Optimizing Safety
Engineering, Systems, Human Factors: Part 1

By Vladimir Ivensky

IN BRIEF
- Part 1 of this article reviews misbalances that can occur among the major elements of a comprehensive safety program (engineering controls, management systems, human factors), potentially affecting those programs' effectiveness in preventing serious incidents.
- It specifically reviews debates on incident causation and behavior-based safety programs, and on the advantages and limitations of those programs.

The ultimate purpose of any occupational safety program is to reduce or eliminate incidents that result in harm to people or the environment. A more detailed definition of the goal (completely eliminate injuries, prevent serious injuries, provide workplace free from recognized hazards) and ways to achieve that goal are the subjects of debates that help to develop the safety profession, its tools and strategies. The trends in occupational injury rates indicate a growing gap between declining minor to medium severity incident rates and serious injury and fatality rates that have not declined at the same pace (Mangan, 2015; Manuele, 2003). That finding is sparking renewed interest in searching for optimally balanced safety programs that are effective in preventing serious incidents.

Content of an Occupational Safety Program

The topics debated within the safety profession include, among others:

1) What is the predominant cause of safety incidents (if it exists)—unsafe acts, unsafe conditions (uncontrolled workplace hazards), operations and management systems deficiencies, or some other causes or their combinations?

2) Do minor and serious incidents have similar causes and is it possible to prevent serious incidents by concentrating on preventing the more frequent minor ones?

3) If the main causes of incidents are known, can preventive strategies be focused accordingly and modified to be more effective?

Errors in answering these questions would result in misplaced priorities, resources and ineffective safety programs. Modern occupational safety programs integrate many elements that simplistically can be classified into three major categories: 1) engineering and technical standards and rules; 2) management and operation systems; and 3) human factors (Figure 1). Examples for each category are provided briefly for illustration only.

Engineering & Technical

ASSE's name, which includes the word *engineers*, implies that the engineering and technical component is at the core of the OSH profession. U.S. federal OSH regulations are mostly technical in nature, providing specifications for tasks or items such as scaffolds, guardrails, trench cave-in protection, de-energizing, confined space entry or personal fall arrest devices. For example, OSHA's construction industry standard 29 CFR 1926.652 requires "safe access and egress to all excavations, including ladders, steps, ramps or other safe means of exit for employees working in trench excavations 4 ft or deeper. These devices must be located within 25 ft of all workers." Violating any of those (and many similar) specifications constitutes an OSHA violation. It is illegal to allow employees to work in an environment that does not comply with OSHA regulations.

Systems

OSHA does not prescribe content for safety management systems. The regulations for the construction industry (29 CFR 1926) indicate that "it shall be the responsibility of the employer to

Vladimir Ivensky, CSP, CIH, has more than 25 years' experience in OSH. He is a corporate vice president of safety, health and environment for a global multidisciplinary consulting and construction management firm. Ivensky holds a master's degree and doctorate (equivalents) in Occupational Safety and Health and Environmental Protection from the Rostov Civil Engineering Institute in the former Soviet Union. He is a professional member of ASSE's Philadelphia Chapter and an author of numerous peer-reviewed articles in a wide range of OSH topics.

initiate and maintain such programs as may be necessary to comply with" the regulations. Safety management systems provide the organizational framework (such as project parties' safety roles and responsibilities) and requirements such as regular inspections of job sites, prohibition of equipment and tools that are not in compliance with the regulations, and requirement for the competent and trained machinery operators [1926.20(b)]. Some state-plan agencies, most notably Cal/OSHA, have requirements for injury and illness prevention programs, which are occupational safety and health management systems.

A typical safety management system includes elements such as management leadership, employee participation, safety planning, implementation of safety plans, evaluation of performance and corrective actions, and management review.

Well-known illustrations of safety management systems' structure and content are presented in the following consensus standards:

•ANSI/AIHA/ASSE Z10-2012, Occupational Health and Safety Management Systems, provides management systems requirements and guidelines for OSH improvement.

•OHSAS 18001, Occupational Health and Safety Management Systems Requirements, an international OHS management system specification.

Another safety program that integrates safety management systems with technical safety is described in U.S. Army Corps of Engineers' EM 385-1-1, Safety and Health Requirements Manual. Section 1 of that manual, Program Management, provides detailed requirements for project safety organization, planning, risk assessments, inspections, deficiencies tracking, hazard analysis, incident reporting, subcontractor selection and management, safety officers and personnel qualifications, and training. In addition, the manual provides mandatory content for a project-specific incident prevention plan, which constitutes a standard safety management system for the project.

