INCIDENT ANALYSIS

Peer-Reviewed

CAUSAL FACTORS ANALYSIS

Uncovering & Correcting Management System Deficiencies

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AS THE OSH PROFESSION CONTINUES TO EVOLVE, a major concern remains: the number of workplace fatalities and serious injury events each year. As incident rates have declined over the years, fatality rates have not significantly changed; they have plateaued and risen slightly. Recent data from Bureau of Labor Statistics (BLS, 2017) indicate 5,190 workers died from an occupational injury in 2016. This number increased by 7% over 2015 and is the highest count since 2008.

In the authors' view, the persistence of serious injuries and fatalities suggests that many organizations have flaws within their management systems in the way they plan, organize, implement, execute, monitor, communicate and improve. One way that OSH professionals can help organizations improve their management systems is through more effective analyses of incidents.

An incident is an unplanned, unwanted event that results in injury or damage (an accident) or an event that could have resulted in harm or loss (a near-hit). All incidents should be investigated, regardless of the extent of injury or property damage.

KEY TAKEAWAYS

- **Incidents and their systemic causal factors are indicators of management system flaws. When identified and understood, these indicators can be used to address deeply rooted deficiencies and prevent recurrence of similar events.**
- **While many methods are available, OSH professionals should select, design and apply a causal analysis process that effectively identifies causes at all levels, from direct causes down to the management system elements and organizational factors. For some situations, a simple five-why process is appropriate, while complex incidents may require more in-depth methods.**
- **This article presents a causal factors analysis model using a sequence of modified methods that can be used to analyze more complex incidents and uncover deeply embedded causal factors.**

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In the authors' experience, most organizations perform some degree of investigation and analyses for incidents resulting in injury, damage or those with significant severity potential. However, the driving forces for conducting incident investigations and analyses can vary for organizations ranging from the need to file insurance claims; complete regulatory compliance records; track lagging indicators; or meet contract requirements from customers. All of these are important, but they do not represent the real purpose of incident causal analysis.

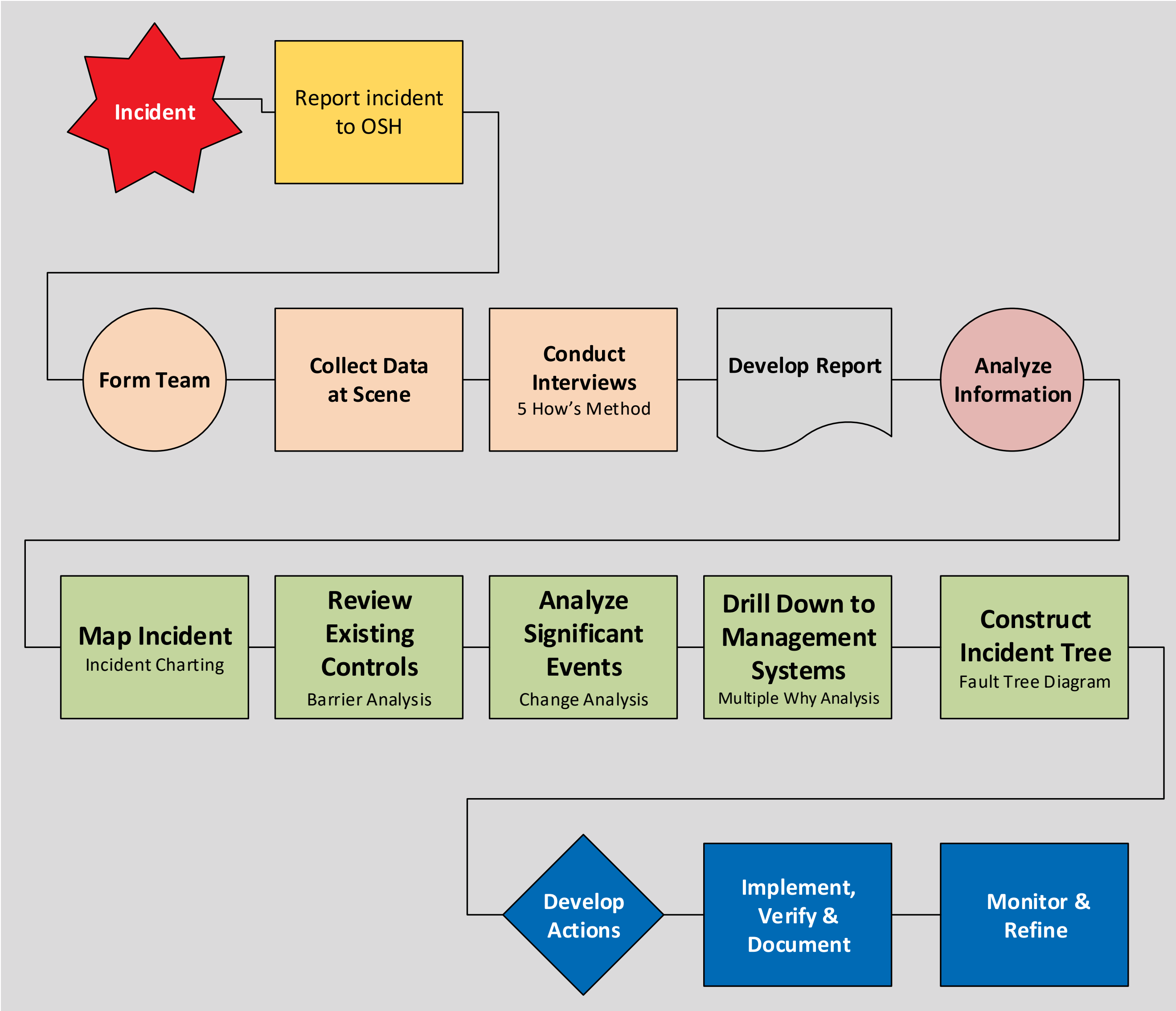
Incident Investigation & Analysis Objectives

The primary objective of investigating and analyzing incidents is simple and straightforward: to gain an understanding of how and why an incident occurred so that similar incidents can be prevented in the future. For an incident investigation and analysis to be effective, it must identify not only direct and indirect causes, but also their underlying causal factors so that corrective actions can be taken to address systemic causal factors. If performed properly, the selected corrective actions will eliminate or reduce not only the direct and indirect causes, but the underlying causal factors within the management system. The approach presented in this model is flexible and encourages customization.

