool box talks are not unique to process safety but they can also contain and frequently do contain information about personal safety. Nevertheless, in a process industry, these daily conversations are an opportune time to remind workers and contractors about process safety hazards and appropriate procedures. In contrast, Payne et al.'s (2010) study found a survey item about routine housekeeping tended to drive relationships in their study.

Finally, contrary to numerous studies in the research literature demonstrating safety climate as a robust predictor of various safety outcomes (Beus et al., 2010; Christian et al., 2009; Nahrgang et al., 2011), general safety climate was not significantly related to either personal or process safety events, making the question if process safety climate predicts events above and beyond general safety climate a moot question. This raises the question why this well-established relationship was not found in the current study. We offer a handful of speculations. First, our department-level sample size of 36 departments was quite small, limiting our statistical power to detect significant relationships. By comparison, Payne et al.'s (2010) study examined 62 worksites which are larger than departments; thus they had more statistical power and examined this relationship a higher level of analysis. Second, the number of safety events was also relatively small, a known challenge when predicting low base rate phenomena. Third, department associations of events were made by organisational personnel and oftentimes appeared to be associated with the department responsible for addressing the underlying issue or root cause rather than the department in which the event took place. Conversations with organizational personnel also revealed that it is very difficult to attribute an incident to only one department. For example, should an event in which Worker A tripped over a tool left behind by Worker B be associated with Worker A's production department, Worker B's maintenance department, or a third department responsible for the equipment in the nearby area. Additionally, the organisation reorganised departments (both consolidated and separated) over the years making the linking of data over time and across sources challenging.

4.1. Limitations

A few other reflections worthy of note. First, the classification of safety events was limited to the descriptions provided. Perhaps not surprising, the quality of these descriptions varied with some being very clear that they were process or personal safety events, whereas others were less so, and in some cases could not be classified at all. This dichotomous classification assumes events are either one or the other, but clearly process hazards that result in events/incidents can have significant personal safety implications, so future research may want to consider a third category of "both process and personal." There were also a considerable number of security breach events that may be worth studying further. Unfortunately, no security personnel completed the survey, perhaps because it was essential for someone to cover their shift if they stepped away to complete the survey. Second, safety event data were aggregated over each calendar year. This is a somewhat arbitrary timeframe and arguments could certainly be put forth for shorter or longer time frames. In order to better inform our practice on this, additional data are needed comparing various time lags (cf. Bergman et al., 2014).

5. Conclusions

Whereas the notion or phenomena of a process safety culture has been formally discussed since at least 2003 by CCPS of AIChE and multiple safety climate/culture studies have been conducted in the process industries, we were only able to locate one empirical peer-reviewed study explicitly measuring process safety climate using BP Baker report survey items and no studies comparing process and general safety climate. This study provides the second empirical examination of process safety climate using the BP Baker report survey items, a publicly available tool that could be used for benchmarking, although there is minimal evidence that it has been used this way (Rodriguez et al., 2011). Consistent with Payne et al. (2010), this study provides some evidence that process safety climate is a lagging indicator of process safety events.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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