

## *Incident Investigation*

# A Problem-Solving Process

*Identifying and correcting root causes*

By Jerome E. Spear

**I**NCIDENTS ARE EVENTS that have the potential to cause injury or damage; they are caused by unsafe acts and/or unsafe conditions. However, unsafe acts and conditions are often symptomatic of an overall organizational problem. Companies can significantly reduce injuries and losses by implementing a continuous incident investigation process that involves the reporting of incidents without fear of being blamed. Such a process uses structured problem-solving techniques to identify and track root causes and follow up on corrective actions.

Heinrich's study in 1931 concluded that for every serious injury, about 29 minor injuries occur with 300 other occurrences that produce no injury (Heinrich 90). In another study, Bird and Germain showed a 500:100:1 relationship among property-damage accidents, minor-injury accidents and disabling injury accidents (Bird and Germain 21). Fletcher reported a ratio of 175:19:1 for no-injury accidents, minor-injury accidents and serious injury accidents (Fletcher 37). Although the precise ratios of these studies differ to some degree, one point is clear—a large proportion of accidents (perhaps greater than 80 percent) are neglected if safety professionals respond only to injury-producing events. Therefore, since the only difference between an incident resulting in no injury and a catastrophe may have been by chance, every problem should be investigated and resolved (Goldberg 33).

Within the context of this article, the author defines an "incident" as a deviation from an acceptable standard or work practice (i.e., an organizational "problem"). The goal of a proactive organization should be to investigate such problems to determine their root causes. However, in the author's opinion, two barriers often keep organizations from doing so:

- Employees do not like to report incidents to management, perhaps due to fear of being blamed.

- Even organizations with an advanced safety culture, where employees openly report incidents, typically do not have enough resources to thoroughly investigate all incidents to their root causes.

The first barrier may be addressed via training and ongoing communication with employees at all levels acknowledging the importance of reporting and investigating incidents. With few exceptions, management should not blame an employee for being injured or being involved in an incident. Such actions are counterproductive and can cause employees to be fearful of reporting future incidents. Periodic audits and inspections are alternatives to identify potential problems.

When the safety culture supports incident reporting without fear of blame, the organization is headed in the right direction. The primary problem, then, is the limited resources available to investigate these incidents. To address this situation, incidents should be evaluated and ranked by risk; those incidents associated with the highest risk should receive priority.

### Setting Priorities

Incident investigation is a problem-solving process. For most technical professionals, problem solving is a primary job function. Often, the most-difficult step in this process is identifying the right problem to solve (Adams 22).

Statistical process control involves the application of statistical techniques to determine whether observed variations within the safety process are due to "common causes" or "assignable causes"

a problem-solving

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**Table 1**

## Prioritization Matrix

Severity Potential	Severity Index	Frequency	Frequency Index
<b>Catastrophic:</b> Hazard may cause death or loss of facility.	0.9-1.0	Likely to occur immediately or in a short period of time.	0.9-1.0
<b>Critical:</b> May cause severe injury, severe illness or major property damage.	0.6-0.8	Probably will occur in time.	0.6-0.8
<b>Marginal:</b> May cause minor injury, minor illness or minor property damage.	0.3-0.5	May occur in time.	0.3-0.5
<b>Negligible:</b> Probably would not cause injury or minor illness.	0-0.2	Unlikely to occur.	0-0.2

*Proactive companies continue to emphasize, through education and actions, that every incident (or organizational problem) must be reported, regardless of the outcome.*

es.” Common cause variations are inherent to a process when it is operating as designed. Assignable cause variations are unnatural variations within a process (Sower 53). Regardless of whether the safety process is “out-of-control” or “in statistical process control,” many incidents (and problems) likely occur each day. As with other business scenarios, the time spent investigating incidents must be prioritized.

Early in the incident investigation process, a useful tool is a prioritization matrix. This matrix allows comparison of both quantitative and qualitative data within the same analysis (Sower 44). It is a risk management tool, since it evaluates both severity potential and frequency of an incident or hazard. Risk is defined as the product of the frequency and severity of potential losses (Brauer 527). One way to prioritize incidents by risk is to categorize each incident with the appropriate severity and frequency weightings. Table 1 presents weightings (developed by the author) that may be used when developing a prioritization matrix.

