Chapter 9

Incident Investigation Programs

People investigate harmful incidents for various reasons.[1] For safety professionals, the primary reason for investigating incidents is to learn about system weaknesses and vulnerabilities so that corrective actions can be identified and implemented, and a secondary reason is to comply with recordkeeping requirements. For legal advisors, the main interest is to properly obtain evidence in order to prepare for possible litigation. For the news media, a single "cause" is sought for a news story. For regulatory agencies, the main reason is to determine what regulations may have been violated. In addition to these common reasons, an incident investigation may be conducted for at least three other reasons. One is to look for evidence of criminal behavior, such as a fire started by an arsonist. A second is to determine the economic value of losses in order to obtain some financial indemnity from an insurer. A third is to learn about ways to make the organization more effective by strengthening management processes (not just safety-related processes). To accommodate these varying needs and perspectives, it helps to have a written policy and standard practices in place before an incident occurs.

This chapter consists of five main sections. The first three sections address the concept of a closed-loop process, common issues to resolve in an *incident investigation policy*, and basic investigative processes. The fourth one explains some useful tools to help investigators with their analysis, and the fifth section provides a graphic model useful for visualizing the various phases and events leading to and following the incident.

Incident investigations fit somewhere on a continuum from shallow to deep. Shallow investigations typically look only at the conditions and events close to the incident, and the report consists of descriptive information called for by an incident investigation form. Deeper investigations extend to root causes—the weaknesses and vulnerabilities that allowed or led to the events and conditions most directly associated with the incident. Clearly, deeper investigations have the potential to yield more insightful conclusions and useful recommendations.

Risk-Reduction Methods for Occupational Safety and Health, First Edition. Roger C. Jensen.

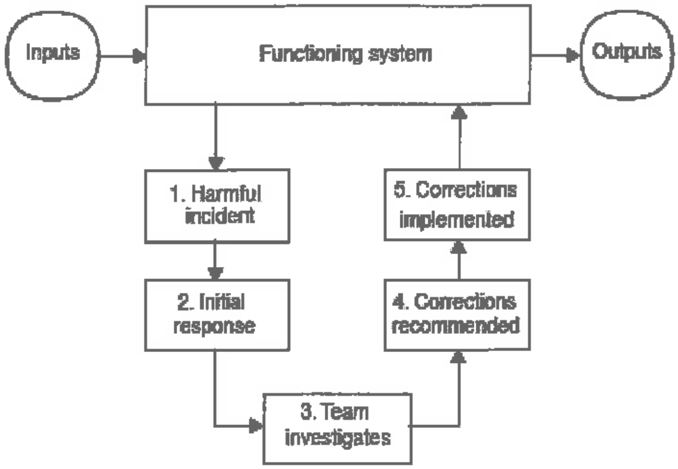

Figure 9.1 Graphic model of a functioning system with a closed-loop process for addressing harmful incidents.

9.1 CLOSED-LOOP PROCESS

A foundation for understanding organizational options for incident investigations begins with understanding the concept of a closed-loop process. The graphic model in Figure 9.1 is used to explain the relationship between a normally functioning system and a closed-loop incident investigation process. The upper part of the model depicts the normal activities of the system simplified into (1) the inputs to the system, (2) the system performing in a normal, predictable manner, and (3) the outputs. The lower part of the model shows the flow of processes for responding to the occasional *harmful incident*.

System inputs include materials, utilities, people, and other resources entering the system. System outputs are goods and services valued by customers and usually some waste. The box depicting a functioning workplace system signifies an operating entity. Some workplace systems are defined by location, such as manufacturing plants, chemical processing facilities, a group of people working together in an office building, construction sites, hospitals, mines, ships, airports, and farming operations. Other workplace systems are defined by an area or region in which they operate, such as local governments, entities operating railroads, courier service providers, and businesses engaged in transportation. Within workplace systems, there are daily variations that are normally tolerable. Successful systems have capabilities to monitor and detect when things start going awry and to make corrections in a routine, relatively easy manner. The correctable deviations are regarded as being within the tolerance of the workplace system. Some deviations go uncorrected, and a portion of these start a chain of uncontrolled events that leads to a harmful outcome.

Figure 9.1 uses rectangles to represent the five processes in a closed-loop investigation. It applies to investigations conducted by a team seeking to learn how to make the workplace safer. It may apply to *form-driven investigations*, provided the investigators are well trained, they come up with useful recommendations, and the organization follows up on those recommendations. When the decision is to conduct a team investigation, all five processes in Figure 9.1 are performed—effectively closing the loop.

The remainder of this chapter emphasizes the importance of each organization tailoring policies to fit its unique needs. No attempt is made to describe a best practice or a preferred "how to" approach for post-incident investigation. Background material for this chapter comes from the author's experiences integrated with advice from numerous authors, especially Bahr, Hughes, and Oakley.[2–4]

9.2 POLICY CONSIDERATIONS

A written policy provides the organizational guidance about what to do after a harmful incident. The organization may conveniently make the policy a section of its official policy for administering an OSH program. Table 9.1 provides an outline of the

Table 9.1 Overview of Some Policy Issues for Responses to Harmful Incidents

Policy application	Issues to resolve
Defining scope of incident investigation policy	What types of incidents will be investigated?
Deciding on depth of investigation	What criteria will be used for deciding which incidents to have a team perform an in-depth investigation?
	Will decision on depth of investigation be based on actual outcome or on what could have been the outcome had the response been ineffective?
Assigning and preparing investigators	How does organization choose investigators? What training will investigators get?
Collecting and preserving evidence	What procedures are expected for (1) collecting evidence and (2) preserving evidence?
	Will policy explicitly call for getting evidence on (1) the normal process and (2) the history of equipment maintenance?
Analyzing evidence	Should all teams use a particular analysis tool?
Reaching useful recommendations	Does organization want to have guidelines for the recommendations contained in investigation reports?
	How will draft recommendations be reviewed prior to finalizing the investigation report?
Communicating findings, recommendations, and lessons learned	Does organization want a policy on (1) assigning corrections to appropriate individuals, (2) a formal verification procedure, (3) distributing the report, or (4) sharing lessons learned outside the organization?

processes and associated policy issues the organization may choose to include in an incident investigation policy. The remainder of this section discusses these issues without attempting to specify a one-size-fits-all approach.

