Preventing Serious Injuries & Fatalities

Time for a Sociotechnical Model for an Operational Risk Management System

By Fred A. Manuele

Results of recent attempts to reduce serious injuries and fatalities cannot be considered stellar. In 2007, a national forum on Fatality Prevention in the Workplace was sponsored by Indiana University of Pennsylvania in cooperation with the Alcoa Foundation. Many speakers suggested tweaking elements in existing occupational risk management systems.

At about the same time, ORC Worldwide (now Mercer HSE Networks), an organization whose members represent about 120 of the Fortune 500 companies, conducted a study to identify the characteristics of serious injuries and fatalities. The intent of the study, which was partially achieved, was to provide member companies information on how to improve reduction efforts.

In announcing the Alcoa Foundation grant to support the fatality prevention forum, Lon Ferguson (2007) said:

> Reliance on traditional approaches to fatality prevention has not always proven effective. This fact has been demonstrated by many companies, including some thought of as top performers in safety and health, as they continue to experience fatalities while at the same time achieving benchmark performance in reducing less-serious injuries and illnesses.

Ferguson's statement still applies, particularly the idea that "reliance on traditional approaches to fatality prevention has not always proven effective." Companies with outstanding records showing reductions in less-serious injuries may not have had similar reductions for serious injuries and fatalities. At Mercer HSE Networks, about 40 companies are involved in a study to determine what can be done to reduce occupational fatalities. Such studies are important, but major innovations in safety management systems are needed as well. Tweaking systems in place will not achieve the substantial improvements desired.

IN BRIEF
- From 1971 to 2005, the occupational fatality rate per 100,000 employees decreased 58%—from 17.0 in 1971 to 4.0.
- From 2006 through 2011, however, the rate has remained relatively stationary, ranging from 3.9 to 3.5, and strategies to reduce the number of fatalities and the fatality rate have made little progress.
- Major and somewhat drastic innovations in the content and focus of occupational risk management systems are needed to improve fatality and serious injury prevention.

Scope of This Article

Serious injuries and fatalities are treated as one subject in this article for several reasons. Many serious injuries could have been fatalities under slightly different circumstances. Thus, data on serious injuries (and near-misses) should be analyzed because the results may provide valuable information on actions to be taken to prevent fatalities and other serious injuries. In addition, causal factors for serious injuries and the

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Table 1

Claims Frequency Trends

Value of claim	Reduction
Less than $2,000	34%
$2,000 to $10,000	21%
$10,000 to $50,000	11%
More than $50,000	7%

Note. *Data from 1999 and 2003, expressed in 2003 hard dollars. Adapted from "State of the Line," by D. Mealy, 2005, National Council on Compensation Insurance News Bulletin.*

Table 2

Serious Injury Claims Decline Lags

Claim value	Reduction
Less than $2,000	25%
$2,000 - $10,000	22%
$10,000 - $50,000	20%
$50,000 - $250,000	14%
More than $250,000	9%

Note. *Adapted from "Workers' Compensation Claim Frequency," by J. Davis & Y Bar-Chaim, 2011, National Council on Compensation Insurance.*

actions necessary to prevent them are identical to those for fatalities. Many organizations do not have fatalities, but they may have serious injuries. As will be discussed, data derived from analyses of serious injuries may be influential in achieving attention to incidents that have fatality potential.

A Statistical Review

Serious Injury Trending

A 2005 National Council on Compensation Insurance (NCCI) research brief states that "there has been a larger decline in the frequency of smaller lost-time claims than in the frequency of larger lost-time claims." As Table 1 shows, the reduction in cases valued from $10,000 to $50,000 is about one third of that for cases valued at less than $2,000. For cases valued above $50,000, the reduction is about one fifth of that for the less-costly injuries. Thus, costly claims—those for serious injuries and fatalities—loom larger within the spectrum of all claims reported.

As the data in Tables 1 and 2 show, claims for serious injuries and fatalities loom large within the spectrum of all claims reported. The data in Table 3 indicate that the fatality record has plateaued in recent years.

