JOURNAL OF ORGANIZATIONAL BEHAVIOR MANAGEMENT
2017, VOL. 37, NOS. 3–4, 283–300
https://doi.org/10.1080/01608061.2017.1340923

Assessing and Preventing Serious Incidents with Behavioral Science: Enhancing Heinrich's Triangle for the 21st Century

Terry McSween and Daniel J. Moran

Quality Safety Edge & Pickslyde Consulting, Joliet, Illinois, USA

ABSTRACT
The rate of occupational injuries has been declining annually, but the rate of decline for fatalities has not kept a similar pace. Behavior-based safety (BBS) contributes to reducing personal injuries, and can be applied to preventing serious incidents. To address serious injuries with greater confidence requires a change in perspective on the causes of fatalities and serious injuries. Heinrich's safety triangle helps describe the ratio between minor incidents and major incidents, but is not adequate in helping to *predict* serious incidents. Adding a special subset to the safety triangle can assist safety practitioners in predicting and influencing such events. Extending the triangle to include more foundational root causes, such as leadership shortcomings and system failures, will expand the scope of the behavior analysis, and including greater specificity about the precursors to serious incidents will help the precision of the behavior analysis. The implications of the expanded triangle for amplifying the effectiveness of BBS for reducing serious incidents are discussed.

KEYWORDS
Behavior-based safety; fatalities and serious injuries (FSIs); Heinrich's safety triangle; precursors

Preventing serious incidents is a crucial area of focus for the safety profession. Industry leaders highlight the need for increased vigilance to the high and stable annual rate of fatalities and serious injuries (FSIs; Bogard, Ludwig, Staats, & Kretschmer, 2015; Krause & Murray, 2012; McSween, 2015), especially when compared to the relatively larger decline of the rate of other incidents. The workplace fatality rate in the United States *increased* from 3.3 deaths per 100,000 workers in 2013 to 3.4 deaths per 100,000 workers in 2014 (Bureau of Labor Statistics, 2016). The same reports indicated an increase in fatalities in construction, private mining, quarrying, oil and gas extraction, and roadway incidents. Manuele (2013) points out that "companies with outstanding records showing reductions in less-serious injuries may not have had similar reductions for serious injuries and fatalities" (p. 51). Past president of the American Society of Safety Engineers (ASSE) Terrie S. Norris pointed out the crux of the issue by saying,

CONTACT Daniel J. Moran dj@pickslyde.com Pickslyde Consulting, 1415 Maple Road, Joliet, IL 60432, USA.

> Despite the dedicated efforts of ASSE's members, employers, workers, the U.S. Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH), the fact that fatalities are not significantly decreasing should be a call for action, not complacency.(American Society of Safety Engineers, 2011)

For over two decades, the annual rate of occupational injuries in the United States has been declining, but the rate of decline for fatalities has not kept a similar pace, especially in the last several years (see Figure 1). The two sets of data appear to have a positive correlation; however, the lower line showing fatalities per 100,000 employees does not demonstrate a similar, steeper downward slope as the nonfatal injuries. Working to prevent serious incidents goes beyond simply looking at fatalities and also includes focusing on lost workday cases (LWCs). McSween (2015) investigated the LWC rate and the total recordable injury rate (TRIR) in manufacturing and construction. In both areas, the TRIR showed a reasonable decline while the LWC rate remained relatively flatter in both industries (see Figures 2 and 3). This disparate trend requires the attention of organizational behavior management (OBM) and behavior-based safety (BBS) professionals, and the traditional behavioral approach should be optimized to focus on preventing serious incidents. In order to properly address this issue, this paper will question and modify the conventional approach to safety processes.

BBS has always encouraged organizations to change the environmental conditions, and not just the behaviors of workers, in order to improve safety

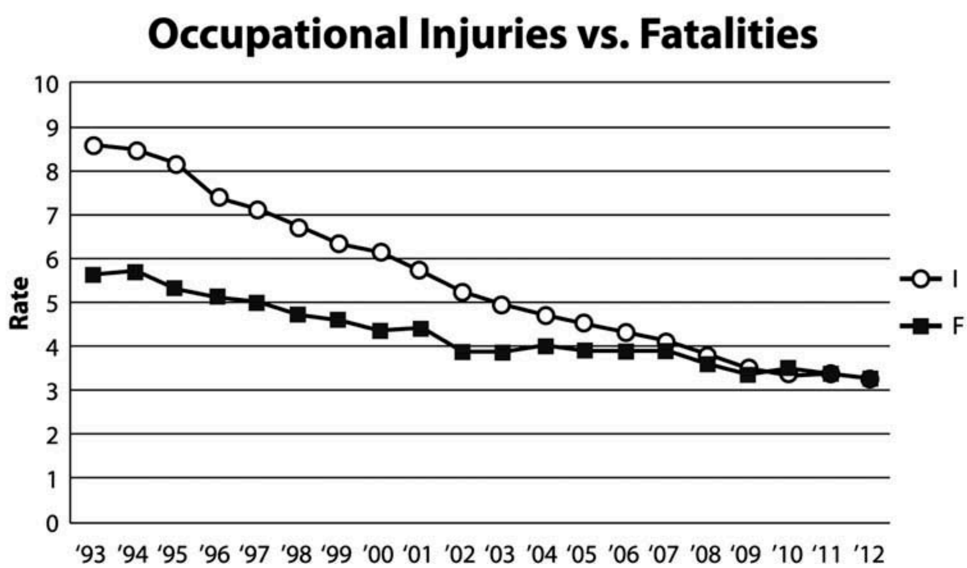

Figure 1. Fatalities per 100,000 employees compared to occupational injuries per 100 employees. Filled squares represent the annual fatalities per 100,000 employees in the United States. Open circles represent the annual injuries per 100 employees in the United States (United States Department of Labor, United States Department of Labor, Bureau of Labor Statistics, 2016).

Figure 2. Lost workday case (LWC) rate compared to total recordable injuries per 100 employees for U.S. manufacturing. Filled squares represent the LWCs and open circles represent the total recordable injuries per 100 employees (United States Department of Labor, United States Department of Labor, Bureau of Labor Statistics, 2016).

