CHAPTER 37

SAFETY ANALYSES AND MANAGEMENT INFORMATION

37-1 PURPOSE OF ANALYSIS

There are several places in this book where analysis is recommended. The preceding two chapters in particular reviewed some of the more prominent analytical procedures frequently used in safety. This chapter considers a few more. Analysis itself can be expensive and can consume many hours of work by many people. Therefore, it is important to consider how much analysis is needed and what the purpose of the analysis is.

One purpose for analysis is to gain understanding. It is not always obvious how things work or what makes things go wrong. Carefully defining the components or elements involved in something and identifying the relationships among them will help provide insights for events, processes, systems, and equipment and will provide understanding of complexities. Analysis makes it possible to discover and observe the intricate relationships between people and the world around them. The need to gain understanding appeals to the human urge to explore.

Another purpose for analysis is to make decisions. Analysis may help managers select the correct action or course of action. It may help managers allocate funds and assign people, equipment, or other resources to ensure that actions are completed in a timely manner.

An additional reason for performing analysis is that it is required. Often laws, regulations, or contracts require people to complete analysis. Someone else may use the information and results in decision making. For example, when someone is involved in a sizeable automobile accident, the vehicle owners must perform enough analysis to prepare a report. In some cases, attending police officers must collect evidence and analyze it to determine if charges should be filed against vehicle drivers or others. Some design contracts require that certain analysis be performed to aid others involved in the design project, production, or use of items being designed.

The dilemma is doing just enough analysis to make decisions with confidence, rather than continuing to analyze something to the point where any further information or results will have no bearing on any more decisions. In safety, analysis helps managers solve the problem "How safe is safe enough?" (see Figure 3-5). Performing analysis for its own sake may be interesting for some, but may not be justified by the usefulness of the results.

From a safety point of view, the purpose of analysis is to prevent accidents. Being able to communicate with managers and explain what hazards exist and what controls should be implemented to eliminate or reduce them is a must, as is the ability to talk in

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management terms about cost of losses and controls, effectiveness of controls, and benefits derived from allocation of funds and other resources.

37-2 INSPECTIONS

A common form of analysis to prevent accidents is inspections. It is possible to chart on paper many of the possible things that can go wrong, but in operating systems, inspections must be performed to detect actual faults and failures in equipment, activities, and workplaces. Inspections are part of a preventive or proactive approach to accident prevention (see Figure 3-4).

Types of Inspections

There are several kinds of inspections: general and detailed. In a general inspection, individuals or teams look for a range of deficiencies. In a plant, a general inspection is a walk-through that considers a wide range of safety problems. Figure 37-1 illustrates a checklist that is typical of a general safety inspection. Pilots of aircraft are taught to conduct a general inspection of the aircraft before every flight. They walk slowly around the aircraft looking for any unusual conditions that could affect the airworthiness of the airplane and flight safety. General inspections can cover many topics, but are very precise.

There are also detailed inspections, which are tailored to the activity and equipment involved. In detailed inspection, people look for very specific conditions. For example, a rigging inspector must be able to identify roughly 20 kinds of defects in wire rope, some of which may be easy to recognize and others that are difficult and require special training and considerable experience. Some aircraft inspections are very detailed, requiring several days to complete.

Inspections may be scheduled or unscheduled. Scheduled inspections are those required regularly. The schedule may be governed by the clock, such as a daily inspection of equipment at the beginning of the shift. Other schedules are based on use time or use cycles. Aircraft are inspected by specialists after a certain number of flight hours. The same aircraft are inspected before each flight by pilots and ground crews. Some inspections are structured around events. A person operating a tool crib inspects tools and items at the time of issue and when they are returned. A field engineer may inspect a product while making a trouble-shooting call on a customer.

Unscheduled inspections may be based on random visits by specialists. They may occur when equipment is brought in for maintenance or repair, at which time someone looks for deficiencies and hazardous conditions throughout the item, not just at the components involved in the repair. A good time for a general inspection of a plant is when it is down for maintenance or installation of new equipment or there is downtime because of low product demand. Railroad companies teach workers to inspect passing trains for shifted loads, bearing and wheel failures, and other kinds of problems.

Inspectors

If the goal is to identify hazardous and defective conditions, who should do the inspection? There are several strategies that apply, with some applying to critical conditions. In some cases, detailed training, knowledge, and experience are necessary to be able to recognize a problem. In other cases, nearly anyone can be taught to identify unsafe conditions and activities. Some inspections may require the use of special instruments and tools and someone who knows proper use and procedures for them.

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Safety Inspection Report

Company/Division ______________________________ Names of Inspectors ______________________________

Address/Location ______________________________

Date of Inspection ______________________________ Committee Members ______________________________

1. Machine Operation. Check to see that guards and devices are in place and in good condition. Look for points of operation where provision of guard could eliminate hazard. Is provision made against accidental starting of machine? Are controls and displays properly color coded and labeled?

	Dept	Date Submitted	Date Comp.

2. Transmission and Machine Equipment. Are belts, pulleys, shafts, revolving parts, and set screws guarded? Are machine disconnects easily accessible, in good working order, and capable of being locked out?

	Dept	Date Submitted	Date Comp.

3. Hand Tools. Look for broken tools, noting condition of handles and heads. Check to see that non-sparking tools are used where provided. Are portable electric tools properly grounded or double insulated?

	Dept	Date Submitted	Date Comp.

4. Housekeeping. Check condition of aisles, work areas, stairs, and outside areas. Are racks and bins provided for small parts and conveniently placed? Are materials in process neatly stored? Are trash receptacles provided and used? Note condition of washroom facilities, ventilation, clothes lockers, etc. Note slip and trip hazards.

	Dept	Date Submitted	Date Comp.

5. Handling Materials. Check hand and power trucks. Are materials piled safely? Are weights of manually handled items OK? Are employees taught to lift properly? Is care taken when loading and unloading trucks, elevators, cranes, and conveyors? Is protective clothing provided? Note condition of material, boxes, skids, totes, etc. Note tasks and workstations that should be evaluated for possible ergonomic improvements.

	Dept	Date Submitted	Date Comp.

6. Industrial Hygiene. Note work areas that may have excessive levels of dusts, vapors, gases, fumes, noise, etc. Are confined spaces properly identified? Are MSDS sheets accessible for review?

	Dept	Date Submitted	Date Comp.

7. Elevators and Other Elevating Equipment. Is every shaft opening gate in good condition? Is elevator pit clear? Is elevator operated by authorized employee and not overloaded? Check light on car and landing, condition of signal system, safety devices, car and shaftway protection, limit switches, and control mechanism. Have cables and hoisting equipment been inspected by and elevator inspector within the past six months? Look for hoistway shear hazards.

	Dept	Date Submitted	Date Comp.

8. Floors, Floor Opening, and Hoistway Openings. Are floors free of protruding nails, splinters, holes, slipperiness, unevenness, and loose boards? Are openings properly guarded?

	Dept	Date Submitted	Date Comp.

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Figure 37-1. Example checklist for a general safety inspection. (Provided by and reprinted with the permission of the Liberty Mutual Group, Boston, MA.)

9. Stairs and Ladders. Note condition of stair treads and supports. Are handrails and lighting adequate? Check condition of ladders. Are they properly stored, or if permanent, firmly fastened in place? Are correct safety feet being used for each job? Note: metal ladders should never be used for electrical repairs!