In 2011, NCCI (Davis & Bar-Chaim) reported that from 2005 through 2009, "after accounting for wage and medical cost inflation, claims below $50,000 exhibited a greater rate of decline than those above $50,000" (Table 2). These data are in concert, generally, with the trending shown for the years 1999 through 2003. Reductions in less-serious injuries are substantially more than those for more serious injuries. In its 2009 State of the Workers' Compensation Line Report (Mealy, 2009), NCCI reported that injury frequency had declined consistently for all injury types except for permanent total disabilities.

In 2011, NCCI also noted that "workers' compensation claim frequency for lost-time claims has increased 3% in 2010. This represents the first increase since 1997 and only the third time that frequency has increased in the last 20 years." This upward claim frequency trend is relative to the increase in fatalities for 2010 (Table 3).

Fatality Trending

Data presented in Table 3 are based on excerpts from *Accident Facts* (NSC, 1995) and the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries, 1996-2011. In both datasets, the fatality rate is the number of fatalities per 100,000 workers.

Data for 2011 are preliminary. BLS expects to issue a final report for the 2011 year in April 2013 (as this issue went to press). For previous years, the average increase in the number of fatalities in the final report was 166. Add that number to 4,608 and the total is 4,775—an increase over 2010 even though fewer people were working with fewer hours of exposure.

Reductions in the number of fatalities and fatality rates are huge and commendable, and they indicate growth in management enlightenment, technology improvements, and an extended application of hazard identification, risk assessment, and avoidance and reduction techniques.

The data in Table 3 indicate that the fatality record has plateaued in recent years. Fatality rates over the past 6 years range from 3.9 to 3.5 with an average of 3.7. Some might say that the low-hanging fruit has been picked and that achieving further substantial reductions will require exceptional efforts.

Developing Fatality Data for Individual Industry Categories

All of the preceding data is macro. It pertains to all occupations. Further studies of industry categories are needed to examine trending of fatali-

Table 3

All Fatalities, All Occupations: 1971 to 2011

Year	Fatalities	Fatality rate
1971	13,700	17
1981	12,500	13
1991	9,800	8
2001	5,900	4.3
2002	5,524	4.0
2003	5,559	4.0
2004	5,703	4.1
2005	5,702	4.0
2006	5,703	3.9
2007	5,488	3.7
2008	5,214	3.7
2009	4,551	3.5
2010	4,690	3.6
2011	4,608	3.5*

Note. **Data for 2011 are preliminary. Adapted from* Accident Facts, *by National Safety Council, 1995, Itasca, IL: Author; and "Census of Fatal Occupational Injuries, 1996-2011," by Bureau of Labor Statistics, Washington, DC: Author, U.S. Department of Labor.*

ties and fatality rates and the types of activities in which fatalities occur. This is so that innovations aimed at reducing serious injuries and fatalities should pertain specifically to operational needs. While generalities can be suggested with respect to the content and order of elements in an occupational risk management system, emphasis in the application of those elements should result from studies that determine where the largest opportunities lie and where the emphasis should be.

Building Interest in Serious Injury & Fatality Prevention

For this discussion, data for the manufacturing industry were selected to illustrate that annual fatality rates are in a narrow statistical range and that the statistical probability of an organization having a fatality is low. Methods to achieve an interest in the subject are also discussed.

Consider the data presented in Table 4. (Select any industry and comparable data can be produced.) Fatality rates fall within a very narrow range. For the 6 years shown, the average fatality rate is 2.27. This author projected data contained in a once-in-5-years report issued by the U.S. Census Bureau for 2007 and estimated that there were about 300,000 manufacturing locations in the U.S. in 2010. BLS (2011) reports that manufacturing had 11,575,000 employees in that year. A small percentage of manufacturers reported the 320 fatalities that occurred in 2010. Many have never had a fatality.

To focus needed attention on serious injury and fatality prevention in organizations that have had no or very few fatalities over a period of many years, SH&E professionals should focus on the potential for serious injuries and fatalities based on:

•serious injuries that occurred;

•less-than-serious injuries that could have been serious in other circumstances;

•selected near-misses that had serious injury potential.

As noted, reducing the number of serious injuries and fatalities will require major innovations in occupational risk management systems.