The beginning of the closed-loop process depicted in Figure 9.1 is an incident of some kind. Organizations need to define what incidents to include and exclude from their incident investigation policy. Will the policy apply to employees, the environment, product users, equipment, facilities, or others? What are the legal requirements for investigations? What level of severity will trigger an investigation?

Another question to resolve is what sorts of events will be investigated with a full team doing an *in-depth investigation*. A policy could specify criteria for equipment damage in terms of estimated financial loss. A policy could specify criteria for human injuries based on severity. If the organization uses a risk-assessment matrix, it may also be useful to mirror the severity categories used in their risk matrix. For example, say the company uses four categories of severity in its risk assessments (e.g., minor, moderate, serious, and catastrophic). It may be advantageous to use the same severity categories in the policy on depth of investigations. Advantages of this include being consistent, limiting complexity, and facilitating comparison of actual harm to the level of harm shown in the applicable risk-assessment document.

The severity of harm can be affected by the post-incident response. A rapid response by emergency medical service personnel can make the difference in life or death. The response by an environmental response team to a spill (e.g., an overturned tanker truck leaking a chemical) can greatly limit the amount and spread of the chemical and thereby reduce the cost of restoring the soil. The response of a fire department to a structural fire can make the difference in a total loss or a repairable structure. Because post-incident response often affects severity, a question for consideration is: Should the policy be based on the outcome severity after the response or on the potential worst case had there not been an effective response? For example, in a petroleum refinery, a small fire started, and an employee noticed it and used a portable fire extinguisher to extinguish it. If based on actual outcome, it would be considered a minor incident warranting an ordinary investigation, but viewed from the perspective of the potential worst case, it would be considered serious incident warranting a full-scale, in-depth investigation.

Some organizations encourage personnel to report near-miss incidents based on the idea that for each actual injury there are many instances of someone coming close to being injured. By obtaining reports and investigating many near-miss incidents, OSH professionals can uncover hazardous conditions, events, or exposures suitable for correcting before any harm occurs. Organizations that ask employees to report near-miss incidents will want a policy or process for investigating or otherwise following up on the reports.

Another policy decision involves terminology. Some people passionately debate the pros and cons of terms used to describe incident outcomes. The U.S. military community uses the word *mishap*. The word "accident" is commonly used in general industry, construction, in reference to major transportation disasters, and by coroners to classify cause of death. The public health community uses words specific to human health such as injury, death, and disease, while avoiding the word "accident" because a substantial portion of the public associates the word with an unpreventable or random event. No attempt is made in this chapter to either criticize these other terms or advocate for the term "harmful incident."

One final policy issue warrants comment. Organizations vary on how much time and money they want to put into incident investigations. Differences result in part from how OSH leaders view the benefits from investigating past events versus time spent on proactive OSH projects. Some safety professionals liken investigating past incidents to a dog chasing its own tail—a never-ending circle of investigating and fixing problems. Some organizations choose to allocate more OSH resources to proactive programs. There is no one-size-fits-all allocation formula.

9.3 INVESTIGATIVE PROCESSES

Critical parts of an incident investigation include (1) collecting and preserving evidence, (2) reaching evidence-based conclusions, (3) developing useful recommendations, and (4) communicating findings, recommendations, and lessons learned.

9.3.1 Collecting and Preserving Evidence

Common types of evidence are photographs, scale drawings of the location, statements by witnesses, and documents in paper or electronic form. Before allowing changes in the scene, take numerous photographs, keep a log of the date, time, and location, and preserve all of it. Obtain measurements for making a scale drawing of the area. Mark or tag tools, equipment, and other items for clear identification in case of litigation. As soon as possible, interview *eyewitnesses*—people who were in the area of the incident and who possibly saw, heard, or smelled something relevant to the incident. Other witnesses to interview are people who have knowledge of how the operations are supposed to work and how things actually work. Interviews with these people may provide information for identifying deviations that may have contributed to the events preceding the harmful incident.

Readers who occasionally investigate workplace incidents can easily identify published material containing advice on investigation methods and procedures.[3,4] For readers who find that their jobs involve regular incident investigations, training courses are typically available through professional societies or agencies in their business domain. Some common domains with need for frequent investigations are found in government agencies that investigate chemical plant fires and explosions, workplace fatalities, and crashes involving aircraft, trains, and buses. Special courses are available for fire and police department investigators who need to look for evidence of arson (deliberate fires started with criminal intent). Property insurance companies also provide training for investigating fires to determine if the fire was covered by the policy, if a third party might have some liability, and the value of losses.

Easily overlooked in incident investigations is the need for evidence with regard to the normal processes, practices, and controls in the affected system. This information will facilitate comparing what normally occurs with the actual events leading to the incident being investigated. That comparison may indicate *deviations from normal* that created a hazardous condition or resulted in a normally effective control being ineffective. An example would be learning that a particular machine frequently malfunctions or that an employee routinely followed a procedure that differs from the standard operating procedures.

9.3.2 Reaching Evidence-Based Conclusions

The various sources of evidence may be viewed as pieces of a puzzle. Once the pieces are assembled, the investigative team can begin putting the puzzle together. Some analytical tools for helping an investigative team complete the puzzle are discussed in this section.