### Root-Cause Analysis

The identification of root causes in any system is fundamental to problem solving and continuous improvement (Senecal and Burke 63). These causes can be identified using 1) unstructured problem-solving techniques, which include intuition, networking (lessons learned) and experience; and 2) structured techniques, which include the systematic tools used in root-cause analysis. Through this systematic process, safety professionals can:

- define the problem;
- gather and prioritize related data;
- analyze solutions;
- evaluate the benefits and cost-effectiveness of available prevention options (Handley 75).

According to Adams, problem solving is not unstructured thinking (22). However, at times, an unstructured approach may be the most-feasible option, such as when investigating incidents that have a low severity potential and a low frequency rating. If the incident has a rating greater than 0.20 on the prioritization matrix (using the severity and frequency ratings in Table 1), structured problem-solving techniques such as change analysis, hazard-barrier-target analysis, events and causal factors charting, tree diagrams and cause-and-effect diagrams should be used.

### Change Analysis

The premise of change analysis is consistent with the words of the Greek philosopher Heraclitus, “There is nothing permanent except change.” Since change occurs constantly, the likelihood of an incident increases if change is not properly anticipated and/or managed. Through change analysis the investigator can identify the cause(s) of a mishap by exploring differences between the problem situation and a problem-free situation.

Change occurs in three ways: 1) mandated; 2) naturally (whether noticed or not); and 3) caused—knowingly or not (Wilson, et al 114). For mandated change, one must look at how the change was implemented. For example:

- What was the magnitude of the proposed change?
- Was the implementation complete?
- Were reinforcing factors considered and included as part of the implementation?

If change occurred naturally or was caused, the difference between an incident and a similar problem-free situation may not be readily obvious.

Change analysis may be performed in either a reactive mode (e.g., incident investigation) or a proactive mode (e.g., identifying potential effects of changes before implementing a new procedure). The typical analysis includes the following steps:

- 1) Define the problem.
- 2) Identify a “problem-free” situation.

**Table 2**

## Hazard-BTA (Line Breaking Incident)

Hazard	Target	Barrier	Analysis
<ul style="list-style-type: none"> <li>• Thermal temperatures</li> <li>• Corrosive chemical</li> <li>• High pressure</li> </ul>	<ul style="list-style-type: none"> <li>• Employees</li> <li>• Other personnel</li> </ul>	<ul style="list-style-type: none"> <li>• Piping, valves, flanges, gaskets</li> <li>• Line breaking procedure</li> <li>• Personal protective equipment (e.g., face-shield, protective clothing)</li> <li>• PPE written hazard assessment</li> <li>• Training</li> </ul>	<ul style="list-style-type: none"> <li>• Process unit periodically becomes clogged and requires employees to open pipelines to unclog unit.</li> <li>• No formal line breaking procedure has been developed.</li> <li>• Employees did not wear thermal protective clothing.</li> <li>• PPE hazard assessment did not address this task.</li> <li>• Line breaking training has not been provided to employees.</li> </ul>
<ul style="list-style-type: none"> <li>• Contamination</li> </ul>	<ul style="list-style-type: none"> <li>• Soil/groundwater</li> </ul>	<ul style="list-style-type: none"> <li>• Piping, valves, flanges, gaskets</li> <li>• Impervious material (or drip pan)</li> <li>• Procedure</li> <li>• Training</li> </ul>	<ul style="list-style-type: none"> <li>• Process unit periodically becomes clogged and requires employees to open pipelines to unclog unit.</li> <li>• No formal line breaking procedure has been developed that includes pollution prevention procedures.</li> <li>• Environmental awareness training is not currently required.</li> </ul>

- 3) Describe the conditions and compare.
- 4) Determine the direction/amount of the changes.
- 5) Examine the changes for their effect on the problem.
- 6) Separate the causes from the problems (Ferry 163).