Figure 3. LWC rate compared to total recordable injuries (both per 100 employees) for U.S. construction companies. Filled squares represent the LWCs and open circles represent the total recordable injuries per 100 employees (United States Department of Labor, United States Department of Labor, Bureau of Labor Statistics, 2016).

outcomes. BBS can be more effective in preventing serious incidents if safety professionals embrace the concept that it is not just behavior, but *specific behaviors* that contribute to serious incidents, and that certain environmental *precursors* set up those specific behaviors. Those working to improve safety should not only focus on the specific behaviors, but on the causes of those behaviors. The causes of those behaviors are found in the design of the system, which may include physical hazards, leadership decisions, and other system failures that result in the rate of serious incidents and fatalities. This paper will first look at the traditional views of safety and behavior as represented by Heinrich's triangle, critique those views, and then provide a more focused approach to preventing serious incidents.

Heinrich's law: Popular but lacking predictive utility

Heinrich's Law (1931) and his "safety triangle" have become ubiquitous in the safety field, and the model implies that there is a standard ratio between the number of near misses, minor injuries, and major injuries at the worksite (see Figure 4). In the original design, Heinrich was implying that for every 300 near misses, there were 29 minor injuries, and 1 major injury. The triangle highlights the categories of incidents and the diminishing probability of the incident while going "up" the triangle vertically. Over the decades, safety professionals have refined the model, and often add other categories of incidents to the original triangle, suggesting that unsafe acts and conditions set the occasion for near misses, first-aid cases, recordable incidents, lost time incidents, and fatalities (McSween, 2003; see Figure 5).

The traditional triangle adequately *describes* the concept that there is a ratio between the number of incidents that could contribute to a possible fatality and an actual fatality (Martin & Black, 2015). Heinrich's work implies the probabilistic nature of catastrophic events: the greater the rate, duration, intensity, and perseverance of at-risk behaviors and at-risk conditions, the more likely a serious incident or fatality will occur. Because behavioral science aims to reduce incidents by investigating the environmental events

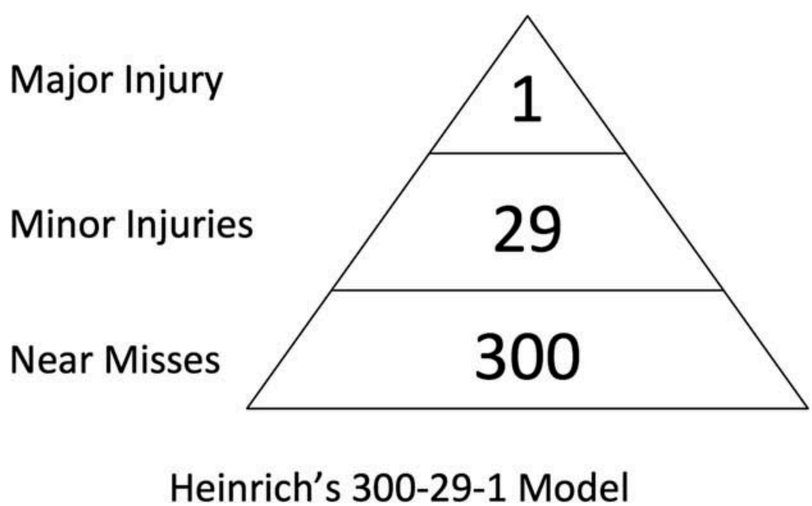

Figure 4. Heinrich's 300–29-1 model (Heinrich, 1931).

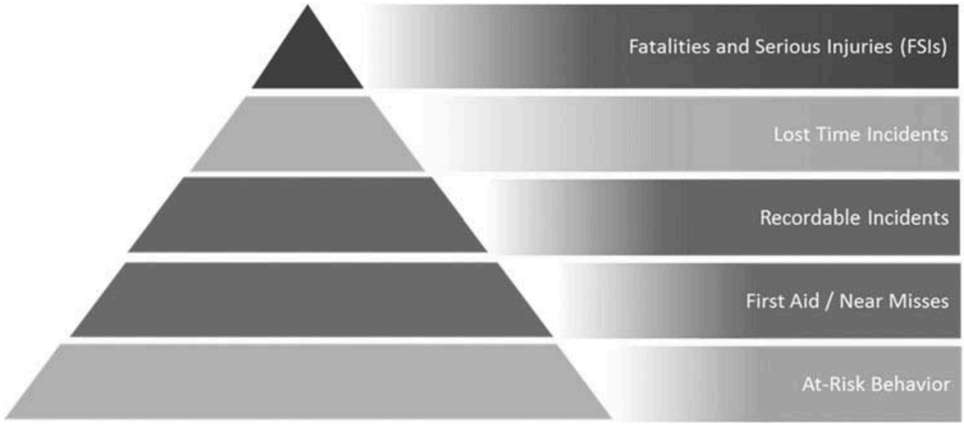

Figure 5. The traditional safety triangle expanded to include other factors (McSween, 2003).

that set the occasion for the unsafe actions and conditions, the triangle has heuristic value.

However, the triangle does not adequately *predict* incidents that lead to fatalities. OSHA and other governing bodies show that injury rates are poor predictors of FSIs (McSween, 2015). The aforementioned data trends showing minor injury rates continuing to drop while serious incident rates are plateauing suggest Heinrich's triangle lacks predictive utility. Krause and Murray (2012) suggest that the "absence of minor injuries is not predictive of an absence of future fatalities" (p. 2), and one dataset (RAND Corporation, 2007) suggests being "leery of drawing overarching conclusions about whether OSHA violations are likelier to contribute to deaths" (p. 132). Ultimately, the traditional triangle does not assist in projecting *which* of the unsafe acts or conditions will lead to a serious incident or fatality. In fact, many of Heinrich's ideas have been questioned (cf. Manuele, 2002). While the triangle is useful in conceptualizing the relationship between different types of injuries, the original ratios have little utility and may restrict our understanding of serious injuries.