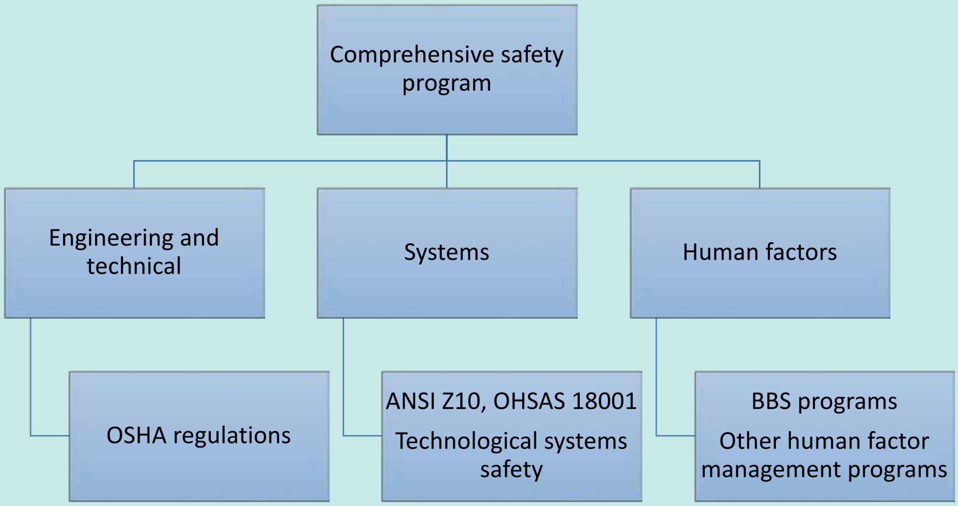
Human Factors

Lack of effective management of human factors has been a contributing factor of many major incidents including the *Piper Alpha* oil rig fire, Esso Longford gas explosion, the passenger ferry capsize at Zeebrugge, the Paddington rail crash at Ladbroke Grove, the explosion and fires at Texaco's Milford Haven plant, the Chernobyl nuclear explosion, the toxic gas release at Union Carbide's Bhopal pesticide plant, and the explosion at BP's Grangemouth refinery (HSE, 2005). For many of these major incidents, the human failure was not the sole cause but one of many causes, including technical and organizational failures that led to the final outcome (HSE, 2005). Human factors safety considerations must be integrated into comprehensive safety programs; it is important to establish optimal ways to control and mitigate human failures to prevent incidents.

Behavior-based safety (BBS) focuses on unsafe behaviors (unsafe acts) of line workers, people who may eventually be involved in an incident and be injured. Many BBS programs are based on a presumption that the majority of incidents are caused by unsafe behaviors that if corrected would prevent an equivalent percentage of incidents. BBS programs are not regulatory driven. Multiple consultancies produce branded BBS packages while other programs are custom-designed for specific companies.

Discussion is ongoing in the OSH profession about incident causation and application of BBS, which this article discusses briefly. Specifically discussed are the causes of human failures, many of which are interrelated to systematic, management, operational and engineering deficiencies (while others can be intentional safety violations or habit-

FIGURE 1
Comprehensive Safety Program



ual acts) leading to the necessity to apply a holistic approach to safety.

Comprehensive OSH Program

To implement an effective safety program, it is important first to ensure that it is correctly designed and balanced (Figure 1):

•Emphasizing regulatory compliance would not guarantee a hazard- and incident-free workplace, as no regulation can envision the many combinations of workplace circumstances that can lead to an incident.

•Properly designed management systems are necessary, but would not work without technical safety rules, technical knowledge, safety culture and safe behaviors.

•Safe behaviors are not a solution in situations where hazards are not recognized or understood, or where no systematic approach exists for safety management. Inevitable unintentional human errors must be controlled by engineering and management systems.

It would be logical to assume that an optimal balance exists between major elements of a safety program, and emphasizing any particular element may be detrimental to the overall success of a resulting safety program. The scope, component balancing and scale of the comprehensive program and senior management support of the program formulate the safety culture and, ultimately, the effectiveness of the program. Improperly selected priorities, strategies and tactics not shared by the employees, disagreements on perceived safety risks and ways to control them, and communication gaps damage the safety culture and the program effectiveness.

BBS: Ongoing Discussions

According to Manuele (2003), most BBS programs fall into one of two diverse schools of thought. One advances a culture change model, the other advocates a worker-focused behavior-based model. Here we primarily discuss the worker-focused BBS program model. That model's main premises and features are summarized by United Steelworkers (2000) as follows:

•Almost all incidents result from unsafe acts.

•For every incident, there are many unsafe behaviors.

•Consultant-employer relationship.

•Worker buy-in.

•Identify key unsafe behaviors.

•Train workers and management to observe workers.

•Perform observations.

•Provide feedback to move away from unsafe behavior.

•Record and use data from observations.

Worker-focused BBS programs aim to identify, observe, modify and correct the unsafe behaviors that lead to unsafe acts that are supposedly the source of the significant majority of incidents. The work behavior observations and behavior-changing interventions are typically performed by coworkers trained to formally observe workplace behaviors, recognize safe and unsafe actions, counsel coworkers on how to work more safely, and reinforce safe behaviors. Observations are reported to a centralized database for analysis and continuous learning. These programs are intended to be a no-blame, employee involvement process providing incentives for safe behaviors and discouraging unsafe acts through discipline and information sharing (personal information withheld). Implementation and management of a BBS program involves significant efforts.

