WHITE PAPER

PREVENTING SERIOUS INJURIES AND FATALITIES (SIFs):

A NEW STUDY REVEALS PRECURSORS AND PARADIGMS

By Donald K. Martin and Alison Black

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IN BRIEF SUMMARY

- Over the past decade non-serious workplace injuries have decreased, but fatalities have decreased at a much slower rate.
- The present study findings call into question decades-long-held assumptions in the safety community.
- Research results show that contributing factors are different between less-serious events and SIF events.
- Precursors to SIFs exist in most organizations and can be identified and measured.
- New paradigms are required to influence step changes in improving serious injury and fatality (SIF).

ABSTRACT

Over the past decade, serious events and fatalities do not show reduction rates comparable to less serious workplace injuries. This problem should raise serious questions and implications for safety leaders at all organizational levels, from the first level of supervision to the senior-most executive and board member, and to the labor leader and government regulator.

Seven multinational corporations experiencing this pattern sought to develop a better understanding of the causes and correlates of SIFs. These organizations submitted two years of accident data related to SIFs, less-serious recordable injuries, and near-misses. In total, this data included 1,028 event cases representing approximately one million global workers and contractors.

The result of this research ultimately leads to a better understanding of SIF causes and establishment of new paradigms for SIF prevention.

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PREVENTING SERIOUS INJURIES AND FATALITIES (SIFS)

A NEW STUDY REVEALS PRECURSORS AND PARADIGMS

Leaders who closely follow lagging and leading safety performance indicators have seen the following national (Figure 1) and global data and they know it points toward questions about the effectiveness of our safety management systems (United States Department of Labor, Bureau of Labor Statistics).

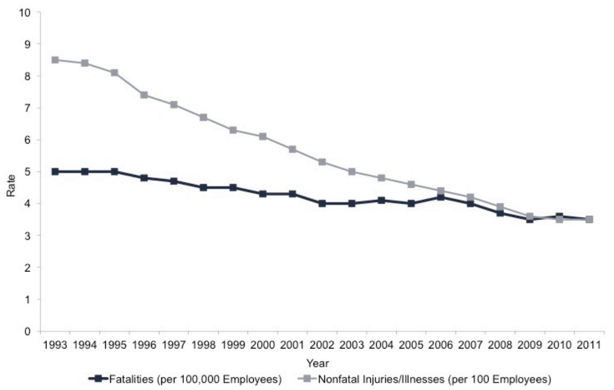

Figure 1. Comparison of fatal and non fatal injury data, 1993-2011. Source: U.S. Department of Labor, Bureau of Labor Statistics.

Figure 1

Non-fatal recordable incidents in the United States have declined steadily over the past two decades. The rate of non-fatal recordable injuries declined 51% in the past fifteen years and 34% just in the last ten. While the U.S. rate of fatalities has also exhibited a decline, it has been much less dramatic, just 12.5% in the last ten years and 25.5% in the last fifteen (United States Department of Labor, Bureau of Labor Statistics). This reduced rate of decline between these rates also surfaces upon examination of data pulled from a sampling of countries with data available through the International Labour Organization (2009). The fatality rates in many of these countries have remained fairly stable since 2002 (Figure 2).

There is evidence of this same pattern of movement at a more granular level also. The 2011 publication of safety performance indicators for the International Association of Oil and Gas Producers shows similarly un-parallel rates of rate reduction among the contractor population across all business functions (Figure 3) (International Association of Oil & Gas Producers, 2011).

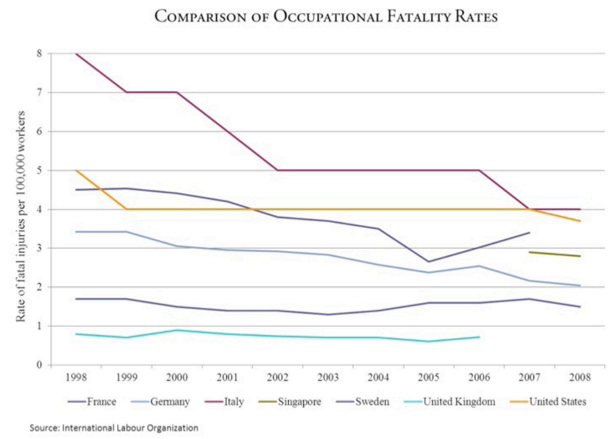

Figure 2. Comparison of occupational fatality rates across different countries.