Innovations to Be Considered

Bringing the necessary attention to serious injury and fatality prevention will require enormous culture changes as well as recognition of how deeply some deterring premises are embedded in many companies. Following are several innovations to consider, and other safety professionals may want to add to the list.

•The premise that OSHA-related incidence rates are accurate measures of serious injury and fatality potential must be dislodged.

•The belief that unsafe acts of workers are the principal causes of occupational incidents must be uprooted and dislodged.

•The broadly held assumption that reducing the frequency of less-than-serious injuries will result in an equivalent reduction in serious injuries must be dislodged.

•Risk assessments must be recognized and established as the core of an operational risk management system.

•Prevention through design concepts must be instituted as an element within an operational risk management system.

•Businesses must understand the ongoing transition concerning the prevention of human error, which directs prevention efforts to the design of the work system and work methods.

•Management of change/prejob planning must be a separate and emphasized element within an operational risk management system.

•Incident investigations must be improved so that shortcomings in management systems related to serious injury and fatality potential can be identified and addressed.

•Internally published operational risk management systems must be revised in relation to the foregoing.

Although this article focuses on serious injury and fatality prevention, improving on or instituting these innovations will help reduce injuries at all severity levels.

Achieving a Culture Change

It will take a major educational undertaking to convince management, and subsequently all personnel, that achieving low OSHA incident rates does not indicate that controls are adequate with respect to serious injury and fatality potentials. For more than 40 years, low OSHA incident rates have been overemphasized, resulting in competition within companies and among companies within an industry group. When achieving low OSHA incidence rates is deeply embedded within an entity's culture, uprooting and dislodging it will be a challenging, long-term effort. A culture change is not a one-time activity. It is a long journey that must engage all members of an organization.

In the culture change process, SH&E professionals must make the case that priority attention be given to recognizing and avoiding hazardous situations with serious injury potential. This approach must be tailored to the given entity's needs and opportunities. For example, consider these three potential courses of action.

1) Collect all incident investigation reports for a 3-year period, then select those that describe situations for which, under slightly different circumstances, the results could have been a more serious injury or fatality. This process could lead to analyses of operations in which the incidents occurred and advance the idea that serious injury potential needs special consideration.

Table 4

Manufacturing

Year	Fatalities	Fatality rate per 100,000 employees
2006	447	2.1
2007	392	2.4
2008	389	2.5
2009	304	2.2
2010	320	2.2
2011	322	2.2

Note. *Adapted from "Manufacturing Employment," by Bureau of Labor Statistics. Washington, DC: Author.*

Further studies of industry categories are needed to examine trending of fatalities and fatality rates and the types of activities in which fatalities occur.

2) Request a report of all workers' compensation claims valued at $25,000 or more for 3 years. Why this level? In the author's experience, a $25,000 cutoff level returns 6% to 8% of the total number of claims and 60% to 80% of total claims values. Of course, there have been outliers. For example, for a manufacturing company that also had a mining operation, 25% of cases valued at $25,000 or more represented 75% of total claims value. In another organization, 90% of total claims value came from 5% of the claims valued at $25,000 or more. In each case, valuable data were produced. Even for very large companies, the report output has been manageable.

3) Engage employees in an information gathering system that continuously reports on hazardous situations with serious injury potential. The system should include near-misses that could have resulted in serious consequences under slightly different circumstances. To succeed, the company must understand that employees who are encouraged to provide input are recognized as valuable resources because of their extensive knowledge about how work is performed. Also, they must be respected for their knowledge and skills. Feedback on employee input is a must.

The data collected should be mined for information to support a proposal that serious injury and fatality potential must be a focus. Specifically, job titles, units or departments that are prominent in the data should be reviewed, as should the types of operations in which the injuries occurred. For example, in several companies, 60% to 80% of injuries valued at $25,000 or more involved employees that were not making product.

SH&E professionals must also identify other methods to produce meaningful and convincing data relating to the inherent risks in an organization and its culture. This presents an opportunity for creativity.

