Preventing Major Injuries

Observations on Theory, Models & a Path Ahead

By David W. Wilbanks

IN BRIEF
- **The downward trend in the rate of workplace fatalities appears to have reached a plateau.**
- **Past and current theories and models are examined to identify lessons and actions that can be reliably incorporated to lower the likelihood and severity of major injury events, regardless of external factors, economic or otherwise.**
- **Broader applications of work permit systems are proposed as one specific priority.**

Major injury events occur in every type of workplace, large and small, sophisticated or otherwise. Those performing maintenance (Reason, 1990), construction and installation services are especially at risk after consideration is given to transportation, farm, forestry and fishing (BLS, 2013).

While the fatal injury rate declined between 2006 and 2011 (BLS, 2013), this good news is not without a caveat. The sharpest decline occurred between 2007 and 2009, a period that coincided with the onset of deep economic recession. This decline has reached a plateau (Figure 1), as has the recession apparently. A reasonable concern is that an improving economy will erase all gains as investment in construction and industry increase.

The inability to point to a specific or even a generalized breakthrough in safety practice does not ease this worry. Only time will affirm or deny this statistical trend. While the hope is that subsequent years will build on the recent gains, it is prudent to consider other strategies. One strategy could be to fundamentally alter the efforts for preventing major injury events for all at-risk workers in every industry segment.

The Perfect Setup

In 2011, 4,609 workers in the U.S. died on the job (BLS, 2013). Examples over a recent 14-day period include (OSHA):

•Florida: Worker killed after falling 30 ft while unloading tools from a forklift.

•Virginia: Worker died from head injuries after being struck by an excavator arm while trimming trees.

•Michigan: Worker installing insulation killed after falling 25 ft from roof.

•Ohio: Employee died from head injuries after falling off scaffolding.

•Michigan: Worker killed after being struck in the eye by a nail from a nail gun.

•Texas: Oil-rig worker killed when a counterweight fell 65 ft onto him during a rig shutdown.

•Illnois: Worker operating laser machine struck and killed by metal debris.

•North Carolina: Worker killed after being caught in saw machine at cabinetry facility.

•Louisiana: Employee crushed and killed by conveyor belt rollers undergoing maintenance.

•Pennsylvania: Employee killed after falling into a sugar hopper.

•California: Worker died after falling 14 ft to concrete on a construction site.

The presumption is that each victim was unexpectedly caught between what was believed to be true (the setup shown in Figure 2), or more specifically a condition of safety, and that which was true, the various and many factors conspiring to produce a nonsurvivable reality. The setup is usefully defined by one organization as a "high-risk situation in which management controls are either absent, ineffective or not complied with, and if allowed to continue or repeat could reasonably result in a serious injury or fatality" (BST, 2011, p. 4). The factors are most always obvious when examined in retrospect.

An example illustrates the setup:

> An employee intended to repair a parts washer basin. He turned the parts washer on its side to make the repair easier to access. Approximately 1 gallon of flammable solvent leaked out and onto the floor. He sprayed water on the floor to

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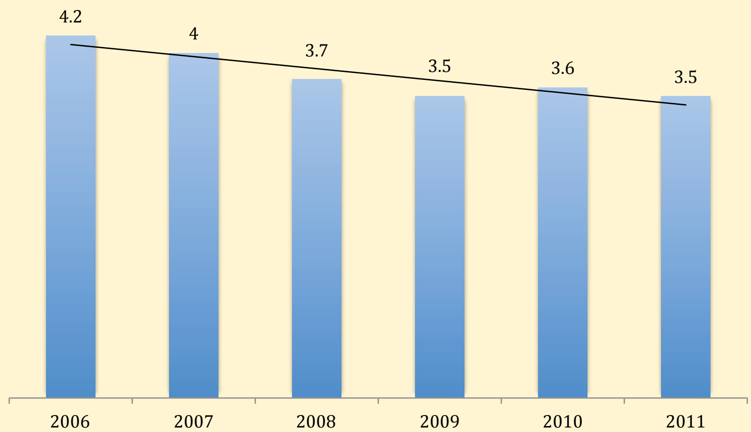
dilute the solvent, believing it would make the area safe to perform hot work, and began welding plates to the bottom of the parts washer solvent tank. The employee soon felt heat to his lower leg and saw that his pants and boots were on fire. He received second- and third-degree burns to his legs.