In addition to the primary objective of preventing recurrence of an incident, incident investigation and analysis are used to identify direct and indirect causes, associated systemic causal factors and corrective measures that address all levels of causes to prevent similar incidents from occurring. Incident investigations are also used to obtain data for completing insurance claims, maintaining regulatory recordkeeping and performing trends analysis.

An important aspect of incident investigation is remaining objective and keeping the focus on finding facts rather than blame. This does not mean that relevant oversights or acts of omission or commission on the part of employees, supervisors or management

FIGURE 1
INCIDENT INVESTIGATION & ANALYSIS PROCESS



personnel should be ignored. Rather, such actions, inactions or errors can be indicators of deeper problems in the management system (Dekker, 2006; Reason, 1990). Reason, Carthey and de Leval (2001) refer to these management system problems as "vulnerable system syndrome" caused by "organizational pathogens" that can render certain system elements more susceptible to adverse events. Organizational pathogens or failures are deficiencies in either the structure of a company or the way it conducts its business that allows safety responsibilities to become ill-defined and warning signs to be overlooked. Certain aspects of safety get lost in the organizational cracks (Reason, 2016). Examples of such organizational pathogens include cultural practices that emphasize production over safety; reliance on incident rates (results-oriented measures) rather than actions performed to manage risk; poor communication; and operations that are reactive instead of active.

In this article, a sequence of modified techniques is used to demonstrate how incidents can be investigated and analyzed to achieve the stated objectives. The model contains 1) forming the team and context; 2) determining the facts through observation, interviews using the five-how's method and document reviews; 3) mapping the incident using incident charting; 4) reviewing controls using barrier analysis; 5) analyzing events using change analysis; 6) drilling down to management system element using five-why analysis; and 7) constructing an incident tree to visually tie incident causes to management system elements using a fault-tree analysis diagram. Figure 1 depicts the sequence of methods presented.

Underpinnings of Incidents

Ultimately, performance in productivity, quality, operational risk and safety are driven by an organization's culture, values and overall management system. It is the authors' belief that organizations with a heightened awareness of their OSH management systems' performance tend to have stronger, more effective management systems. This awareness is partially gained through the organization's practice of risk assessment, incident investigation and analysis, and continuous identification and improvement of system weaknesses.

Unfortunately, many organizations may not be self-aware of their management system's performance and potential weaknesses. Deficiencies and weaknesses in management system elements often go unnoticed or even ignored. Manuele (2017) refers to CSB's report on the *Deepwater Horizon* incident regarding the need to expose management system deficiencies to prevent disasters, fatalities and serious incidents. In the report, the CSB (2016) states:

> The broadest learning impact can be achieved when investigations extend beyond the immediate technical causes of an incident. Addressing deficient safety management systems and inadequate organizational practic-

es can result in findings that go beyond the immediate chain events that preceded any one incident. There is the danger of concentrating on the exact mechanism of the previous incident rather than identifying broad lessons.

Manuele (2014a) suggests that OSH professionals who view incident investigations as a source for selecting measures that improve the safety management system will better serve their organizations' interests. When performed well, incident investigations will reveal existing deficiencies in technical and organizational methods of operation as well as culture. OSH management system models such as ANSI/ASSP Z10, OSHAS 18001 guide and ISO 45001 are based on a systems approach using the continuous improvement concept of plan-do-check-act (PDCA). The foundation of these management system models is built on management leadership and employee involvement. For the purposes of this article, the authors have selected the Z10 model in the incident analysis case study.

Common Causal Factors Embedded in Systems

A similarity exists between a list of common causal factors related to disasters identified by Abkowitz (2008) and deficiencies often found in management system elements. Research conducted by Abkowitz suggests that all disasters, whether accidental, intentional or natural, share common causal factors. His list can be compared to corresponding management system elements from ANSI/ASSP Z10-2012 (R2017) presented in Table 1. Note that most of these cited causal factors can be linked to management-level decisions, actions or activities such as communication, responsibility and accountability, planning, resources and prioritization, risk assessment, design review and management of change. It is rare to find an incident where some of these elements are not partially linked to the contributing causal factors. It is also rare to find incident investigations that identify such links.

Investigation Scope & Team

As in any effort, the scope of the investigation and analysis should be clearly and carefully defined at the outset. Specification of the beginning and the end of the incident, limitation to related factors, team makeup, resources and methods should be considered in the scope. Some organizations segment incidents by potential severity and complexity to provide appropriate resources and time. For instance, minor incidents may be first-aid type cases that are relatively simple, while more severe incidents may involve more serious injuries, damage or multiple parties. All incidents (things that went wrong) including near-hit events should be evaluated as to their potential for more severe consequences and given the appropriate level of investigation and analysis.

In many organizations, incidents are often investigated by the area supervisor, frontline management or person in charge. Such situations can cause a conflict of interest when the person investigating the incident is the person in charge of supervising and managing the injured worker or work area being investigated (Manuele, 2014b). It is to an organization's advantage to employ a qualified team that includes OSH professionals to facilitate and coordinate the process. Team members require qualifications such as technical knowledge and familiarity of the situation; objectivity; inquisitiveness and curiosity; tact in communication; intellectual honesty; an analytical approach to problem solving; and skills in investigation and analysis techniques.

The team leader should have management status, the authority to get the job done and the experience to do it right. The team leader's duties should include controlling the scope of the

TABLE 1

ALIGNMENT OF Z10 MANAGEMENT SYSTEM ELEMENTS & CAUSAL FACTORS IDENTIFIED BY ABKOWITZ

ANSI Z10 management system elements	Causal factors in disasters identified by Abkowitz
I. Management/supervisory leadership a) Policy b) Responsibility and authority	•Political agendas; •Individual and organizational arrogance; •Lack of uniform safety standards; •Not taken seriously by decision makers until it occurs; •Failure to communicate.
II. Employee participation	•Individual and organizational arrogance; •Lack of planning and preparedness; •Failure to communicate.
III. Planning a) Budgeting and allocation of resources b) Staffing c) Prioritization	•Flaws in design and construction; •Lack of planning and preparedness; •Lack of uniform safety standards; •Economic pressure and lack of resources; •Failure to communicate.
IV. Implementation and operation a) Hazard identification and risk assessment b) Design review and management of change c) Procurement d) Contractors e) Emergency preparedness f) Training, awareness and competence g) Communication h) Document and records	•Risk level is unknown/unmanaged; •Flaws in design and construction; •Lack of uniform safety standards; •Failure to communicate; •Deviation from set procedures; •A convergence of multiple risk factors overwhelming control measures.
V. Evaluation and corrective action a) Monitoring, measurement and assessment b) Incident investigation c) Audits d) Corrective/preventive actions e) Feedback	•Not taken seriously by decision makers until it occurs; •Lack of uniform safety standards; •Failure to communicate.
VI. Management review	•Failure to communicate.

effort; assignment of tasks and schedules; leading meetings; gathering all potentially useful data; leading the investigation and analysis; keeping stakeholders apprised; overseeing report preparation; and arranging liaison with employee representatives, government agencies and media.