Countering the Premise That Unsafe Acts Are the Principal Cause of Occupational Incidents

Manuele (2011) suggests that two myths related to the work of H.W. Heinrich need to be dislodged from the practice of safety. One of those myths is the premise that workers' unsafe acts are the principal cause of occupational incidents. Manuele addresses topics such as moving preventive efforts from a focus on employee to a focus on the work system; the design of the work system and the work methods; the complexity of causation; and human error occurring at organizational levels above the worker.

Response in support of the article was good. The feedback received indicates how deeply Heinrich's premise that 88% of accidents are caused by workers' unsafe acts is embedded in the organizations that safety practitioners advise. To more effectively prevent serious injuries and fatalities, this myth clearly must be dislodged from the practice of safety.

Reducing Injury Frequency Will Not Equivalently Reduce Severity

Heinrich's premises with respect to what had become broadly known as his 300-29-1 ratios varied in the first three editions of his book *Industrial Accident Prevention.* The following statement appeared in the third and fourth editions.

> Analysis proves that for every mishap resulting in an injury there are many other similar accidents that cause no injuries whatever. From data now available concerning the frequency of potential-injury accidents, it is estimated that in a unit group of 330 accidents *of the same kind and involving the same person* [emphasis added], 300 result in no injuries, 29 in minor injuries and 1 in a major or lost-time injury.

On its face, this statement cannot be substantiated. Heinrich also wrote that "in the largest injury group—the minor injuries—lies the most valuable clues to accident causes." That became the premise from which educators taught and many safety practitioners came to believe that reducing accident frequency will achieve equivalent reduction in injury severity. This myth is also deeply embedded in the minds of some safety practitioners and the management personnel whom they advise. It must also be dislodged. Statistical data presented in this article refute the premise. Based on thorough research through all four editions of Heinrich's book, the author has concluded that the 300-29-1 ratios are not supportable.

On Risk Assessments

Risk assessments should be established as the core of an operational risk management system as a separately identified element following the first element that would be comparable to management leadership, commitment, demonstrated involvement and accountability.

Europeans have long advocated risk assessments as a core value in injury and illness prevention. Other activity around the globe also promotes risk assessments. For example:

1) Guidance on the Principles of Safe Design for Work issued in 2006 by the Australian Safety and Compensation Council, an entity of the Australian government, includes a risk management process and promotes integrating risk management into the design process.

2) Requirements for risk assessments are more explicit in the 2007 revision of BS OHSAS 18001:2007, Occupational Health and Safety Management Systems—Requirements. Commonly known as 18001, this British Standards Institution publication states, "The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment and determination of necessary controls."

3) In 2008, the U.K. Health and Safety Executive issued "Five Steps to Risk Assessment." By law, all employers in the U.K. must conduct risk assessments.

4) ANSI B11.0: Safety of Machinery—General Safety Requirements and Risk Assessments applies to a broad range of machinery. Note that *risk assessments* is included in the title. It describes

procedures for identifying hazards, assessing and reducing risks to an acceptable level over the life cycle of machinery.

5) In March 2011, DOT's Pipeline and Hazardous Materials Safety Administration proposed modification of HazMat regulations to require that risk assessments be made of loading and unloading operations.

6) In August 2008, the European Union (EU) launched a 2-year campaign focusing on risk assessment. EU says this about the campaign:

> Risk assessment is the cornerstone of the European approach to prevent occupational accidents and ill health. If the risk assessment process—the start of the health and safety management approach—is not done well or not at all, the appropriate preventive measures are unlikely to be identified or put in place.

It is highly significant that the EU declared that "risk assessment is the cornerstone of the European approach to prevent occupational accidents and ill health." That statement is foundational and should be supported by safety professionals. Johnson (1980) expressed a companion view: "Hazard identification is the most important safety process in that, if it fails, all other processes are likely to be ineffective" (p. 245).

Two components must be addressed in developing a risk assessment—probability of occurrence and severity of outcome. Hazard identification and analysis establishes severity—the probable harm or damage that could result if an incident occurs. To convert a hazard analysis into a risk assessment, a probability of occurrence factor must be added. Then, risk levels can be established (e.g., low, moderate, serious, high) and priorities can be set.