Figure 2

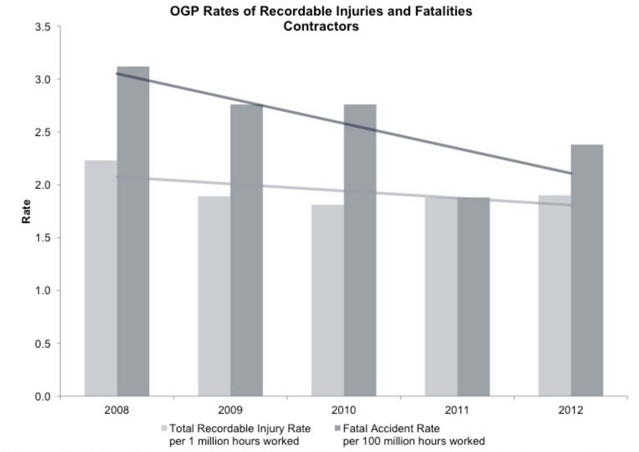

Figure 3. Rates of recordable injuries and fatalities among the contractor population of oil and gas organizations

Figure 3

Many organizations are observing this phenomenon among their own population. As an example, Figure 4 captures actual data from a global organization (identity protected).

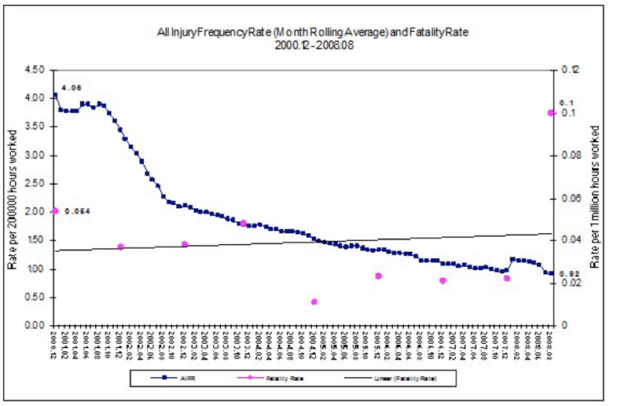

Figure 4. Comparison of injury frequency rate and fatality rate within one organization (identity protected).

Figure 4

The purpose of this paper is to provide insight into factors behind these trends, approaches for data analysis, and new conclusions regarding the prevention of Serious and Fatal Injuries. For the purpose of this study SIF cases were defined as life-threatening, life-altering, or fatal injuries and illnesses (see Table 1 for a complete definition of SIF).

Injuries of ergonomic origins and catastrophic multiple-fatality incidents of PSM/fire/explosion origins were purposefully excluded in the design of this research project. Researchers from BST and participating organizations were specifically interested in the attributes of single-fatality workplace events and felt that inclusion of ergonomic/musculoskeletal and multiple-fatality/PSM events might bias the findings. Researchers are recommending that future studies should include multiple-fatality events as they may shed additional insight on the fatality causation question and reveal the existence or non-existence of biases.

Serious Injury or Fatality (SIF) is any injury that resulted in:	*Examples include, but are not limited to:*
Fatality	---
Life-threatening injury or illness: one that if not immediately addressed is likely to lead to the death of the affected individual, and will usually require intervention of internal and/or external emergency response personnel to provide life-sustaining support.	• Laceration or crushing injuries that result in significant blood loss • An injury involving damage to the brain or spinal cord • An event that requires application of CPR or an external defibrillator • Chest or abdominal trauma affecting vital organs • Serious burns
Life-altering injury/Permanent Disability: An injury that results in permanent or long-term impairment or loss of use of an internal organ, body function, or body part.	• Significant head injuries • Spinal cord injuries • Paralysis • Amputations • Broken or fractured bones • Serious burns

Table 1.Definition of SIF

METHOD

Seven multinational organizations expressed interest and concern over the observed pattern of decreasing minor injuries and increasing SIFs. These organizations represented the following industry sectors: Food Service Contractors, Basic Organic Chemical Manufacturing, Industrial Gas Manufacturing, Crude Petroleum and Natural Gas Extraction, Marine Cargo Shipping, Grain Farming, and Ore Mining. The estimated workforce of each participant company ranged from 5,000 to over 230,000, with a mean and median of approximately 100,000 workers.

