Accident Investigation Techniques

- **Basic Theories**
- **Analytical Methods**
- **Applications**

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Contents

This book is dedicated
to my wife and son.

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Preface

All companies at some point must conduct accident investigations, and each company must decide how thoroughly to investigate and how much time and attention should be paid to the investigations. Many companies perform excellent accident investigations, but then fail to take corrective actions to fix the problems. Other companies do the opposite—they fail to determine the underlying causes of the accident, but just try to produce a "quick fix." Many techniques can be used to help companies and safety professionals to analyze accidents and feel assured that causes have been determined and corrective actions will prevent recurrence. This book presents techniques that can be applied to small, medium, and even large-scale accident investigations. By using these analytical techniques, you can prevent accidents at your workplace.

The book is divided into four parts and includes an Appendix of worksheets and charts. You may remove or copy these forms for your own use.

Part I is an introduction to the accident sequence. This part focuses on the theory of accidents, the accident sequence (sequence of events that happen before and during an accident), and the analytical approach to accidents. Research in the area of accidents, accident sequence, accident theory, root cause, and analytical approaches is discussed.

Part II describes the organization of accident investigations: starting the investigation, gaining knowledge about the accident, collecting evidence and data, and using appropriate investigative techniques. It includes instructions for gathering information, interviewing,

documenting, preserving evidence, retrieving data, and analytically processing this information to determine exactly what happened.

Part III provides thorough explanations of analytical techniques that are useful in investigating accidents. Numerous examples and worksheets are included, and the benefits, weaknesses, and appropriateness of each technique are discussed. Four chapters of Part III are devoted to specific techniques, and a fifth covers other specialized and computerized techniques.

Part IV is devoted to accident prevention. After you use analytical techniques to determine what happened, the next step is to use that information to prevent future accidents. This part covers accident documentation and follow-up activities, and tells how to develop recommendations and corrective actions.

Jeffrey S. Oakley

Part I

INTRODUCTION TO THE ACCIDENT SEQUENCE

Accidents do not just happen—they are caused, and the key to accident investigation is to find the causes. The first step in finding the cause of an accident is to examine the sequence of events that led up to it. Discovering this sequence is the goal of many of the analytical techniques discussed later in the book. This part of the book includes many theories that have been developed to determine how accidents occur. Many have been and continue to be used, and many others have been disproven. This book will mention many theories, but will focus on those that are based on the accident sequence.

The objective of this book is to present an analytical approach to accident investigations—gathering evidence, using analytical techniques and the analytical process to determine the accident sequence, and using this information to discover the causes and to recommend changes to prevent future accidents.

Objectives for Part I:

- Understand that accidents have a sequence of events and be able to determine this sequence.

- Be familiar with several accident causation theories and know how each applies to the accident sequence.
- Be aware that most accidents have multiple causes.
- Be able to break down accidents and use an analytical approach to investigate them.

CHAPTER 1

An Accident Happens:

What Do You Do?
How Long Do You Do It?

These two questions are major issues of accident investigation that must be addressed and answered. Answering the first is simple: provide emergency response, protect the employees involved from further harm, and try to determine what happened so that measures can be taken to prevent its happening again. Answering the second question is more difficult. Some companies commit a specific amount of time to an accident investigation—a day, two weeks, or a month, for example—depending on the severity of the accident. In a perfect world, there is no time limit—an accident investigator investigates an accident until he or she is reasonably certain of what happened and why. This book answers the first question—it tells you what to do—and it provides ways to decrease the amount of time it takes to do it.

Accident investigations are a dreadful part of a safety professional's job. Accident outcomes may include injuries, fatalities, and property or equipment damage. It is sometimes difficult to "get over" the outcome of an accident, especially if there is a fatality or an employee is hospitalized because of it. However, accident investigations are a necessary and critical part of the occupational safety process. A

to produce injury, death, or property damage so that causal factors can be determined and corrective actions can be taken. Any occurrence that has a sequence of events can be investigated by analytical techniques—first-aid cases, OSHA-recordable injuries or illnesses, fatalities, property damage, or near misses. The steps in an accident investigation are analyzing the facts, developing an accident sequence, finding the causes, and recommending corrective action.

The next definitions have to do with the accident itself. Safety professionals use various terms for the basic terminology of the profession (Sorrell 1998); this book simplifies the definitions.

Causal Factors

The causes of the accident are called the *causal factors*. A causal factor is an event or circumstance that produced an accident. Other books may use the the term "root cause" to mean something similar. Causal factors can be at the basic (worker or equipment) level, the intermediate (supervisory) level, and the upper management level. The causal factors of an accident answer the question "What happened?" After causal factors are determined through an analytical process, *corrective actions* are developed to prevent similar types of accidents.