	Dept	Date Submitted	Date Comp.

10. First Aid. Are first aid supplies adequate? Is a trained first aider always available? Are all injuries reported and treated?

	Dept	Date Submitted	Date Comp.

11. Electrical Equipment. Note condition of switchboard, transformers, wiring, controlling, and operating apparatus. Is equipment properly protected and isolated? Is area clear of tools or refuse? Report loose or disconnected wires. If wire is in rigid conduit or BX cable, report any point where conduit or BX is broken or separated. Is high voltage equipment locked up and posted with warning signs? Report location of any switch box or open switch where floor is frequently wet or where operator might come in contact with plumbing fixtures. Are rubber gloves, rubber mats, and fuse puller provided.

	Dept	Date Submitted	Date Comp.

12. Fire Prevention. Are exits adequate, well located, marked, clear, and well lit? Do fire doors close freely? Are they equipped with fusible links? Is fire fighting equipment conveniently placed and ready for immediate use? Check extinguishers and other equipment. Check to see that materials are not piled too close to sprinkler heads. Is plant kept free of flammable waste? Are flammable, chemical, and explosive materials properly handled and stored? Is power exhaust provided for solvent vapors?

	Dept	Date Submitted	Date Comp.

13. Elevated Runways and Platforms. Are they in good condition? Clear of obstructions? Equipped with top and midrails, and toeboards?

	Dept	Date Submitted	Date Comp.

14. Boilers, Pressure Apparatus. Note when last inspected. Are safety valves, water gauges, and engine stops checked and tanks drained regularly? Are gas cylinders stored sway from sun and fastened securely in place with separate storage places for different gases? Code requirements met?

	Dept	Date Submitted	Date Comp.

15. Safe Practices. Are machines stopped before cleaning and locked out/tagged out during repairs? Is personal protective equipment (eye, face, foot, head, hearing, etc.) in good condition, worn when necessary, and stored properly? Are any unsafe acts observed?

	Dept	Date Submitted	Date Comp.

16. Safety Education. Are posters and safety signs displayed? Number? Well located? Is safety literature distributed? How often?

	Dept	Date Submitted	Date Comp.

The illustrations, instructions and principles contained in the material are general in scope and, to the best of our knowledge, current at the time of publication. No attempt has been made to interpret any referenced codes, standards or regulations. Please refer to the appropriate code, standard or regulation making authority for interpretation or clarification.

Figure 37-1. *continued*

Some inspections need to be carried out by someone who is not directly involved in performing work on the item or the area being inspected. This results in an independent look at a situation and removes some bias from the inspection task. People may not see their own mistakes or may be too familiar with some equipment to notice that something is amiss.

In some cases, two inspectors are necessary. Consider inspection of completed work. The person who performed the work should be the first inspector, and a coworker, supervisor, or specialist should be the second inspector. The second inspector may be more knowledgeable and experienced. The double inspection provides redundancy to the task.

Each situation dictates who is qualified to conduct an inspection. Inspectors can be workers, coworkers, supervisors, specialists (engineers, safety specialists, and others), or special teams. In some cases, inspectors need to be certified for the inspections they perform. Recertification is also important to make sure that inspection skills are kept high and knowledge is up to date.

Inspection Tools

The most common tool for inspectors is a checklist. Because humans are not good at remembering a long or complex list of items. A checklist helps remove memory errors. Because humans are not good at keeping track of what items in a list have been completed, a checklist provides a means for marking which items have been inspected and what was found. Checklists also provide a place for an inspector's signature, which attests to the fact that a particular person completed the items on a checklist and that the inspector has recorded all significant findings. Signing for someone else is a misuse of a signature block on an inspection form.

When visual inspection is not sufficient, special tools and instruments are needed. Instruments may range from air sampling and analysis devices for confined space entry to special test instruments for pressure and light level assessment and special tools for opening covers on machines.

Inspection Procedures

Here are a few important guidelines for completing inspections.

- Be selective. Look for particular things.
- Know what to look for. Know what failures and abnormal conditions look like.
- Use helps, such as checklists.
- Practice observing.
- Look for facts that are relevant.
- Guard against habit and familiarity. Vary the order of items. Be thorough.
- Be ready to sign that everything has been checked and is in order and that problems are noted.
- Record observations accurately.
- Avoid conversations and distractions that may inhibit careful inspections.
- Obtain additional help to verify a finding if there is any question about something not being in order.
- Continue to report faulty conditions until they are corrected.
- Make sure the inspection report gets to someone who can do something about a deficiency.

37-3 SAFETY AUDITS

Safety audits are systematic procedures for reviewing management procedures and practices implemented to achieve safety. They can include a compliance review, similar to a safety inspection. The audit process also allows for reviewer suggestions and recommendations for improvement. Audits may be part of more general practices to ensure that management systems are in place and applied, such as those covered by ISO standards.[1,2] Some standards detail auditing procedures. Audits can apply to systems, processes, products, programs, or services.

As soon as the scope of an audit is established and it is determined whether internal personnel or contractors or others will conduct the procedures, the audit team is formed and the audit is planned in detail. The members of the audit team should have qualifications suitable to the contents of the audit.

The overall audit process typically involves the following:

- An opening meeting in which the audit team meets with senior management and reviews the process to be followed.
- Information gathering through interviews, examination of documents, observation of activities and operations.
- Documentation of observations and findings, particularly any not in compliance with written standards, policies, and procedures.
- Meetings of the audit team to collaborate on audit activities, progress, and findings.
- A closing meeting by the audit team with senior management to summarize the key results of the audit process.
- Preparation of a written audit report detailing the process, findings, and recommendations and providing the report to senior management.
- Establishing corrective action plan.
- Follow-up on progress in the action plan.

37-4 ACCIDENT INVESTIGATION

Another form of analysis is accident investigation. Although accidents are to be prevented, when they do occur, often valuable lessons are learned. Investigations are part of the reactive approach to accident prevention depicted in Figure 3-3.

Purposes

There are several purposes for investigations of accidents. A primary purpose is to prevent future accidents. Another purpose is to identify causes of accidents and injuries, because such information is necessary to prevent future accidents of a similar nature. A third purpose is to compile legal or liability evidence to be used in the event of claims or lawsuits for losses or injuries. Accident investigations may help assess the degree of damage and the value of losses. For some accidents, data are collected for insurance claims related to injury or property damage.

A general reason for accident investigations is gathering facts. One should use multiple factor accident theories (see Chapter 3) in an investigation so items that may be important are not overlooked. Seldom do accident investigations have the purpose of placing blame or finding fault. When they do, it is for legal purposes and insurance claims in a fault-based claim process.

Types of Investigations

There are two main types of investigations: general and special. Special investigations can be divided into many additional categories.

General General accident investigations are typical of investigations related to most in-plant accidents. A supervisor may look into causes and prepare a report. In some cases, specialists within the organization may participate in the investigations. Some procedures are generic and do not involve special methods and instruments. General investigations use interviews and visual observations. Investigators interview witnesses of the accident or postaccident events. Investigations may include a meeting of all witnesses to discuss potential causes and corrective actions. Data are limited to company investigation forms. Photographs may be taken and included with a written report.