To better understand this issue, the following data provided by six of the global firms was analyzed: monthly frequencies of first aids, medical treatment cases, restricted duty cases, lost-workday cases, serious injuries, and fatalities for 2008 and 2009. Data included both employees and contractors and was broken down by division and region.

Additionally, researchers requested each organization provide comprehensive narratives for all serious injuries and fatalities over the two-year period, and a sample of non-SIF recordable injuries, and near-miss incidents over the same timeframe (Table 2) for both the qualitative and quantitative assessment of SIF precursors. Researchers chose to request an equal number of narratives from each organization to balance the representation of industries (and thus the type of work and exposure to risk) within the sample.

While all participants had comprehensive incident investigation systems and reporting structures, there was large variability in the maturity and information contained in their individual databases. The least sophisticated systems contained little more than unique incident identification numbers, indications of actual consequence, and narrative descriptions of the incident. Due to this variation and the extensive resources some organizations felt would be involved in obtaining the requested information, the group agreed to each provide 30 SIF

Organization	Serious injuries and fatalities	Non-SIF recordable injuries	Near-miss incidents	Total
A	30	30	30	90
B	19	26	0	45
C	30	30	17	77
D	30	30	30	90
E	5	30	30	65
F	30	30	30	90
Total	**144**	**176**	**137**	**457**

Table 2. Data obtained from organizations in study.

narratives, 30 narratives of other recordable injuries (not actually resulting in a SIF), and 30 near-miss narratives. The samples were obtained using random-number/seed generators.

As the study progressed, the researchers requested additional random samples of narratives of recordable cases to further study the early finding that non-SIF cases had different causes than SIF cases. A total of 571 narratives were obtained and assessed. Sampling was proportionate to the total incidents in each organization (Table 3). Using the SIF exposure assessment

Organization	Non-SIF incident comprehensive narratives
A	54
B	55
C	63
D	300
E	49
F	50
Total	571

Table 3. Number of random sample narratives collected.

methodology, it was determined that a small percentage of these cases originally thought to be non-SIF did in fact have SIF exposure potential. The SIF exposure potential rate was determined for each organization and the overall mean was calculated giving each organization equal weight to reflect equal representation of each industry sector.

RESULTS

The Heinrich Triangle is accurate descriptively.

Heinrich (1931) asserted that less severe injuries occur more frequently than more serious injuries. The analysis of data from the participating companies confirmed that there is an inverse relationship between frequency and severity of injuries. Although this confirmed the widely known claim, this research indicated that the ratio of less to more severe injuries varies among companies, and there is not a constant ratio as is frequently asserted. This finding validates specific criticisms about Heinrich's 300:29:1 ratio (Figure 5) (Anderson & Denkl, 2010; Manuele, 2002 & 2011).

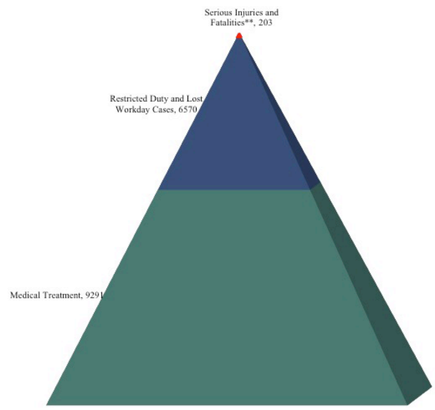

Figure 5. Heinrich's 300:39:1 ratio.

Figure 5

A subset of reported incidents will have SIF exposure potential.

During the case-by-case analysis, a pattern emerged whereby a percentage of cases originally reported as non-serious contained the potential for something significantly worse to happen. An injury case was determined to have SIF exposure potential when the incident resulted in an actual SIF or when the exposure could have reasonably and realistically resulted in a fatality or serious injury outcome if repeated. Examination of the entire context of these cases revealed numerous outcomes that could have easily changed to a SIF. Subsequently additional decision logic was established to enable a consistent, valid and reliable methodology to determine SIF exposure. Using this logic, inter-rater reliability for determining SIF potential was determined to be greater than 90%.

When all of the cases from all of the organizations were totaled, it was determined that 21% of all reported cases had SIF exposures (Figure 6).

The Heinrich triangle is not accurate predictively.