Identifying precursors to FSIs using form and context analysis

One significant flaw in the extension of Heinrich's triangle in Figure 5 is the assumption that by reducing the rate of all the at-risk behaviors, the organization will reduce the chance of incidents higher up the triangle, including FSIs. While behavior is correlated to the occurrence of an incident or injury, *the form and context* of the behavior will ultimately influence the severity of the outcome, not the mere occurrence of behavior. The form and context analysis looks at the topography of responses and the environmental events surrounding the behavior, and enables us to identify possible precursors to future FSIs. For instance, working at a significant height (context) without wearing fall protection (form) is considered an at-risk behavior and an OSHA violation. Using safety glasses (form) when a full face mask is required because of a high amount of fly ash in the work area (context) is also an at-risk behavior and an OSHA violation. They would both be occurrences of at-risk behavior in Figure 5, but the fall protection violation is more likely to relate to an FSI than the eye protection violation. Understanding the form and context of certain behaviors is crucial for accurately assessing risk and preventing serious injuries.

Analyzing the form and context of a work activity is important to understanding and addressing injuries and near misses. For instance, an associate could sustain a significant knee contusion requiring first-aid attention for a variety of reasons. In one instance, the associate was looking at his or her phone on the way to the lunch break (form), and fell down a well-marked, two-step staircase (context). In another, the associate was climbing (form) a poorly maintained railroad tank car (context) and slipped off the curved ladder because lubrication was leaking on the rungs. The form and context of both behaviors in the above incidents are significantly different from each other, but led to the same outcome—injury. They were both first-aid cases, but falling from the oil tanker has a significantly higher likelihood of causing a serious injury (and even a fatality) than falling down two cafeteria stairs. In the first example, the behavior (form) was clearly the more important feature of the accidental fall down a well-marked staircase. In the second example, both form and context played a possible role in the resulting injury.

When looking at all four examples of violations and injuries, Heinrich's triangle (and its derivatives) misrepresents the uniformity of risk between all of the single incidents in each section of the triangle. Because the traditional triangle aggregates each occurrence into the category rows without discriminating the form of the behavior or the context in which it occurred, it cannot be adequately used for the prediction and control of serious incidents. Ultimately the traditional triangle "suggests that the ratios may exist, [but] we cannot predict that we will reduce serious injuries just because we have reduced minor injuries" (McSween, 2015, p. 11). Behavioral scientists can look at form and context as *precursors* to serious incidents; this added dimension will help with prediction and control of safety outcomes.

The traditional triangle can be modified to include the form and context of worker activities as *precursors* of serious incidents. A precursor of serious incidents "is defined as a high-risk situation in which management controls are either absent, ineffective, or not complied with, and which will result in a serious or fatal injury if allowed to continue" (Krause & Murray, 2012, p. 3). According to Wachter and Ferguson (2013), precursors include both "unmitigated high-risk situations" and "high-risk activities." Both can simultaneously occur as "high-risk event combinations" when the form and context of behavior merge to accelerate risk. Focusing on precursors in order to discriminate the differences in these events will assist in the goal of prediction and control of serious incidents.

Adding additional detail to the safety triangle refines the analysis of incidents. In Figure 6, the shaded middle section represents the range of the triangle that includes high-risk situations, activities, or event combinations, all of which may be precursors to an FSI. The dots in the inner triangle represent serious injury precursors, that is, the subset of behaviors, incidents, and hazards in the shaded area could potentially have been serious injuries or fatalities. As such, the events in this subset require special attention from safety professionals, safety committees, and leadership. Notice how the middle section subsumes the two riskier examples from the previous discussion, and the less-risky examples are still on the triangle in the same row, but not within the middle section. This added range makes the incident analysis more robust.

The example of not wearing fall protection at significant height is in the At-Risk Behavior row of the triangle, and also *inside* the middle section of serious incident precursors. This single incident is only in the At-Risk Behavior row because the person did not get hurt, but there was a potential for death or significant injury. Similarly, the example of wearing glasses instead of a full face mask around fly ash is also in the At-Risk Behavior row; however, it is not in the middle section of the triangle, which could be affiliated with potential death. Previously, the traditional triangle treated these two incidents as equivalent. Adding the middle section of the triangle helps discriminate the more precarious at-risk behaviors, and helps highlight the events that need attention for preventing serious incidents.

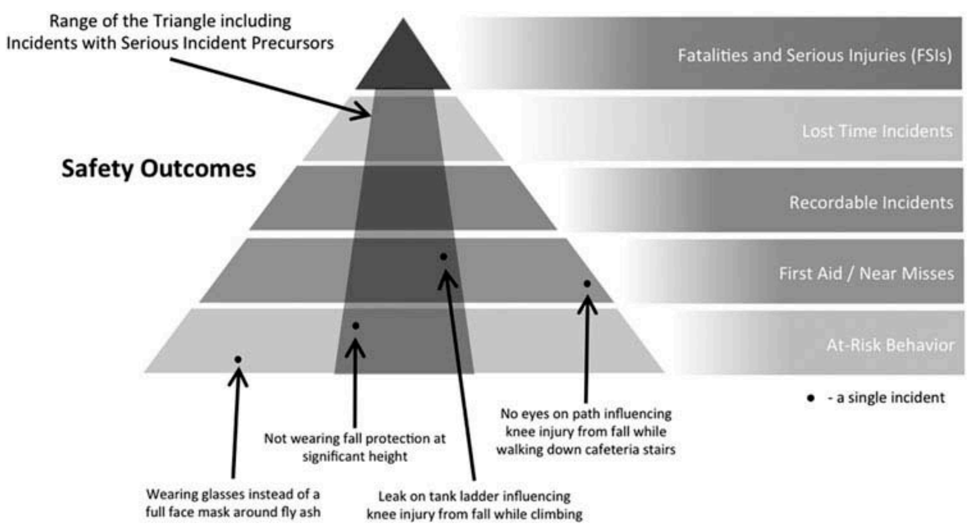

Figure 6. A proposed safety triangle with a third section representing high-risk situations, activities, or event combinations.