Special Special accidents investigations are those that require particular knowledge and skill of investigators. Special investigations are necessary for particular kinds of accidents and incidents. For example, there are fire investigators and methods for fire investigations, and there are special investigators and methods for aviation accidents, train accidents, and automobile accidents. There was a national investigating team during the early 1980s that investigated elevator explosions. Special investigations often require particular tools, instruments, and procedures. For example, fire inspectors need to have kits for taking samples to test for the presence of flammable materials. There are special procedures to avoid contamination of samples and for "reading" what happened in a fire from char and rubble.

Which Accident to Investigate

It may be too expensive to investigate all accidents, and at the very least, it is not possible to bring in specialists for every accident, compile a lot of data, and perform physical, chemical, or computational analyses. Deciding which accidents to investigate can be simplified by using the following criteria.

High Cost and High Severity Accidents with high property, life, and injury losses are worth investigating. In fact, several parties probably will conduct independent investigations of the same accident to protect liability and other legal interest for different people. When there are high loss rates, there are bound to be arguments over who should pay for the losses.

High Frequency High frequency accidents should be investigated because accidents that have similar patterns offer the potential for significant preventive actions. A pattern of events and causes may be detected. The trend may appear from accident and incident reports or may arise from customer claims or complaints, from field reports, or from repair or work orders.

High Public Interest Accidents that gain a great deal of public attention should be investigated. For either a company or public official, there is a need to deal with public concern from a factual basis rather than from a speculative one. If a company has an accident that affects the community around it, an investigation is probably necessary to provide a basis for protecting the company image and dealing honestly with the public.

High Potential Losses Incidents that may end in large losses of property or human life should be investigated. There is a high potential for preventing such losses in future accidents.

Investigation Tools and Data

Some of the basic tools for accident investigations are rope or security tape to secure the area. Imprinted tape will help keep the curious from damaging or removing evidence. Use of note and sketch pads also is essential. Use of photographic and videotape equipment can be very useful, because some evidence has a short life. A tape recorder is essential for interviewing witnesses. Depending on the kind of accident involved. Special instruments may be important. For radiation releases, Geiger counters or similar instruments are appropriate. For chemical spills, colorimeters, direct reading instruments for particular chemicals, and sampling equipment should be available. Other necessities are uncontaminated containers for specimens of various types, identification tags for marking items of evidence and samples, and tape measures to establish accurately the location of items at an accident scene. In automobile accidents, for example, location data for vehicles and tire marks can be critical.

The data needed may be dictated by law. For example, in certain automobile accidents, police officers are required to acquire information on alcohol and drunkenness. There are standards and guidelines for the data needed in particular kinds of investigations. Photographs and sketches of physical conditions, the surround, and damages are important. Videotape or movie film data may be important, if the occurrence lingers. Statements of witnesses must be compiled accurately. Tape and video recordings, even those from security cameras, and transcripts can help accuracy. Information about where people were, when they were there, and what they saw or heard are important. It may be necessary to collect specimens and samples of various kinds, use recording instruments to collect data on environmental or other conditions, collect damaged equipment or remaining parts, and collect data on injuries. These are some general kinds of data that are collected in an investigation. Particular kinds of accidents require many other items of data.

When to Investigate

The best time to investigate an accident is as soon after the occurrence as possible. Many types of data and evidence disappear or deteriorate with time. Witness recollections also deteriorate with time, and details that may be important can be lost if investigations are delayed.

Investigation Methods and Procedures

There are a few references that detail methods for accident investigation. Figure 37-2 shows the classical steps in accident investigation. In reality, the steps do not occur one at a time; several may overlap and occur at the same time. Figure 37-3 is a general flow chart of accident investigation procedures. Figure 37-4 is an expanded process for the investigative phase.

Analyzing Investigation Data and Report Results

Analysis is a critical part of the investigation process. Many different methods may be used. Some methods are general and valuable to the accident analysis process. Examples are fault tree analysis and management oversight and risk tree (MORT) analysis. For automobile cases, accident reconstruction computer tools are valuable. There are also computer tools for reconstructing some fire behavior in buildings and estimating exiting behavior of people.

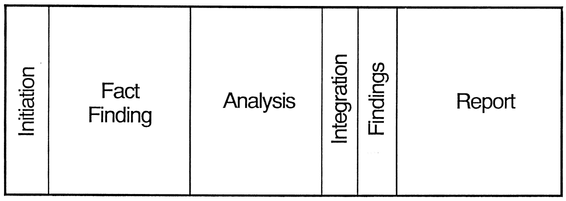

Figure 37-2. Classic steps in accident investigation. (From Accident/Incident Investigation Manual, 2nd ed., DOE/SSDC 76-45/27, SSDC 27, U.S. Department of Energy, Washington, DC, November, 1985.)

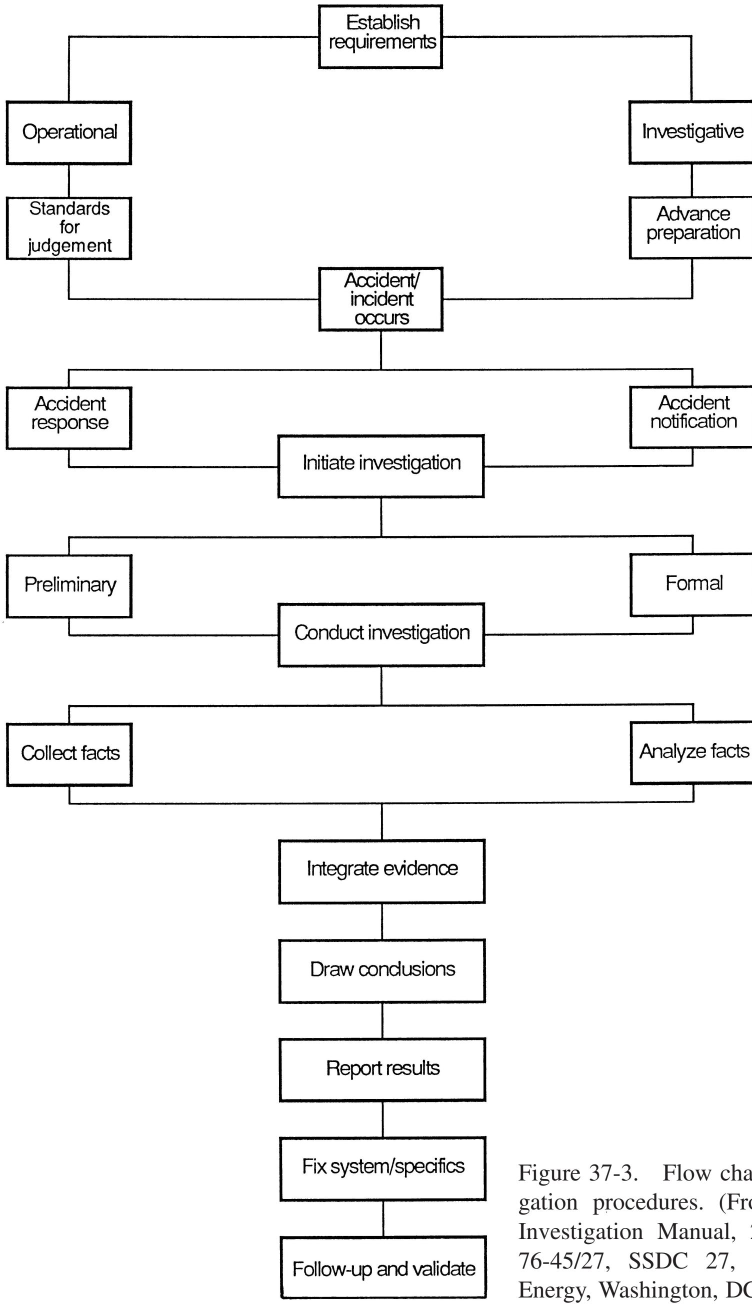

Figure 37-3. Flow chart of accident investigation procedures. (From Accident/Incident Investigation Manual, 2nd ed., DOE/SSDC 76-45/27, SSDC 27, U.S. Department of Energy, Washington, DC, November, 1985.)