Incident investigators should strive for evidence-based conclusions. While that may sound obvious, it can be tempting to do the opposite. The opposite is reaching a conclusion and then sifting through the evidence to find support for that conclusion, while discounting or ignoring evidence that conflicts with the conclusion. To avoid that pitfall, organizations may choose to specify methods for keeping investigators on track. Three logical steps for taking the path from evidence to conclusion are

1. Develop the accident sequence,
2. Analyze it, and
3. Determine causal factors.[4]

In Step 1, the investigation team uses the evidence to explain the sequence of events. It is often helpful to start by describing the scene where the incident occurred. This can include such information as the place and conditions existing before, during, and after the incident. Typical types of evidence for this step are photographs and a scale drawing of the location.

In Step 2, the investigative team seeks to provide a plausible explanation for all the reliable evidence. Some techniques the team may use to analyze the evidence are described in books by Oakley and Stephans.[4,5] One such tool—the events and causal factors chart—is explained later.

In Step 3, the investigation team reviews their results from Steps 1 and 2. From this foundation, the team extracts the factors that contributed, enabled, or directly caused the events in the sequential chain. Following the three-step process should lead to evidence-based conclusions as well as identifying factors in need of change.

Investigators should recognize their investigation is what statisticians call a sample of one. Therefore, investigators should be cautious about trying to generalize their findings beyond the scope of their investigation. It is best to limit the findings and conclusion to your case. Later, others may develop generalization after reading your report and many other reports. Also keep in mind that the ordinary occupational incident investigation team lacks the resources, and perhaps the expertise, to adequately assess organization-level issues. This contrasts with highly funded multidisciplinary investigations of major disasters involving ships, passenger planes, nuclear power plants, petroleum refineries, and space flights.

9.3.3 Developing Useful Recommendations

As a practical matter, the investigation team should attempt to focus on making recommendations that are feasible to implement economically, technically, and legally. Consider the alternative. If the team makes a recommendation that never gets implemented, the organization may find its nonresponsiveness used against it in future litigation. To illustrate how such a scenario might unfold, consider a general contractor in the building construction business. They had a subcontractor employee seriously hurt when he fell from a roof. The investigation team recommended that the general contractor should closely monitor and enforce fall protection for elevated work performed by all subcontractor employees. Now suppose three years later an employee of a subcontractor falls from a roof and gets seriously hurt. The employee could sue the general contractor claiming failure to exercise due diligence by not making sure all subcontractor employees always use fall protection. As evidence, the injured employee's attorney can introduce the report from three years ago that recommended the general contractor should enforce fall protection by its subcontractors. The attorney will argue that the general contractor failed to exercise due diligence by not fully implementing the recommendation in the prior report. In essence, the recommendation may have imposed a legal duty on the general contractor that did not previously exist. Thus, before finalizing its report, it will be wise for the investigation team to consider each recommendation for legal implications as well as for economic and technical feasibility.

Another matter to consider when developing recommendations involves prior risk assessments. If the organization already has an RA applicable to the investigated events, it makes sense to review it. The RA can provide information useful for the incident investigators, and the findings from the incident investigation can be useful for reassessing the RA.

If not all the risk-reduction tactics in the RA were in place when the incident occurred, the investigation team would most likely recommend actions to reimplement the tactics. If all the tactics were in place, the team needs to reassess the RA and consider revisions to correct deficiencies. Another option would be to conclude that the risk was acceptable before the incident and continues to be acceptable into the future. This second conclusions could be quite appropriate for an incident of equipment damage. But if an employee was harmed, this conclusion would leave the impression that the employer is coldhearted and lacks genuine concern for employees. In reality, people expect the investigation team to make some sort of recommendations for change, either to reimplement risk-reduction tactics or modify the RA.

9.3.4 Distributing Findings, Recommendations, and Lessons Learned

Before wrapping up the investigation, the team needs to distribute their findings, recommendations, and lessons learned. Clearly, the final investigation report should be distributed to the individuals most affected by the incident. If not given a copy, they might suspect something important is being hidden from them. A distribution list should include everyone with a possible role in implementing recommendations.

Although an incident investigation team is responsible for making recommendations, the team has no authority to assign managers to implement the recommendations. Therefore, an organization intending to have a closed-loop process needs to transfer recommendations from the incident report to managers with authority to implement. Since busy managers may not find the time to read the entire report searching for findings and recommendations applicable for their units, some mechanism is needed to highlight the specific responses applicable to each manager. One approach could be to distribute the report to managers with an accompanying memo highlighting items applicable to the manager. Another approach could be an oral presentation on the investigation at a management meeting.

There is also a need to follow up on implementation. A process to verify proper implementation of corrective measures contributes to overall safety by providing (a) impetus for managers to implement recommendations applicable to their operations, (b) assurance for the organization that corrections were made, and (c) documentation of closing the loop.

The investigation team may want to share important lessons learned with others. Some organizations with multiple sites have mechanisms for sharing lessons learned at one site with counterparts at other sites. Similarly, some industry groups have shared reporting of lessons learned. The nuclear power industry, for example, developed an information sharing system because of a mutually recognized need to operate all nuclear plants in the world safely. Another example of sharing is found in the fire protection community. Journals and magazines routinely publish reports about major fires and explosions, and these typically contain lessons learned.

9.4 PRACTICAL TOOLS FOR INCIDENT INVESTIGATORS

In this section, practical tools for incident investigation teams are explained. The first tool helps the team use the evidence to develop a sequential chart of events and associated contributors to those events. The second tool can help the team think broadly about potential corrective actions to reduce future risks. The third helpful tool is the use of prior investigation reports found in published literature and reputable websites. The fourth section briefly explains three other analysis tools.