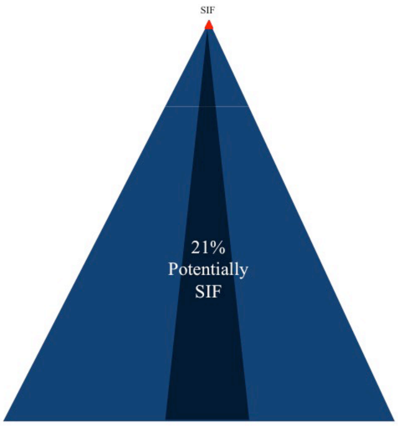

Figure 6. On average, 21% of all reported cases across the organizations had SIF exposures.

Figure 6

The evaluation of the case descriptions and narratives clearly pointed out that not all incidents had the potential to be a serious or fatal injury. This logically leads to a conclusion that reducing the frequency of the less severe incidents at the bottom of the triangle does not necessarily reduce the number at the top in a proportional way. This confirms the data seen at the national, sector, and organizational levels, indicating the discrepancy between the rates of reduction (BLS). The potential for a fatality or serious injury is variable across the range of less serious injuries that occur, reflecting the fact that SIF potential varies among different types of exposure. (For example, a back strain from lifting a load has little SIF exposure potential, while a fall from an elevated work position has high SIF exposure.) As a result, an initiative can be highly effective in reducing the number of injuries with low SIF exposure while having little or no impact on the exposures with high SIF exposure potential.

Data analyzed in the study showed the percentage of non-serious injuries that had potential for SIF exposure varied among companies, ranging from 10% to 36% (Figure 7).

This indicates that the percentage of all injuries that have SIF exposure potential is organization and location specific, and in all cases is a subset of all reported lower severity injuries.

The contributing factors for SIFs are different than those that underlie non-SIFs.

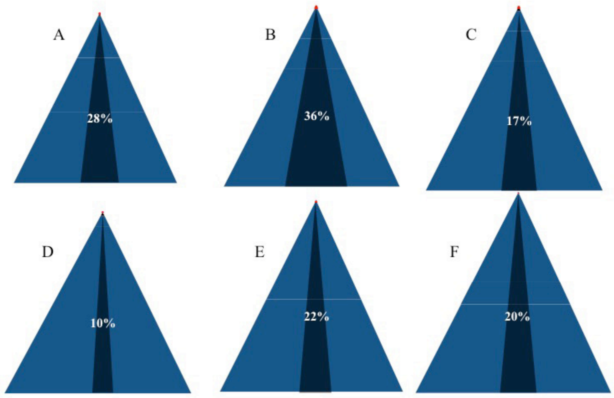

Figure 7. Comparison of incidents with potential for SIF exposure among study organizations. 14

Figure 7

The study design called for a comparison between qualitative analysis of case narratives and quantitative analysis using a statistical tool. This comparative assessment demonstrated that the qualitative approach yielded results comparable to a more rigorous quantitative approach. The causes and roots of SIFs and non-SIF are measurably different as determined by both qualitative and quantitative analyses. The study examined and contrasted the correlates and causal roots of two categories of injury and incident events (including near-misses) in which the organizations were able to provide adequate detail and narratives.

Qualitative Results

A qualitative analysis approach would be more practical for those organizations that do not have ready access to statistical tools and expertise. In such cases, many organizations have the resources to analyze no more than about 100 cases at one time. Considering these typical limitations, researchers chose a similar sample size for the qualitative assessment.

In this analysis, a root cause evaluation was performed on a random sample of the original 457 narratives collected to draw comparisons between two groups created based on SIF exposure potential:
Group 1: SIFs and non-SIF injuries and near misses with potential to become SIFs (n = 55)
Group 2: Non-SIF injuries and near misses with no reasonable potential to become SIFs (n = 35)

The data shows the causal roots of Group 1 incidents are markedly different than those of Group 2. Group 1 incidents are strongly related to deficiencies in management systems related to Life Saving Policies and Programs (refer to Table 4 for definition) and Pre-Task Risk Assessments, Group 2 incidents are more likely to be related to other human factors.

Life-saving safety rules, policies, and programs are those processes designed specifically for the preservation of human life in the workplace. Typical life-saving policies and programs identified by the research partners included:
• Lockout/Tagout.
• Confined Space Entry.
• Working at Elevations/Fall Arrest.
• Machine Guarding – Barricades.
• Operations of Mobile Equipment.
• Suspended Loads.
• Equipment and pipe opening.
• Hot work permits.
• Excavations, trenches.
• NFPA 70E – Arc Flash Protection.