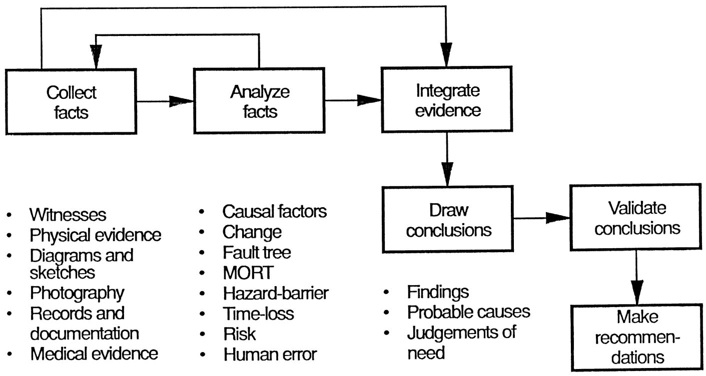

Figure 37-4. Details for the investigation phase of an accident investigation process. (From Accident /Incident Investigation Manual, 2nd ed., DOE/SSDC 76-45/27, SSDC 27, U.S. Department of Energy, Washington, DC, November 1985.)

The analysis leads to findings and conclusions. Written reports should include procedures used. participants, data compiled, analysis and results of analysis, findings, conclusions, and recommendations to prevent such incidents in the future.

Applying Findings

It is not sufficient to end an investigation with a report. The report needs to reach managers, public officials, or others who can do something about the recommendations provided in an investigation report. Recommendations should lead to engineering changes, procedural changes, changes in policy, rules or regulations, improved training, and other kinds of actions.

37-5 SAFETY PERFORMANCE

Management approval for safety programs may be won because the justification analysis may show significant savings or other benefits. Allocation of funds allows implementation of actions to reduce hazards and losses. The question remains whether the real results of corrective actions are similar to those projected in the justification analysis. There are many techniques to determine the effectiveness of safety programs. Some approaches are statistical, some empirical; some are objective, others subjective. Each method has some value for particular situations. Manuele[3] reviews a variety of approaches. A few are discussed here. Others, like inspections, audits, and risk analysis, were discussed previously.

Statistical Approaches

Accident Statistics Some accident statistics were covered in Chapter 8 in a discussion of record keeping. The most common statistics are weekly, monthly, or annual accident or incident occurrences and frequency and severity statistics. These general statistics give an overall picture of an organization's safety performance. For certain industries and types of businesses, performance can be compared with the entire industry group. Frequency rates and some other statistics are available for particular industries from the National Safety Council,[4] from the Bureau of Labor Statistics, and from insurance companies offering workers' compensation insurance.

Although these statistics help measure performance at a global level, they may not be sensitive enough for use in individual departments or small organizations. The accident frequency may be so low per month that individual accidents cause major changes in statistics. Severity rates can shift dramatically because of one long-term disability case. Therefore, it may be necessary to rely on other statistics, such as claims, cost, or others.

A wide range of statistical methods can be applied to determine if a safety program has any effect on accident or incident rates, severity rates, or other measures of performance. Reference to a standard textbook on inferential statistics is helpful. For example, the mean accident rate for 6 months before implementation of a program can be compared with a 6-month period after the program begins. The effect of a program can be determined by comparing the change to a control group or by using multivariate analysis, such as regression analysis and factor analysis, to determine which of several elements of a program has the greatest impact on safety performance. Which statistics apply depends on the information available and the way the program is conducted.

Control Charts When sampling events, such as accidents and incidents, there is some random variation in events among sampling periods. For example, the number of accidents for a company will vary each month. A problem is knowing whether the variation is strictly random or whether some program or control has produced desired results. Control charts provide a statistical basis for determining whether results of one sampling period are truly an indicator of change or whether the results are the result of random variation.

Figure 37-5 illustrates the idea of a control chart. The number of accidents per month is plotted for a company over a 1-year period. Upper and lower bounds are represented by two horizontal lines, one above and one below the mean and each some distance from the mean number of accidents for the 1-year period. One is the upper control limit and the other is the lower control limit. The limits are based on some statistical level of signifi-

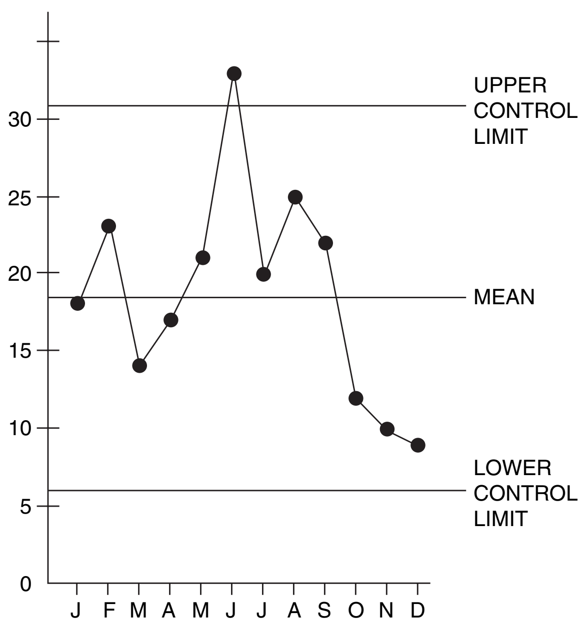

Figure 37-5. Accident control chart.

cance, such as 95% (two standard deviations from the mean) or 99% (three standard deviation from the mean). If the number of accidents for 1 month falls outside these boundary lines, the variation is most likely the result of something other than random effects. Such a deviation indicates that something is out of control or influenced by some factor. Consider an accident frequency control chart. If both a mean accident frequency and a standard deviation for that data are available, then the upper control limit (UCL) can be computed from

$$\text{UCL} = x + z_{0.025}S, \tag{37-1}$$

where

x is the mean frequency,

z is the standard normal distribution for the normal curve at the 0.025 probability level, and

S is the standard deviation for the population.

The lower control limit (LCL) can be computed from

$$\text{LCL} = x - z_{0.025}S. \tag{37-2}$$

Example 37-1 An organization compiled accident frequency data for 12 months and wants to establish a control chart for the data. The number of accidents for each of 12 months are: 18, 23, 14, 17, 21, 33, 20, 25, 22, 12, 10, and 9. The mean is 18.67 and the standard deviation is 6.57. From a table of z values for a 0.025 probability level, $z = 1.96$. Then UCL and LCL are

$$\text{UCL} = 18.42 + 1.96(6.34) = 31.55$$

and

$$\text{LCL} = 18.42 - 1.96(6.34) = 5.79.$$

The results are those shown in Figure 37-5. From the control chart, one can see that only one of the months was outside the control limits, even though there was considerable variation in frequencies among the 12 months.