9.4.1 Events and Causal Factors Chart

A useful tool for sorting out the sequence of events is depicted in Figure 9.2. Called an *events and causal factors* chart, it displays the events in boxes arranged in order from left to right. The text in the event boxes indicates the actor (person or thing) and the action. The action description should simply state the action and avoid judgmental words such as unsafe, improper, or erroneous. Ovals connected to events are for noting conditions and factors associated with the event. For the example chart, there was one

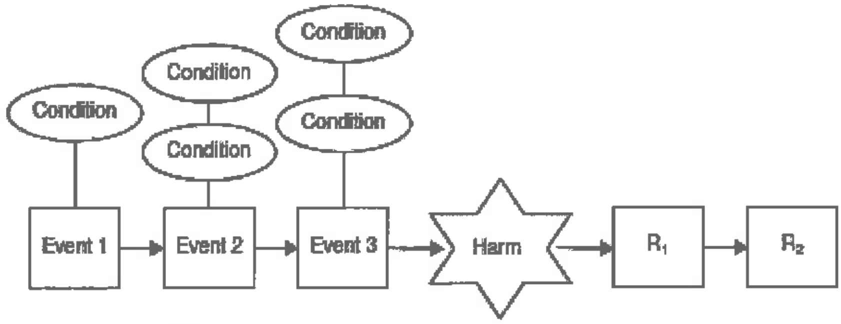

Figure 9.2 Basic format of an events and causal factors chart.

condition relevant to event 1 and two conditions relevant to events 2 and 3. The point where the harm occurred is depicted by a star-shaped figure. Although some organizations use a diamond shape, this may not be ideal because it gives too many meanings to the diamond—in the conventional flowchart a diamond shape is used for decisions, and in analytical trees a diamond shape is used for an undeveloped event or condition. In the figure, two response events (R_1 and R_2) are depicted to the right of the star. These are useful for documenting the performance of the first response and subsequent actions to mitigate the harm.

An events and causal factor chart can help not only the investigation team, but also those who read the final report. It depicts the main events and associated conditions, and it provides an organizational structure for writing the incident scenario. Although the chart shown makes this whole effort seem very simple, possibly trivial, it can be invaluable when sorting through scenarios that are more complex. For one thing, the "conditions" described in the chart can be used for various types of information relevant to the event, four of which are noted below.

1. Enabling conditions that had to occur in order for the event to occur (e.g., the machine was connected to the building's electrical system). This kind of condition is recognized in legal circles as being one element of a negligence case. It is the element involving proof that the harm would not have occurred "but for" the condition existing.
2. Omitted events or nonevents such as noting the victim omitted a step in a procedures (e.g., entering a confined space without first checking the concentration of flammable vapors).
3. Contributing factors such as a warning sign was not visible, lighting was poor, or the employee had been working extra hours for three straight days.
4. Basic facts relevant to the event such as noting the distance of a fall, the weight of an item involved, or the fact that the company required a particular item of PPE.

The text in ovals should be concise and avoid judgmental adjectives. Some organizations and authors will use an additional symbol to show why a particular condition existed (Oakley uses a hexagon).[4] Thus, events and causal factors charts provide considerable flexibility for sorting out the sequence of events, conditions associated with the events, and the causes of the conditions and events. All this information will directly help the investigators understand how and why the incident occurred.

An example of an occupational fatal fall is offered to illustrate how the events and causal factors chart can be used to clarify the sequential events. Figure 9.3 uses three rows to organize events into three phases. The top row contains the preliminary events that set up and allowed the man to fall. The second row contains the sequential events from loss of control to injury. The third row contains the relevant response events subsequent to the injury.

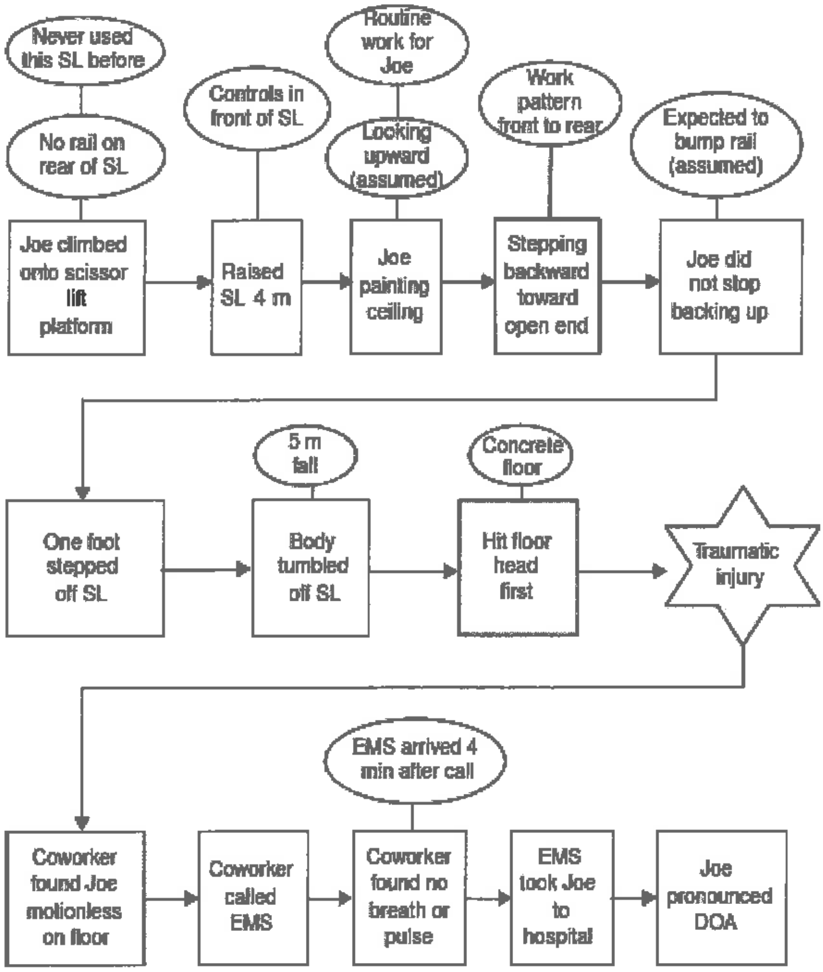

Figure 9.3 An event and causal factors chart for fall from a scissor lift.