The vertical, middle section of the triangle is also pragmatic when analyzing our injury examples. The two dots in the First-Aid/Near Misses row represent incidents requiring attention, but only one is put in the shaded range of the triangle that is related to potential fatality. Of course, professionals would prudently analyze the form and context for both knee-injury incidents; yet, the one that included falling from an oil tank car due to poor maintenance is going to require significantly more attention because it could have led to a significantly worse injury. The traditional triangle implies that falling down two cafeteria stairs and falling off a tank car were equivalent because the outcome was similar (they were both first-aid cases); however, these incidents in the First-Aid row were not equivalent regarding potential for FSIs. Heinrich's triangle is not useful for prediction and control since it views both occurrences as equal in risk for catastrophe. If professionals would like to predict and control the FSIs, this middle vertical section of the triangle needs to be added to the analysis to help discriminate between the incidents in each row that have the potential for death or serious injury. Categorizing and focusing on precursor events, and mitigating their potential to cause FSIs, are crucial aspects for safety management.

Precursors and safety absolutes

Behaviors that are precursors to serious injury are often known to be high-risk activities and are often codified in the company's safety rules (Krause, 2012). Some companies refer to this set of safety rules as their "Safety Absolutes" or other phrases that identify them as the rules that help prevent serious injuries and death. The safety absolutes typically include such practices as fall protection, lockout/tagout, and the use of permits. The safety absolutes should be included on the BBS observation checklists so the BBS process helps identify potential precursors for additional analysis and action planning. To further ensure precursors are addressed, the organization should influence BBS observers to increase the frequency of observations during high-risk tasks. A well-designed BBS process should help employees learn to identify serious incident precursors in their workplace and what they can do to minimize their risk associated with the hazards. It should also help encourage reporting of close calls, especially those related to process safety. These simple steps can alter the typical BBS process to be more effective at preserving life and preventing catastrophic events.

Extending the foundation of the traditional safety triangle

In addition to placing another section in the triangle by assessing the risk of precursors, it is prudent to extend the focus on context by expanding the safety triangle to include other foundational environmental characteristics at the bottom of the triangle. At-Risk Behavior cannot stand alone at the bottom of the triangle. In both a root cause analysis and a functional analysis, a worker's behavior cannot be deemed the sole root cause of an incident. Behavior analysis assumes that behavior is a function of environmental events (Malott & Shane, 2016; Skinner, 1953), and modern root cause analysis posits that incidents have multiple causes—often including unapparent events (Johnson, McSween, & Polluck, 2016). A worker's actions are influenced by so many other variables, so the employee's work context must be analyzed in order to have a true influence on safer actions in the workplace. Because prediction and control of serious incidents is a goal for the safety profession, behavioral scientists need to emphasize the fact that antecedents and consequences significantly influence at-risk behaviors, and these functional stimuli are often governed by the existence of context concerns including operational issues, physical hazards, and other system failures such as poor leadership. When talking to critics, adding form—observable, pinpointed, safe behaviors—to context can make BBS more acceptable and embraceable.

Figure 7 illustrates the distinction between "Process Issues" and "Safety Outcomes." This is important because safety professionals and safety committees need to understand that behavior is part of the safety process. BBS provides a measure of behaviors that are critical to safety outcomes. Observation data is a process measure, not an outcome measure. It is analogous to measures of temperature, flow rates, pressure, and other measures used to ensure that a process remains in control and results in outcomes that are within allowable parameters. Critical behavior within a process must remain within control limits in the same way (Hyten &

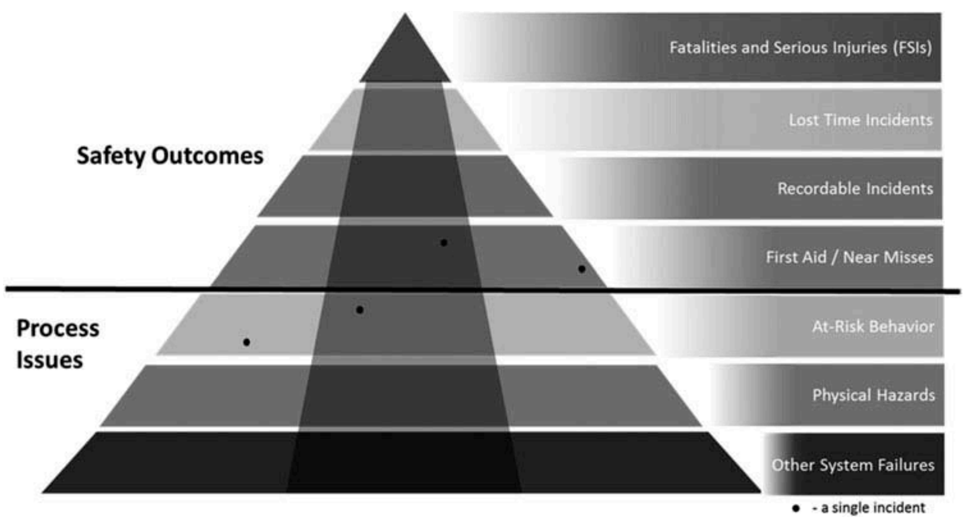

Figure 7. A further extension of the proposed safety triangle that adds systems issues such as physical hazards and other system failures.

Ludwig, 2017). Like temperature and pressure, behavior is a function of the system, but it is not an outcome. Injuries, equipment damage, and barrels of product are outcome measures, but measures of behavior are process measures, not outcomes.

Figure 7 has important implications for addressing and preventing serious injuries by communicating to leaders and safety committees that action plans, especially for serious injury precursors, must go beyond those addressing at-risk behaviors. For incidents in the precursor section of the triangle, action plans should identify and address behaviors by carefully analyzing the other elements of the process represented by different levels of the triangle. Ideally, hazards are eliminated from the work environment, or additional engineering controls prevent the possibility of injury; however, if that is not possible, then other layers of protection should be added.