Gather Facts Related to the Incident

Following any incident, the first course of action is to take care of the injured, protect people and assets from harm, and secure the scene. This article does not cover incident response practices; however, OSH professionals should be knowledgeable in this area and can further review the subject from various resources, articles and books.

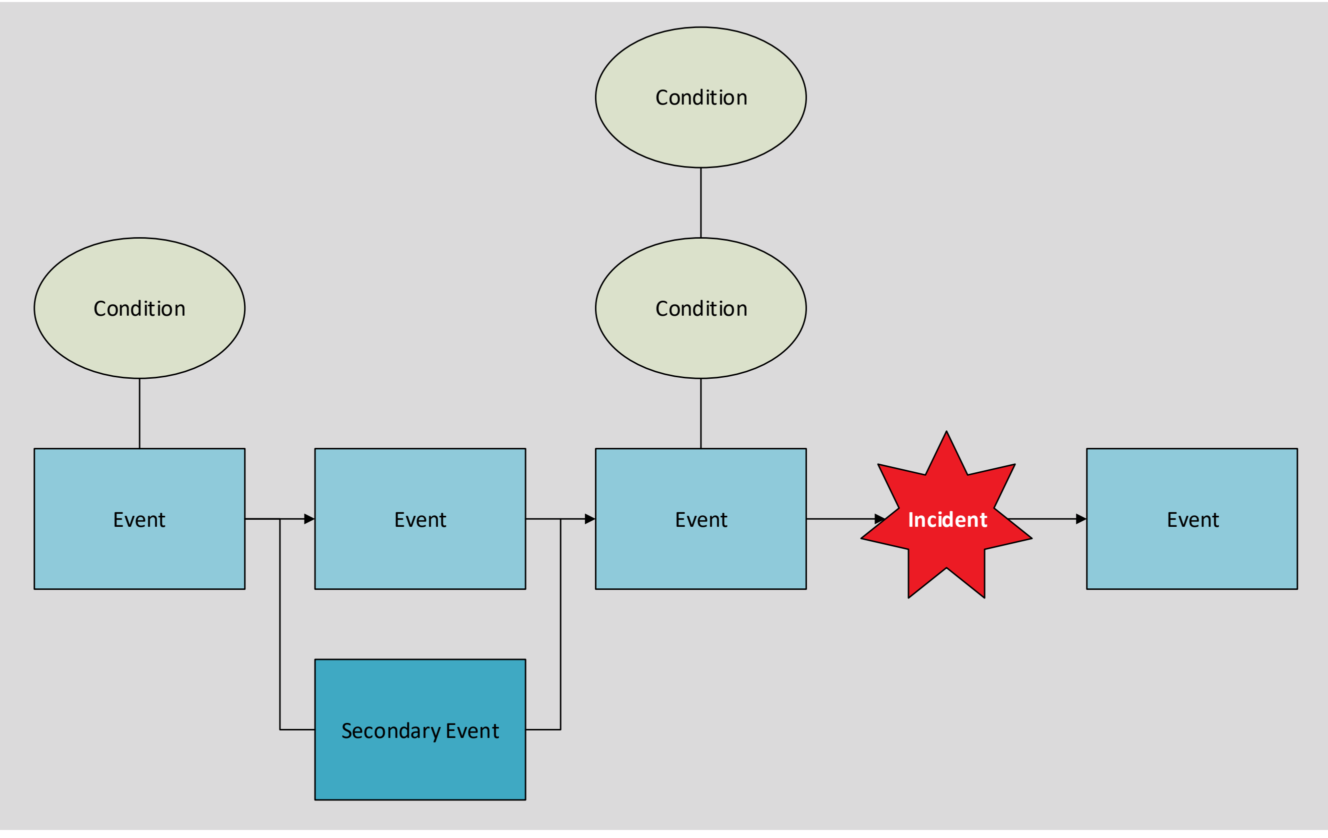
The seriousness and complexity of the incident will determine the team's level of effort, size and makeup, and the time taken. Typically, facts related to the incident are collected through: 1) observations of the scene; 2) investigation of equipment, materials and conditions; 3) interviews and discussions with those involved; and 4) review of pertinent documents, procedures and similar incidents. The use of photographs and digital video is valuable to document observations, damage, hazards, conditions and controls to further analyze. In certain situations, collecting samples (industrial hygiene type sampling) or securing evidence may be necessary. An investigation kit with data collection tools can be useful including pen/paper, graph paper, tape measures and rulers, digital distance measurement tools, infrared cameras, digital cameras, small tools, audio recorder, sound level meter, light level meter, PPE, marking devices (e.g., flags), sample collection container or bags, and permanent marker pens. Today, smartphone features and apps can aid in collecting information at the scene.

A review of pertinent documents is performed to gather information. Sources for the team to analyze include management system documentation, equipment manuals, maintenance instructions, machine specific lockout/tagout procedures, written standard operating procedures, job safety analyses, training, safety data sheets or other written specifications related to the incident. The team should also review reports, investigations and analyses of similar incidents and lessons learned from these investigations.

Reconstructing the events (and potential causal factors) that led up to the incident is a critical part of the investigation. Piecing together the sequence of events and conditions requires collecting and combining individual accounts of the occurrence through individual interviews. Each person involved in the incident is asked to provide their understanding of the events and conditions. The setting and tone of the interview should be comfortable, nonthreatening and focused on finding the facts. One way this can be achieved is through one-on-one interviews using the question "how."

According to Conklin (2016), a proponent of human and organizational performance, "the how is more important than the why" when investigating causal factors. Conklin posits that many of the conditions that lead to failures and incidents are not uncovered with traditional methods or hazard identification tools. He suggests that by asking how it happened rather than why, the investigation can learn more and gain a better understanding of the incident's framework and underlying causes.

FIGURE 2
INCIDENT MAP EXAMPLE



While either one can be used, the authors believe that using the question "how" can be helpful in one-on-one interviews with affected parties, while the question "why" is useful in a tabletop upper-level analysis of the events and conditions.