A painter named Joe was painting a high-bay ceiling with a roller brush. He was working from a scissor lift (SL) elevated to about 4 m, making his center of gravity about 5 m above the floor. The SL was borrowed from another subcontractor with a crew at the site. The railing on the lift platform was intact on the front and both sides. Elevation controls were attached to the front rail. When the SL was new, the rear of it had a swinging, self-closing rail at approximately hip height and a chain for use as a midrail. Workers could enter the platform by either crawling under the rail or using the rail as a door. However, the old borrowed SL no longer had the rail. It also did not have a chain.

Information obtained from other painters after the incident enabled the investigators to determine the normal method they use to paint a high ceiling from a SL. Painting a ceiling involves constantly looking upward. Workers fill their brush, and then start in the front of the platform and work backward until they feel their hip bump the back rail. They even call this a "bump bar." Once they feel it, they walk back to the front to begin another cycle. After obtaining photographs of the SL, statements from a coworker, and interviews with other painters, the event sequence was pieced together as shown in Figure 9.3.

The chart begins with Joe climbing onto the SL platform. Other investigators may elect to start further back in time in order to elucidate why Joe borrowed a SL instead of using one owned by his employer. They might also ask why Joe would choose to use a SL he could easily see was lacking a rail. Thus, one of the issues facing incident investigators is where to begin.

Benner proposed a place to begin an investigation.[6] He recommended looking for an event that started an uncontrolled chain of events based on a general model of a functioning system. A brief explanation of this model will help readers appreciate his rationale. Think of the daily activities of a functioning system operating in a normally controlled manner or in homeostasis. In that state, many events go as expected, and the occasional deviation from normal (Benner called it a perturbation) can be easily dealt with by human response or engineered adjustments. When something unusual occurs and fails to be detected and adequately corrected, homeostasis is lost—initiating of a potentially uncontrolled chain of events. The chain of events may lead to various outcomes ranging from no harm to very serious harm. Once the investigators know what events led to the harm, Benner advises that they take their investigation back in time to the original deviation. At that starting point, the investigators try to determine why and how the deviation occurred and what happened afterward.

In the illustration, the deviation was identified as Joe climbing onto the platform of the unfamiliar SL with a missing gate. That was the deviation event—when he deviated from his normally successful method of painting a ceiling using his own company's SL. Thus, the event sequence in the top row of Figure 9.3 starts with the deviation event and ends with the failure of the last hazard control—Joe keeping mental focus on his body position relative to the opening. The ergonomics principle of single-channel processing tells us that humans are poor at concurrently performing two or more mental processing tasks. Joe was trying to concurrently process both body position and the roller brush applying paint to the ceiling. His normally successful stop in the correct position was the only fall prevention tactic. The failure of that tactic ended his postural control.

The second row of the chart begins with Joe no longer having control of his body—he was falling and could do nothing about it. Other *intermediate events* in this row led to his head hitting the concrete floor, causing traumatic injury.

It is the nature of intermediate events that multiple outcomes are possible. Outcomes can range from catastrophe to close but unharmed. In the example case, outcomes would have been different if Joe had been wearing a harness connected by a lanyard to a fixture on the platform, if he had tumbled differently and landed on a different body part, or if he had landed on a half-empty cardboard box instead of a hard floor. All these variations in possible outcomes illustrate the importance of including the details of the intermediate events in the chart.

To appreciate a chart such as this, it helps to initially read the descriptions in the event boxes, and then go back and look at the ovals. The two ovals above the first event box illustrate different types of conditions. The first (never used this SL before) was a contributing condition. The second (no rail on rear of SL) was an enabling condition. The condition above the second event box (controls in front of SL) is a fact that merely makes clear that Joe must have gone to the front of the SL to raise the lift. The two ovals above the third event are contributing factors for the painting work Joe was doing. The first one (routine work for Joe) was determined from witness statements obtained from other painters who had worked with Joe. The second (looking upward) was assumed as being necessary to properly paint a ceiling. The oval concerning work pattern being from front to rear is to make clear that an assumption was associated with this event. The last oval in the top row (expected to bump rail at rear) was another assumption based on interviews with other painters.

Investigators can include in their events and causal factors chart any events or conditions that helped mitigate the severity of harm. These are generally located just to the left of the star symbol in the chart. For example, if Joe had landed on a half-empty cardboard box, that would be identified as an event that reduced the deceleration at the bottom of his fall. As another example, if a dropped object impacts the hard hat of a worker below, the mitigating effect of the hard hat would be shown as an event. If the driver of a car loses control and the car hits a tree, mitigating events might be "seat belt holds driver in seat" and "air bag cushions driver's head." On the other hand, if a normally effective safety device was not in use or unavailable, the chart should indicate the absence in an oval.

Figure 9.4 contains two charts for car wrecks. Figure 9.4a shows how to include the role of safety devices. Since the contributions of the seat belt and air bag occur at the same time, they are shown as parallel events. Figure 9.4b shows how to indicate the lack of safety devices. The two ovals are placed above the event they influence—driver slams into steering wheel. Thus, events and causal factors charts can show safety devices contributing (in event boxes) or failing to contribute (in ovals).