Figure 1
U.S. Rate of Fatal Injuries



Note. *U.S. rate of fatal injuries per 100,000 full-time workers. Adapted from "Census of Fatal Occupational Injuries," by Bureau of Labor Statistics, 2013.*

The fatal injury rate declined between 2006 and 2011. However, the sharpest decline occurred between 2007 and 2009, coinciding with the onset of deep economic recession. This decline has reached a plateau.

Humans Interacting in Complex Systems

Words such as *needless* are often used to describe the circumstances surrounding major injuries. More than needless, these events are usually meaningless in the technical sense because there is nothing to be learned. Modern society knows how to prevent most such events and has known for many years. Energy control and fall prevention failures comprise more than 50% of all fatal injuries (BLS, 2013), excluding transportation and homicides, and should easily provide the greatest overall improvement leverage. However, related lapses in countless examples give rise to a perpetual sense of what Yogi Berra calls "deja vu all over again."

- System failures? Yes, assuming protective systems were available to the deceased, but this must not be assumed.
- Risk taking rewarded? Possibly.
- Inadequate hazard awareness? Clearly.
- Inadequate compliance or legal oversight? Legal requirements are likely not met in many examples.

Harsh commentary has occasionally been offered in response to such incidents, essentially describing them as evolution in action; such an assertion diminishes both in wit and utility with a single step toward the lives of those harmed. But the societal coping mechanism of such humor reveals a collective frustration experienced, even among safety professionals, when humans interacting within complex systems (people, equipment, materials and the environment) appear to contribute directly, even excessively, to their own demise (Bird, Germain & Clark, 2003). Mainstream terminology still recognizes *human failures* (CCPS, 2008b, p. 16). But this simple term cannot responsibly be introduced as a conclusion to a complex problem. Rather, it must be treated as an important question requiring an answer (Dekker, 2002). It is only a starting point.

Figure 2
Focus of Heinrich's Central Factor Theory

Note. *Adapted from* Industrial Accident Prevention *(p. 13) by H.W. Heinrich, 1941, New York, NY: McGraw Hill.*

Relevant Models: Lessons, Past & Present

Heinrich

Seventy-five years ago, Heinrich's (1941) pioneering central factor (domino) theory helped many to better grasp the concept of cause and effect. Especially appreciative were safety practitioners who for the first time were provided a unified causation theory that could be communicated, understood and applied. It also affirmed, and with an air of science, what all intuitively just knew: careless people caused incidents. This is because the theory emphasized the unsafe act that could be quickly identified with the fault of one or more persons.

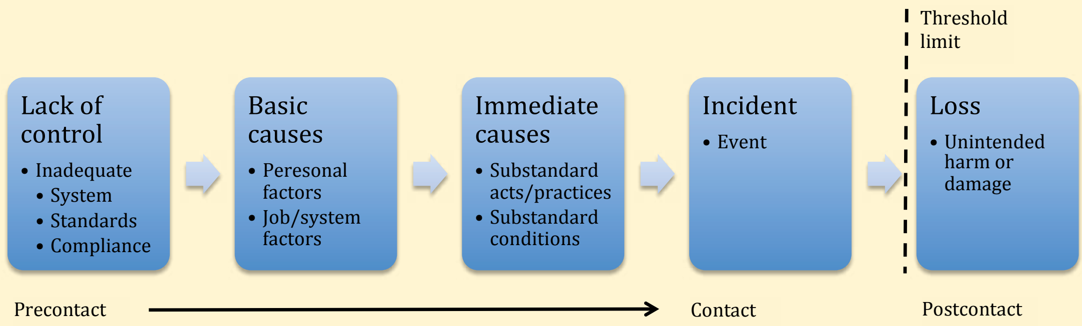
In retrospect, the importance placed on the unsafe act is no more useful than Darwinian suggestions of cause when examined today. Manuele (2003) believes that emphasis on the unsafe act has had the "greatest impact on the practice of safety, and has also done the most harm—since [it] promotes preventive efforts being focused on the worker, rather than on the operating system" (p. 142).