Much like the five-why analysis approach, the question "How did this occur?" can be applied in a sequential manner to allow the person to explain the circumstances and motivations that led to the incident. In this approach, the individual being interviewed is asked to describe their activities prior to the incident. This can be with a question such as "How did your work day start?" With each event, condition or deviation recounted by the individual, the interviewer asks the follow-up question "How did this occur?" As the individual describes how things unfolded from his/her perspective, a more vivid picture of the incident starts to take shape. The multiple-how approach almost takes the interview to a third-person perspective reducing the notion of blame. Of course, this information is documented in each interview, and compared and analyzed in the following steps.

Mapping the Incident

Once the facts have been collected, the incident can be reconstructed in an incident map or chart. Incident mapping (a.k.a., incident charting, causal factors analysis, events and conditions analysis) is a method used to outline the sequence of events and conditions leading up to the incident. Using the evidence gathered from the investigation, a sequenced model or map of the incident is developed to help visualize the events and conditions that led to the incident. This can be done on paper, a computer software program or on a large white board using sticky notes, then transferred to a document (NRI Foundation, 2014; Oakley, 2012). Definitions of the incident components follow:

FIGURE 3
CONTROLS LEGEND

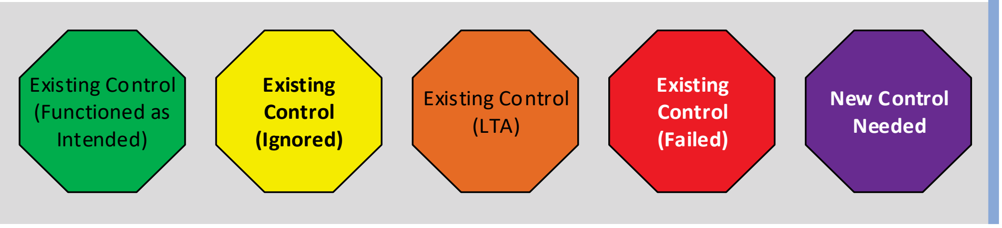


FIGURE 4
INCIDENT MAP WITH BARRIER ANALYSIS EXAMPLE

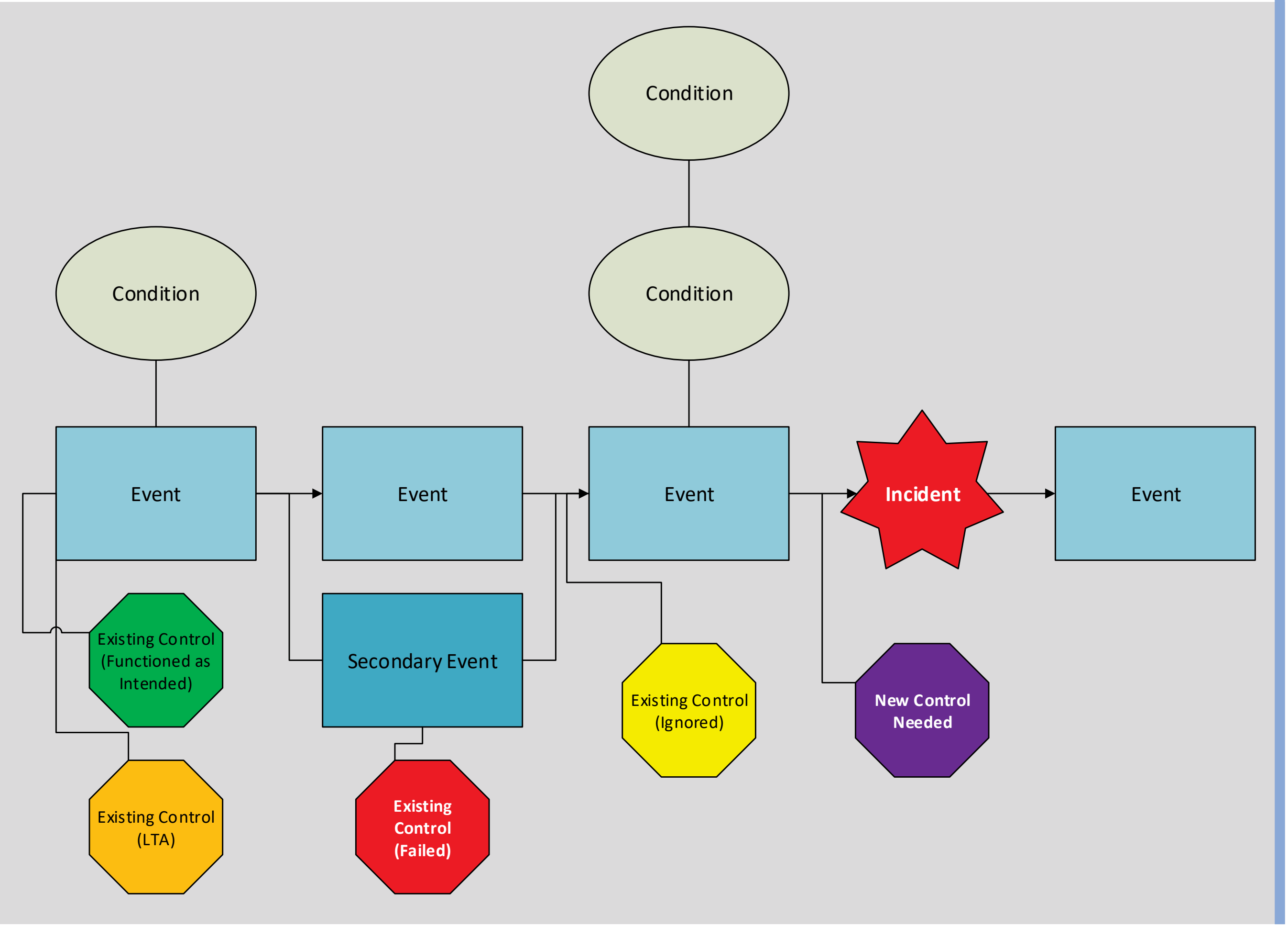


TABLE 2
MANAGEMENT SYSTEM ELEMENTS, DECISIONS, ACTIONS & ACTIVITIES

Element	Decisions, actions and activities
I. Management/supervisory leadership a) Policy b) Responsibility and authority	1) OSH policies communicated to all parties. 2) Safety responsibilities defined for management, contractors and employees. 3) Responsibilities clearly communicated. 4) All parties fully enable to carry out safety responsibilities. 5) Safety responsibilities measured. 6) All levels held accountable. 7) Supervision, coaching and enforcement.
II. Employee participation	8) Know and follow safety procedures. 9) Participate in JSAs, safety activities, meetings. 10) Report hazards, incidents and ideas for improvement.
III. Planning a) Budgeting and allocation of resources b) Staffing c) Prioritization	11) Personnel selection (including contractors, short service and temporary staff). 12) Adequate staffing and proper equipment (including safety equipment). 13) Planning and task allocation. 14) Procedures and technical information. 15) Design of tasks, hardware and premises.