The events and causal factors chart is a useful tool for understanding and presenting a harmful incident. It may also help the investigators identify potential recommendations for system improvements. Another useful tool to help with recommendations is the Haddon Matrix.

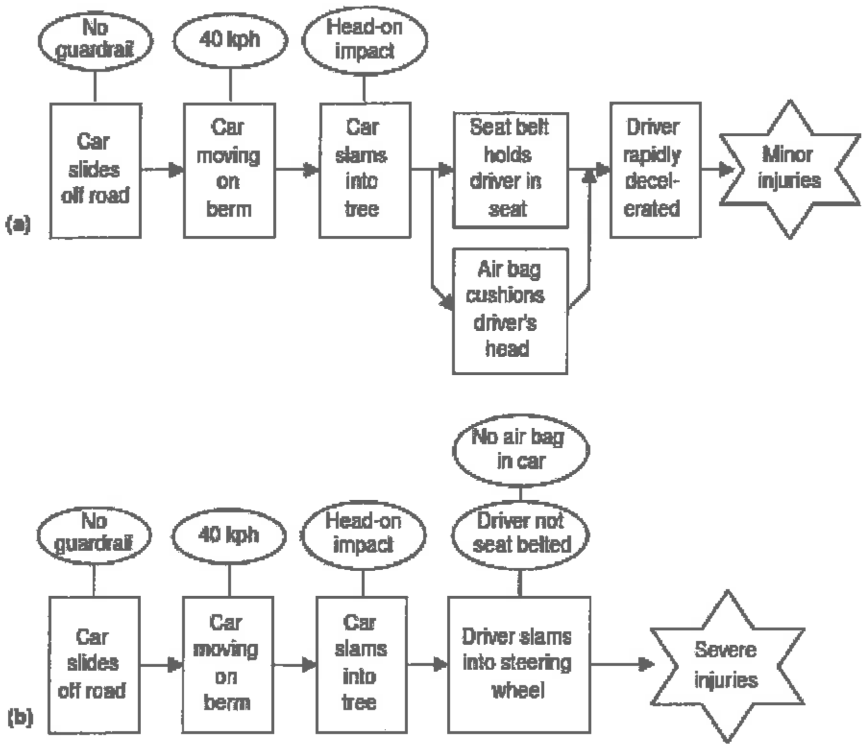

Figure 9.4 Event charts for severity-mitigating factors that helped (a) and failed to help (b).

9.4.2 Haddon Matrix for Countermeasures

The investigation team may use a Haddon Matrix to generate and organize possible recommendations for what Haddon called "countermeasures" applicable to highway injuries and fatalities.[7] He presented a matrix with three rows to categorize the phases of a highway crash: pre-crash, crash, and post-crash. Columns were for elements of highway systems that could be modified. The cells of the matrix were used to record possibilities for making the system safer. Obviously, the cells are intended only for short descriptions of each potential countermeasure.

Figure 9.5 shows a form of Haddon Matrix with three rows and four columns suitable for most workplace systems. The three rows are like Haddon's except terms more suited for occupational incidents are used. The "pre-incident operations" row is for noting ways the system can better control deviations from normal operations. Success with items in this row will prevent an uncontrolled chain of events. This row is also useful for noting preparations for the second and third phases. The second row is for noting ways to alter the event sequence between the loss of control and the

	System Element			
PHASE	Human	Equipment	Environment	Management systems
Pre-incident operations				
During incident				
Post-incident response				

Figure 9.5 Matrix for risk-reduction recommendations.

harmful event. This is the row for entering ways to stop the chain of events, avoid aggravating factors, and use mitigating factors. The third row is for noting ways to make the response as effective as possible.

When using a Haddon Matrix, confusion can occur when deciding in which row to put safety devices. To appreciate this confusion, first consider personal protective equipment such as hard hats and personal fall protection devices. On the one hand, it makes sense to put them in the pre-incident phase because that is when personnel need to start using the devices. On the other hand, these devices provide mitigating value in the during-incident phase. Using another example, seat belts in cars, the driver and passengers need to latch their seat belts in the pre-incident phase, but the injury mitigating value would be realized in the during-incident phase. Using both rows is an effective way to get the most benefit from a Haddon Matrix.

Similar confusion can arise with response activities. One could argue that planning and preparation for effective responses occurs in the pre-incident phase, so these activities belong to that row. One could also make the argument that the value from first responders occurs in the post-incident phase, so that row would be more appropriate. Different organizations may prefer one or the other row. Again, using both rows is the most effective way to benefit from a Haddon Matrix.

9.4.3 Learn from Prior Incident Investigations

OSH professionals can learn innumerable lessons by studying incident reports found in journals, magazines, and websites of governmental agencies. Unfortunately, many in the OSH field fail to believe that lessons learned in one industry may be useful to other industries. Lessons learned about weaknesses in management system are often applicable across industries, as the following examples illustrate.

A large team of highly-regarded professionals investigated the 1986 Space Shuttle Challenger explosion. They dug deeply into NASA's management system and practices. One of the most notable chapters in their report was entitled the "The Silent Safety Program."[8] That title came from findings that major decisions about launching were made by a team of engineers and managers with no input from a safety representative. Moreover, the placement of safety offices within the organizations was "under the supervision of the very organizations and activities whose efforts they were supposed to check." These findings supported a recommendation to change the organization by placing the safety, quality, and reliability functions at a higher position within NASA, where it would have more independent authority. This lesson about making the safety function independent of production management applies to many organizations, not just NASA.

The more recent Space Shuttle Columbia disaster investigation also delved into management systems.[9] Both NASA investigations provide lessons for other organizations regarding the need for a closed-loop process something like that described earlier in this chapter.