Corrective Actions

Corrective actions are the actions taken to prevent recurrence of the accident. Causal factors link to corrective actions to address all levels of causes and accountability (see Exhibit 1.1, Definitions).

Exhibit 1.1

DEFINITIONS

Accident—The occurrence in a sequence of events that produces unintended injury, death, or property damage.

Incident—An unintentional event that may cause personal harm or other damage.

Near Miss—An occurrence in a sequence of events that had the potential to produce injury, death, or property damage but did not.

Accident Investigation—A structured process of uncovering the sequence of events that produced or had the potential to produce injury, death, or property damage to determine the causal factors and corrective actions.

Causal Factors—Events and circumstances that produced the accident. Causal factors incorporate "root causes," "basic causes," "immediate causes," lower level causes, upper level causes, and management causes. When discovering causal factors, it is important to analyze all causes at all levels.

Corrective Actions—The actions taken to prevent recurrence of the accident. Corrective actions are the "fixes" to prevent future accidents. These fixes should be performed at the appropriate level

Goals of Accident Investigation

Determine the Accident Sequence without Placing Blame

An accident investigation determines the accident sequence and finds the causal factors of an accident. Its purpose is not to find fault or assign blame.

How do you keep from finding fault when an individual disregards a major safety policy? The answer is to be fair and consistent with your policy. If there is no accountability for violating a safety policy or disregarding the safety program, then the safety program will eventually fail. The main issue is to find out why the individual violated the safety policy. The accident investigator must determine why the safety program allowed the individual to disregard the rule and why

thorough accident investigation can be of great benefit to your organization, not only by preventing the same type of accident from happening again, but also by finding systemic problems that could cause more severe accidents in the future. The main purpose of an accident investigation is to find the causes (what happened) and fix the problems to prevent the accident from recurring. "Accidents do not just happen, but are caused" (Marshall 2000, 29).

Definition of Terms

Accident

There are many definitions for "accident." Most books agree that an accident is an undesired event that causes injury or property damage (Bird and Germain 1985). Many companies use the term "incident" rather than "accident" because "accident" implies human error, while, according to the National Safety Council, "an incident is an unintentional event that may cause personal harm or other damage" (National Safety Council 2001, viii). The definition of "accident" that best captures the analytical approach to accident investigation is "That occurrence in a sequence of events that produces unintended injury, death, or property damage" (National Safety Council 2001, viii). These definitions and others are listed in Exhibit 1.1.

Near Miss

The difference between an accident and a near miss is usually luck or chance. A near miss is an occurrence in a sequence of events that had the *potential* to produce injury, death, or property damage but did not. Near misses can and should be investigated the same way accidents are.

Accident Investigation

An accident investigation is a structured process that attempts to uncover the sequence of events that produced or had the potential

supervisors did not enforce the rule. While these types of situations are rare, it is imperative for companies to correct problems with their safety programs to keep accidents from happening (Sorrell 1998).

Recommend Corrective Actions

Accident investigations determine corrective actions so that future accidents are prevented and the overall safety program is improved.

Update the Overall Safety Program

By identifying hazards from the worker level up to the management systems level, the safety program can be updated and improved.

Accident Reporting

Thorough Reporting Is Necessary

Accidents cannot be investigated if they are not properly reported. All accidents, including fatalities, injuries, and property damage, as well as potential accidents (near misses), should be reported. Formal company policy and employee training must spell out how to properly and consistently report accidents, near misses, and property damage (Vincoli 1994). Individuals must have no fear of repercussions for informing the company or the safety department of an accident or near miss. If people fear punishment or repercussion (accusation of fault or blame) for accidents, they are less likely to report them (Speir 1998). It is crucial to a company's safety program and to the prevention of future accidents that all accidents and near misses be reported so that all of the problems in the safety program can be found.

Incentive Programs Must Reward Reporting

Incentive programs have been developed to reward safe behaviors. Unfortunately, many of them do not actually reward safe behavior but instead inhibit the reporting of accidents and near misses because

employees fear losing their incentives. Such incentives do not improve safety programs. Reporting accidents and near misses, finding causal factors, and determining corrective actions, however, will improve them. Reporting accidents and near misses should be rewarded, and incentive programs should be designed to reward the reporting of all accidents and near misses.

Why Do We Need Accident Investigations?