IV. Implementation and operation a) Hazard identification and risk assessment b) Design review and management of change c) Procurement d) Contractors e) Emergency preparedness f) Training, awareness and competence g) Communication h) Document and records	16) Hazard identification and risk assessment. 17) Procurement of supplies. 18) Verifying readiness before use/start of work. 19) Competence assurance. 20) Housekeeping. 21) Inspection. 22) Maintenance. 23) Coordination between groups. 24) Change management. 25) Emergency systems.
V. Evaluation and corrective action a) Monitoring, measurement and assessment b) Incident investigation c) Audits d) Corrective/preventive actions e) Feedback	26) Monitor work and stop unsafe activities. 27) Measure safety performance (completion of responsibilities by all parties). 28) Audit and evaluate actions and conditions observed. 29) Corrective/preventive actions identified, selected, implemented. 30) Track and measure corrective actions. 31) Obtain and incorporate feedback. 32) Investigate and analyze incidents (near-hits, accidents).
VI. Management review	33) Periodic review and revision of policies, procedures, practices. 34) Continually improve process by incorporating lessons learned, feedback, observations.

•Events. The sequence of events leading up to the incident are placed on the map (in a rectangle). An event has three components: 1) a person; 2) an action; and 3) an object. When describing an event all three components should be identified [e.g., forklift operator (person) backing (action) the forklift (object)]. Each event should have only one person and one action.

•Secondary events. It is possible to have multiple simultaneous events that contributed to an incident. Any parallel events are recorded (in a rectangle) below the primary event. For example, a secondary event may be "spotter's view of forklift was obstructed by pipe rack while forklift was backing."

•Conditions. For each event, any conditions that influenced that event are placed on the map (in an oval) above the event. Conditions are included only when they are needed to help explain why the event occurred. Conditions can include:

a) environmental conditions (e.g., temperature, weather, wind, light levels, noise, walking/working surfaces, air quality, flammable atmosphere);

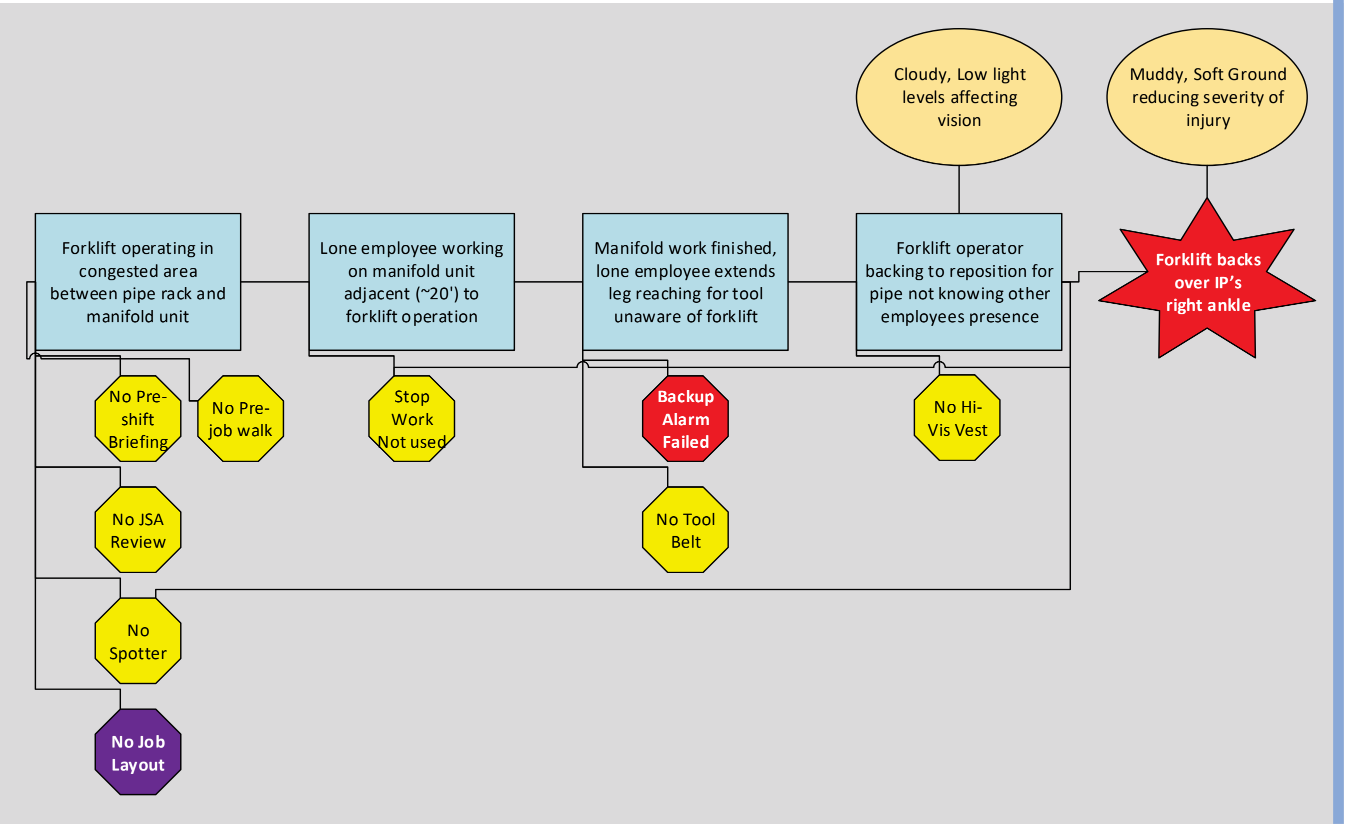
b) condition of equipment or tools used;

c) decisions or instructions given by others;

d) position or exposure to hazard.

•Incident and postincident events. In the map, the incident is recorded (in a red star) followed by any significant events after the incident (Figure 2, p. 52).