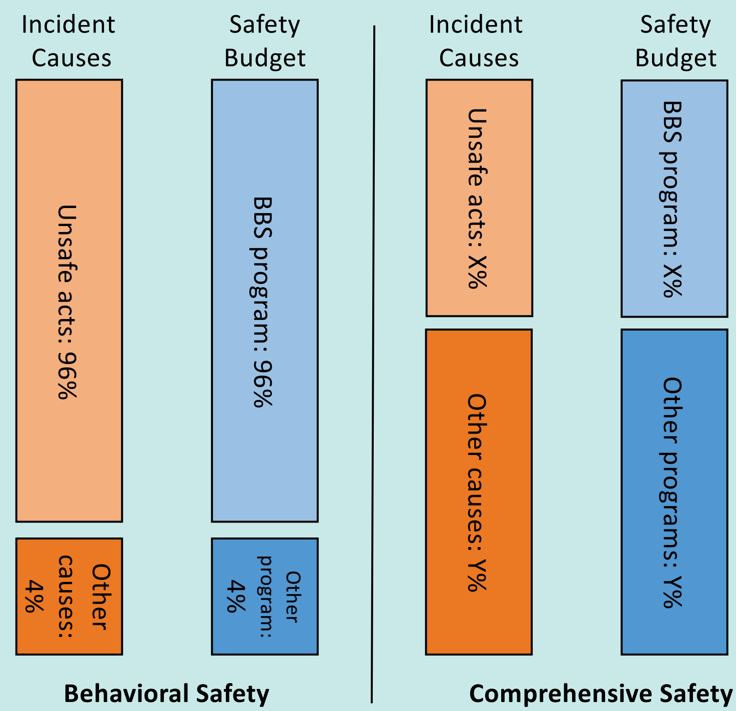
Companies planning to implement BBS programs should be aware of the advantages and limitations of these programs, and aware of ongoing discussions on BBS among OSH professionals. It might be easy to be confused by opposing opinions regarding the BBS programs.

Is BBS a magic bullet, instrumental in achieving injury-free work environment? Geller's (2000) discussion of 10 myths about BBS addresses the idea that it is a magic bullet:

> In fact, there is "magic" involved. Behavior-based safety stimulates and facilitates interdependent teamwork, which leads to innovation and creative synergy. To watch this transformation at work is a magical process. But this magic does not come easily nor quickly. It happens with proper top-down support and bottom-up involvement. Expecting too much too soon from behavior-based safety can result in disappointment and a label of "failure."

FIGURE 2

Allocating Safety Program Resources Based on Presumed Incident Cause Distribution



Is BBS a completely wrong solution for effectively preventing incidents and injuries at work?

> There comes a time when an idea is so prevalent it is accepted and applied without question. When this happens we are so conditioned to the correctness of it we fail to examine its basic premise. I believe we are at that point when it comes to behavior-based safety. At the risk of invoking the wrath of those safety professionals who advocate its use I am going to suggest it's time to re-examine the behavior-based safety (BBS) model. (Smith, 1999)

Or, more recently:

> The [popular brand of BBS] program should be eliminated as soon as possible, because it's founded on a misguided management principle: "If anything goes wrong around here, it must be the fault of the workers." In consultant-speak, this self-serving concept is called "behavioral safety." (Monforton & Martinez, 2015)

According to Geller (2016), "Behavioral safety has provided a platform for constructive debate, and the conflicting opinions have challenged the safety professional to learn more about the psychology of injury prevention."

Representatives from both camps may skew the optimal balance of a safety program one way or another. The well-chosen title of "The Steelworker Perspective on Behavioral Safety: Comprehensive Health and Safety vs. Behavior-Based Safety" (United Steelworkers, 2000) emphasizes the hazard of overwhelming application of BBS. The union's position paper states that BBS skews the safety program, emphasizing the behavioral aspect and sacrificing other important elements.

The same criticisms would be fair for safety systems that ignore human behavior aspects. This author suggests that while "the safety professional has to learn more about the psychology of injury prevention" (Geller, 2016), behavioral psychologists involved in OSH may benefit from learning more about the technical, engineering and operational aspects of safety to ensure the proper balance and the maximum effectiveness of a resulting product—a comprehensive safety program.

These concerns were summarized by HSE (2005) as follows:

1) Imbalance between engineering controls (hardware) and human issues, focusing only on engineering or only on human issues.

2) Focusing on behavioral aspects of personal safety rather than on control of major hazards.

3) Focusing on operator error at the expense of system and management failures.

The author adds that BBS programs may not distinguish between an error and violation, classifying both as an unsafe act and ignoring the fact that most operator errors are unintentional and uncontrollable by an individual, and that their root causes may lay in management and system failures.

BBS: Unsafe Act as a Main Cause of Incidents

> An important theme is that the assumptions about accident causation that one carries around in one's head are critical to the manner in which one then organizes a corrective response. If you believe, for example, that accidents are almost always caused by "stupid and careless workers," then you will focus your efforts in accident prevention on "policing workers"—close supervision, discipline and training will be your chief activities. If, on the other hand, you believe that the ultimate causes of accidents are the inappropriate policies, operations and structures within management, then you will address organizational problems such as responsibility, authority and accountability. (Strahlendorf, 2003)

The percentage of workplace incidents attributed to unsafe acts by some practitioners is typically 88% or more. The origin of that number is linked to H.W. Heinrich's studies from the 1930s, which led to his famous 88:10:2 ratio of direct and proximate accident causes (i.e., 88% of accidents are attributable to unsafe acts, 10% to unsafe conditions and 2% are unpreventable). This study is also a source of the motto that "there is no such thing as unpreventable incident" (2% are treated as statistical noise and the remaining 98% of incidents can be prevented by correcting unsafe behavior, 88%, and unsafe conditions, 10%).

Other studies provide a similar and even higher percentages of incidents caused by unsafe acts, attributing up to 95% (Krause, 1997), 96% (DuPont) and 98% (Difford, 2012) of all occupational incidents to unsafe acts.