Recognizing the limits and errors of early theo-

Bird's model recognized the management system as the greatest opportunity for incident control.

Figure 3

Bird's Loss Causation Model



Note. *Adapted from* Practical Loss Control Leadership *by F.E. Bird, G. Germain and M.D. Clark, 2003, Duluth, GA: Det Norske Veritas.*

ry is critical to current progress. Still, the domino analogy provides an important, vivid reminder that interrupting the incident sequence will stop or alter the event. This includes the major injury event, the label and associated burden of the term *unsafe act* notwithstanding.

Bird

Heinrich's work was adapted by Bird, et al. (2003), who made several valuable improvements. The terms *substandard act* and *substandard condition* replaced the unsafe act; both were considered symptoms of an event's underlying basic or root causes (Figure 3). The management system was identified as the greatest opportunity for incident control, and the concepts of precontact, contact and postcontact control were incorporated. More recent improvements to this terminology are *standard* and *nonstandard* as better descriptors than substandard (W. Johnson, personal correspondence, Feb. 12, 2012). This is a nuanced but important distinction directing focus to observable, objective facts and not to the presumed faults of those present during the event.

This model arguably remains the most widely recognized and useful description for understanding incident causation and prevention theory. However, many who are victim to the setup resulting in major injury do not enjoy the benefit of a highly developed management system and likely will not, at least in the context found in a modern manufacturing environment of a Fortune 500 company, for example. It is also true that organizations with highly developed safety and health management systems continue to incur major injury events, however infrequent. Thus, the management systems solution is not yet fully satisfying even if it remains the most promising prospect.

Reason

A third model used in the context of human error is Reason's (1990) dynamics of causation (Figure 4).

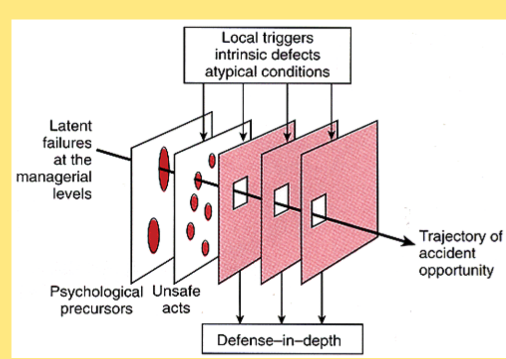
> [His diagram] shows a trajectory of accident opportunity penetrating several defensive systems. This results from a complex interaction between latent failures and a variety of local triggering events. It is clear from this model that the chances of such a trajectory of opportunity finding loopholes in all of the defenses at any one time is very small indeed.
>
> [Furthermore,] in highly defended systems, one of the most common accident scenarios involves the deliberate disabling of engineered safety features by operators in pursuit of what, at the time, seems a perfectly sensible goal. . . . On other occasions, the defenses are breached because the operators are unaware of concurrently created gaps in system security because they have an erroneous perception of the system state. (pp. 208-209)

Models & Major Injury Events: Conclusions

It is important to recognize that Reason's (2009) model is presented in the realm of understanding the contribution of human error to accident occur-

Figure 4

Reason's Dynamics of Accident Causation



Note. *Adapted from* Human Error *(p. 208), by J. Reason, 1990. Cambridge, U.K.: Cambridge University Press. Copyright 1990 Cambridge University Press. Reprinted with permission of Cambridge University Press.*