Table 4

This analysis identified seven themes related to injury causes. Three of the themes accounted for 82% of SIFs and 91% of non-SIFs:

- 42% of SIF's were related to breakdowns in the processes surrounding Life-Saving policies and programs, while 0% of non-SIFs had this relationship.
- 29% of SIFs and 17% of non-SIFs were related to the performance of routine tasks where exposure changed from a planned state, was unrecognized, and could have been prevented by effective pre-task risk assessment processes.
- 11% of SIFs and 74% of non-SIFs were related to human factors that were not connected to the implementation of a life-saving rule process. (Table 5)
- It is important to note that the researchers designed these thematic categories to be mutually exclusive to ensure that any case could only be assigned to one category, thereby preventing double-counting.

Theme	SIF or SIF potential incident n=55	Non-SIF potential incident n=35
Performing a routine operation/production or a maintenance/repair task, connected with a breakdown in an established life safety rule program/process	42%	0%
Performing a routine operation/production or a maintenance/repair task (not governed by an established life safety rule program/process) connected to an exposure that changed from a "normal state", was not anticipated/recognized/controlled and likely could have been prevented by an effective pre-task risk assessment (PTRA) process	29%	17%
Other human factors that are not connected to an established life safety rule program/process or not usually conducive to PTRA. Involved in either a routine operation/production or a maintenance/repair task.	11%	74%
Involved in routine operation/production or a maintenance/repair task, and a connection to an equipment/facility/process/engineering design flaw has been established.	5%	3%
Involved in routine operation/production or a maintenance/repair task, and a connection to predictive and preventative maintenance and inspection, and reliability systems have been established.	5%	6%

Table 5

Quantitative Results

To conduct a quantitative analysis, the research team evaluated supervised machine learning techniques for classification. These techniques evaluate the properties and patterns of explanatory (independent) variables in terms of the targeted outcome (dependent) variable. Decision trees were selected in part because the output diagrams are simple to understand, leading to enhanced practical application (Hastie, et al, 2009). After the evaluation of several types of decision trees based on the data analysis and model validation, a Chi-Squared Automatic Interaction Detector (CHAID) was used. These not only predict the outcome variable (SIF/Non-SIF) but detect interactions between the explanatory variables. Validation of the model was based on the partitioning of the dataset into training and testing sets.

Analysis was conducted on all of the original 457 case narratives obtained. This dataset used the SIF determination as the target variable and included:
Group 1: SIFs and non-SIF injuries and near misses with potential to become SIFs — 319 cases examined.
Group 2: Non-SIF injuries and near misses with no reasonable potential to become SIF — 138 cases examined

The model developed in *Figure 8* correctly classified incidents with an overall accuracy of 78% and accurately categorized SIF incidents with 82% accuracy. This analysis showed that Group 1 injuries had a greater association with two variables than Group 2 injuries:

- Type of Work Activities and Work Situations included: operation of mobile equipment, water craft, working under suspended loads, and working at elevations. Of 126 injuries sustained in association with these activities, 114 (90.5%) were Group 1, and only 12 injuries were Group 2. Among these activities, 36 were coupled with factors such as poor or risky standard operating procedures or a deviation or drift from normal procedures over time.
- Type of Exposure Sources and Safety Controls: Equipment and pipe opening of hazardous chemicals lock out tag out, machine guarding and barricades, confined space entry, use of hot work permits. Of 47 injuries sustained in association with the Type of Safety Control, all 47 injuries were Group 1.

This finding provides confirming evidence that data on high-potential non-SIF outcome cases can be useful in defining exposure to SIF. These exposures, or SIF precursors, will form the basis for intervention efforts.

The qualitative and quantitative analyses were conducted independently by different members of the research team to reduce potential for bias. When the results of each analysis were compared to each other, it was observed that each analysis approach yielded essentially the same