Several well-known researchers point to complicated networks of underlying causes that lead to an incident, including safety management, operation systems failures and engineering controls failures.

The postulation that the overwhelming majority of incidents and injuries are caused by unsafe acts would logically imply that a similar proportion of available resources in OSH should be spent on observing, correcting and preventing these unsafe acts.

The discussion here, therefore, is not purely philosophical; it is about safety program strategies, resource allocation and directions for further improvement, as if the base premise that safety should almost exclusively focus on unsafe acts is incorrect, the safety resources will be allocated improperly (Figure 2).

Several well-known researchers (Petersen, Manuele, Hopkins, Reason) point to complicated networks of underlying causes that lead to an incident, including safety management, operation systems failures and engineering controls failures.

Heinrich's results were challenged by Manuele (2003) who concludes:

- The methodology used in arriving at those ratios cannot be supported.
- Current causation knowledge indicates that the premise is invalid.
- The premise conflicts with the work of others.
- Among all of Heinrich's premises, application of these ratios has done the greatest harm, since they promote preventive efforts being focused on workers rather on the operating system.

> No matter what definitions they give for the term *unsafe act*, they immediately moved from those figures to addressing means of resolving the at-risk behavior of employees though behavior modification methods, with minimum or no consideration of system casual factors. That's absurd. (Manuele, 2003)

The "mono-causality" of the BBS approach is pointed out by Hopkins (2006). As Reason (2000) and Hopkins (2006) illustrate, an almost infinite network of causes can contribute to an incident, all of them causes in the sense that, had they been different, the incident would likely not have occurred.

While Manuele (2003) suggests that Heinrich's premise that 88% of occupational incidents are caused by unsafe acts is a "huge problem" as it makes the safety profession focus on the wrong priorities, Difford (2012) insists that multiple causation theory is disproved by him and revises Henrich's 88% to "a logical 98%." According to Difford (2012), the management failure as a cause of incidents is a myth.

The multiple causation theory and Difford's statement that "human behavior, suitably defined will be the underlying cause of any accident" (natural phenomena aside) cannot coexist. Difford states that "organizations with systems that are in full legal compliance and that achieve 100% in their audit returns are simply awaiting an injury-producing or environment-damaging accident." Difford, however, concurs that those systems must be in place.

The logical questions are then: Why must those systems be in place? What role do they play? How much attention must be paid to management systems and engineering controls?

BP's Comprehensive List of Causes incident root-cause analysis system utilized by many companies classifies incident causes by immediate causes and system causes. It lists actions (four categories) and conditions (four categories) among the immediate causes, and personal factors (six categories) and job factors (nine categories) among the system causes. A total of 23 categories or immediate and system causes are further divided into multiple subcategories, providing almost 300 incident cause options for an investigator to choose from. This tool provides a good illustration of multiplicity of incident causes. The behavior category is listed among personal factors (such as physical capability, physical conditions, mental state, mental stress and skill level). The Comprehensive List of Causes system allows for limitless combinations of various incident cause parameters.

Behavioral Psychology Model

The behavioral psychology model is one incident causation theory. A review of incident causation theories by Board of Canadian Registered Safety Professionals (BCRSP) discusses 24 such theories, and more exist. Following is the brief description of the behavioral psychology model:

> The Behavioral Psychology Model assumes that individuals are not receiving the right mix of positive rewards and negative sanctions to reinforce safe behavior. This branch of psychology, which is somewhat outdated, treats the human mind like an unknowable "black box." A worker's reluctance to wear protective equipment is not addressed as an issue of cognitive persuasion or as an issue of answering the worker's

> concerns, but is instead viewed as a problem of changing physical behavior—habits—with assumption that a good attitude will follow the physical habit rather than the other way around. "Behavior-based safety" techniques are founded on behavioral psychology. An excellent source for the behavioral psychology approach is Scott Geller's text, *The Psychology of Safety Handbook*. . . . Behavior is motivated by its consequences, not primarily by thinking and free will. Self-esteem, attitudes and intentions cannot be scientifically studied according to this approach, but behavior can be studied and controlled. As Geller states: The basic idea is that behavior can be objectively studied and changed by identifying and manipulating environmental conditions (or stimuli) that immediately precede and follow a target behavior. The antecedent conditions ("activators") signal when behavior can achieve a pleasant consequence (a reward) or avoid an unpleasant consequence (a penalty). Therefore, activators direct behavior, and consequences determine whether the behavior will recur. Accordingly, people are motivated by the consequences they expect to receive, escape or avoid after performing a target behavior. The concepts are summarized as the "ABC Model"—activator-behavior-consequence. The ABC model decreases at-risk behaviors to avoid failures. (Strahlendorf, 2003)

Unsafe Act: Error, Habit or Violation?

While the percentage of incidents caused by unsafe acts is debated, some percentage of incidents clearly involve a human act—an error, a habitual action or an intentional safety violation. The error can be defined as "an unintentional deviation from an expected behavior" (Conklin, 2016), and a violation can be defined as a "deliberate, intentional act to evade a known policy or procedure requirement for personal advantage usually adopted for fun, comfort, expedience or convenience" (Conklin, 2016). Under workers' compensation acts, willful misconduct by an employee means that s/he intentionally performed an act with the knowledge that it was likely to result in serious injuries or with reckless disregard of its probable consequences.