A hazard is defined as the potential for harm. Hazards include all aspects of technology and activity that produce risk. Hazards are the generic base of, as well as the justification for, the existence of the practice of safety. If no hazards—no potential for harm—existed, safety professionals need not exist. The entirety of purpose of those responsible for safety, regardless of their titles, is to manage with respect to hazards so that the risks deriving from them are acceptable.

Thus, the case can be soundly made that risk assessment should be the core of an operational risk management system. In the author's experience, if workers at all levels have more knowledge and awareness of hazards and risks, fewer serious injuries and fatalities will occur. Getting the required knowledge embedded into workers' minds requires a major, ongoing endeavor. Specifically directed communication and training must be crafted to achieve the awareness and knowledge required—and to achieve the necessary culture change.

Risk assessment literature is abundant. For example, ANSI/ASSE Z690.3, Risk Assessment Techniques, reviews 31 techniques such as primary hazard analysis, fault tree analysis, hazard and operability studies, bow tie analysis, Markov analysis and Bayesian statistics. Uncomplicated systems that could be introduced to supervisors and frontline employees are not as prevalent. However, such a system is contained in an extension of the EU bulletin as a five-step approach:

1) Identify hazards and those at risk.
2) Evaluate and prioritize risks.
3) Decide on preventive action.
4) Take action.
5) Monitor and review results.

Empowering employees to competently assess risks and encouraging them to adopt a mind-set whereby identifying and analyzing hazards and their risks become integral to how they approach and think about work would be a major step forward in injury and fatality prevention. Having knowledge of hazard identification and analysis and risk assessments become rooted within an organization's culture is the type of innovative action needed to further reduce serious injury and fatality potential.

Prevention Through Design

Australia's Guidance on the Principles of Safe Design for Work discusses the contribution of machinery and equipment design to that country's fatality and injury rate. "Of the 210 identified workplace fatalities, 77 (37%) definitely or probably had design-related issues involved. Design contributes to at least 30% of work-related serious nonfatal injuries" (p. 6). The author's review of incident investigation reports (not limited to machinery) concluded that more than 35% had implications of workplace and work methods design inadequacies.

Therefore, to reduce serious injury and fatality potential, prevention through design (PTD) should be established as a separately identified element within an operational risk management system. To help educate designers, safety professionals can develop supportive data on incidents in which design shortcomings were identified and undertake a major effort to have ANSI/ASSE Z590.3-2011, Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes, accepted as a design guide.

> Z590.3 Scope: This standard provides guidance on including prevention through design concepts within an occupational safety and health management system. Through the application of these concepts, decisions pertaining to occupational hazards and risks can be incorporated into the process of design and redesign of work premises, tools, equipment, machinery, substances and work processes including their construction, manufacture, use, maintenance, and ultimate disposal or reuse. This standard provides guidance for a life-cycle assessment and design model that balances environmental and occupational safety and health goals over the life span of a facility, process or product.

Z590.3 says the goal is, as far as is practicable, to ensure that the design selected meets these criteria:

•An acceptable risk level, as defined in this standard is achieved.

If workers at all levels have more knowledge and awareness of hazards and risks, fewer serious injuries and fatalities will occur. Getting the required knowledge embedded into workers' minds requires a major, ongoing endeavor.

•The probability of personnel making human errors because of design inadequacies is at a practical minimum.

•The ability of personnel to defeat the work system and prescribed work methods is at a practical minimum.

•Prescribed work processes consider human factors (ergonomics)—the capabilities and limitations of the work population.

•With respect to access and maintenance, hazards and risks are at a practical minimum.

•The need for PPE is at a practical minimum, and aid is provided for its use where it is necessary (e.g., anchor points for fall protection).

•Applicable laws, codes, regulations and standards have been met.

•Any recognized code of practice, internal or external, has been considered.

Proposing that PTD be a specifically defined element in an operational risk management system is also influenced by ongoing transitions in the methods to eliminate or reduce the occurrence of human error.