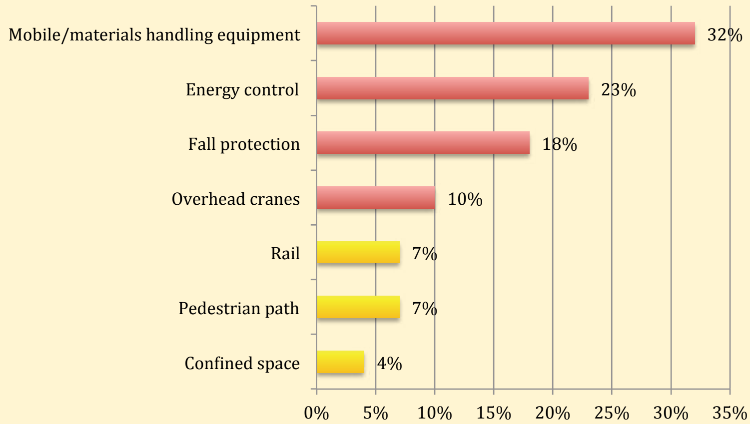
rence. He does not presume an unsafe worker but seeks to understand the basis for human error. When understood, human error illuminates effective strategies for better defending the system. Reason's model reinforces Heinrich's accident sequence interruption concepts and also acknowledges the influence of the larger system (managerial levels) as part of the setup for the worker's action, and so reinforces Bird, et al. (2003), as well.

The leverage for major injury prevention, then, is at least twofold: systems and human performance. It is not one or the other, but decidedly both: systems because they provide for generalized improvement and output predictability; and workers, not because they are the problem, but because they are integral to solving it or at least interrupting it. Remember, the worker always pays the dearest price and must frequently make independent, real-time decisions under pressure based on evolving data received during task performance. "Workers are in the best position to identify conditions and precursors that could lead to error" (Wachter & Yorio, 2013, p. 63).

Broadly defined, the worker includes airline pilots, ship captains, drilling roughnecks, electricians, operations managers, underground miners, temporary employees, construction workers, janitors, scientists and all others. In no way does this minimize the employer's responsibility to have and maintain a workplace free of serious hazards; however, it is acknowledged that all decision makers need help to make better decisions. All workers make decisions.

Figure 5

Steel Industry Fatalities



Note. *Steel industry fatalities, North America, 2006-2012.*

Data from the steel industry demonstrate that more than 80% of deaths, excluding industry-specific hazards, are from four exposures: mobile equipment, energy control, falls and overhead cranes.

Who Moved My Pyramid?

Much discussion in current literature jousts with the long-held and oft-cited incident ratio paradigms. The central tenet of common causes is the facet of the ratio models that are most ardently invoked. This tenet proposes that eliminating the causes of less severe but more frequent incidents will also proportionately reduce the frequency of greater severity events. Not so, says Krause (2012) who offers that "traditional safety efforts often fail to address serious injury and fatalities because they are not designed to" (p. 54). This can be principally ascribed to the fact that:

> Industry has long relied on Heinrich's safety triangle as an accurate depiction of the relationship between types of injuries. While it turns out that the model is accurate descriptively (less severe injuries do occur more frequently than more severe injuries), it is not accurate predicatively (there is not a constant ratio between injury types, as some people assert). (Krause, 2012, p. 54)

No stones are cast here at these models or at those who have voiced varying related opinions and clarifications. However, one can quickly become lost after just a few steps into what can be an academic journey. Even to the interested observer, the discourse can appear to have established a pattern of ever smaller and accelerating concentric circles until the listener's attention span is at risk of being lost.

The nightmare scenario for worker, family, coworker, organization and safety professional is the major injury event. But it is important to recognize that the latter group is rarely allowed to focus exclusively on major injury prevention, and that for many organizations an incident with lost days is considered a major injury. This presents a wide spectrum of conceivable outcomes that require control: the catastrophic multiple-fatality event to the relatively low-severity-potential event that prohibits a worker's return for as few as 1 day, and for what sometimes can be a relatively benign circumstance. Just as all causes are not created equal, nor is every major injury event.

The high(er) ground for all concerned with major injury prevention is that which can be gained (only) through the perspective of risk. This is simply defined as a function of probability (how often the hazard is encountered and the likelihood of a problem when it is encountered), and severity (how significant the loss is likely to be). This conclusion is born of a practical necessity to fish where there are fish.

Data informally collected by Steel Manufacturers Association (SMA) and shared with its membership (K. Gleason, Aug. 21, 2013) demonstrate that more than 80% of deaths, excluding industry-specific hazards, are from four exposures: mobile equipment, energy control, falls and overhead cranes (Figure 5). SMA's safety committee enjoys high participation and meets regularly to actively share best practices targeted at preventing all incidents, but with emphasis given to the hazards most associated with major injuries. The steel industry has performed its risk assessment and works to fish where there are fish.