The reduction and elimination of unsafe acts is a legitimate but not a comprehensive strategy due to a simple fact that humans tend to make unintentional errors. Human error studies form an extensive library. Dhillon (2013) provides a list of more than 500 publications on safety and human error. The human-error-proofed engineering controls would be the preferred solution. Human errors can be classified as operator errors, design errors, assembly errors, inspection errors, installation errors, handling errors, and maintenance errors (Dhillon, 2013).

The safety incident implications of those errors can include a person involved in a particular task, other people in the vicinity of that task or users of the product damaged by an error at some manufacturing phase.

HSE (2005) classifies unsafe acts into two major categories: intended actions and unintended actions (errors). Unintended actions (errors) are classified as:

1) slips: attention failures;
2) lapses: memory failures;
3) mistakes: rule-based (misapplication of a good rule or application of a bad rule) and knowledge-based (HSE, 2005).

Intended actions can be:

1) mistakes (same as above);
2) violations.

Violations can be:

1) routine: habitual deviation from regular practice;
2) exceptional/situational: nonroutine, directed by extreme/local circumstances;
3) acts of sabotage.

The ABC model and related BBS programs appear to be more applicable to the category of intended actions than to errors due to slip of attention, memory failure or a mistake. Selecting qualified personnel, providing training and controlling fatigue would lead to reduction of errors. Engineering controls would eliminate the effect of some errors. In addition, the level of errors would probably not be affected by the level of safety culture in the group but rather by group members' competence, physical and mental condition and level of fatigue. The level of safety violations would be a function of safety culture plus additional factors. For example, habitual failure to wear PPE would be a function of a safety culture and availability of PPE. According to Reason (2000):

> The human error [or unsafe acts and related incident] problem can be viewed in two ways: the person approach and the system approach. Each has its model of error causation and each model gives rise to quite different philosophies of error management.
>
> •The person approach focuses on the errors of individuals, blaming them for forgetfulness, inattention or moral weakness.
>
> •The system approach concentrates on the conditions under which individuals work and tries to build defenses to avert errors or mitigate their effects. (Reason, 2000)

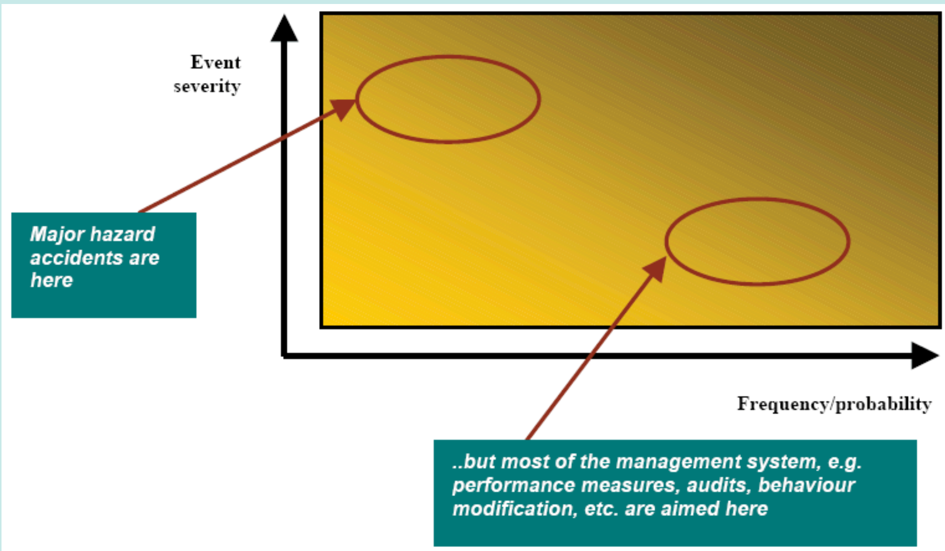
Reason (2000) further comments:

> Serious weakness of the person approach is that by focusing on the individual origins of error it isolates unsafe acts from their system context. As a result, two important features of human error tend to be overlooked. Firstly, it is often the best people who make the worst mistakes—error is not the monopoly of an unfortunate few. Secondly, far from being random, mishaps tend to fall into recurrent patterns. The same set of circumstances can provoke similar errors, regardless of the people involved. The pursuit of greater safety is seriously impeded by an approach that does not seek out and remove the error-provoking properties within the system at large. (Reason, 2000)

In other words, even assuming that Heinrich is correct and that 88% or more incidents are caused by unsafe acts, the root causes of those incidents can be related to unsafe conditions of work and

FIGURE 3

Misplaced Priorities in Safety



Note. From "Inspectors Toolkit: Human Factors in the Management of Major Accident Hazards," by Health and Safety Executive, 2005, Figure 6, p. 17.

systematic, programmatic, management and engineering deficiencies. Reason suggests:

> High-reliability organizations—which have less than their fair share of accidents—recognize that human variability is a force to harness in averting errors, but they work hard to focus that variability and are constantly preoccupied with the possibility of failure. (Reason, 2000)

Conklin (2016) concurs that 90% of operational upsets (incidents) are caused by a human error and the remaining 10% by equipment failures. However, according to Conklin, 70% of human-error-related operational upsets are system-induced and 30% are "slip, trip or lapse" or intentional violation. Only a small percentage of "unsafe acts" incidents are caused by intentional safety violations. According to Reason (2000), "in aviation maintenance some 90% of quality lapses were judged as blameless." Errors are seen as a result of the limitations of human nature (Conklin, 2016):

- stress;
- avoidance of mental strain;
- inaccurate mental models;
- limited working memory and attention resources;
- limited perspective;
- susceptible to emotion;
- focus on goal;
- fatigue.