To Avoid Spending Money on Accidents in the Future

Accidents are a major expense for companies. According to the 2003 edition of *Injury Facts,* in 2002 the total cost of unintentional injuries at work was $146.6 billion dollars (National Safety Council 2003). This monetary figure does not reflect the cost of human pain and suffering as a result of accidents. In 2002, 4,900 fatal occupational injuries occurred and 3.7 million injuries were reported (National Safety Council 2003).

Bird and Germain compare the costs of an accident to an iceberg—like an iceberg, most of the costs of an accident are not obvious and are not seen. For every dollar of medical and insurance costs an injury or illness incurs, the uninsured costs are $5 to $50 and miscellaneous costs are $1 to $3. The uninsured costs include damage to equipment, tools, and products; production delays; and legal expenses. The miscellaneous costs include accident investigation expenses, hiring replacement workers, and loss of business (Bird and Germain 1985).

As expensive as an accident may be, the resulting investigation can ultimately save money by helping to prevent future accidents and update safety programs. Future savings will be found in identifying systemic problems in the safety program and correcting them. Near misses are excellent opportunities to prevent costly accidents and identify and deal with systemic problems in the safety program.

Accident costs come directly from a company's bottom line. While saving money is a great motivator for improving safety procedures, a bigger motivator is avoiding the pain and suffering accidents produce. The field of occupational safety is very dynamic, with theories and concepts that change over time. However, most people would agree that "the ultimate goal of all efforts in safety engineering should be to reduce accidents and harmful exposures" (Marshall 2000, 6).

To Prevent Future Accidents

An accident investigation cannot do anything for the person already injured, the machine already damaged, or the product already destroyed. Its value is in preventing future accidents. Although investigations are performed reactively, they allow companies to be proactive in improving their safety programs.

To Comply with the Law and Determine the Total Cost of an Accident

Accident investigations must also be performed to complete workers' compensation claims, to comply with legal requirements and Occupational Safety and Health Administration (OSHA) regulations, and to determine the total costs of accidents.

Decisions to Be Made Before an Investigation Begins

Determine the Level of Investigation

Companies define levels of accidents and levels of accident investigations to help answer questions about how an investigation will be conducted—such as how much detail the investigation should uncover and how long the investigation should take. In general, the more serious an accident is, the more detailed the investigation will be and the longer it will take. The philosophy of this book is that

whether an accident is minor or catastrophic, the investigation process still follows the same steps—develop the accident sequence, analyze it, determine causal factors, and recommend corrective actions. The levels of accidents and types of accident investigations are listed in Exhibit 1.2.

Decide Who Will Investigate

Once the accident level and the depth of investigation are determined, your company must decide whether to use an individual or a team to do the investigation. Many people from throughout your organization may be able to perform adequate accident investigations. The key is to choose the person (or persons) who is in the best position to discover what really happened and determine how to

Exhibit 1.2

CATEGORIZATION OF ACCIDENTS

LEVELS OF ACCIDENTS	TYPES OF ACCIDENT INVESTIGATIONS
1. Near miss	Near misses can range from potentially minor to potentially catastrophic accidents. At the least, document the near miss on a form, determine its causes, and recommend corrective actions.
2. Minor injury or first-aid case	Investigate, interview injured employee, determine causes, and recommend corrective actions. Document on a form.
3. Major injury or recordable injury	Investigate, interview the injured employee and witnesses, use analytical techniques, determine causes, and recommend corrective actions. Write a short report.
4. Catastrophic injury (fatality, many injured, or major property damage)	Team investigation. Interview injured, eyewitnesses, and other employees; use analytical techniques; determine causes; and recommend corrective actions. Write a full report explaining the analytical techniques used.

prevent it from happening again. Foremen and supervisors are excellent choices if they are able to look beyond their departments to systemic causes—problems with the overall system of safety management. They usually understand the workers' jobs and the roles supervisors should play. Safety professionals can do investigations, but usually they do not fully understand all of the workers' job functions, so they must spend time learning job duties and sequences. A more useful role for safety professionals is providing assistance to accident investigators, since safety professionals are trained to uncover and analyze systemic causes and management system causes.

The Team Approach

For large or complex accidents, the team approach to accident investigation seems logical because more information must be analyzed than with less serious accidents. The usual team approach is to appoint a team leader who oversees and manages the investigation. The number of individuals on the team will vary depending on the accident's complexity. Normally, subject matter experts will be used to lend expertise about the complex issues that will be uncovered in the accident investigation.