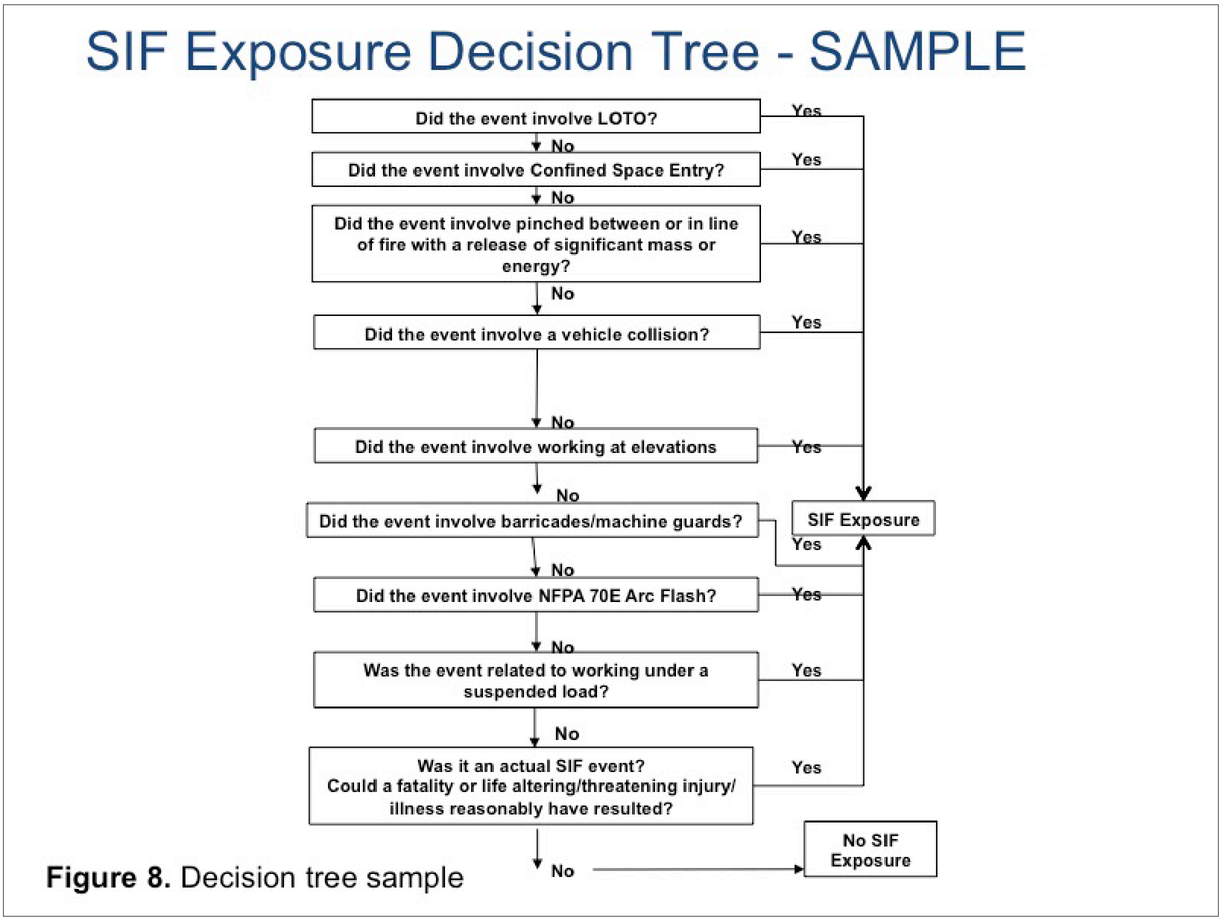

Figure 8. Decision tree sample

Figure 8

conclusions—the factors contributing to SIF cases and non-SIF cases are notably different, that SIF precursors are discoverable in low-severity cases with SIF exposure potential, and that the integrity and reliability in Life-Saving Rule Programs are important areas to focus on for SIF prevention.

SIF Exposure Cases have discoverable precursors

A systematic review of the submitted cases revealed that the occurrence of a major event requires a special and infrequent configuration of factors—a high risk situation must be present, the safety controls designed to protect against injury must fail, and this combination must be allowed to continue. This series of factors all must occur, and this is what the research team referred to as an SIF precursor (Table 6).

Definition: *An SIF precursor is a high-risk situation in which management controls are either absent, ineffective, or not complied with, and which will result in a serious or fatal injury if allowed to continue.* The team's other accepted, and more succinct definition, of SIF precursor is: *An unmitigated high risk situation, which will result in a serious or fatal injury if allowed to continue.* In our group discussions, research, and experience it is clear that SIF precursors have a central unifying theme – they are conditions, behaviors, practices, exposures, situations, and factors that lead to or contribute to the causation of a serious injury or fatality.