It is important to emphasize that the ways to address an intentional safety violation (with disciplinary program) would differ from ways to address a human error or a habitual repetitive unsafe act.

It appears that the ABC model is more applicable to intentional safety violations or to simple reparative habitual acts (e.g., buckle up in a car, wear hard hat and safety glasses at a project site) and less to human errors in more complicated tasks or addressing the systemic root causes of such errors.

Applying disciplinary actions to an error judged blameless would be impractical and would lead to situations where errors, omissions, near-hits or even incidents would not be reported out of fear of the disciplinary action or lengthy bureaucratic incident investigation. That in no way contradicts the necessity to have effective and implementable disciplinary programs to deal with intentional safety violations and to develop and implement programs to reduce the errors or mitigate their effects.

Simplistically, following are the major ways to eliminate an incident:

1) Eliminate unsafe acts through incentives, discipline and work observations.

2) Eliminate unsafe acts through safety management system improvements.

3) Eliminate the consequences of committed unsafe acts (engineering controls).

4) A combination of the above.

Human Factors in the Hierarchy of Safety Controls

Several authors (Hopkins, 2006, United Steelworkers, 2000) have pointed out that BBS is concerned with the lower end of the hierarchy of safety controls. They have also commented that a focus on behavioral safety can lead to the abandonment of a commitment to the hierarchy of controls. Hopkins (2006) and United Steelworkers (2000) suggest that behavioral safety is one element of the administrative control—"changing the way people work." It is an important but not the dominating aspect. Abandonment of the hierarchy of safety controls may lead to situations in which the hazard management and engineering control aspects of safety are overwhelmed by the administrative controls, damaging the resulting program efficiency and regulatory compliance.

Human Factors in Limited Site Control Situations

Safe behaviors and prevention of unsafe acts are critical in situations where engineering controls may not be readily available, for example, during initial inspections of abandoned buildings where recognition, assessment and avoidance of hazards is a predominant way to avoid an incident and injury. As the project site develops, the level of control and assurance would increase, more engineering control options would become available and behavioral safety aspects would become less critical.

Human Factors in Reducing the Incident Rates

BBS program developers and users report significant reductions in occupational injuries through modifying workers' unsafe behaviors (Byrd, 2007).

The promise of significantly reduced occupational injury rates is difficult to evaluate. Their use by best-in-safety companies hinders evaluation, as these companies already demonstrate serious attention to safety. In addition, since injury rates become a key performance indicator, more attention is applied to postincident case management (Ivensky, 2015). Incident underreporting caused by fears of being blamed or becoming part of a lengthy, difficult investigation process is documented (Myketiak, 2015). In addition, the declining rate of serious injuries and fatalities is lower than that of minor incidents (Mangan, 2015).

Other studies indicate incident underreporting in application of BBS programs. According to a report by U.S. House of Representatives' Committee on Education and Labor (2008):

> Rewarding good behavior or punishing bad behavior, according to [BBS] philosophy, can prevent accidents. But experts in analyzing accident causation note that, since workers are human and inevitably make errors, the consequence of rewards or punishment is often a failure to report incidents, rather than a reduction of injuries and illnesses.

The case study involving KFM, a construction consortium rebuilding the eastern span of the San Francisco Bay Bridge in California, reported by Brown and Barab (2007), documents how the BBS process effectively suppressed reporting of worker injuries and illnesses on site. KFM reported injury and illness rates 55% to 72% lower than other bridge builders in the Bay Area, but Cal/OSHA issued willful citations to the consortium in June 2006 for failing to record 13 worker injuries on its OSHA 300 Log as required by law.

Placing the Blame & Fear of Reporting

Even if unsafe acts lead to incidents, this does not mean that employees should be blamed. "In the majority of cases—from 80% to 95%—accidents are caused by unsafe behavior. This statement emphatically does not mean that the injury is the employees fault" (Krause, 1997).

However, many employee groups and unions perceive BBS as a blame-the-worker program. In that aspect, a willful safety violation, habitual unintentional action or an error may be confused by an investigator. Corrective actions would study and modify a particular person's behavior. Even in the absence of disciplinary actions, being at the center of an investigation that involves members of the senior management team is not enjoyable for an injured worker unless the investigative team removes blame in situations that do not involve willful intentional safety violations or negligence.

The problem of placing blame for errors, associated fear of reporting and "blame culture" impeding improvements is well studied, for example, in the medical field (as related to medical errors). Myketiak (2015) summarizes the following effects of blame culture in the medical field:

- Staff becomes resistant to report errors after they occur.
- Underlying issues leading to the error do not get broached.
- The frequency of errors is overlooked.
- Good employees may lose their jobs (and others may choose to go into other careers).
- Patients become fearful.
- Bad publicity occurs.
- Transformational change is unlikely.

In addition, she summarizes the drawbacks of blame culture in the medical field:

- fear and anxiety about potential errors;
- guilt and shame after making errors;
- lowered reporting of medical errors;
- limited dialogue about errors because of fear of retribution;
- lack of understanding about the causes of medical errors;
- inability to prevent future errors.