Human Error Prevention

During ASSE's "Rethink Safety: A New View of Human Error and Workplace Safety" symposium, speakers commented on topics such as cognitive theory, properties of human cognition, variable errors and constant errors, imperfect rationality and mental behavioral aspects of error. Regarding the sources of human error and corrective actions, some of the commentary was surprising. For example:

•The first step to be taken when human errors occur is to examine the design of the workplace and the work methods.

•Managers may wish to address human error by "getting into the heads" of their employees with training being the default corrective action; training will not be effective if error potential is designed into the work.

•It is management's responsibility to anticipate errors and to have work systems and work methods designed so as to reduce error potential.

Given this, SH&E professionals should study the specifics of a particular situation and the types of errors that may occur, such as those involving complacency when high-hazard tasks are performed repetitively. Dekker (2006) provides insight into what is happening in the human error field. Several excerpts from *The Field Guide to Understanding Human Error* follow.

> Human error is not a cause of failure. Human error is the effect, or symptom, of deeper trouble. Human error is . . . systematically connected to features of people's tools, tasks, and operating systems. (p. 15)

> Sources of error are structural, not personal. If you want to understand human error, you have to dig into the system in which people work. You have to stop looking for people's shortcomings. (p. 17)

> "Rather than being the main instigator of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking." (p. 88, citing Reason, 1990, p. 173)

> The systemic accident model . . . focuses on the whole [system], not [just] the parts. It does not help you much to just focus on human errors, for example, or an equipment failure, without taking into account the sociotechnical system that helped shape the conditions for people's performance and the design, testing and fielding of that equipment. (p. 90)

> System accidents result not from component failures, but from inadequate control or enforcement of safety-related constraints on the development, design and operation of the system. (p. 91)

This transition in the human error field—moving from a focus on attempting to change worker behavior to an emphasis on improving the design of the system in which people work—also supports the premise that PTD be a specifically defined element in an operational risk management system.

Management of Change/Prejob Planning

Management of change (MOC)/prejob planning is a process to be applied before modifications are made and continuously throughout the modification activity to ensure that:

•hazards are identified and analyzed, and risks are assessed;

•appropriate avoidance, elimination or control decisions are made so that acceptable risk levels are achieved and maintained during the change process;

•new hazards are not knowingly created by the change;

•the change does not have a negative effect on previously resolved hazards;

•the change does not make the potential for harm of an existing hazard more severe.

In the MOC process, safety professionals should consider the safety of employees making the changes, employees in adjacent areas and those who will be engaged in operations after changes are made. Other considerations include environmental issues, public safety, product safety and quality factors, and avoiding property damage and business interruption.

The author's review of more than 1,700 incident investigation reports, mostly for serious injuries and fatalities, supports the need for and the benefit of MOC systems. These reports showed that a significantly large share of the incidents occurs:

•during unusual and nonroutine work;

•in nonproduction activities;

•in at-plant modification or construction operations (e.g., replacing a motor weighing 800 lb on a platform 15 ft above the floor);

•during shutdowns for repair and maintenance, and startups;

•where sources of high energy are present (electrical, steam, pneumatic, chemical);

•where upsets occur (situations going from normal to abnormal).

Having an effective MOC system would reduce the probability of serious injuries and fatalities occurring in these operational categories.

Petersen (1998) was an early promoter of giving particular attention to serious injury prevention.

> If we study any mass data, we can readily see that the types of accidents that result in temporary total disabilities are different from the types of accidents resulting in permanent partial disabilities or in permanent total disabilities or fatalities. The causes are different. There are different sets of circumstances surrounding severity. Thus, if we want to control serious injuries, we should try to predict where they will happen. Today, we can often do just that. (p. 12)

The key to Petersen's message is prediction. The prior list of work activities was based on reviewing injury and fatality reports. Each entity should develop its own list based on inherent risks and history.

Tom Krause (personal communication) provides additional and substantial support for having an MOC system. Seven companies participated in a 2011 study. Incidents with serious injury or fatality potential were separated from the reports collected. Prejob planning shortcomings were noted in 29% of the incidents that had serious injury or fatality potential. For the nonserious injury potential group, these inadequacies were identified in 17%.