FIGURE 5
FORKLIFT CASE STUDY INCIDENT MAP & BARRIER ANALYSIS



Evaluating Existing Controls

Within the incident map, the team identifies all existing controls related to the events and conditions of the incident. This is often called a barrier analysis. All controls, procedures or barriers that should have been in place are identified and reviewed for each event or condition that occurred in the map. Controls are then evaluated as to their role and performance in the incident and identified by color-coded octagons (Figure 3, p. 53).

Color-coding in this example represents the following control conditions: 1) green octagon: existing control functioned as intended; 2) yellow octagon: existing control that was not used or ignored; 3) orange octagon: existing control that was less than adequate (LTA); 4) red octagon: existing control that failed to work as intended; and 5) purple octagon: additional control needed. Each evaluated control is labeled within its color-coded octagon and placed within the map connected to the affected event(s) and condition(s) (Figure 4, p. 53).

Analyzing Deviations of Events & Conditions

Using the completed incident map and barrier analysis, the causal factors within each significant event of the incident are analyzed individually. Change analysis is a method of comparing the events as they occurred in the incident with what is expected to occur. This analysis is used to identify and analyze deviations that occurred and their causal factors (NRI Foundation, 2014; Oakley, 2012). Several variations of change analysis have been developed. (Noordwijk Risk Initiative Foundation offers several incident analyses models including versions of change analysis, called change control cause analysis, or 3CA, at www.nri.eu.com/3ca.html.)

In change analysis, the significant event(s) are analyzed as to what deviations occurred and how control measures performed. A significant event can be defined as one that significantly decreased the control over subsequent events or increased the risk of subsequent unwanted events (NRI Foundation, 2014). Each recorded significant event is compared to what should have happened to identify the deviations and the existing controls that were involved. Following are the process steps of change analysis (Figure 6, p. 56, in the case study provides an example of a change analysis):

1) List the significant events for the incident in the first column.

2) Describe existing controls that should have prevented the event from occurring.

3) Describe what happened and why the controls failed to prevent the event from occurring.

4) Evaluate and list the underlying management system elements that contributed to the event.

5) Make recommendations to address not only the direct causes, but also measures that will address the underlying management system elements.

Identifying Systemic Factors

As noted, the ultimate purpose of incident investigation and analysis is to understand and address the underlying causes of an incident to prevent similar occurrences from happening. Unfortunately, many investigations focus on the direct and indirect causes but do not uncover the systemic causal factors. When investigations only identify and correct the immediate causes such as replacing missing guards, retraining employees in procedures or adding PPE, the latent, underlying causes remain, and the event will likely recur.

FIGURE 6
FORKLIFT CASE STUDY CHANGE ANALYSIS

1) Event Describe the event.	**2) Controls** Describe existing controls that should prevent the event.	**3) Deviation** Describe what happened and why controls were ineffective.	**4) Causal factors** Underlying elements.	**5) Actions** Describe needed actions to prevent future events.
Forklift operator was backing near another worker	Preshift briefing	Site management did not hold a preshift briefing leading to unsafe work near forklift.	Planning; accountability.	Implement safety performance measurement system to track safety tasks performed at sites. Measure and reward site management based on performance of duties. No tolerance for nonperformance.
	Review of JSA	Site management did not require employees to review JSA.	Accountability; employee involvement.	Employ safety tracking system same as above. Review JSAs for clarity and accuracy.
	Prejob inspection	Site management did not require a prejob inspection	Planning; accountability.	Employ safety tracking system same as above.
	Spotter	Site management and forklift operator did not require a spotter.	Enforcement; accountability; employee involvement.	Employ safety tracking system same as above.
	Stop work authority	Site management and employees did not use stop work authority.	Enforcement; accountability; employee involvement.	Employ safety tracking system same as above.
	Hi-visibility vest	Site management did not provide hi-visibility vests.	Budgeting and resources; accountability.	Review management's allocations for safety equipment.
	Forklift backup alarm	No PM schedule. Site management did not correct.	Maintenance; accountability.	Include safety features for all equipment in the PM schedule. Create a priority work order for safety-related repairs.

A simple problem-solving method called a five-why or multiple-why analysis can be used to uncover deeper rooted causes. The five-why method was originally developed by Sakichi Toyoda, founder of Toyota Motors Corp., and Taiichi Ohno, a Toyota engineer, as a problem-solving tool for production and quality problems. Toyoda and Ohno viewed a problem as an opportunity to learn and improve, as a kaizen or continuous improvement opportunity. Whenever a problem was encountered, Ohno would instruct a team to explore the problem without preconceptions, observe the work, then ask why about every matter (Mind Tools, 2017; Toyota Motor Corp., 2006). The concept of "go and see" what is happening and find out why it is occurring is an effective and simple way for OSH professionals to approach risk assessment and solve safety-related problems.

Using the five-why analysis method, each significant event is analyzed to drill down to the management systems level, where the causal factors exist, and potential problems originate. Each event is analyzed and questioned until the underlying management system elements are exposed. The method promotes involvement of individuals in the investigation group who are close to the work performed; critical and systematic thinking; and meaningful discussion to lead to agreed-upon causal factors. This technique can be used for any hazard and risk-related incident (e.g., employee injury or illness, incident involving a nonemployee, product quality and safety, property damage resulting from a fire, incident resulting in business downtime, damage to properties other than the organization's, environmental incident). The basic steps for conducting a five-why analysis are:

1) Provide the team with a thorough description of the incident.

2) The leader starts by asking why the incident happened, and to each response continues asking why until the group agrees on the systemic causal factors that can be controlled.

3) The leader keeps participants focused on factual data, steers discussions beyond symptoms to get to causal factors and avoids placing blame.

4) Consider using a white board to record and make visible responses to the why questions.