The accurate use of control charts depends on the distribution of data being similar to the statistical normal distribution. Some statistical assumptions are violated unless there is a sufficient sample size and if there are factors that cause a sudden change in data. To ensure that a control chart is valid, there should be somewhere near 60 sampling periods (typically months). In addition, if there is a sudden change in conditions (the number of employees changes, there is a major change in program, etc.), then there should be a new basis for computing a control chart. In Example 37-1, the last 3 months seem to show a significant change in accident frequency. The trend should be looked at further. If a special promotion was underway, the change may be a result of it, in which case the last 3 months may need to begin a new set of data for setting control limits.

Control charts can be used for evaluating safe behavior.[5] The procedures involve use of work-sampling techniques of industrial engineers and work methods. The study could evaluate the effect of a safety program on errors or unsafe behaviors. A series of observations before the program starts could establish a background for the evaluation. Through random sampling of behaviors, one records the portion of observations in a sampling period that were not completed safely. After the program is introduced, the behavior can be tracked similarly. Control limits on the results of the background period form a basis for judging whether the program affected behavior. If, after the program is introduced, the portion of unsafe behaviors decreased and exceeded the control limits, the program had positive effects.

The computation of control limits for proportions is

$$\mathrm{UCL} = p + 1.96\left[\frac{p(1-p)}{n}\right]^{0.5} \tag{37-3}$$

and

$$\mathrm{LCL} = p - 1.96\left[\frac{p(1-p)}{n}\right]^{0.5}, \tag{37-4}$$

where

p is the mean proportion of observed behaviors that are unsafe or safe for all observation periods and

n is the number of observation periods.

The number of readings, N, required for a certain level of accuracy at a 95% confidence level is

$$N = \frac{4(1-p)}{S^2 p}, \tag{37-5}$$

where

p is the proportion of safe or unsafe acts observed during the study and

S is the desired accuracy (percent per 100 readings).

The accuracy of readings is the proportion observed plus or minus some percent accuracy. For example, the average portion of observed unsafe behaviors across observation periods is 18% ± 10% or 18% ± 2%.

Example 37-2 A study wishes to determine how often workers at 15 workstations involving similar tasks made errors that could lead to accidents. The data will serve as a baseline for a corrective program, if the error rate is excessive. The study must determine the baseline within 15% accuracy of the real behavior. How many work cycles (observations) must be included to achieve this accuracy at a 95% confidence level? A preliminary study found a 24% error rate.

The number of observations required is

$$N = \frac{4(1-0.24)}{(0.15)^2(0.24)} = 563 \text{ observations},$$

which amounts to 563/15 = 38 observations per workstation.

Subjective Methods

Rating and Attitude Scales Another approach used by some organizations is to use validated attitude questionnaires, which may be given to managers and workers. Various scales built into the surveys assess the attitudes and opinions toward safety and safe behavior. The results may be useful in determining if safety programs change management and worker views toward safety and potential behavior.

Judgment During safety audits and other evaluation processes, one or more persons may make subjective judgments about particular aspects of a safety program. Comments logged for items in an inspection checklist may be subjective judgments. The judgments may alert specialists to perform a more detailed evaluation.

Combinations of Methods

Any one method may not be adequate for evaluating the effectiveness of safety programs. If you want to consider the effect on conditions, risks, the attitudes and behavior of personnel, knowledge of workers, management support, compliance with safety standards and company rules, and accident and incident rates, one measure will not provide adequate detail on such a wide range of matters. Some companies have devised their own evaluation system that incorporates many different measures. The problem of assessment is particularly difficult when different departments or divisions of a company have very different operations and hazards.

An example of an evaluation form[6] is shown in Figure 37-6. It is a safety report card of sorts for major organizational unit. It uses a point system distributed over five major areas of evaluation. Most areas have several independent elements. Points for the statistical analysis elements are taken from additional guidance for raters found in Table 37-1.

37-6 PRESENTING RESULTS OF ANALYSES

When results of safety analyses are completed, they are typically presented to managers and others for decision making, training, and other purposes. The way in which results are presented is a key to successful communication. With today's computer tools, it is easy to generate a wide variety of tables and charts. Even three-dimensional graphs can be generated with relative ease. If trends are important, line and bar graphs are very useful. Figure 37-7 gives an example of each. Pie charts are useful for communicating relative portions of a whole. Figure 37-8 gives an example of a pie chart.

To compare organizational units, bar charts can be useful. Various types may be suitable. Stacked bar charts show the contribution of each unit to the whole for different periods or topics. Bar charts that show values in descending or ascending order help compare different groups. Figure 37-9 shows one type of bar chart for communicating safety information. Tables are better than graphs for presenting precise data and complex sets of data.

37-7 COMPUTER SYSTEMS, THE INTERNET, AND SAFETY

Like other professions, the safety specialists today must use computer tools to manage, analyze, and communicate information. This section identifies some of the safety applications for various types of computer software and systems. There are many general computer tools and safety applications that are not covered. The discussion mainly refers to capabilities for microcomputers and software for it. With the emergence of the Internet as a standard resource for everyone, one can access information from everywhere, conduct business and transactions with company customers and clients, and manage information and communications internally within a company. Safety and health applications on the Internet or based on Internet technologies provide new capabilities and resources for a

	Points	
	Possible	Earned
1. Statistical Analysis	**20**	
A. Incidence rate for pervious fiscal year	10	
B. Workers compensation claim costs in relation to standard premium	10	
2. Inspection for Compliance with Safety Standards	**15**	
A. Material handling and storage B. Machine guarding, interlocks and controls C. Health and hygiene D. Fire protection E. Other standards	15	
3. Risk Analysis	**25**	
4. Line Management Support	**10**	
A. Top management	5	
B. First Line supervision	5	
5. Safety Program	**30**	
A. Inspections	5	
B. Training	5	
C. Safety coordinator function	10	
D. Safety promotion	5	
E. Safety committee	5	
TOTAL	**100**	

Figure 37-6. An example of a form used in evaluating a safety program. (Reprinted with permission from Brigham, C. J., "Safety Program Evaluation: One Corporation's Approach," *Professional Safety*, May:31–34 (1981), official publication of the American Society of Safety Engineering. Form from Rexnord, Inc.)

wide range of safety functions. They give quick access to information, analysis methods, data collection, and service providers.

Database Management Systems

Database management systems (DBMS) are the workhorses of management information systems. Today the development of applications is quite easy, because DBMS products contain features that eliminate many of the programming tasks. Some DBMS products also produce compiled code for the applications that can be given to other users without additional cost. Most DBMS products allow data entry forms and output reports to be designed on the screen, and all have the ability to query data through some convenient method, such as query by example, by selecting data elements from a list. Data can be selected for standard reports and ad hoc queries, transferred to other programs, or converted to business graphics. Many DBMS products have security features that limit

TABLE 37-1 Guidelines for Scoring Certain Elements of the Safety Analysis and Evaluation (Shown in Figure 37-6)

Incident Rate

Based on No. of OSHA Lost Workday Cases	Points
0.0	10
0.1–0.5	9
0.6–1.0	8
1.1–1.5	7
1.6–2.0	6
2.1–2.5	5
2.6–3.0	4
3.1–3.5	3
3.6–4.0	2
4.1–4.0	1
>4.5	0

Worker's Compensation Cost

Claim Cost Incurred (Dollars per Employee)	Points
0	10
1–17	9
18–33	8
34–50	7
51–66	6
67–83	5
84–100	4
101–116	3
117–133	2
134–149	1
>149	0

Compliance with Safety Standards

1. Two points are deduced for each *serious* deviation from standards that could result in one disabling injury or significant property damage or repeat violation from previous inspection.