Physical hazards

An at-risk behavior cannot result in an injury without the presence of a hazardous condition. Leadership and frontline workers have a responsibility to mitigate physical hazards in the workplace. Whether a behavior is at-risk can depend upon context. For example, if we look at the behavior of cigarette smoking, we can say that the action of holding a lit cigarette at the workplace is neutral. It is relatively harmless from a serious incident perspective (cardiovascular health issues for the individual, notwithstanding) when the action is happening in a designated smoking area that is free of flammable debris, visited frequently in a trafficked area, and has commercial ashtray receptacles. The behavior in that context is not at risk for serious incidents because there are no significant physical hazards in the context. At the other end of the spectrum, if the safety inspection system at an oil refinery is faulty, leadership has not spent the right amount of money for procuring the safety equipment to reduce the likelihood of a gas leak during a transfer, ignored workers' requests for a designated smoking area, and neglected to train the workers about the dangers of smoking in some work areas, then the same exact formal behavior of holding a lit cigarette—which was not particularly dangerous in the previous context—becomes an at-risk behavior in this current context.

At-risk behavior often happens because of an environmental context, and if physical hazards are present, then the actions of a worker are simply a contributing factor to the incident. The presence of a physical hazard sets the occasion for a serious incident. The hierarchy of hazard controls must be applied to the context of work to eliminate or minimize risk for FSIs. Often, in certain industrial settings, physical hazards can only be mitigated, and not completely eliminated. Thus, the organization has to move down the hierarchy of controls, making the safety intervention less effective. How leadership, training, procurement, and budget influence both the environmental context and the workers' behaviors is foundational to the entire risk situation (Gravina, et al., 2017; Hyten & Ludwig, 2017; Ludwig, 2017).

Systems and leadership failures

Other system failures establish the base of the expanded safety triangle articulating contributing factors to serious incidents. Many dynamics in industrial settings can set the occasion for physical hazards and at-risk behaviors that could be potential precursors for FSIs. How leaders behave, the effectiveness of training, and the financial resources of a company can contribute to systems failures (Figure 7). When a mechanic fails to learn all of the steps in a lockout procedure, training has failed. This system failure would fall under the shaded area of the "Other System Failures" level of the triangle. When any of these domains are mishandled, they can eventually have a deleterious impact on safety (Ludwig, 2017).

People in leadership positions are still "workers," who engage in behavior having antecedents and consequences, and behavioral science can be used to improve such behavior (Daniels & Daniels, 2007; Houmanfar, Alavosius, Morford, Herbst, & Reimer, 2015; Krapfl & Kruja, 2015; Moran, 2010). Influenced by market forces, production goals, and public relations objectives, leaders often have to make day-to-day choices governed by those contingencies. Oftentimes, those antecedents and consequences influence leadership behavior to be less focused on the primacy of safety goals. When a plant manager is competing with other companies to achieve a record-production year, pursuing the board of directors' expectations to meet aggressive costs containment goals (antecedents), and has a history of financial bonuses for meeting performance goals (consequence), the environment may program the manager up to engage in at-risk behavior. Under such conditions, a manager might cut the safety budgets, reduce overtime in a way than impacts safety training session, and take other steps that may compromise safety or even mechanical integrity. Reducing the effectiveness of training, not procuring proper personal protective equipment (PPE), and mishandling the maintenance of equipment are all system failures. When the plant manager focuses on more proximal and probable reinforcers, those choices contribute to the foundation of this safety triangle. When doing a root cause analysis, professionals attempt to "get to the bottom" of a problem, and a leader's misguided behavior can be a noteworthy system failure functioning as a precursor to FSIs.

How can 21st century BBS assist with FSIs?

As stated previously, form and context function as precursors to FSIs. Identifying precursors requires analysis of form (behaviors) as well as context (process issues). Behavior, including decision making, plays an integral role in process issues as well as safety outcomes. BBS has the potential to make a significant impact on the safety outcomes (e.g., Sulzer-Azaroff & Austin, 2000). Martin and Black (2015) suggest that BBS is a significant and under-used process for addressing serious injuries and fatalities (p. 42). Their observation reflects the fact that most BBS processes do not distinguish between serious injury precursors and other at-risk behaviors. The first problem is that most safety committees managing a BBS process treat all at-risk behaviors with the same analysis and problem-solving methods. The second problem is that action plans to address behavior often do not give adequate consideration to addressing the hazard and other process issues as part of their strategy to address at-risk behaviors. BBS has been shown to be effective for reducing incidents and injuries and "the behavior science community and its industry partners must build on what has been accomplished with personal safety" (Bogard et al., 2015, p. 76). The basic principles and applications of a 21st century BBS can be reorganized to affect change in serious incidents and fatalities.

In brief, BBS has a multistep implementation process (for a more complete description of BBS, see McSween, 2003). Safety professionals work with their safety committee to assess the organization's incidents and injuries, and then operationally define which behaviors need to occur in order to improve safety in that work environment. Those pinpointed behaviors are observed and workers are given feedback about their behavior. As data is collected on safe and at-risk behaviors, the observer provides immediate acknowledgment of safe behaviors, which may prove to be positively reinforcing as they increase in the future. The observer also discusses alternatives for at-risk behaviors with the worker. Those data are aggregated, and after a certain period of time the organization assesses if the behaviors observed meet a certain criteria of safety. If so, the group celebrates meeting that objective. This can serve as a reinforcer as well, and maintains people's safer actions on the job. In addition, trends in at-risk behaviors are analyzed to discover the environmental contexts that set the occasion for dangerous actions. This leads up to management endeavors to create safety action plans to properly address these contextual factors.

Although BBS typically focuses on reducing individual worker injuries, the same assessment-observation-feedback-reinforcement process can be used for reducing FSIs. When doing the assessment, professionals would do well to look at the organization's potential for contextual and behavioral precursors. According to Martin and Black (2015), precursors of serious injuries are identifiable through observations and discussion in 87% of the incidents reviewed. He goes on to describe three types of precursor events: high-risk tasks, high-risk behaviors, and complex or changing circumstances.

The implications for BBS are clear. Those designing a BBS process should study the serious injury precursors and attend to those tasks that could result in FSIs in their organization. The middle section of the triangle can provide an incisive perspective on incidents at each particular workplace. In addition, extending the triangle's base to include physical hazards and other system failures, such as leadership shortcomings, will also assist when looking at the root cause of incidents.