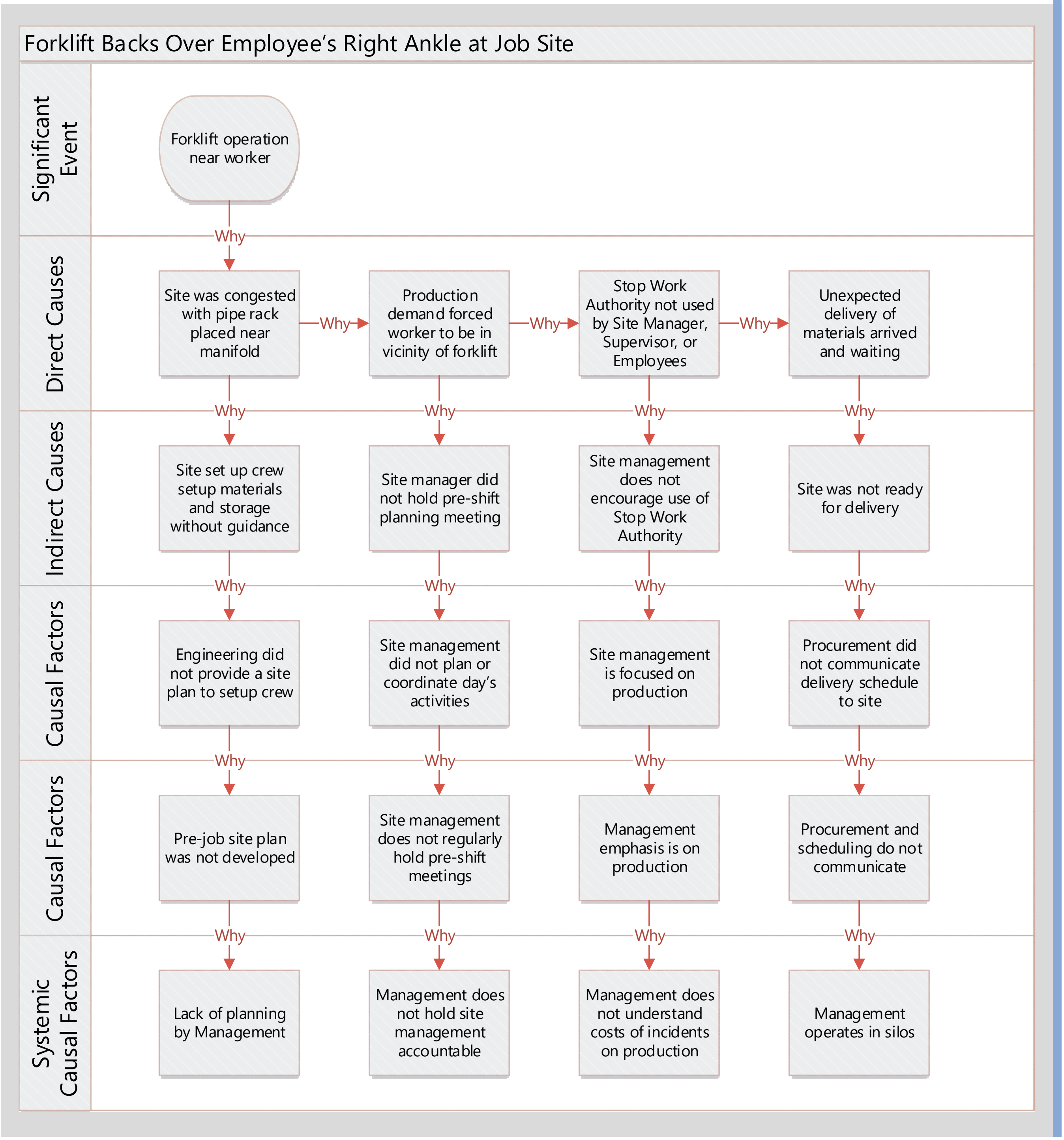
5) If discussions reveal more than one path contributed to the occurrence, discuss each path. Identifying all pertinent causal factors cannot be achieved if each path is not explored.

6) Be cognizant of the time to end discussions.

7) When root-causal factors are identified, assign responsibility for agreed-upon recommendations to avoid recurrence of a similar type of incident, stipulating individuals responsible and time for completion.

FIGURE 7

FORKLIFT CASE STUDY MULTIPLE PATH FIVE-WHY ANALYSIS



8) Action on the recommendations should be followed to a logical conclusion.

Causal Factors Diagramming

Using the information developed, a causal factor tree diagram is constructed. A causal factor tree diagram can be useful in illustrating an incident's breakdown, tracing the causal factors from the direct causes to the indirect causes, all the way down to the root levels (management system elements). The diagram can also be useful in identifying control measures that address the management system elements and allows management and employees to clearly visualize the causal factors and needed controls. The diagram uses a fault-tree structure with symbols and gates to construct the incident (top event) and its causal factors. (An example of a causal factors tree diagram is presented in Figure 8, p. 58, of the case study.)

Identifying Management System Factors

To prevent future recurrences of similar incidents, the underlying causal factors within the management system must be identified. The management system model provided in ANSI Z10 contains six primary sections or elements. For each element, there are specific actions, activities and decisions that occur as part of the system. Table 2 (p. 54) illustrates the management system elements and their specific actions.

As the analysis is completed, the team places its focus on identifying the key management system deficiencies tied to causal factors of the incident, and the needed corrective measures and improvements.

Documenting & Communicating Findings

Upon completion of the analysis, the causal factors analysis report with recommendations is prepared. In general, the report should include the investigation/analysis team members' names, a management or executive summary with the overall findings, a completed incident report form, a detailed narrative statement concerning the events and recommended actions. Photographs, videos, witness statements and drawings should be included to help describe the situation, configuration, conditions and environment. The overall purpose of the final analysis is to provide management with risk-based information concerning the incident and needed control measures and actions to prevent similar events from occurring.

Implementing & Monitoring Corrective Measures

All corrective measures generated from incident analyses must be monitored to verify they are in place, operating as intended and be refined as needed. Documentation of their implementation along with the date and responsible party should be maintained.