Experience in the auto industry also highlights the benefits of an MOC system. A United Auto Workers (UAW) bulletin covering 1973 through 2007 (no longer available) indicated that 42% of fatalities involved skilled-trades workers, who made up about 20% of the membership. UAW personnel provided data in 2012 (via personal e-mail and phone correspondence) indicating that from 2008 through 2011, 47% of fatalities involved skilled-trades workers. Skilled-trades workers in every industry are often involved in unusual and nonroutine work, at-plant modification or construction operations, shutdowns for repair and maintenance, startups and where sources of high energy are present. The data clearly establish that having an MOC system in place as an element within an operational risk management system can diminish the potential for serious injuries and fatalities.

Incident Investigation

Incident investigation reports may include valuable data on predictive indicators pertaining to serious injury and fatality potential. But, the gap between issued investigation procedures and what actually takes place can be huge. Even in the best safety management systems, incident investigation can be low quality. For example, one large organization determined that if its safety staff promoted adoption of a system as uncomplicated as the five-why technique to improve incident investigation and achieved a B+ grade in 2 years it would be an astounding result.

Therefore, incident investigations should be assessed to identify areas for improvement. Such evaluations often indicate that culture problems exist and that it has become accepted practice for supervisors, managers and safety practitioners to sign-off on shallow investigation reports.

Because of the significance of the information that can be produced, incident investigations must be high quality to reduce the potential for serious injuries and fatalities. Successful investigation systems for near misses that could have resulted in serious results in slightly differing circumstances may also produce critical predictive indicators.

Macro Thinking: The Sociotechnical Concept

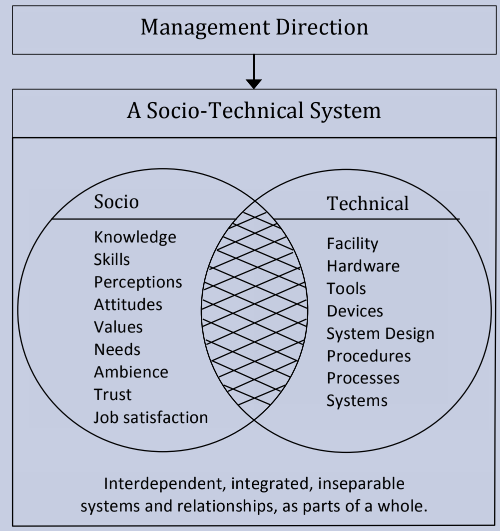
Taking a macro view of systems as a whole and adopting the sociotechnical concept (Figure 1) will advance the state of the art in the practice of safety. Several writers say that the term *sociotechnical* was coined in the 1960s by Eric Trist and Fred Emery, then consultants at the Tavistock Institute in London. Researchers at Tavistock said that, based on their research and experience, highly effective operations require a good fit between an organization's technical subsystems and its social subsystems.

According to Trist and Emery, the interdependency of the technical and social subsystems must be recognized in the design process. Thus, the decision makers would be aware of the effect each subsystem has on the other and design accordingly to ensure that the subsystems work in harmony.

Although the term *sociotechnical systems* is not prominent in the current literature about the organization of work, the idea it conveys is dominant in conventional thinking about the interrelationship between the technical and social aspects of operations. As noted, Dekker (2006) speaks of "the sociotechnical system":

> The systemic accident model . . . focuses on the whole [system], not [just] the parts. It does not help you much to just focus on human errors, for example, or an equipment failure, without taking into account the so-

Figure 1
Sociotechnical System



Highly effective operations require a good fit between an organization's technical subsystems and its social subsystems.

Systemic Sociotechnical Model for an Operational Risk Management System

The board of directors and senior management establish a culture that requires maintaining acceptable risk levels in all operations.

Management leadership, commitment, involvement and the accountability system, establish that the performance level to be achieved is in accord with the culture established by the board.