### Hazard-Barrier-Target Analysis (Hazard-BTA)

A hazard-BTA considers potential hazards, examines how damage occurs, and assesses the adequacy of installed barriers or other safeguards that should either prevent or mitigate an incident. Like change analysis, it may be used as a reactive tool or proactive tool.

For a damage-causing incident to occur, there must be a target, a hazard and a less-than-adequate barrier. By identifying potential hazards along with possible targets, barriers can be analyzed. A target is something of value; it may be a person, part, system, procedure or process. A barrier separates the target from the hazard and may be physical (such as personal protective equipment, machine guards or safety valves), administrative (procedures or directives) or personal (employee training and supervision) (Wilson, et al 133).

For example, suppose two employees were opening a process line at a flange joint in order to unclog the line. As the line was opened, the clog shifted, causing the product inside the line to splash the workers. As a result, each suffered multiple second- and third-degree burns. In this case, a hazard-BTA (Table 2) proved to be an efficient assessment tool that provided valuable information in a relatively short period of time.

### Events & Causal Factors Charting

According to Wilson, et al, events and causal factors (E&CF) charting is the best root-cause analysis tool to employ when investigating an injury or other damaging consequence—especially when one must document the chain of events (42). An E&CF chart (Figure 1) is essentially a flowchart that depicts the sequence of events leading up to the event causing the injury or property damage and assesses emergency response activities. For each event, relevant causal factors or conditions are identified and noted on the chart. The goal is to uncover the root causes for the preceding events in order to break the chain of events leading to a negative outcome.

### Tree Diagrams

A tree diagram is a graphical display of the contributing factors of each event. Common techniques include fault tree analysis (FTA) and the management oversight risk tree (MORT). Both techniques use standardized symbols to construct the tree diagram.

Figure 2 presents a modified approach that categorizes root causes by management system. The concept behind this model is that incidents are events which have the potential to cause injury or damage and are caused by unsafe acts and/or conditions; as noted, such acts/conditions are merely symptoms of overall organizational problems. Thus, the top event (usually an injury) is actually caused by failures within the management system (Stalnaker 37).

Therefore, employees should not be blamed for being injured. Rather than punish workers, management should strive to examine these failures and correct the underlying faulty management system—a

## Change Analysis

Through change analysis the investigator can identify the cause(s) of a mishap by exploring differences between the problem situation and a problem-free situation.

- 1) Define the problem.
- 2) Identify a "problem-free" situation.
- 3) Describe the conditions and compare.
- 4) Determine the direction/amount of the changes.
- 5) Examine the changes for their effect on the problem.
- 6) Separate the causes from the problems.

system that did not anticipate or discover these failures before they caused an accident. Most work-related injuries are ultimately caused by management system failures, not employee infractions (Speir 29). Even if the injury was caused by an unsafe act, the supervisor (part of the management system) may have unknowingly encouraged those at-risk behavior(s).

Questions (and thus diagram construction) should continue until all relevant "whys" have been answered

(Sorrell 40). Once the investigator reaches a point where management can no longer provide a corrective action to eliminate the preceding event, the root causes have been discovered for the respective "tree" branch. Root causes are located at the bottom of the tree and are the most-fundamental causes that can be reasonably corrected to prevent recurrence.

Essentially, corrective actions must be able to be assigned to the root causes (Sorrell 40).