Case Study: Construction Site Forklift Backs Over Employee's Foot

Initial Incident Description

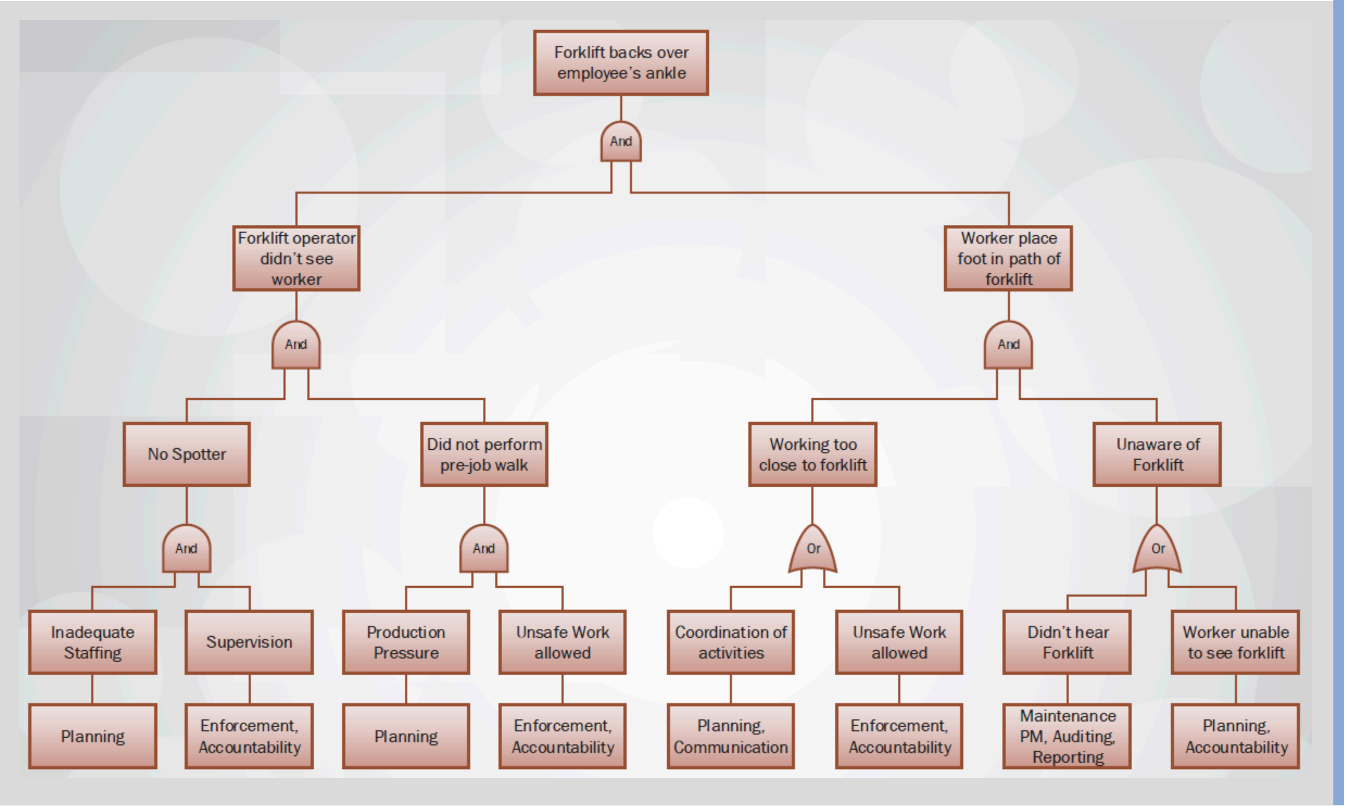
At 4:40 p.m. on July 7, 2017, at Far Meadow Site, the crew had just completed Phase 1 and was about to begin the process of connecting pipe. Three employees were using the all-terrain forklift in muddy conditions to hang pipe near the catwalk while another employee (injured party, IP) was working on a choke manifold unit adjacent to the forklift work.

The forklift operator drove the forklift between the choke manifold unit and the pipe rack to help supply employees connecting pipe on the opposite end. While the employees were connecting pipe, the employee (IP) working on the manifold was completing his work. Once completed, the IP knelt and leaned over one of the diverter lines to reach inside the manifold unit to grab a wrench he left behind. As he reached from a kneeling position, he extended his leg into the path of the moving forklift as it was backing. With the employee's leg in the direct line of the forklift tire, the forklift operator began backing up to reposition without seeing the IP. As the operator backed up, he was unaware the employee was in the path of travel and backed over his ankle in the soft mud. The IP screamed, notifying the operator of his presence and the forklift pulled forward.

Incident Map

Using the information and facts collected during the investigation, the team lays out the sequence of events and related conditions of the incident. Only events and conditions that were material to the incident. Four events were identified in the case study: 1) forklift operating in congested area between pipe rack and manifold unit; 2) the injured employee was working on a manifold unit adjacent to the forklift activity; 3) the injured employee was unaware of the forklift and extended his led in the path of the forklift; and 4) the forklift operator could not see the other employee when backing up. Two conditions were identified: 1) reduced visibility on the site; and 2) muddy conditions, which reduced the severity of the injury.

FIGURE 8
CAUSAL FACTORS TREE DIAGRAM



Barrier Analysis

Upon completion of the incident map, a barrier analysis of available controls is performed. Using the color-coded legend, controls are labeled, placed in the map and connected to the affected events and conditions (Figure 5, p. 55). In the case study, the barrier analysis determined:

- One new control is needed, prejob planning.
- Seven existing controls were ignored or not used: 1) preshift briefing; 2) review of the JSA; 3) prejob walk-around inspection; 4) stop work authority; 5) use of a spotter; 6) use of toolbelt; and 7) use of high-visibility vests.
- One control failed, forklift backup alarm.

Change Analysis

Each significant event is described as it occurred and compared to what should have occurred. Using the form in Figure 6 (p. 56), the primary significant event from the case is described, along with existing controls, deviations that occurred causing the control to be ineffective, the underlying causal factors tied to the deviation and actions necessary to address the underlying causes.

Five-Why Analysis

It may be necessary to conduct a five-why analysis of the events to determine the management-system-level causal factors. In the case study, a multiple path five-why analysis was used to analyze the multiple reasons that were discovered for the significant event (Figure 7, p. 57).

Causal Factors Tree Diagram

Using a fault-tree diagram, the incident's causal factors are broken down and traced back to the management-level elements. In the case study, the causal factors are shown in Figure 8. Along with the diagram, a report narrative is provided to management. The report is designed to describe the facts of the incident, the events and conditions, the performance of control measures, and the recommended actions that will address direct causes, intermediate causes and, most importantly, the management-level causal factors.

Conclusion

Some or all of the tools presented in this article may be needed in certain incident analyses. It is important to remember the ultimate purpose of incident investigation and analysis: the development of solutions that will prevent similar incidents from occurring and reduce the impact of incidents that occur.

Today's OSH professionals face multiple challenges. Diversifying their skills and applying multiple methods to uncover deficiencies within the management system elements will promote the value of those who practice safety. Those skills may include the role of change agent and influencer of culture change. The degree to which an organization's culture supports its incident investigation system is critical. As Fred Manuele (personal communication) has said to the authors, "An organization's culture must support its incident investigation system; to improve on an existing system will often require a culture change, and that success will not be achieved without senior management buy-in, direction and involvement." **PSJ**

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