If lower-risk hazards can be improved through controls that are common to high-risk hazards, they should be enthusiastically confronted. If both battles can be fought well, one should fight both high and low. But it is always more important to fight high(er)-risk hazards first, remembering that even Maslow offered long ago that self-actualization was not worth much without survival (Cherry). Should resource and reality dictate a practical choice, an industrial or other workplace equivalent to Sophie's Choice [a "choice between two persons or things that will result in the death or destruction of the person or thing not chosen" (Wiktionary, 2013)], choose well. Risk assessment helps one do so.

Permit Me, Please

Wilson (2013) notes that employees err most when frustrated, rushing, fatigued and/or complacent. Workers who otherwise would have performed their tasks with little or no risk are now confronted with much higher risk of incident because they are more prone to critical errors.

Manuele (2008) reports:

> A large proportion of incidents resulting in serious injuries and fatalities occur:
> - when unusual and nonroutine work is being performed;
> - when upsets occur, meaning normal operations become abnormal;
> - in nonproduction activities;
> - where sources of high energy are present;
> - in what can be called at-plant construction operations (e.g., a motor that weighs 800 lb and sits on a platform 15 ft above the floor needs to be replaced, and the work will be performed by in-house personnel). (p. 34)

Considering these two contributions and building on the prior discussions, one can conclude that systems designed to reduce the likelihood of the triggers for human error (noted by Wilson, 2013) during the performance of higher-risk activities (noted by Manuele, 2008) are basic keys to preventing the major injury event. This is exactly the environment for which permit-to-work systems are uniquely suited to be of benefit.

Work permits are the backbone for ensuring safety when performing tasks in process, chemical and allied industries, and are virtually assumed in an effectively implemented management of change system. As evidence, permit-to-work systems are scarcely discussed in *Guidelines for Management of Change for Process Safety* (CCPS, 2008b).

Health and Safety Executive (HSE, 2005) states:

> Permit-to-work systems form an essential part of the task risk assessment process. When a task is identified an appraisal should be carried out to identify the nature of the task and its associated hazards. Next, the risks associated with the task should be identified together with the necessary controls and precautions to mitigate the risks. The extent of the controls required will depend on the level of risk associated with the task and may include the need for a permit-to-work. (p. 5)

Lessons should be garnered where they are found. One lesson that is not in dispute is that process and chemical industries together report a rate that is approximately half that of all industries for cases with days away from work (BLS, 2012). The control of high-risk moments through the use of appropriately systematic checking methods such as work permits are posited as a strongly differentiating behavior.

Avoid dismissing too quickly the comparison on the basis of dissimilar risk exposures of other industries. Construction, maintenance, use of contractors, work at heights, energy control and work environments unprotected from weather are all hallmarks of the process and chemical industry's workplace realities as well as those observed in general and service industries. It can be agreed, however, that key variables include resources, safety system availability and reliance on them, and perspectives about risk.

Are these generalizations too broad? Possibly. However, before giving too much credence to the dissimilarities between chemical plants and construction sites, or food producers or small manufacturing, consider one of the most instructive of all work sites and its increasing adoption of work permits: hospital emergency and critical-care centers.

Gawande (2009) notes that in the face of rising error rates, infections and patient mortality, legal pressures and the importance of doing no harm, a Johns

HSE Permit-to-Work System Description

A permit-to-work system is a formal recorded process used to control work that is identified as potentially hazardous. It is also a means of communication between site management, plant supervisors and operators, and those who carry out the hazardous work. Essential features are:

- clear identification of who may authorize particular jobs (and any limits to their authority) and who is responsible for specifying the necessary precautions;
- training and instruction in the issue, use and closure of permits;
- monitoring and auditing to ensure that the system works as intended;
- clear identification of the types of work considered hazardous;
- clear and standardized identification of tasks, risk assessments, permitted task duration and supplemental or simultaneous activity and control measures.