To achieve acceptable risk levels, management establishes policies, standards, procedures and processes with respect to:

Providing adequate resources

Risk assessment, prioritization and management
- Applying a hierarchy of controls

Prevention through design
- Inherently safer design
- Resiliency

Maintenance for system integrity

Competency and adequacy of staff
- Capability—skill levels
- Sufficiency in numbers

Safety-related systems
- Training—motivation
- Employee participation
- Information—communication
- Work methods, scheduling
- Permit systems
- Inspections
- Incident investigation and analysis
- PPE

Management of change/prejob planning

Third-party services
- Relationships with suppliers
- Safety of contractors—on premises

Procurement—safety specifications

Emergency planning and management

Compliance assurance

Performance measurement: Evaluations are made and reports are prepared for management review to support continuous improvement and to ensure that acceptable risk levels are maintained.

> ciotechnical system that helped shape the conditions for people's performance and the design, testing and fielding of that equipment. (p. 90)

Dekker explains that operating systems should be considered and examined as a whole to properly determine solutions to problems. Definitions of a sociotechnical system vary in detail although they maintain the substance of what the originators of the term intended. The following definition is a composite that takes a holistic view:

> A sociotechnical system stresses the holistic, interdependent, integrated and inseparable relationship between humans and machines and fosters the shaping of both the technical and the social conditions of work in such a way that both the output goal of the system and the needs of [workers] are accommodated.

The technical aspects of a system include the facility, hardware, tools, devices, system design, physical surroundings and prescribed procedures. The social system consists of the knowledge and skills of employees, from the most senior management level to the newly hired; the attitudes that derive from their beliefs, values, needs, job satisfaction, respect, trust, relations with each other, workplace spirit and ambience, authority structures and reward system; and whether the site has an open communications system through which the views of all can be heard.

When seeking to improve an operational risk management system, SH&E professionals should consider a systems approach to determining the specifics of the recommendation and how the improvement may affect other operational aspects. In taking a sociotechnical systems approach, several concepts should be understood:

- An organization's technical and social systems are inseparable parts of a whole.
- The parts are interrelated and integrated.
- Changing one system may affect others.
- The organization and its employees are not well served if, when resolving a risk situation, the subject at hand is considered in isolation rather than as part of an overall system.

Through this approach, emphasis is given to the importance of the whole as an integrated system and the interdependence of its parts. A feedback process would be created to monitor alignment.

The Sociotechnical System & Safety Culture

Many definitions of safety culture include terms such as shared beliefs, attitudes, values and norms of behavior; shared assumptions; individual and group attitudes about safety; and entrenched attitudes and opinions which a group of people share. This author has used such terms. Note the frequent use of the term *shared.*

However, such definitions need examination. An organization's safety culture, which is a subset of its overall culture, derives from the decisions made at the executive level. An organization's culture with respect to occupational safety, environmental safety, public safety and product safety is determined by the outcome of management decisions as measured by the risk levels in a facility's technical and social aspects. Management owns the culture. Employees may or may not share the views and beliefs held by management with respect to safety and operational risk levels. For example, employees may believe that an operation is overly risky while management accepts the risk level. The culture created by management is the dominant factor with respect to the risk levels attained, acceptable or unacceptable.

Conclusion

The safety profession must consider adopting a systemic sociotechnical model for an operational risk management system (sidebar above, left) as a substantially different means to improve serious injury and fatality prevention. In this model, sociotechnical concepts should be foundational:

•at a board level, where establishing a culture begins;

•in the decisions made at a senior management level to demonstrate its involvement to achieve the culture and acceptable risk levels;

•in policies, standards, procedures and processes established;

•throughout the administration of all of the individual aspects of the operational risk management system.

It is close to the top level on a probability scale that acceptable risk levels can be achieved and maintained if an operational risk management system is built on this model and that superior financial results would be achieved as well. Effectively adopting the elements in this model will reduce serious injury and fatality potential. It will have the same effect on the occurrence of all other injuries.

Safety professionals are encouraged to take elements from this model, sequentially, that they believe can be fit into the management systems in place and which are compatible with an organization's culture. That said, each element in this model should be included in the ideal for an operational risk management system.

The model presented is a major departure from other outlines for a safety management system. However, it supports the position that "major and somewhat drastic innovations in the content and focus of occupational risk management systems will be necessary to achieve additional progress in serious injury and fatality prevention." **PS**

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