In order for a team investigation to work effectively, the team leader must assign each subject matter expert to work in his or her area of expertise. Having the subject matter experts work separately on the overall investigation rather than concentrating on their own areas is a waste of time. Each subject matter expert should have a separate area to focus on, such as a technical or engineering issue, training, management systems, supervision, emergency response, etc. The team leader coordinates all of the efforts and ensures that all of the subject matter experts are working toward a common goal— finding out what happened and how to prevent it.

Decide How Much Time Will Be Allotted to the Investigation

Deciding how much time the investigators will be given to perform the investigation and document the findings is a difficult decision. Many companies allot a set amount of time based on the level of the accident and the type of investigation to be performed. Ideally, the company should allow enough time to find out what happened and determine how to prevent it from recurring. In most cases, a first-aid case or an OSHA-recordable case will take a few days, while a major injury, fatality, or other complex accident may take anywhere from a couple of days to a month. Investigations of catastrophes with multiple fatalities and involving complex systems (plant explosions, plane crashes, etc.) usually take from a month to several years. The time needed to perform investigations at any level depends on the amount of data collected, the number of interviews, the number of people helping with the investigation, the analytical methods used, the complexity of the systems involved, and the length of the final report or form.

Determine Whether Additional Resources Will Be Needed

For the most part, this book discusses nonproprietary investigation techniques that do not require extra expenses. However, in many investigations, consultants (subject matter experts, medical doctors, lawyers) or special equipment (testing equipment, external testing, laboratory work, computer software) may be needed. Coordinating these resources will extend the time needed to perform an investigation.

Summary

The basic requirement for a successful accident investigation program is a formal accident-reporting policy with proper and consistent reporting of all accidents and near misses from employees who do not fear repercussions. In the past, most accident investigations began with the question "Who did it?" In a modern investigation, the accident investigator must concentrate on causal factors and corrective actions and not place blame. Accident investigations should be conducted by a qualified individual or team. The purpose of the investigation is to find the causal factors of the accident and determine the corrective actions to prevent recurrence of the accident as well as to find systemic causes and thus prevent other types of accidents in the future.

Accident investigations are a necessary part of the occupational safety process. Although proactive accident prevention and loss control strategies are the main purpose of a safety program, accidents will occur. The company and the accident investigator must learn from each accident and revise the safety program as needed.

REVIEW QUESTIONS

1. What are the goals of accident investigations?
2. Why is it important to conduct accident investigations?
3. What are the levels of accidents?
4. Accident investigations can point out what types of problems in the safety program?
5. Who should conduct an accident investigation?

CHAPTER 2

A Short History of Accident Theory

There are many theories about why and how accidents occur, and understanding them is important. An accident investigator must understand how an accident occurs in order to properly analyze it, find its causes, and prevent future accidents. This book presents several accident theories. You will need to use all of them—and perhaps challenge them, too.

Accident theories are continually challenged and revised, and some of the theories discussed here contradict each other. Each accident investigator and company has a view about how accidents occur and which theories they prefer. This book emphasizes finding the sequence of events that occurred as an accident unfolded. It teaches the analytical techniques you can use to find accident causes as well as the multiple causation theory discussed in this chapter.

Most accident investigators and safety professionals have read about and used the domino theory, which will be discussed later in this chapter. H. W. Heinrich developed this theory, and many researchers after him, including Frank Bird and George Germain, have researched and updated it. While the domino theory can be useful, it seems to force investigators to follow a strict model. Since every accident and

every investigation is different, a simpler theory that emphasizes the uniqueness of each accident is needed—one that helps the investigator to discover the unique sequence of events that led to an accident.

You may have watched television shows or movies about criminal investigators who seem to have special powers that allow them to discover how a crime took place. Unfortunately, most real-life accident investigators do not have these special powers and must learn analytical techniques to help them determine the sequence of actions and inactions that caused an accident. This book will help you to do that.