In the nuclear power industry, much has been learned by examining multiple investigation reports. The in-depth investigations of specific incidents at nuclear power plants have provided insights into specific cases, but to maximize lessons learned for the benefit of the worldwide nuclear power industry, it helps to examine these cases to find common underlying lessons. Matthews examined multiple incidents and arrived at two important conclusions.[10] The first was that a history of no accidents at a facility tends to make people complacent. The second was that safety performance requires both safety-oriented managers and safety-oriented personnel. One without the other is inadequate. These lessons from nuclear industry incidents also apply to other industries.

The trend for investigations of seriously harmful incidents, particularly in the chemical industries, has been to examine the role of management systems and organizational culture. An investigation of an explosion in a French dynamite factory serves as an example.[11] The investigators demonstrated that information about management systems can be obtained with modest increase in investigation resources by using an evidence collection approach focused on a list of desirable organizational dimensions. This finding might be useful to many other organizations, but unfortunately many people in the safety field will look at a report like this as being applicable to only one French dynamite factory. This narrow perspective discourages the transfer of useful information from one industry to another.

9.4.4 Other Analysis Tools

System safety specialists have developed numerous techniques for analyzing past incidents. The summary descriptions in this section are for three practical techniques.

The change analysis technique involves comparing two situations or event scenarios. It was originally developed for comparing an existing system with a proposal to change the system. It can also be used after a harmful incident to compare the events that occurred with the events in an ideal scenario (e.g., the standard operating procedures). As an example, the change analysis might reveal an employee was using work practices different from the standard practices used in the past. To perform this analysis, the investigators develop two sequential event charts—one for a no harm scenario and the other for the harmful incident scenario. The events are then compared directly to find differences.

The barrier analysis technique helps the investigation team identify various means by which the system prevents a hazard from harming a "target" (that which we want to protect). Known as barriers, these means include physical barriers and administrative approaches. Some are no brain devices such as barriers used for machine guards and radiation shields. Others are engineered systems capable of monitoring processes, identifying when safe tolerances are exceeded, and responding in an appropriate manner, such as initiating corrective responses or communicating with employees by causing an alarm or warning light to activate. Employees perform barrier functions when they monitor processes to detect and correct deviations. Administrative barriers include work practices, checklists, and procedures. Some software programs function as barriers by not allowing operators to select options inconsistent with safe procedures. The team performing a barrier analysis looks for barriers that were in place but inadequate, barriers that should have been in place but were not, and barriers that might be helpful if adopted in the future.

The analytical tree technique helps the investigators use deductive logic to find failures and faults that contributed to the unwanted events. For example, if a fault tree has the top event matching the event being investigated, the team can work downward to examine each lower fault event. Evidence can be examined for each lower event to determine if it occurred or not. This analysis is particularly useful for eliminating some hypothesized failures from being the cause.

9.5 METHOD FOR MODELING HARMFUL INCIDENTS

Numerous respected experts have proposed models of the accident process, but none of these models has achieved broad acceptance. The model presented here makes use of the three Haddon phases, the concept of deviations and *deviation-control mechanisms*, and the flexibility of the events and causal factors charting tool.

Figure 9.6 depicts a model for integrating the concepts presented in this chapter. The three rows are those of Haddon, slightly modified to model occupational incidents. These phases are labeled pre-incident operations, during incident, and post-incident responses. In the core of the graphic, activities and events are depicted according to phase. During pre-incident operations, the system operates as it should. This does not mean it operates perfectly. At various times, equipment malfunctions, people make errors, and other deviations from normal occur. Most workplace systems have informal or formal mechanisms for avoiding, detecting, and responding to deviations. These deviation-control mechanisms include various means for addressing deviations to restore normal operations. Foreseeable deviations that have the potential for causing serious harm warrant multiple control mechanisms, each capable of stopping a particular deviation from developing into a full-blown problem. Each

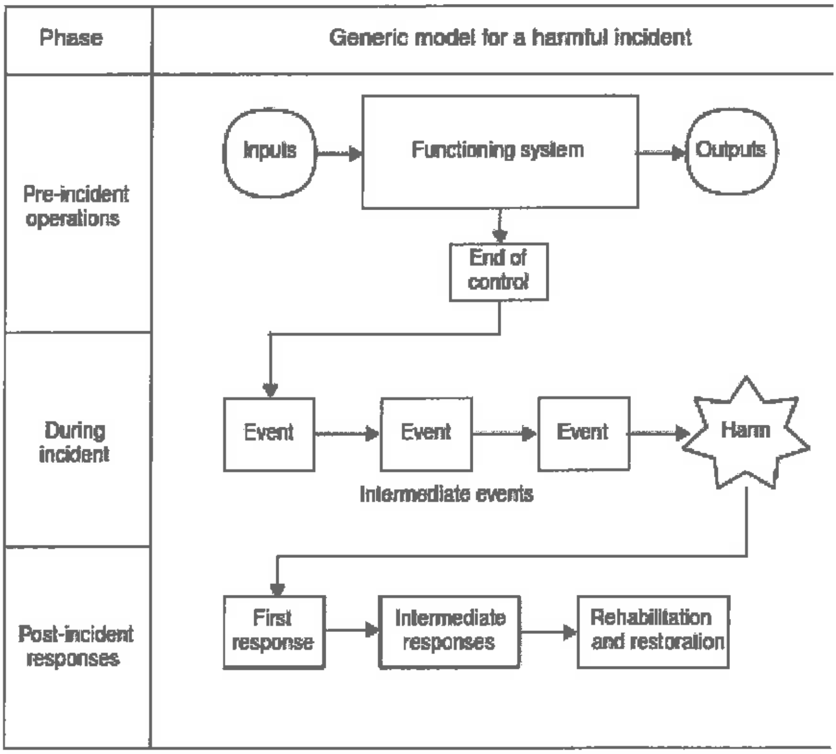

Figure 9.6 Generic model for a harmful incident organized by phase.

additional independent deviation-control mechanism makes the system more resilient to the effects of that particular deviation.