2. The formulas below define the points deducted for each *nonserious* deviation from standards. There is a maximum of one point deducted for cumulative deviations from one standard.

Group	No. Employees	Point Formula
I	400 or more	1 for every four items of noncompliance
II	250–399	1 for every four items of noncompliance
III	125–399	1 for every three items of noncompliance
IV	70–124	1 for every three items of noncompliance
V	<70	1 for every two items of noncompliance

Risk Analysis

Based on 23 five-point rating scales on program and procedures. The score is based on the percent of the maximum points possible on the rating scales and that allowed on the rating form.

Line Management Support

Based on structured interviews with top management and line supervisors. Five-point rating scales are used to evaluate the responses to each interview question. Points are based on a percent of maximum points possible.

Safety Program

Based on a review of how safety programs are implemented. A series of questions have five-point rating scales. Points are determined as a percent of maximum points possible.

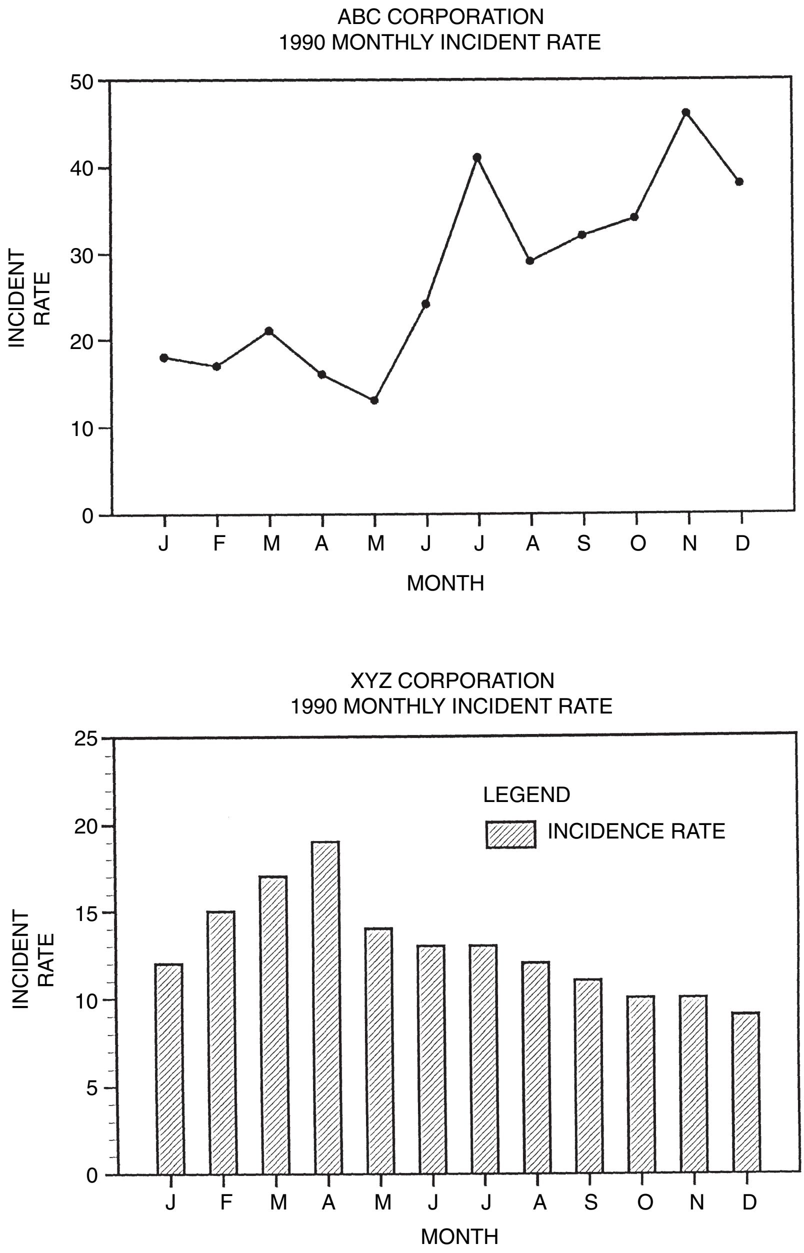

Figure 37-7. Examples of line and bar graphs.

access of certain people to certain data. Having the power of relational database structures gives the user a great deal of information management capability while minimizing data storage.

Over the last decade or so, there have been many commercial DBMS products for managing safety data. Some have survived the rapid rate of change in computer systems and the competition.

There has been a rapid growth in the data required for safety. Some time ago, there was little need for information other than accidents and incidents. Today, it is essential to

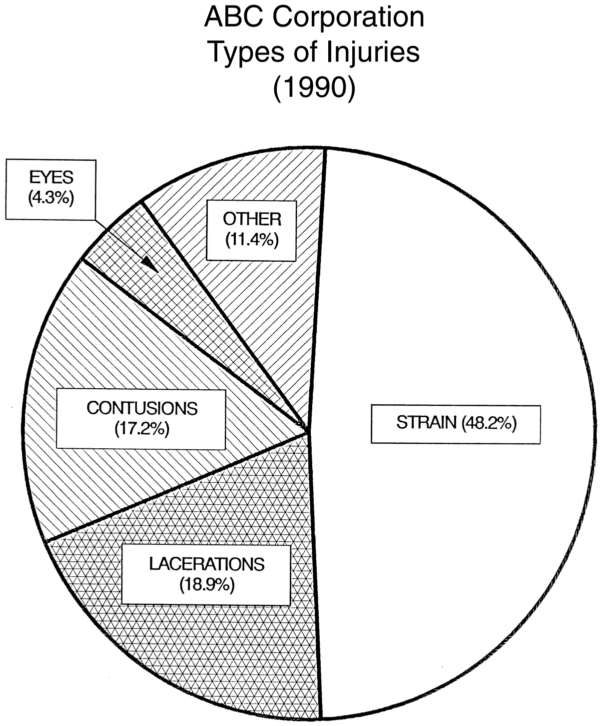

Figure 37-8. Example of a pie chart.