When analyzing the precursors, the BBS process designers should ensure that (a) high-risk tasks are frequently observed, (b) the behaviors critical to those tasks are clearly included on the observation checklist, and (c) the safety committee makes it a priority to review the observation data and identifies precursors—both behavioral and environmental—for additional analysis and intervention. Table 1 presents a comparison of design considerations for serious injuries as compared to BBS efforts to reduce injury frequency. In most BBS processes, the critical behaviors are defined based on data of injuries from the past three to five years. The behaviors are the basis for an observation checklist used for frequent observations in the workplace. When designing a BBS process to prevent serious injuries and fatalities, the critical behaviors often must be identified from a hazard analysis of the workplace, often done by the local safety professional. These behaviors must either be included on conventional BBS checklists, or a separate Serious Incident Prevention (SIP) checklist used for reviewing the specific critical tasks. An additional difference is that the BBS process must focus observation on the hazardous tasks common to fatalities and serious incidents within the facility. For example, in construction, the checklist would often have critical behaviors related to fall protection and scaffolding, and special observations should be taken of those working at heights. In most manufacturing contexts, observations should be routinely performed on jobs requiring lockout/tagout procedures to control energy release.

Furthermore, once the BBS process is in place and providing data from the work samples, the safety committee must communicate all serious injury precursors to the leadership team for review, and an action plan must be recommended. Ultimately, the leadership is responsible for ensuring that serious injury precursors are addressed with an appropriate level of control. If observations document at-risk behaviors related to serious injury

Table 1. A Comparison of Design Considerations for Behavior-Based Safety When Targeting a Reduction in Injury Frequency Versus Prevention of Serious Injuries and Fatalities.

To reduce and prevent	Source of critical behaviors	Observations
Occupational Safety and Health Administration (OSHA) recordable incidents	Identified through analysis of 3–5 years of data	Conducted at random
Serious incidents and fatalities	Hazard analysis by subject matter experts	Conducted during high risk tasks

precursors, leadership must respond with additional layers of protection to ensure that safety practices stay consistent and under control.

BBS safety committees typically analyze observation data to identify where at-risk behaviors are occurring. When these data identify an at-risk behavior that is occurring frequently (number of occurrences) or consistently (percent at-risk) in the previous month's data, they identify a target level of improvement and develop an action plan to increase the related safety practice. The target behavior is not a serious injury precursor according to Figure 8. For this type of target, the action plan might be fairly simple, such as communicating the target behavior, reviewing the topic during safety meetings, and asking observers to increase the frequency of feedback for the target behavior.

Such simple, low-cost interventions are not appropriate for the precursors of serious incidents. If the safety committee identifies an at-risk behavior that is a precursor to a serious incident, both the analysis and the action plan must be more rigorous and complete. Ideally, the analysis of those behaviors and hazards should be addressed through engineering those concerns out of the workplace. When that is not possible, adding additional layers of protection must address the systems issues. For example, in construction, practitioners may not be able to eliminate the task of working at heights, but might ensure a safety professional or supervisor participates in the pre-job briefing and reviews all the controls (such as fall protection, guardrails, and toe boards, etc.) at the beginning of the job, throughout the day, and any time the circumstances change.

As shown in Figure 9, if the safety committee finds *a single instance* of the precursor behavior, they should do a careful functional analysis of the Antecedent, Behavior, and Consequences (an ABC analysis). Then, based on that analysis, develop an action plan addressing the behavior, the hazard, and potential other

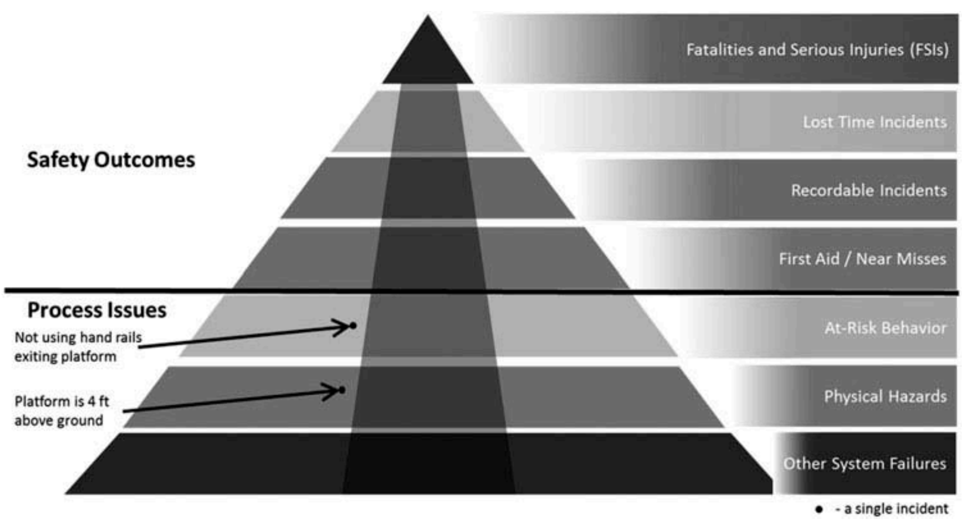

Figure 8. For at-risk behaviors that are not precursors to serious injury, action plans may target improving behavior through feedback, tracking the behavior to ensure that it improves.