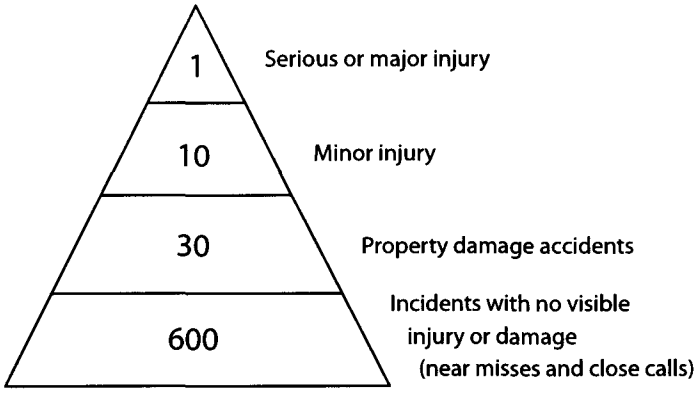
Accident Ratio Study

The Accident Ratio Study is not an accident causation theory per se, but it demonstrates an interesting fact: *A near miss or property damage event usually takes place before a major accident with injury.* This well-known study analyzed 1,753,498 accidents reported by 297 companies from 21 industrial groups. Three billion work-hours and 1,750,000 employees were represented. The study found that for every one serious or major injury, there were ten minor injuries, thirty property damage accidents, and six hundred incidents with no visible injury or damage (near misses) (Bird and O'Shell 1969). This accident ratio is shown in Exhibit 2.1. "The 1-10-30-600 relationships in the ratio indicate quite clearly how foolish it is to direct our major effort at the relatively few events resulting in serious or disabling injury when there are so many significant opportunities that provide a much larger basis for more effective control of total losses" (Bird and Germain 1985, 21).

What this study shows is that if all near misses and property damage events were investigated, major accidents might be avoided. Understanding this concept is important for people who perform accident investigations and people who are responsible for safety program enhancement. In most companies, there is some tolerance for

Exhibit 2.1

ACCIDENT RATIO STUDY



Bird and Germain 1985, 21

near misses, a little less tolerance for minor injuries and property damage, and very little tolerance for major injuries. Major accidents are usually investigated thoroughly, and the problems discovered in the investigation are fixed so that the same kinds of accidents do not happen again. Minor accidents, however, do not receive the same attention, even though "fixing" them may prevent more serious accidents. Companies must encourage the reporting of near misses and property damage accidents, and they must support the thorough investigation of less-serious accidents in order to prevent more-serious ones.

Domino Theories

Heinrich's Domino Theory

G. W. Heinrich developed his *domino theory* of accident causation in 1931. It was the first domino theory of accidents (Heinrich 1931; Heinrich 1959), although more were developed later. Heinrich's version of the domino theory illustrates how an accident occurs by comparing

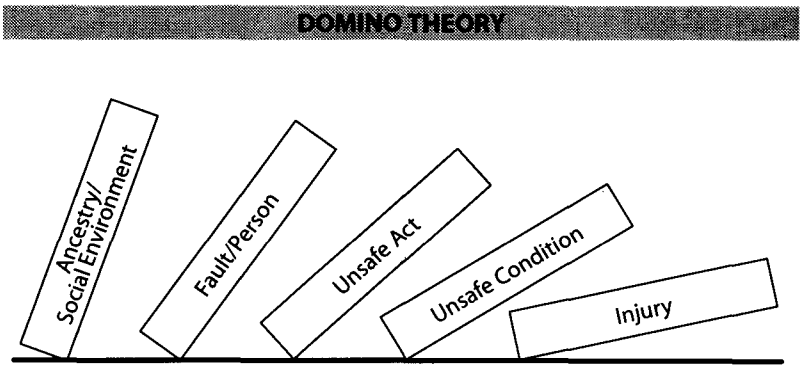
the events leading up to it to a set of dominos. The first domino (the first event) sets the stage and starts the accident sequence. When it falls, it pushes the next, and that pushes the next, until the last domino, which represents the accident or injury, is toppled. The domino theory is illustrated in Exhibit 2.2.

Heinrich identified five types of action that comprise an accident sequence: *ancestry and social environment, fault or person, unsafe act, unsafe condition,* and *injury.* "Heinrich showed that by removing one of the intervening dominos (a preventative action) the remaining ones would not fall, and there would be no injury" (Ferry 1981, 127). Heinrich's domino theory not only defined how accidents occur, but it also helped investigators to develop interventions and preventative measures to prevent accidents.

Bird and Germain's Domino Theory: The Loss Causation Model

Many safety professionals and accident investigators have refined and updated the domino theory since Heinrich's time. One of the more noteworthy updates is Bird and Germain's Loss Causation Model.

Exhibit 2.2



Domino Theory — The first domino starts the accident sequence.