Further, Myketiak (2015) suggests alternatives to the blame culture:

- a culture where learning and accountability are balanced with responsibility;
- a holistic, multifaceted approach to error management that engages the entire system;
- a reporting procedure that is not based on fear but on how the system and individuals can learn from and prevent errors.

Depressed reporting of minor- to medium-severity incidents and near-hits is an important characteristic of a developed blame culture. Severe incidents will continue to be known as they are more difficult to hide. That characteristic matches the current trends in occupational injuries with a growing gap between declining minor- to medium-severity incident rates and serious injury and fatality (SIF) rates that have declined at a slower pace (Mangan, 2015; Manuele, 2003). Setting up extreme goals for safety performance where each minor incident is considered unacceptable and causes wide-ranging effects may help create a blame culture. Incident investigators must be trained to separate willful safety violations or negligence from human errors, and must look beyond the immediate causes into the root causes of incidents that may include systemic and operational deficiencies.

Serious Incident Prevention

Concentrating on high-frequency/probability, simple and easily observable events (e.g., speeding, not wearing a hard hat, wrong lifting techniques), while beneficial, may obscure addressing more sophisticated and not easily observable hazards that require professional safety support and may delay implementation of needed engineering and systemic controls, the ultimate area of concentration (Figure 3).

HSE (2015) suggests finding the real, controllable key performance indicators. This may include compliance with critical safety procedures, compliance with the company policy on working hours,

Each element of an occupational safety program plays an important role, yet many organizations continue to stress one at the expense of the others, creating an unbalanced and ineffective OSH program.

detailed review and monitoring of occupational exposures to chemical substances, identified and corrected safety deficiencies or hazards or procedure reviews.

Manuele (2003) shares a similar concern:

> Unfortunately, many safety practitioners continue to act on the premise that if efforts are concentrated on the types of accidents that occur frequently, the potential for severe injury will also be addressed. That results in the severe injury potential being overlooked, since the types of accidents resulting in severe injury or fatality are rarely represented in the data pertaining to the types of accidents that occur frequently. A sound case can be made that many accidents resulting in severe injury or fatality are unique and singular events.

Manuele (2003) also states that Heinrich's related premise that the predominant causes of no-injury incidents are identical to the predominant causes of incidents resulting in major injuries is invalid.

Mangan (2015) suggests that:

1) A typical BBS observation does not probe deep enough to discover and document SIF exposures, so the observation process must be modified.

2) Observation sheets must include not only behaviors, but also conditions and management controls.

3) Observers must receive specialty training so they are able to observe high-risk situations and can effectively interview the worker on the exposures and management controls.

Mangan (2015) also suggests that the discrepancy between minor incident rates and serious incident rates exists, in part, because practitioners treat all incidents the same, while roughly only 20% of incidents have a potential to become an SIF. He indicates positive development in BBS-driven programs toward integration in a comprehensive safety model:

1) According to Mangan (2015), observation sheets must include conditions (site hazards) and management controls in addition to behaviors. That modification would make them comprehensive safety inspection/audits with the integrated BBS element. Management system controls are difficult to observe (or if observed, difficult to judge whether appropriate) without the review of multiemployer project management system, contracts and documentation such as safety and health plans. Recognition of exposures to critical site hazards caused by deficiencies in engineering controls may also require special technical, engineering and safety knowledge.

2) Specialty training for the observer must include basic safety training (e.g., OSHA 30-hour construction course) and should include a basic understanding of safety management at multiemployer project sites, not just additional interviewing skills.

High-Hazard Industries

The key point here is that the universal lagging indicator of safety performance is OSHA's recordable incident rates. While this may seem logical, focusing on occupational injury rates as the main (and often only) indicator of any company's safety performance has shortcomings, especially for high-hazard industries. As Hopkins (2000) states, "Reliance on lost-time injury data in major hazard industries is itself a major hazard."

The importance of correctly selected key performance indicators is well illustrated by an example from the airline industry. Airlines would define their safety performance by the number and severity of plane mishaps per year or per million miles, not by the number of strains and sprains sustained by pilots. According to Anderson (2006):

> The majority of major hazard sites [in high-hazard industries] still tend to focus on occupational safety rather than on process safety and those sites that do consider human factors issues rarely focus on those aspects that are relevant to the control of major hazards. For example, sites consider the personal safety of those carrying out maintenance, rather than how human errors in maintenance operations could be an initiator of major accidents. This imbalance runs throughout the safety management system, as displayed in priorities, goals, the allocation of resources and safety indicators.

The same point is included in the report of the 2005 Texas City refinery disaster investigation:

> [The company] uses the Comprehensive List of Causes (CLC) for both personal safety accidents and process safety accidents. As a result, the checklist CLC approach may tend to bias the analysis toward looking at human error as opposed to engineering and management issues. In the Panel's opinion, the causal factors involved in occupational or personal safety inci-

> dents and process safety incidents typically are very different. The use of personal safety incident hypotheticals as the only examples in some of the training materials that the Panel reviewed may inadvertently reinforce this bias. . . .
>
> The human error analysis, which focuses investigators' efforts on personal safety aspects of incidents rather than on all aspects of an incident, may introduce additional bias in the analysis toward finding behavioral root causes. (BP U.S. Refineries Independent Safety Review Panel, 2007)

As Hopkins (2000) says, "creating the right mind-set is not a strategy which can be effective in dealing with hazards about which workers have no knowledge and which can only be identified and controlled by management."