Note. *From "Guidance on Permit to Work Systems: A Guide for Petroleum, Chemical and Allied Industries," by Health and Safety Executive, 2005, p. 7.*

Hopkins Hospital critical care specialist established the disciplined use of a checklist in a physician culture, which frequently disdains such structure, for a simple, frequent task: central-line infusions.

> On a sheet of plain paper, he plotted out the steps to take in order to avoid infections when putting in a central line. Doctors are supposed to 1) wash their hands with soap, 2) clean the patient's skin with antiseptic, 3) put sterile drapes over the entire patient, 4) wear a mask, hat, sterile gown and gloves, and 5) put a sterile dressing over the insertion site once the line is in.

Nurses kept a record of conformance over 1 month. It revealed that the procedure was performed incorrectly more than one-third of the time. The checklist was instituted as an agreed team commitment. Fifteen months later it was observed that:

•The 10-day line-infection rates dropped from 11% to zero.

•Forty-three infections and eight deaths were likely prevented given previous experience over a similar period.

•$2 million in costs were eliminated (Gawande, 2009, pp. 37-39).

In the broadest sense, a work permit is no more than a checklist that individuals and teams agree is integral to their work. Certainly, different environments require different approaches, detail and rigor. It is the basic tool used by pilots to fly planes, and it is a construct that workers thought to be among the most skilled and knowledgeable of all workers (i.e., surgeons) are now found foolish to ignore.

Wachter and Yorio (2013) describe the concept of concurrent verification/peer checking. All are variations of a theme; they encompass aligned concepts that can be plotted on a continuum of risk control measures uniquely suited for use by workers to interrupt the incident sequence if other barriers fail. Gawande (2009) argues enthusiastically that it is a universal truth, whether the workplace is a hospital, construction site, financial investment firm or airline cockpit. In the safety context, regardless of workplace setting, its product is major injury prevention. According to HSE (2005):

> Permit-to-work systems are normally considered most appropriate to:
>
> •nonproduction work (e.g., maintenance, repair, inspection, testing, alteration, construction, dismantling, adaptation, modification, cleaning, etc.);
>
> •nonroutine operations;
>
> •jobs where two or more individuals or groups need to coordinate activities to complete the job safely;
>
> •jobs where there is a transfer of work and responsibilities from one group to another. (p. 9)

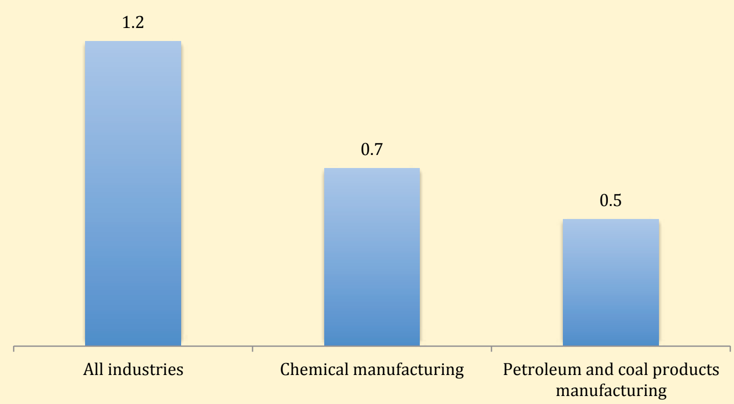
These parameters are not the exclusive domain of chemical and petroleum industries. Efforts are needed to more thoroughly introduce appropriate safe work permit systems to the broader workplace. The trick, always, is in the doing. Education must be the first step.

Conclusion

The safety field has never enjoyed as much understanding of the problem identified. Much progress has been made, but it remains a prob-

