

Optimizing Safety Engineering, Systems, Human Factors: Part 1

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. 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.

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. Government 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, construction industry standard 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. Violating any of those (and many similar) specifications constitutes a violation. It is illegal to allow employees to work in an environment that does not comply with Government regulations.

Systems

Government regulations do not prescribe content for safety management systems. 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.

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:

- ISO 18001 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.

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 capsized 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 . 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 . 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 habitual 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:

- 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

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 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.

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.

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%).

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.

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

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.

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.

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 knowledgebased (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 42 Professional Safety January 2017 www.asse.org 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 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.

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" .

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). Mykietiak 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, it 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. 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 .

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

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.

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.

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 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.

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