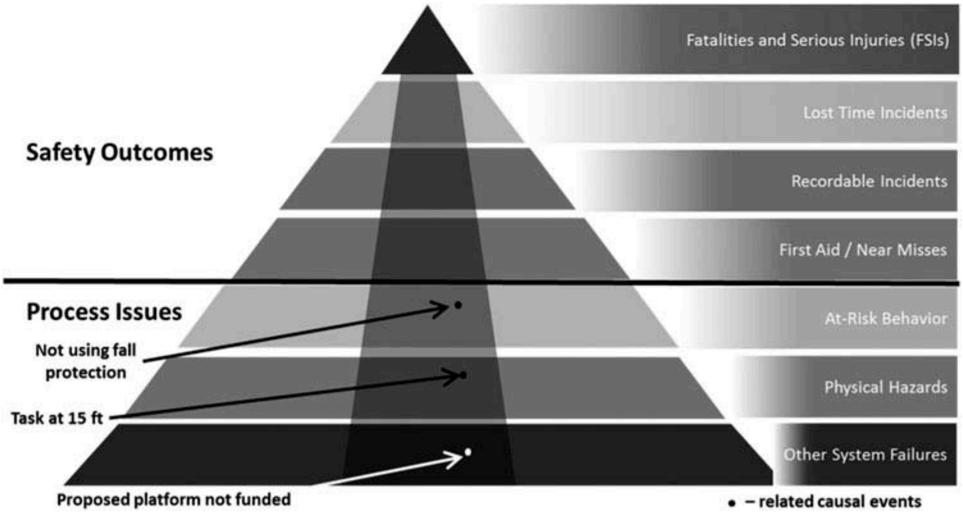

Figure 9. Behavior-based safety can help identify serious injury precursors, such as employees working at heights without fall protection. For precursors, the hazards should be addressed through engineering and additional layers of protection. Action plans for such precursors should address all levels, not just added feedback to address the behavior.

aspects of the process. In the diagram, observations identified that an employee was working on the top of a tank car (at a height or over 15 feet) without fall protection. The action plan should look at ways to eliminate or reduce the hazard. Appropriate interventions might include a permanent or mobile platform, creating better tie-off points for fall protection, or even finding ways to automate the task that do not require climbing on top of the rail car. A more robust analysis might look to see if they have experienced near misses and other historical facts related to the task.

The safety committee's interventions should ensure a level of control appropriate to the hazard or risk in the workplace. Precursors to serious injury often justify the capital expenditures typically associated with robotics or new equipment that eliminate the serious injury hazard. Interventions addressing serious injury precursors and at-risk conditions may require equipment upgrades that reduce the hazards or help support safe behavior. As a final fail-safe, the leadership team should review the analysis, planning, and implementation of actions taken to address serious injury precursors.

Extending these concepts to process safety

Process safety combines managing and engineering skills with an aim to prevent catastrophes. In the petrochemical industry, process safety generally refers to "keeping it in the pipes," which implies ensuring that the facility does not experience any release of product that contaminates the environment or results in a fire or explosion. Maintaining accurate records of process upsets in shift log books, communicating process events at shift change, relaying new leadership decisions, and maintaining accurate process and instrumentation diagrams are all behavioral issues influencing the likelihood of catastrophic events (Rodriguez et al., 2017). All are subject to review through behavioral observations and to the same factors as those shown on the enhanced safety triangle.

Catastrophic process events are admittedly more complex and involve *multiple* causes, often existing at different levels of the organization (Ludwig, 2017). In his book, *Failure to Learn*, regarding the Texas City Refinery explosion, Andrew Hopkins described the unfortunate deviations of critical actions at many levels, including the behaviors of operators, problems with the design and instrumentation, leadership failures, and even regulatory agencies. Hopkins (2010) identifies organizational root causes including "an inappropriately focused remuneration system; cost cutting without regard to safety consequences; an organizational structure that disempowered safety experts; and a senior leadership that discouraged bad news and failed to understand the distinctive nature of process safety" (p. 4). These factors were causal events not just in the Texas City disaster, but also in BP's failure to learn from six close calls in the 10 years prior to the explosion in 2005. Figure 10 presents a simplified way to illustrate some of the factors that might have been identified and addressed from an analysis of the close calls preceding the 2005 explosion, such as an operator overfilling a vessel, explosive vapor release, and budgetary constraints.

Critical behaviors abound, all with their own context and causal factors. Leadership behavior often has a significant contribution to the causal factors. For example, in Hopkins's discussions of the 2005 BP Texas City Refinery disaster, he commented, "A final factor in this story is the failure of leadership at the very

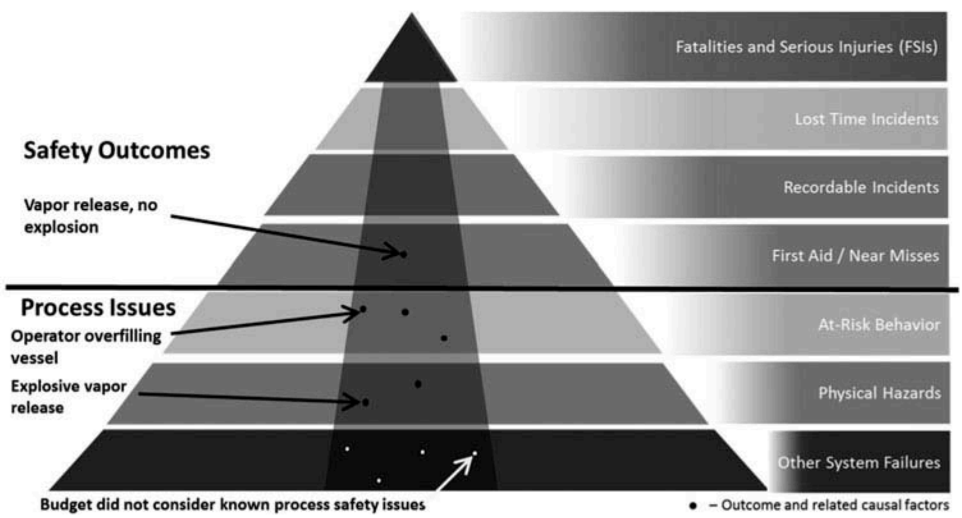

Figure 10. Safety leadership teams should investigate close calls that could have been catastrophic events, identify critical behaviors and hazards, then develop action plans that address engineering and systems issues. Feedback and training alone are inadequate for addressing these issues.

highest level. The CEO was perceived by those around him as unreceptive to bad news about safety. Consequently he was never informed about the deleterious impact of cost cutting at the Texas City site (p. 5)." The same ineffective leadership behavior would retroactively become known as a contributing factor in the 1986 space shuttle Challenger disaster, and again in the 2010 BP Deepwater Horizon oil spill. An emphasis on leadership does not negate the requirements of safe behavior and proper safety engineering, but it simply adds another element to be considered for ensuring serious incident prevention. The challenge for BBS professionals is to apply our technology in ways that address behaviors at all levels, and not just those of the frontline employees.