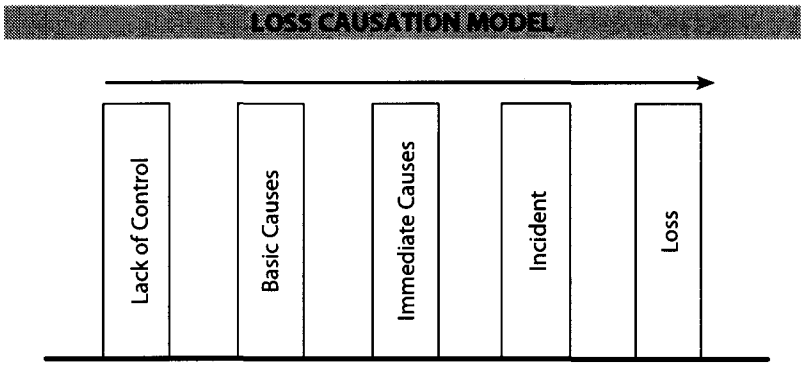
Their domino theory also uses five dominos, but they have different titles—*lack of control, basic causes, immediate causes, the incident,* and *people/property/injury damage* (see Exhibit 2.3).

Each domino represents a step in an accident sequence:

- **Lack of control** includes failure to maintain compliance with adequate standards.
- The **basic causes** are the personal and job factors that started the accident sequence.
- The **immediate causes** are the substandard practices and conditions that existed at the time of the accident.
- The **incident** is what actually happened—What was struck? What was struck by something? What fell? What got caught? What made contact with something it shouldn't have? Who overexerted him- or herself?
- The **loss** is the injury or property damage that occurred (Bird and Germain 1985).

This domino model is widely used today in the safety profession, and the terms Bird and Germain use to explain their theory are also

Exhibit 2.3



Loss Causation Model — The accident sequence starts with lack of control and eventually leads to loss.

Bird and Germain 1985, 22

widely used, unfortunately sometimes out of context. The meanings of "basic causes" and "immediate causes" are subjects of debate. Many accident investigators use these terms without understanding what Bird and Germain intended them to mean. Understanding these two domino theories is extremely important to accident investigations and the theory of accident causation, and accident investigators must understand the terms and models associated with them. Many accident investigation training courses still study these models, and they are still actively used.

Unsafe Acts and Unsafe Conditions

The concept of "unsafe acts and unsafe conditions" was introduced in Heinrich's original domino theory of accident causation. Unsafe acts and unsafe conditions are the most important factors in determining the causes and corrective actions for accidents. These two concepts eventually evolved into a separate theory—to prevent accidents, you must remove the unsafe act or unsafe condition; to investigate accidents, you must determine the unsafe act or unsafe condition that caused the accident (Peterson 1978).

As part of researching their loss causation model, Bird and Germain developed lists of unsafe acts and conditions that can be considered "immediate causes" of accidents (their middle domino) (see Exhibit 2.4). You will notice that an unsafe act is usually something done by a person, while an unsafe condition is a failure of equipment or a problem in the work environment.

Many accident investigators and safety professionals in the 1970s and 1980s used Bird and Germain's lists to analyze accident causes. For each accident, they chose immediate causes that seemed to fit the accident from the "acts" and "conditions" lists, but they did little to investigate or analyze the accident. The loss causation model focuses on human error, and for many years human error and unsafe acts seemed to be the most common causal factors in accident reports.

Bird and Germain's lists represent a very simplistic view of accidents and do not include all of the causal factors of accidents. Researchers

have calculated percentages indicating what proportion of all accidents each cause is responsible for, but the percentages are not included in this book because it is very possible that the accidents they were based on were not thoroughly investigated. Despite its drawbacks, however, the overall concept of the loss causation model is good—if we reduce the number of unsafe acts and conditions in our workplaces, we will have fewer accidents.

Exhibit 2.4

IMMEDIATE CAUSES OF ACCIDENTS IN THE LOSS CAUSATION MODEL

UNSAFE ACTS	UNSAFE CONDITIONS
1. Operating equipment without authority	1. Inadequate guards and barriers
2. Failure to warn	2. Inadequate or improper protective equipment
3. Failure to secure	3. Defective tools, equipment, or materials
4. Operating at improper speed	4. Congestion or restricted action
5. Making safety devices inoperable	5. Inadequate warning system
6. Removing safety devices	6. Fire and explosion hazards
7. Using defective equipment	7. Poor housekeeping, disorder
8. Failing to use PPE properly	8. Noise exposure
9. Improper loading	9. Radiation exposure
10. Improper placement	10. Temperature extremes
11. Improper lifting	11. Inadequate or excess illumination
12. Improper position of task	12. Inadequate ventilation
13. Servicing equipment in operation	
14. Horseplay	
15. Under influence of alcohol and/or other drugs	

Bird and Germain 1985, 37

The Multiple Causation Theory

Accidents usually have more than one cause—they are rarely caused by one act or condition. The multiple causation theory expands the domino theory and the concept of unsafe acts and unsafe conditions: it proposes that each accident is usually the result of many acts, many conditions, and causes of many types—complex, simple, obvious, obscure, and systemic. The most important part of this theory is that investigators must use an analytical approach and analytical techniques to investigate an accident and find all of its causal factors. Most of the analytical techniques discussed in this book focus on finding multiple causes for accidents.