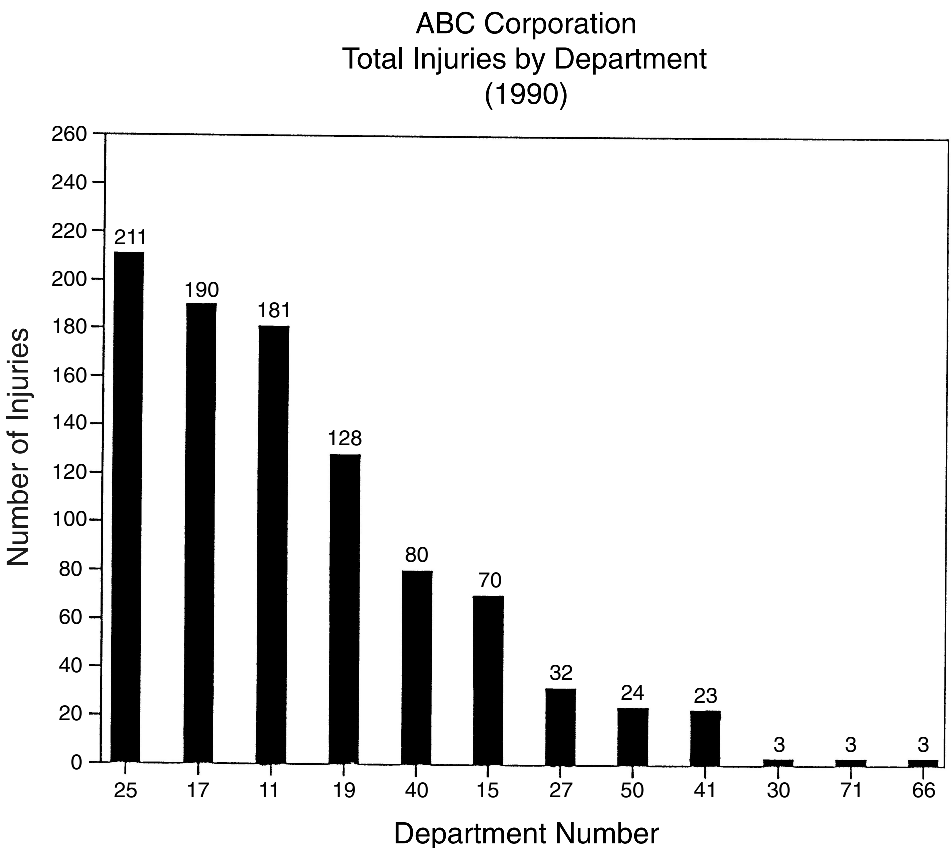

Figure 37-9. Example of a bar chart comparing different departments.

keep track of personal protective equipment and other items issued for safety purposes, environmental exposures of employees, and training given to workers and when training must occur again. There is a need to track hazardous materials data. It may be important to keep track of fire extinguishers, hoses, hydrants, and data about them, such as manufacturer, date of purchase, date of inspection, and tests performed. In safety analysis, hazards and what controls are implemented must be listed, controls must be followed up, and testing and maintenance must be recorded. In addition, manufacturers may track products for recalls, servicing, and modifications.

Relational data bases allow separate but related lists or tables of data to be maintained and help eliminate duplicate data. An example is training people in safety. A person may attend more than one training session in a year, and a single list would contain the course and data about it (title, when given, duration, where given, etc.) and the attendees and data about them (name, department, age, address, phone number, etc.). Building a single list around the training would produce duplicate data for attendees if they attend more than one course, and building the single list around attendees would produce duplicate data about the course a group attended. In a relational data base, data could be divided into at least two tables, one for training and one for attendees. Having one common data element in each list (such as course number or a person's name or identifying number) allows information from each list to be merged.

Figure 37-10 illustrates the structure of tables in a relational data base for an employer who must track many safety matters. Each table contains information about the items included in it, including employees, training, accidents and incidents, equipment issued, exposures, and physical tests (hearing, pulmonary function, biological limit value (BLV) tests, etc.).

Modeling

Another use for computers in safety is modeling the behavior of physical phenomena, people, and other entities. Modeling allows people to anticipate what might happen or what did happen. The accuracy produced by the model depends on the availability of accurate data, the inclusion of factors that can affect the phenomenon, and adequate representation in the mathematical manipulations. There are reasonably successful models in safety for automobile accident reconstruction, for gas dispersion, and for fire behavior in small buildings.

Accident reconstruction models allow analysis of what happened in the sequence of events before, during, and after collision. The models depend on accurate information about particular automobiles and data from crash sites.

Gas dispersion models allow the formation and movement of gases released from point sources to be plotted. The models are useful in planning emergency procedures for accidental releases, but are limited for real time use in deciding what action to take from moment to moment. The limitations arise from difficulties in making sure that actual wind conditions and atmospheric conditions are represented in the model.

The National Institute for Standards and Technology has developed models of fire behavior and exiting behavior of building occupants during a fire. Work in modeling fire behavior in small buildings has been most successful. These systems allow for analysis of the adequacy of building designs and what happened in certain building fires.

Training

Training people about safety must fulfill many requirements. A variety of media are available to accomplish successful training. Computer-based training (CBT) has advanced

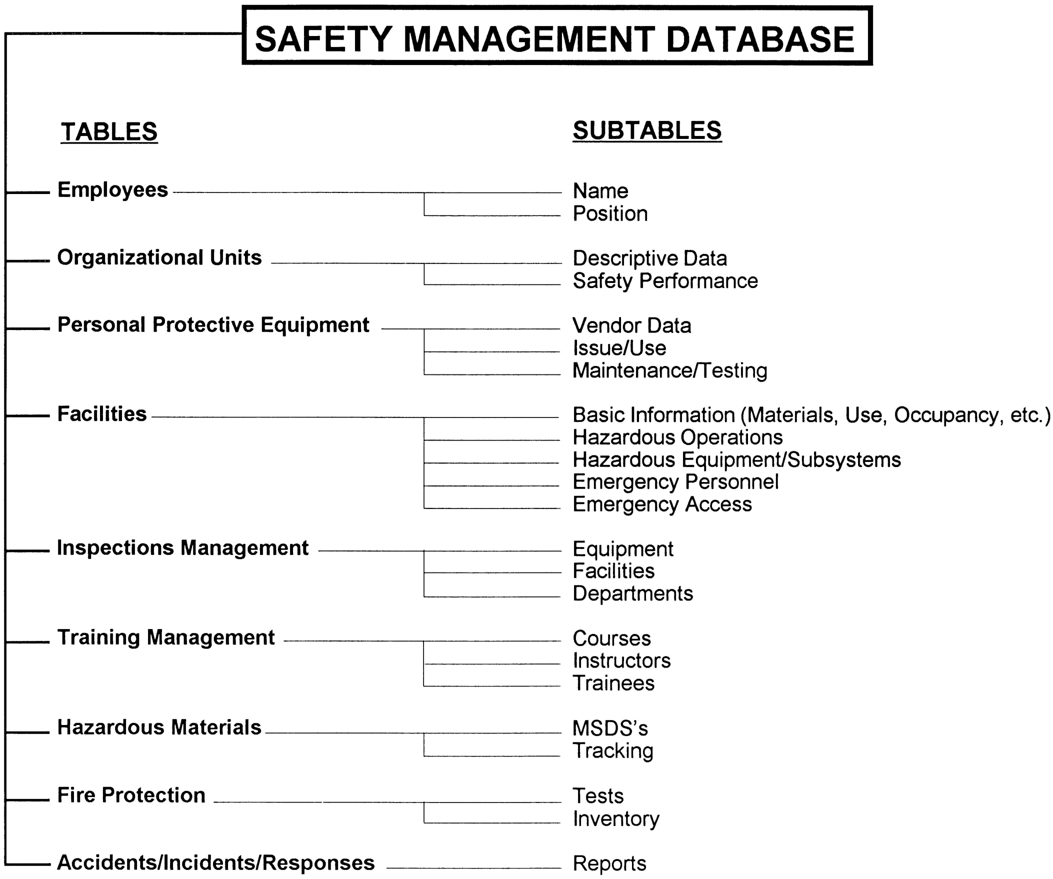

Figure 37-10. Example of a structure for a safety management data base.

rapidly as a tool for training and tracking training accomplished. An important feature that is unique to CBT is the ability to customize training to individuals. A training package may contain remedial or background material that students access if they do not understand the standard material presented. CBT removes peer pressure from the learning process and can record very precisely what learning is achieved in a training session. It allows students to make mistakes without creating accidents and injuries and it can provide immediate feedback on errors.