Conclusion: Part 1

The three key elements of a modern occupational safety program are engineering and technical standards and controls, management and operation systems, and human factors. Each element plays an important role, yet many organizations continue to stress one at the expense of the others, creating an unbalanced and ineffective OSH program. The human factor is present in most every incident, yet often the focus is too narrowly trained on blaming at-risk behaviors or unsafe acts rather than on identifying and addressing the conditions, systems and norms that enable or cause those errors.

Part 2 of this article (coming in February 2017) will examine how employers can better incorporate engineering and system elements into human-factor-oriented initiatives to create a more comprehensive approach to OSH and thereby better understand incident causes, reduce incident rates, confirm regulatory compliance, and prevent serious injuries and fatalities. **PS**

References

Anderson, M. (2006). Behavioral safety and major accident hazards: Magic bullet or shot in the dark? Merseyside, U.K.: Health and Safety Executive.

ANSI/ASSE. (2012). Occupational health and safety management systems (ANSI/ASSE Z10-2012). Des Plaines, IL: ASSE.

BP U.S. Refineries Independent Safety Review Panel. (2007, Jan.). The report of the BP U.S. Refineries Independent Safety Review Panel (Baker Panel Report). Retrieved from www.csb.gov/assets/1/19/Baker_panel_report1.pdf

British Standards Institute (BSI). (2007). Occupational health and safety management system requirements (BS OHSAS 18001:2007). London, U.K.: Author.

Brown, G.D. & Barab, J. (2007). "Cooking the books"—Behavior-based safety at the San Francisco Bay Bridge. *New Solutions: A Journal of Environmental and Occupational Health Policy*, *17*(4), 311-324.

Byrd, H. (2007). *A comparison of three well-known behavior-based safety programs: DuPont STOP Program, Safety Performance Solutions and Behavioral Science Technology* (Thesis). Rochester Institute of Technology.

Conklin, T. (2016). Human performance improvement. Los Alamos National Laboratory.

Dhillon, B. (2013). *Saftey and human error in engineering systems*. Boca Raton, FL: CRC Press.

Difford, P. (2012, Jan.). The cause of the next industrial accident: Will it be man . . . or will it be myth? Retrieved from www.neucom.eu.com/documents/replytoassemanuele.pdf

Geller, E.S. (2000, Apr. 11). The 10 myths of behavior-based safety. Retrieved from www.ishn.com/articles/83587-the-ten-myths-of-behavior-based-safety

Geller, E.S. (2016). How to get more people involved in behavior-based safety: Selling an effective process. Retrieved from www.behavior.org/resources/332.pdf

Health and Safety Executive (HSE). (2005, Oct.). Inspectors toolkit: Human factors in the management of major accident hazards. Retrieved from www.hse.gov.uk/humanfactors/topics/toolkit.pdf

Hopkins, A. (2000). *Lessons from Longford*. Sydney, Australia: CCH Australia.

Hopkins, A. (2006). What are we to make of safe behavior programs? *Safety Science*, *44*(7), 583-597.

Ivensky, V. (2015, Aug.). Reporting and recordkeeping requirements: Their influence on safety management in the U.S. and the U.K. *Professional Safety*, *60*(8), 34-37.

Krause, T.R. (1997). *The behavior-based safety process: Managing involvement for an injury-free safety culture*. New York, NY: Van Nostrand Reinhold.

Mangan, M.D. (2015, Feb. 21). Safety in practice: Applying behavior-based safety to serious and fatal injury prevention. *Safety + Health*, *50*.

Manuele, F. (2003). *On the practice of safety* (3rd ed.). Hoboken, NJ: Wiley-Interscience.

Monforton, C. & Martinez, J. (2015, Aug. 20). Monforton and Martinez: There's nothing 'safe' about DuPont. Retrieved from www.chron.com/opinion/outlook/article/Monforton-and-Martinez-There-s-nothing-safe-6456101.php

Myketiak, C. (2015). *Blame discourses*. London, England: Queen Mary University of London.

Reason, J. (2000, Mar. 18). Human error: Models and management. *BMJ*, *320*(7237), 768-770.

Smith, S. (2007, Oct. 1). Behavior-based safety: Myth or magic? *EHS Today*. Retrieved from http://ehstoday.com/safety/ehs_imp_75429

Smith, T.A. (1999, Sept.). What's wrong with behavior-based safety? Retrieved from www.mocalinc.com/id59.htm

Step Change in Safety. (2001). *Changing minds: A practical guide for behavior change in the oil and gas industry*. Aberdeen, U.K.: Author.

Strahlendorf, P. (2003). Accident theories. In *Board of Canadian Registered Safety Professionals (BCRSP) Study Guide*. Mississauga, Ontario: BCRSP.

U.S. Army Corps of Engineers. (2014). Safety and health requirements manual (EM 385-1-1). Washington, DC: Department of the Army, Author.

U.S. House of Representatives Committee on Education and Labor. (2008, June). Hidden tragedy: Underreporting of workplace injuries and illnesses. Washington, DC: Author.

United Steelworkers Local 343. (2000). Local 343 says no to behavioral safety at Alcan. Retrieved from http://www.oocities.org/local343/new.html

United Steelworkers. (2000). The steelworker perspective on behavioral safety: Comprehensive health and safety vs. behavior-based safety. Retrieved from http://assets.usw.org/resources/hse/Resources/uswbbs.pdf