Figure 6

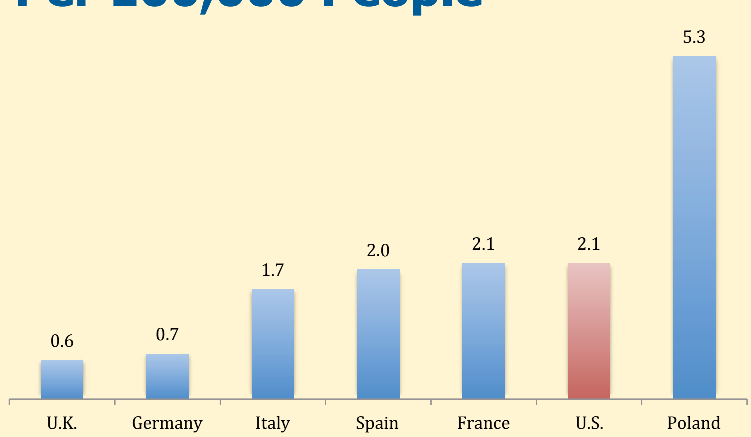
Lost-Time Incident Rates Per 100 Workers



Note. *Adapted from Table 1, "Injuries and Illness Incidence Rates of Nonfatal Occupational Injuries and Illnesses by Case Type and Ownership, Selected Industries, 2011," by Bureau of Labor Statistics, 2012.*

Figure 7

Fatal Injury Rate Per 100,000 People



Note. *Adapted from "Census of Fatal Occupational Injuries," by Bureau of Labor Statistics, 2013; and "Statistics on Fatal Injuries in the Workplace 2011/12," by Health and Safety Executive, 2013.*

Health and Safety Executive (HSE) reports a workplace injury death rate of 0.6 per 100,000 workers. This equates to roughly 70% less than the rate reported by the U.S. (acts of violence and motor-vehicle crashes excluded). HSE data also show the U.S. to be on par with France and Spain, with Italy not far ahead.

Par and excellence are not compatible pursuits, and only a revolution achieves a workplace injury death rate of 0.6 when the starting point is 2.1.

lem inadequately treated. Twenty years ago, Hansen (1993) called all to (r)evolution for achieving world-class safety. He emphasized a culture in which shared ownership replaced forced accountability by the few.

Today, the call is renewed, but with special emphasis now given to the prevention of major injury events. Asking for a revolution may be a bit too dramatic for some, but the proposition is not positioned for emotional appeal.

HSE (2013) reports a workplace injury death rate of 0.6 per 100,000 workers. This equates to roughly 70% less than the rate reported by the U.S. (acts of violence and motor-vehicle crashes excluded) (Figure 6). The HSE data also show the U.S. to be on par with France and Spain, with Italy not far ahead. Poland is more than twice worse (Figure 7). This standing is fine if par is concluded to be good enough. But par and excellence are not compatible pursuits, and only a revolution achieves a rate of 0.6 when the starting point is 2.1. Germany demonstrates that the U.K. does not enjoy exclusivity.

The current fatality prevention performance in the U.S., a bellwether statistic for major injury prevention, is poor when compared to available benchmarks. The nation's recently improved fatal worker incidents statistical trend will worsen without new and creative approaches. Workers will continue to fall victim to setups that readily can and must be bested. Is this another call for revolution? Yes.

Lessons derived from models, current data and discourse demonstrate several things:

1) Humans interact in complex and often rapidly changing systems.

2) Rapidly changing conditions, the absence of controls and participating in high(er) risk tasks can result in a setup for major injury events. Maintenance, construction and service workers (i.e., those who frequently perform nonroutine tasks) are especially at risk.

3) The incident sequence can be diagramed and understood. Interrupting this sequence often prevents the major injury event. Strategies for interrupting the sequence are multiple and, when implemented, are analogous to a well-defended system.

4) A focus on unsafe practices or workers is counterproductive. Understanding human error, however, provides leverage for major injury prevention.

5) Systems-based thinking provides an opportunity for incident prevention but not all workplaces have rigorous or effectively deployed safety systems. Too often workers must survive on individual wit and determination.

6) Better application of risk thinking (e.g., tools, assessments, techniques, awareness) that the worker can deploy to make better decisions will be basic to general improvement. To the worker, good tools are more valuable than good theory. It is balm to the learned, however, that good tools are always rooted in good theory.

7) Broader application of permit-to-work systems provides a conceptual model and means for major injury prevention. Process industries have led the way. These industries enjoy significantly lower incident rates than observed in general and service industries. Work permit systems are believed to be one differentiating behavior. A checklist is a work permit. Even doctors use them. **PS**

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