The multiple causation theory is consistent with the analytical techniques and theory of accident causation that government agencies use. *Management Oversight and Risk Tree (MORT) Root Cause Analysis,* developed by the Department of Energy, states:

> "When considering why an accident or incident occurred, more than one root cause must be considered. Very seldom will just one root cause create a condition that results in an accident. In most cases it requires a chain of root causes that reaches from top management to the lowest level of the work process. Correcting the specific root causes generally will only correct the bottom-level conditions. Correcting the systemic root causes is more likely to correct all of the root causes in a particular chain that reaches from management to the bottom work processes" (SSDC 1989, ii).

Discovering *all* of the causal factors of an accident is the key to fixing the problems that exist and preventing more accidents. If accident investigators analyze only "acts and conditions," they may miss many higher level issues. Dan Peterson discusses this principle in *Techniques of Safety Management:*

> "Today we know that behind every accident there lie many contributing factors, causes, and subcauses. The theory of

> multiple causation states that these factors combine together in random fashion, causing accidents. If this is true, our investigation of accidents ought to identify as many of these factors as possible—certainly more than one act and/or condition" (Peterson 1978, 16).

A comparison of the multiple causation theory of accident investigation and the unsafe acts and unsafe conditions model is shown in Exhibit 2.5.

To find multiple causes, you must systematically and exhaustively ask questions and break down the accident into its parts so that you uncover all of the potential causes—from simple to complex—and thus help to prevent recurrence of the accident. The analytical techniques discussed in this book were developed to perform this type of analysis. If you do not find all of the causal factors during your investigation, more accidents may occur.

The Epidemiological Model

In the last fifty years, there has been much research on epidemiology—the study of how often diseases occur, how they are distributed, and how to control them. Scientists study the Epidemiological Triangle, which consists of the host (the person who gets a disease), the agent that causes the disease (virus, bacteria, etc.), and the vehicle or environment that carries the disease (mosquito, tick, water sources, etc.). In a similar way, investigators who use the epidemiological model of accident investigation identify a host (the person who was injured), the agent (what did the injuring), and the vector, vehicle, or environmental factor (what conveyed the agent) (Robertson 1998). These concepts are used to create a model of how the injury occurred.

Agents of injury are forms of energy—mechanical, thermal, chemical, electrical, or ionizing radiation. (In some cases, insufficient energy may be the agent.) The epidemiological model is excellent at determining the specific form of energy (agent) that caused the injury,

Exhibit 2.5

MULTIPLE CAUSATION THEORY VS. UNSAFE ACTS/UNSAFE CONDITIONS

INVESTIGATIONS USING THE UNSAFE ACTS/UNSAFE CONDITIONS MODEL

Unsafe Act: An employee uses a defective ladder.

Unsafe Condition: The defective ladder.

Corrective Action: Take the defective ladder out of service. (While this is definitely a corrective action, other more systemic factors may need to be investigated.)

INVESTIGATIONS USING THE MULTIPLE CAUSATION THEORY

- Why did the employee use the defective ladder?
- Why was the ladder defective?
- Did any maintenance or inspections occur?
- Why did inspections not determine that the ladder was defective?
- Was the employee trained to recognize the hazards of defective equipment?
- Why was the employee not trained?
- Was a Job Safety Analysis performed on the job?
- Did the supervisor determine whether the job and equipment were safe?
- Is there a policy that describes how to take equipment out of service?
- Did the employee know that he or she had the right to stop the job if equipment was defective?

These questions could lead to finding multiple causes of the accident, including systemic ones that should be analyzed to prevent future accidents.

Adapted from Peterson 1978

illness, or damage. This agent can then be analyzed to find out how and why the agent produced the accident. An in-depth analysis not only will find causal factors, but also will help the investigator design preventive interventions and corrective actions that can be used to reduce the agent to a level that will not cause injury, illness, or damage.

Vehicles of injury include motor vehicles, equipment, guns and even the environment. Investigators must study vehicles of energy to determine how the agent was released. Was it expected or accidental? How did the release of energy cause the injury, illness, or damage?