### Cause-and-Effect Diagrams

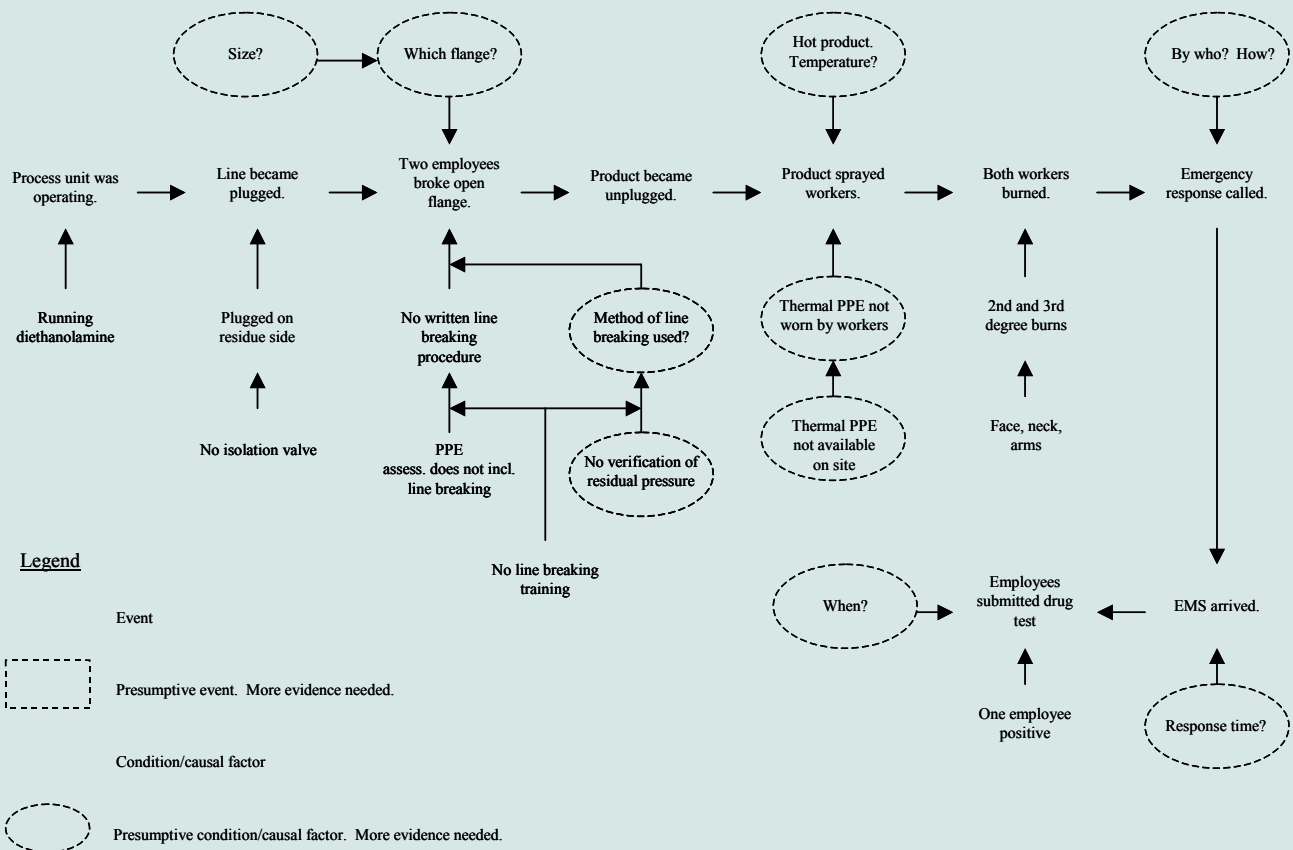
A cause-and-effect diagram is best used to facilitate a "brainstorming" meeting early in the incident investigation process because it helps to organize ideas on possible causes. For example, when investigating a lost-workday injury incurred from pushing a commercial dumpster, a cause-and-effect diagram was constructed (Figure 3) during the preliminary stages of the investigation. Initially, possible causal factors were listed, then as information and facts were obtained, those factors listed were either confirmed or deleted.

### Trend Analyses

Trending analyses should include not only large incidents, but also incident precursors and all other safety problems (Stalnaker 38). Data obtained from a well-established incident investigation process allow management to perform a trend analysis using a Pareto diagram (Figure 4). This diagram sorts root-cause categories from highest to lowest frequency and also identifies cumulative frequen-