The graphic model depicts the functioning system as usually working with various deviations being controlled. This is essentially the same starting point as the "deviation model of accidents" attributed to Kjellén.[12,13] The concept is that deviations from normal operations, if uncorrected, can start an uncontrolled chain of events, possibly ending in a harmful outcome. The concepts of deviations and deviation-control mechanisms should lead incident investigators to seek an understanding of (1) the manner in which the system normally operates, (2) the initial deviations, (3) the deviation-control mechanisms that were supposed to control deviations, and (4) the reasons the mechanisms were ineffective in the incident under investigation.

The next phase of the model begins once a deviation manages to get through or around all deviation-control mechanisms. Events in this during-incident phase, such as those shown in Figures 9.2, 9.3, and 9.4, are charted in the second row of the model. Starting with an out-of-control event, subsequent intermediate events open up various possibilities for the outcome. Intermediate events can alter the end result by aggravating the harm, mitigating the harm, or avoiding harm. Some of the no harm cases will be recognized as near misses. The model in Figure 9.6 depicts a case ending as a harmful event because that is usually the reason for doing the investigation, but the charting model is equally suited for analyzing near-miss incidents.

The third phase is the same as Haddon's third phase. It contains the first response events, secondary responses, and longer term events that involve rehabilitating an injured employee, returning an injured employee to work through a modified duty program, restoring the environment, repairing damaged equipment, and similar efforts to reduce the final extent of harm.

Figure 9.6 may fit some incidents such as a glove, while others may not fit the model very well. Some examples of good fits are single workplace incidents resulting in traumatic injury or damage to property, a short-term contact with a chemical or blood-borne pathogen, cases of asphyxiation, and onset of heat or cold disorders. It is not suited for modeling harm that occurs over a period within a functioning system, such as cumulative trauma disorders from highly repetitive hand activities, lung diseases that develop gradually over long periods of exposure to airborne dust, and diseases attributed to long-term exposure to low concentrations of chemicals.

LEARNING EXERCISES

1. Incident investigators have different reasons for investigating. Which reason serves as the basis for following the closed-loop process described in Section 9.1?
2. Explain the role of barriers for supporting normal system operations.
3. What is the use of a written incident investigation policy?
4. Why should an incident investigation policy define precisely what incidents will be investigated?
5. Why should the post-harm response be included in an incident investigation policy?
6. An incident investigation policy can provide guidance for deciding the level of an investigation. What three factors are mentioned for inclusion in that guidance?
7. What are the three essential topics to include in the incident investigation policy regarding evidence?
8. Suppose a person was an eyewitness to an event that injured a coworker. An hour after the incident, the witness wrote a description of what she heard and saw, and then signed and dated the document. Is what she described evidence or fact?
9. Explain what an incident investigation team can learn about barriers from a prior RA of the process involved in an incident.
10. Suppose you chair an incident investigation team. After completing a report, you present it to the organization's highest managers. You get asked several questions. One manager asked if the report distribution could be limited to

those with a need to know. Other managers used the expressions "sweep it under the rug" and "don't air you dirty laundry." What reasons can you give for taking the opposite tack and widely distributing the report?

11. Regarding the example of the painter falling from a scissor lift platform (section 9.4.1), answer these questions.
    (a) What hazard control tactic was used to keep Joe from falling off the back of the platform?
    (b) Explain why this hazard control had a low chance of being effective.
    (c) What ergonomics principle explains why the hazard control tactic had low reliability?
12. Give two examples of lessons learned by investigators of nuclear power incidents that may be broadly applicable to other technical industries.
13. The speaker at a seminar suggested two techniques for helping supervisors improve their injury investigation reports.[14] Provide a brief response for each of the two techniques.
    (a) Four reports from another plant of the company were obtained—two good ones and two poor ones. These were shared with the supervisors during a training session and used for discussion. How do you think that using these reports as a basis for discussion among the supervisors could help improve the quality of supervisors' investigations and reports?
    (b) Adopt a standard practice of having supervisors present their reports to managers or the safety committee. How do you think that process might help improve the quality of the reports?
14. Which risk factor, severity or probability, is reduced by an effective barrier?
15. Which risk factor, severity or probability, is reduced by mitigating factors?

TECHNICAL TERMS

Deviation-control mechanisms	Various means for addressing deviations to restore normal operations. Engineered systems and personnel function as deviation controllers by monitoring processes, detecting deviations, and taking corrective actions. Effective deviation-control mechanisms make a system more resilient.
Deviations from normal	The difference between how an employee or business process actually performs and the performance considered normal. Generally, small deviations are tolerated or easily corrected and large deviations are more challenging.
Eyewitnesses	Individuals who were in the area of the incident and who possibly saw, heard, smelled, or otherwise sensed something relevant to the incident.

Form-driven investigation	The process of collecting data on incidents as required for a report form. These are usually performed by one person who gathers the information required by the form.
Harmful incident	A sequence of events resulting in harm to a valued entity—most commonly injury to persons, damage to property, roadway crashes, fires, and contaminant releases to the environment. A near-miss incident is similar to the initial events but ends without harm.
Incident investigation policy	An organization-specific guide for investigating incidents.
In-depth investigation	The process of collecting evidence, developing the incidence sequence, analyzing it, determining causal factors, reaching conclusions, and making recommendations. In-depth investigations are usually performed by a team of people with different expertise and generally involve incidents that ended in a high-severity outcome.
Intermediate events	Events occurring during the period starting with the moment system control is lost and ending with a harmful outcome or near miss.
Mishap	An unplanned event or a series of events resulting in death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.[15]

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