CBT systems typically include a microcomputer, DVD player, and software. Lessons stored on DVD can have a rich collection of photographic material from field situations. Authoring software for preparing CBT lessons helps design and preparation of text and graphic materials for presentation as well as assists the lesson developer in the preparation and evaluation of materials and examinations. The evaluation items diagnose student deficiencies and guide them to supplemental materials to help them achieve lesson objectives. Presentation software manages the presentation. The student may take several routes to achieve the lesson objectives and may receive extra help when diagnostics indicate the need. Presentation software also can time and score student progress and record completion of a lesson for training management.

Tracking

There is a need to follow the movement of items from location to location. Computers can assist in tracking hazardous materials, documents, and other items from a safety perspective. Bar code devices, optical character readers, magnetic strips, radio frequency transmitters, global positioning systems, and other automated identification technologies are essential. For example, a bar code label can be placed on the containers of a hazardous material. At check points along its normal path of movement and use, the bar code is read and the readings are fed into a common database. Reports from the database can detect time or location deviations and signal an alert.

Another example is tracking safety-related repair and maintenance activities. When a work request comes in, it is assigned an identifying bar code. The maintenance worker logs information about the problem, actions completed, and item repaired on a portable data collection device. The data are loaded daily into a database and subsequent analysis on the database shows what was called in, what was done, what parts were replaced or fixed, and when these tasks were accomplished.

People also can be tracked. For example, to limit access to only authorized personnel, people entering a check point may have to place an identification card in a reader to gain access to the restricted area. Today, security devices can read fingerprints, retinal patterns, voices, and other biological characteristics.

Monitoring

Another important use of computers in safety is monitoring. Sensors and data capture devices are strategically placed to detect the occurrence of unsatisfactory conditions. The data are fed to a computer that analyzes the information to determine if it should act by sounding an alarm. There are monitoring systems for particular gases, for excessive heat or fire, and to detect system failures, such as excessive heat and pressure.

Data Banks

Data banks are another important tool for safety people. Most data banks are now accessed via the Internet. In relying on Internet sources, one must take care to establish the reliability of the source of information. They can help people keep up with rapidly changing laws and regulations and provide convenient knowledge and information for special safety problems. Central organizations may compile information useful to many others and may charge a fee for access and use. Some have bibliographic records, accident and incident records, and other safety-related information. There are data banks on such things as pesticides and their effects, chemical hazards, auto safety, radiation, earthquakes, lightning, tornados, and other topics. There are data bases on legal claims related to products liability and product recalls.

Expert Systems

Expert systems, both inductive and deductive, may prove to be useful computer tools. They help perform some reasoning. One type of application is diagnostics. Expert systems have several uses in safety. They have the potential of assisting someone with little knowledge of a special topic to work through the topic to form and form a decision. There has been some work on identifying hazards in ladders and scaffolding and the use of that equipment, in construction safety and in managing products liability lawsuits and economic decisions about continuing a case, as well as an application to mining safety.

Computer-Aided Design and Drafting

Computer-aided design and drafting (CAD) also is a useful computer capability for safety. It may be useful for charting hazardous areas on site maps or building floor plans and is useful for isolating the safety systems (alarms, fire protection, etc.) in facilities and processes. Separate layers in CAD drawings may be dedicated to these features. Some use a layer in new designs to communicate construction hazards and procedures as reminders to crafts people to ensure that the correct precautions are in place. Process facility drawings may show level of hazard or other characteristics through color or shading. CAD drawings may have special symbols or components of interest to safety. For example, compressed air lines and terminals with 30 lb/in^2 or less may have a particular designation. Pressure-relief devices may be specially identified in a list of drawing entities. Safety DBMS systems can be linked to drawings, drawing symbols, and layers and can be managed interactively with drawing changes.

The interface of CAD information with DBMS is valuable. This provides the capability to extend management from safety information even further. For example, there may be a need to associate accident data by department with floor plans to indicate the location and frequency or severity of accidents. In a similar way, risk could be computed and represented by color or shading on a floor plan or site map and hazards could be classified by type or severity and be drawn with each class shown in a different layer in the drawing or represented by color. A list of elements (such as fire extinguishers) in a drawing important for safety could be generated and related with data from DBMS tables about vendors and replacement costs. With the interface between CAD systems and DBMS, one can accomplish all these information management tasks.

Special Computer Devices

There are a number of special computers or computer applications in safety. Some companies have programs and special devices for assessing hearing loss and logging test results into data bases. There are special computers for evaluating pulmonary functions and lifting tasks and there are special computers (some very small and worn on a person) to monitor noise exposure and compute noise dose. There are computer applications for laser hazard analysis, analysis of manual materials handling (computations related to the NIOSH lifting equation), design of ventilation systems, risk analysis, gas monitoring systems, and other safety applications.

EXERCISES

1. A company has the following accident frequency by month over a 2-year period:

Year	J	F	M	A	M	J	J	A	S	O	N	D
1st	19	12	32	24	27	18	26	30	16	20	28	32
2nd	16	36	17	23	29	21	30	18	25	28	13	33

Prepare a control chart for these data and plot the actual data. Calculate and show the upper and lower control limits with the mean frequency. Determine if the frequency for any month extends beyond the control limits.

2. A team was sent to a number of departments to monitor worker behavior. The goal was to determine how safe worker activities were. The team found that 82% of the behavior was safe. The team sampled each department during 20 observation periods. Frequency data suggest that it could be better. A new safety program will be implemented to improve the performance.

(a) If there are 18 departments and a 95% confidence level is applied, what are the upper and lower control limits for evaluating the behavior in particular departments?

(b) If the follow-up study is to have an accuracy of 10%, how many observations must be made in each department to achieve this accuracy at a 95% confidence level?

3. Obtain a copy of a report of the National Transportation Safety Board accident investigation of an airplane accident. Find out what procedures were followed, how many investigators participated, and what the findings were.

4. Identify Internet resources for

(a) regulations and standards

(b) state and federal laws

(c) safety equipment and personal protective equipment

(d) training materials and services

(e) record keeping systems

(f) professional development conferences

(g) accredited safety and health certifications

(h) safety and related academic programs

REVIEW QUESTIONS

1. What are three purposes for analysis?
2. Where do accidents fit in the process of preventing accidents?
3. What types of inspections are there? Give an example of each applied to safety.
4. Who is qualified to be an inspector?
5. What tools are used in inspections?
6. Where do accident investigations fit in the process of preventing accidents?
7. Why are accident analyses important?
8. What kinds of accident investigations are there? Give an example of each type.
9. Should all accidents be investigated? If not, why?
10. If not all accidents are to be investigated, what strategies can be used to select particular accidents?
11. What tools are used in accident investigations?
12. Describe the classical accident investigation process.
13. What methods can be used to evaluate the safety performance of an organization?

14. Identify four kinds of business graphs that may be useful in presenting results of analysis. When is each more useful than the others? Give an example of each kind of graph.

15. List six kinds of computer tools that are useful for safety? Give an example of how each can be used.

NOTES

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