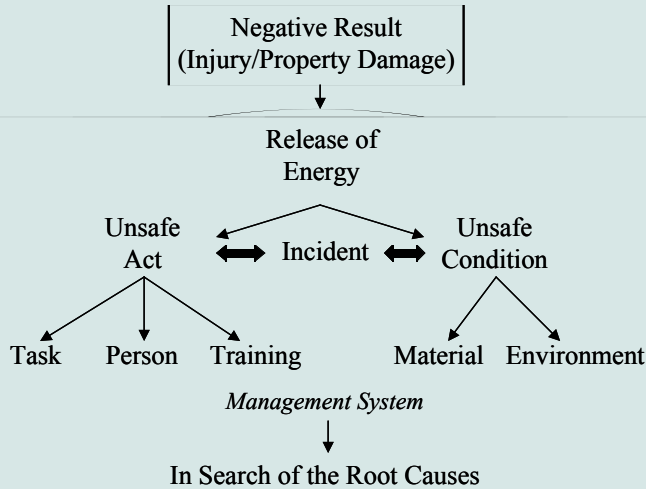
Figure 1

## Events & Causal Factors Chart



**Figure 2**

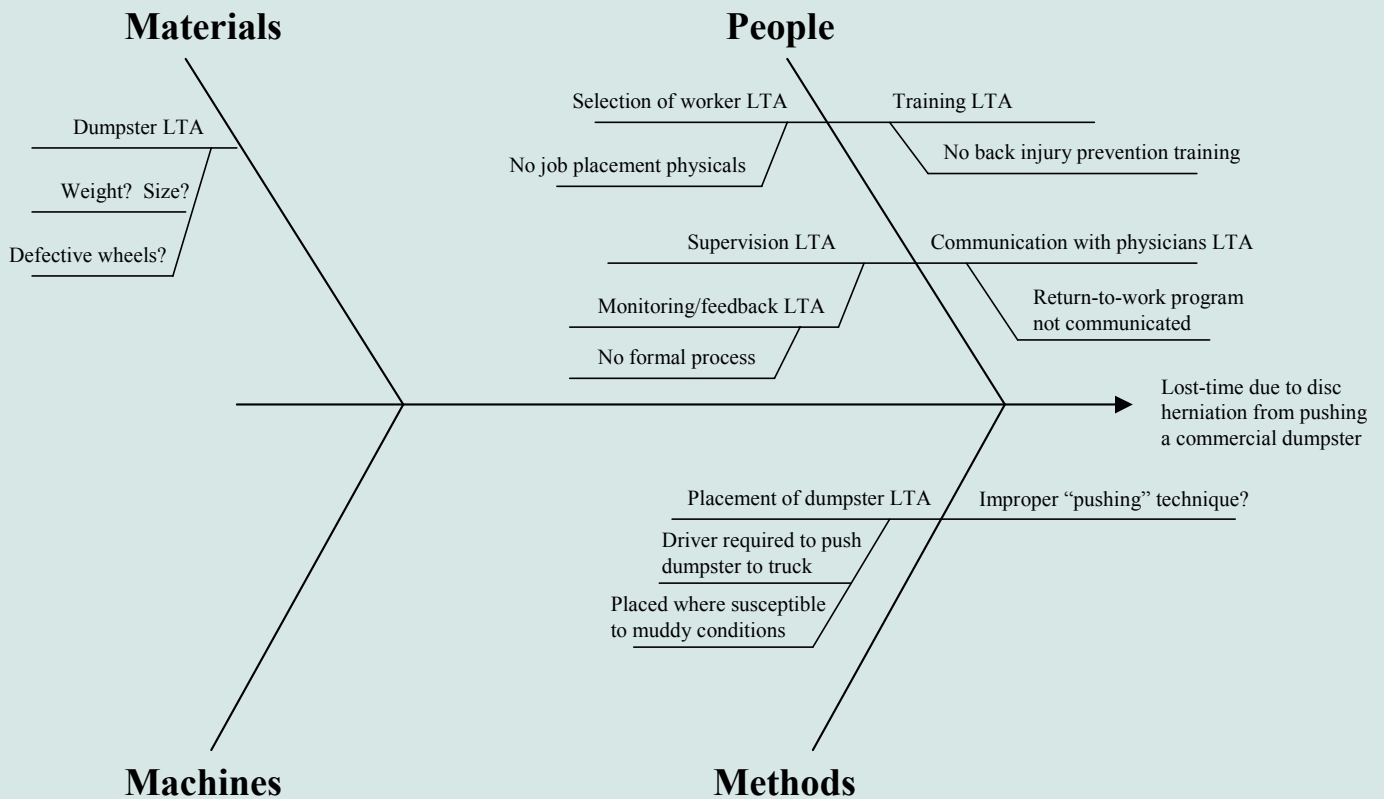
**Tree Diagram Model**



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**Figure 3**

**Cause-and-Effect Diagram**

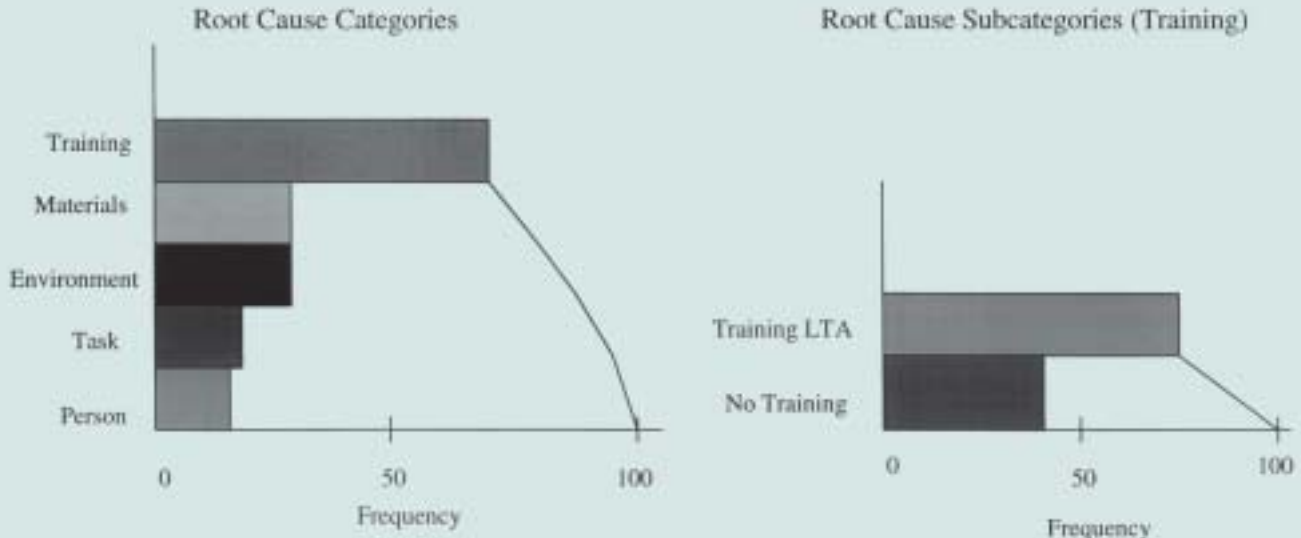


LTA = Less Than Adequate



Figure 4

## Pareto Diagrams



gies. This enables management to better understand where available resources should be allocated.

In conjunction with a Pareto diagram, a “run chart” can track root-cause categories by month to ensure that the company is improving. A run chart is a graphical representation of the variation in root-

cause categories over time (Sower 36). The categories are represented on the vertical axis, time periods on the horizontal axis.

One essential step often omitted in the problem-solving process is following up on corrective actions. A run chart provides a mechanism to indicate whether corrective actions are sufficient and have been adequately implemented. Corrective actions may be misunderstood or the appropriate action may be taken initially, only to be discontinued later, making follow up essential (Stalnaker 37).

### Conclusion

As a quality improvement initiative, root-cause analysis is not a static process. Continual evaluation, measurement, follow up and review of the effectiveness of solutions are critical to ensuring that these causes have been properly identified and that the problem does not recur (Handley 76). Proactive companies continue to emphasize—through education and actions—that every incident (or organizational problem) must be reported, regardless of the outcome. Blaming employees who are injured or who report incidents seriously stifles the problem-solving process. To prevent this, structured analytical tools should be used to identify root causes. This

process enables appropriate corrective action to be implemented. Once root causes are identified, management must follow up to ensure continuous improvement of the incident prevention process. ■

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