The epidemiological model is probably too narrow in scope to be the only technique an investigator uses to study accidents. However, it works well in determining the local causes of the injury, illness, or damage and the immediate cause, and this model is still valid in the realm of disease control.

The Haddon Matrix Theory

One of the most useful accident investigation theories is the Haddon matrix, which is a way to graphically correlate the factors and phases of injury (Haddon 1972). It works with many dimensions of the accident sequence and the factors involved in the accident. In the Haddon matrix theory an accident has three distinct phases—*pre-injury, injury,* and *post-injury.*

In accident investigation terms, the pre-injury phase means the causes of the accident. For a person who fell from a ladder, the pre-injury phase could be climbing a wet ladder with oily boots, the injury phase would be the person's impact with ground, and the post-injury phase would be the concussion the person suffered. These phases of injury represent the entire accident sequence.

During each of the three phases, three factors influence the outcome of the event: human factors, equipment factors, and environmental factors. Investigators develop a matrix to categorize the factors that occurred during each phase. Once the matrix is filled in, it is possible to isolate and compare the interactions, develop causes, and recommend corrections (Metzgar 2003). The Haddon matrix theory is useful in determining how an accident occurred and finding causal factors. (See Exhibit 2.6.)

Exhibit 2.6

A HADDON MATRIX

PHASES	FACTORS: Human	Equipment	Environment
Pre-Injury	Time pressure to perform the job (rushing job)	Oily boots	Rainy
Injury	Feet and hands slipping on ladder	Distance to ground (distance of fall)	Slippery ladder
Post-Injury	Concussion	Ladder fell over on top of employee	Emergency medical response late due to rain

Other Accident Causation Theories

Technical or Engineering Approaches

Technical or engineering approaches to accident investigation are very specific and discover lower level causes and system failures. They are excellent for investigating system or equipment failure, but too narrow in scope for most other types of investigations.

Human Error or Human Factors Theories

Many types of human error methodologies have been created, but they are difficult to use without appearing to assess blame. However, some of the human factors theories that discuss interactions are very useful. These systems allow investigators to discover the interactions between humans, machines, and the environment. These types of human factors analyses are very important and useful in accident investigations.

MORT

The most widely known management approach to accident causation is the Management Oversight and Risk Tree (MORT) system,

mentioned earlier in this chapter. The MORT approach links causes from the worker level up to the management level. The MORT system is widely used, although full MORT investigations are rarely used for accident investigations.

Sequence of Events Theory

This last theory is not so much a theory of accident causation as it is a theory of accident investigation. The idea is to document the sequence of events that led up to the accident, because if an accident investigator determines the correct chronological accident sequence, it will be easier to apply analytical techniques to find the causes of the accident. Some of the analytical techniques presented in this book will help you to determine an accident's sequence of events. All of them can help to validate a sequence and/or use the sequence of events to determine the causal factors.

Although it is possible to determine causal factors and recommend corrective actions without actually listing an accident's sequence of events, it is important to understand how and why the accident happened. For some types of accidents, it may be extremely difficult to determine the sequence of events. In fatalities or explosions, for example, some of the facts may be missing or impossible to find, but it is still important to discover as much of the accident sequence as possible. Even if an accident sequence is not fully understood, the investigator can record some of the steps in the sequence and use them to develop tests or engineering experiments to discover the rest.

Suppose, for example, that an explosion occurred at your plant, and you know exactly what happened until two minutes before the explosion. You can perform experiments to try to learn how the explosion could have been initiated in only two minutes, and that data may be crucial to the investigation. It is important to try to find as much data and discover as much of the accident sequence as possible even if you cannot find everything.

Summary

Several accident theories have come and gone as modern safety practices have evolved. Through the years, many of these theories have been modified from their original form. These theories have shaped the way safety professionals look at problems in today's workplace. The original theories are responsible for much of the terminology and many of the accident investigation techniques we use today.

Many of the accident theories discussed in this chapter can be used not only to find out how an accident occurred, but also to help prevent accidents. This book concentrates on the multiple causation theory and finding the sequence of events of an accident in order to find out what happened and how to prevent it.

REVIEW QUESTIONS

1. What is the Accident Ratio Study and what does each level represent?
2. According to the Accident Ratio Study, what level should we look at to make the most impact on safety?
3. Who first came up with the domino theory and what were the five labeled dominos?
4. Which domino theory has essentially become a separate theory?
5. Do most accidents have more than one causal factor? What theory is used if more than one causal factor is involved?
6. Think of an accident that you have been associated with. Use two of the accident causation theories described in this chapter and show how each could be applied to the accident.