Table 6

For example: a worker is on a scaffold 30 feet above grade level, conducting a valve replacement job. The worker is improperly tied off to an electrical cable tray suspended from the ceiling, and the scaffold itself has a poorly secured top railing. The worker trips while removing the heavy valve assembly, crashes through the railing, and falls to the ground when the cable tray that he was attached to collapses. The investigation reveals further that the scaffold had not been inspected and that the supervisor authorized the use of the improvised anchor point, thinking that the site policy allowed him the authority to do so. When other work crews and supervisors were interviewed, they revealed that workers routinely used improvised anchor points that were not formally evaluated and approved by engineering, and that scaffold erection occurred by a contracted crew and the inspection and turnover procedure was irregularly followed. Workers were trained in the proper use of fall arrest devices, but the training did not require demonstration of use. In this instance the management control program—"Working at Elevations"—did in fact exist, but was certainly ineffective—and the process deficiencies were allowed to continue long enough that eventually a fatality occurred.

The precursors for this SIF event were discoverable through observation processes, inspections, interviews, near-miss reports, and other injury reports. One technique that is particularly useful in identifying SIF precursors is longitudinal analysis (correlational research involving repeated observations of reported events over long periods of time) of available data, which can identify that SIF precursors have been in existence in an organization/site for long periods of time. When this blind spot is removed, it becomes equally obvious that the occurrence of an SIF event should not be viewed as a "one-off" or "fluke" event.

DISCUSSION

Summary of Research Results
From the study, the following conclusions were reached:

- The Heinrich Triangle is accurate descriptively.
- The Heinrich triangle is not accurate predictively.
- A subset of reported safety incidents will have SIF exposure potential.
- The causal factors for SIFs are different in kind than those that underlie non-SIFs.
- It is unlikely that a serious injury event is a "one-off," considering that the precursors leading to it have been present all along.

Limitations in Data and Interpretations

As discussed earlier, there was large variability in the data available. First, some of the organizations simply did not have enough incidents to provide the requested 30 narratives. For example, Company E only had five cases that resulted in a SIF and Company B did not have a near-miss reporting system making them unable to provide their 30 narratives in this category. However, the researchers feel this would have only a negligible effect on the findings.

The most significant limitation was the differences in the length and detail of the narratives provided, which could range from several sentences to several pages. While this may have potentially led to some bias or misinterpretation in the analysis and results, the researchers feel confident that their assessments were valid based on their knowledge of the workplace conditions and tasks associated with the incidents.

The New Paradigm for Prevention of Serious Injuries and Fatalities (SIFs)

As a result of this research, a new paradigm is proposed for understanding and preventing SIFs (Figure 9). A number of new concepts are introduced for the consideration of safety professionals, organizational and labor leaders, and safety regulators.

1. Don't Expect SIF Prevention by Working Outside of the SIF Triangle. On average, 21% of reported cases will have SIF exposure. Because the causes of SIF cases are different than non-SIF cases, working in the 79% non-SIF section of the injury triangle is unlikely to prevent SIF cases.
2. The Recordable Injury Log is Misleading When it Comes to SIF Exposure. Organizations should review all reported EHS incidents and identify those with SIF exposure potential. All recordable injuries are not equal. A broken foot caused by stepping on a rock in the parking lot has significantly less SIF exposure than a broken foot that was driven over by a forklift. On the OSHA 300 log these two cases have the appearance of being identical due to outcome, but the exposure situation tells a different story. Most organizations do not have consistent visibility of this data because it is buried in the category of "recordable injuries" and without distinguishing those with high and low potential for SIF (Manuele, 2008). The research team encourages the addition of a new column to the OSHA 300 log—"SIF Y/N" as a way to gain a more true measure of what really matters.