If the potential for a catastrophic event is identified (whether through behavioral observations, review of near-miss events, or rigorous hazard analysis), organizations should strive to minimize the risk through design. A critical task for behavioral technology is to provide behavioral measures that identify and address problems before catastrophic events occur.

Conclusion

Preventing serious incidents with behavioral science requires proper assessment and intervention. The BBS approach discussed in this paper includes identifying critical behaviors and hazards, incorporating judicious leadership choices, and developing action plans addressing engineering and systems issues. Advanced 21st century BBS implementations are not only broader and more inclusive than the common traditional approaches, but also provide better effectiveness to an organization's safety interventions. When traditional observation and feedback processes are improved so they accelerate change in leadership behaviors and other behaviors critical to process safety, then organizations will have more robust safety successes to celebrate and repertoires to reinforce.

References

American Society of Safety Engineers. (2011). Retrieved January 16, 2016, from http://www.asse.org/asse-says-latest-bls-workplace-fatalities-report-should-be-a-call-to-action

Bogard, K., Ludwig, T. D., Staats, C., & Kretschmer, D. (2015). An industry's call to understand the contingencies involved in process safety: Normalization of deviance. *Journal of Organizational Behavior Management*, *35*, 70–80. Doi:10.1080/01608061.2015.1031429

Bureau of Labor Statistics. (2016, April 21). Revisions to the 2014 Census of Fatal Occupational Injuries (CFOI). Retrieved April 30, 2016, from http://www.bls.gov/iif/cfoi_revised14.htm

Daniels, A. C., & Daniels, J. E. (2007). *Measure of a leader: The legendary leadership formula for producing exceptional performers and outstanding results*. New York, NY: McGraw Hill.

Gravina, N., Cummins, B., & Austin, J. (2017). Leadership's role in process safety: An understanding of behavioral science is needed. *Journal of Organizational Behavior Management*, *37*(3–4), 316–331.

Heinrich, H. W. (1931). *Industrial accident prevention: A scientific approach*. New York, NY: McGraw-Hill.

Hopkins, A. (2010, July). Why BP ignored close calls at Texas City. *Risk and Regulation*, 4–5.

Houmanfar, R., Alavosius, M. P., Morford, Z. H., Herbst, S. A., & Reimer, D. (2015). Functions of organizational leaders in cultural change: Financial and social well-being. *Journal of Organizational Behavior Management*, *35*, 4–27. Doi:10.1080/01608061.2015.1035827

Hyten, C., & Ludwig, T. (2017). Complacency in process safety: A behavior analysis toward prevention strategies. *Journal of Organizational Behavior Management*, *37*(3–4), 240–260.

Johnson, D., McSween, T. E., & Polluck, R. (2016, June 27–29). Applying systems thinking to improve safety. *Proceedings of the ASSE Professional Development Conference and Exposition*, Atlanta, GA.

Krapfl, J. E., & Kruja, B. (2015). Leadership and culture. *Journal of Organizational Behavior Management*, *35*, 28–43. Doi:10.1080/01608061.2015.1031431

Krause, T. R. (2012). New perspectives in fatality and serious-injury prevention. *Presentation at Fatality Prevention Forum 2012*, Coraopolis, PA.

Krause, T. R., & Murray, G. (2012, June 3–6). On the prevention of serious injuries and fatalities. *Proceedings of the ASSE Professional Development Conference and Exposition*, Denver, CO.

Ludwig, T. (2017). Process safety behavioral systems: Behaviors interlock in complex process safety meta-contingencies. *Journal of Organizational Behavior Management*, *37*(3–4).

Malott, R. W., & Shane, J. T. (2016). *Principles of Behavior*. New York, NY: Routledge.

Manuele, F. A. (2002). *Heinrich revisited: Truisms or myths*. Itasca, IL: National Safety Council.

Manuele, F. A. (2013, May). Preventing serious injuries & fatalities: Time for a sociotechnical model for an operational risk management system. *Professional Safety*, 51–59.

Martin, D. K., & Black, A. (2015, September). Preventing serious injuries & fatalities—Study reveals precursors & paradigms. *Professional Safety*, 35–42.

McSween, T. E. (2003). *The values based safety process: Improving your safety culture with behavior-based safety* (2nd ed.). New York, NY: John Wiley.

McSween, T. E. (2015). Preventing serious injuries and how BBS can contribute. *Journal of Applied Radical Behavior Analysis Proceedings of the 9th BBS & OBM European Conference*.

Moran, D. J. (2010). ACT for leadership: Using acceptance and commitment training to develop crisis-resilient change managers. *International Journal of Behavioral Consultation and Therapy*, *6*(4), 341–355. Doi:10.1037/h0100915

RAND Corporation. (2007). *In the name of entrepreneurship? The logic and effects of special regulatory treatment for small business*. S. M. Gates, & K. J. Leuschner (Eds.), Kaufmann-RAND Institute for Entrepreneurship Public Policy. Santa Monica, CA: Author. http://www.rand.org/content/dam/rand/pubs/monographs/2007/RAND_MG663.pdf

Rodriguez, M. A., Bell. J., Brown. M., & Carter. D. (2017). Integrating Behavioral Science with Human Factors to Address Process Safety. *Journal of Organizational Behavior Management*, *37*(3–4), 301–315

Skinner, B. F. (1953). *Science and human behavior*. New York, NY: Macmillan.

Sulzer-Azaroff, B., & Austin, J. (2000, July). Does BBS work? Behavior based safety & injury reduction: A survey of the evidence. *Professional Safety*, 19–24.

United States Department of Labor, Bureau of Labor Statistics (2016) Census of Fatal Occupational Injuries. 2012 Census of Fatal Occupational Injuries (revised data). http://www.bls.gov/iif/oshcfoi1.htm

Wachter, J. K., & Ferguson, L. H. (2013, July). Fatality prevention: Findings from the 2012 forum. *Professional Safety*, 41–49.