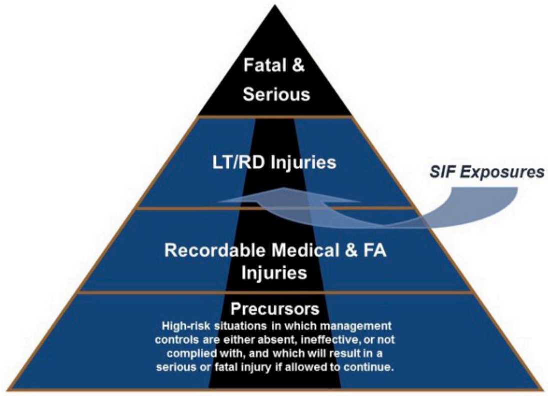

Figure 9. New paradigm for the prevention of serious injuries and fatalities

Figure 9

3. The SIF Blind Spot is Significant. While many organizations are aware of non-SIFs that have high potential, few have the consistent visibility needed to address precursors in sustainable ways (Busse, et al., 2008; Nash, 2008). Since OSHA Total Recordable Incident (TRI) rate changes are not indicative of changes to SIF potential, in the absence of measuring incidents with SIF potential organizations have no way to assess whether they are making progress in reducing the exposures that contribute to SIFs (Manuele, 2008).
4. The Organization's View on SIFs Must Evolve.
   a. Educate Senior Leaders on SIF. They need to understand this problem before they can act on it. The solutions to the SIF problem require their attention, so enlisting their sponsorship is critical (Krause, 2005).
   b. Provide Visibility to SIF Exposure. Develop a new working definition of "Serious Injury" within the organization. Determine the SIF exposure potential for each reported event and calculate an SIF Exposure Rate.
   c. SIF Precursors are Discoverable and a Key to Intervention Design. They are imbedded in high risk/high exposure tasks (and the research data showed that 81% of these exposures occurred in the conduct of routine tasks). Management control systems can be missing, deficient, or not complied with, and these deficiencies have been allowed to continue. Establish an ongoing process for the identification and remediation of precursors. This includes the examination of all data including incidents, near misses, safety observations, audit findings and interviews with employees. Include process safety exposures as well as personal safety exposures.
   d. Integrate Interventions into Existing Safety Management Systems. In most organizations systems such as Life Saving Safety Rules, Pre-Task Risk Assessments, Stop-Work Authority, Incident Handling Systems, Audits, and Safety Observations already exist, and the solutions to SIF precursors can be built into these systems.
5. Accident Reporting and Investigations Are Not Effective as They Should Be. The case narratives are critical to understanding the context of an SIF exposure situation. Longitudinal analysis will point out significant opportunities for improvement. For example:
   a. Identification of multiple contributing factors and precursors
   b. Effectiveness of corrective and preventive actions
   c. Effectiveness of communicating and implementing lessons learned

Highly effective accident reporting and investigation systems can be instrumental toward achieving transformation to high performance organization.

6. The Role for Behavior-Based Safety is Significant and Underused. The study team further examined a sample size of 55 SIF/SIF-potential cases and confirmed that the SIF precursors, pre-conditions, and exposures that contributed to the occurrence of these incidents would be discoverable through interviews, and/or observations in 87% of the cases. More work needs to be done in this area to develop the capabilities of observers to discover SIF precursors.
7. SIF Exposure Events Are Not One-Offs. Because the precursors to these events have been in place long before the SIF event occurred, management's vocabulary ("out of the blue", "freak accident") and reaction (confusion) to SIF occurrences must change. It is now known that certain kinds of situations trigger, precede, or cause SIFs, and that SIFs don't occur randomly and they are virtually never isolated events (Manuele, 2008).

The purpose of this study was to gain a better understanding of the causes of SIFs to enable the development of improved approaches for the reduction of SIFs. The findings suggest potential flaws in the way organizations traditionally think about SIFs. Many organizations are aware of EHS events that have high potential, but few have the consistent visibility needed to address precursors in sustainable ways (Phimister, Bier, Kunreuther, 2005).

Companies that do track serious injuries and fatalities find that it represents a clear line of differentiation from other types of injuries (Nash, 2008). Losing your life, your sight, or mobility, or other injuries of similar magnitude are different from injuries that heal without life changing consequences. All managers want to reduce and eliminate every type of injury, but consideration should be given to the allocation of safety resources specifically targeted to the reduction of potential for serious and fatal events.

Unless this issue is addressed we will likely continue to see the pattern described earlier in this paper of flat or no improvement in the occurrence SIFs. Lack of visibility makes it unlikely that the factors underlying SIFs will be addressed effectively. The kinds of things most organizations are doing presently will not provide the visibility needed to address the issues underlying SIFs. Doing more of the same is not going to reduce SIFs.

The New Paradigm recognizes a different strategy is required to prevent SIFs. Intervention is needed to change the course and direction of how resources are used in order to affect SIF exposures. The core objective such an intervention is to identify and remediate precursors, not as a one-time activity but as an ongoing process. How each organization approaches the specifics will depend on many factors including level of safety maturity, strength of existing safety systems, capability of the organization to undertake change, and strength of safety leadership and culture.

ACKNOWLEDGEMENTS

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