Chapter 2

Key Terms and Concepts

The literature on safety and health makes extensive use of three terms—*hazard*, *risk*, and *risk reduction*. This chapter discusses these terms and clarifies their usage in this book.

2.1 HAZARD

2.1.1 Sample of Definitions

Of the many attempts to define hazard, several representative attempts are listed in Table 2.1.[1–8] The first two entries are from dictionaries, the next four from books by respected authors, and the last two from committees. Each definition is separated into three elements: (1) a brief description of a source, (2) words expressing the mechanism of transfer to cause harm, and (3) a description of the harmful consequences. The definitions appear to agree on the following order:

$$\text{Source} \rightarrow \text{Mechanism of transfer} \rightarrow \text{Harmful consequence.}$$

Other than agreeing on order, the definitions differ markedly when compared element to element. For the source element, some definitions appear to include everything and every activity imaginable. These include the phrases "a source of," "all aspects of technology or activities," and "something." The other definitions provide examples of attempts to be more specific. For the mechanism of transfer element, all eight definitions contain bridging words that differ somewhat but convey the concept that a source requires a means to cause some sort of harm. For the harmful consequences element, all eight definitions contain words about the sort of harm or what will be harmed, but the words differ substantially. Three concise phrases are (1) injury, pain, or loss; (2) harmful effects; and (3) significant harm. The most specific one, found in MIL-STD-882D, is "injury, illness, or death to personnel; damage to or loss of system, equipment, or property; or damage to the environment."

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

Table 2.1 Representative Definitions of "Hazard"

Source of hazard	Mechanism of transfer	Harmful consequences	Reference
All aspects of technology or activities	that produce	risk	1
A source of	exposure or liability to	injury, pain, or loss	2
A condition	that can cause	injury or death, damage to or loss of equipment or property, or environmental harm	3
The potential for an activity, condition, circumstance, or changing conditions or circumstances	to produce	harmful effects	4
Something	that can cause	significant harm	5
An unsafe personal act and/or the unsafe physical or mechanical condition	without which no accident can occur	(accident implied)	6
Any real or potential condition	that can cause	injury, illness, or death to personnel; damage to or loss of a system, equipment, or property; or damage to the environment	7
A condition, set of circumstances, or inherent property	that can cause	injury, illness, or death	8

Because many hazard analysis methods begin with identification of hazards, a definition is needed that sets some parameters for distinguishing what is and is not a hazard.

2.1.2 Proposed Definition of Hazard

The approach to defining hazard is to start with a simple, easily quotable primary definition as the foundation, supplemented by additional definitions of key words in the primary definition. This approach is used extensively in scientific literature when an equation with several variables is presented, followed by specific definitions of each variable. Thus, the primary definition used in this book is

A *hazard* is a source with potential for causing harmful consequences, where

Source is a form of energy, weather or geological event, condition, chemical substance, biological agent, musculoskeletal stressor, or the violent actions of people;

Potential for causing means the sourc
harmful consequence; and

Harmful consequences are outcomes a

Parts IV and V of this book contain extensive
The harmful consequences element is op
industry group can enumerate whatever ou

2.1.3 Additional Rationale a

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uses the inclusive but vague word "sour
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particular sources is provided.

For the source part of the definition, en
in both potential and transitional states. Th
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transitional state takes several forms. Kin
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include current traveling in a transmissio
static discharges, and arcs. Electromagne
ionizing radiation and nonionizing radi
transitional state include active chemical
produce heat, gases, and high pressure. Pre
high pressure to a location of low pressur

Heat energy hazards often arise from
reactions and electricity passing through
energy in workplaces deserves specific
energy states. Heat transfers from a warm
convection, or radiation. These transfer pr
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enough heat to a person to cause a disord

Severe weather and geological ever
multiple forms of transitional energy. H
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volcanic eruptions.

For the source part of the definition, th
includes static situations such as a slippery
that vary substantially, and a room contain
forms of potential energy such as a stretch

Potential for causing means the source is sufficient to bring about at least one harmful consequence; and

Harmful consequences are outcomes an organization wants to avoid.

Parts IV and V of this book contain extensive discussion of each item in the source list. The harmful consequences element is open ended, so each organization and/or industry group can enumerate whatever outcomes it values and wants to protect.

2.1.3 Additional Rationale and Clarification

This subsection is for readers interested in more in-depth discussion of the foregoing definitions. The source phrases in Table 2.1 include several ways to describe the sources of hazards. The definition from Merriam Webster's Collegiate Dictionary uses the inclusive but vague word "source."[2] The other definitions in Table 2.1 demonstrate the challenge of trying to be more specific or more general. In this discussion, the limitations of these attempts are noted, and the rationale for listing particular sources is provided.

For the source part of the definition, energy is a major component. Energy exists in both potential and transitional states. The potential state of energy involves stored energy such as a compressed or stretched spring, gravitational potential energy, thermal energy within materials, compressed gases, and magnetic fields. The transitional state takes several forms. Kinetic energy consists of materials moving from one place to another, as well as objects rotating. Electrical energy hazards include current traveling in a transmission line and electrons moving in lightning, static discharges, and arcs. Electromagnetic radiation contains harmful forms of ionizing radiation and nonionizing radiation. Chemical energy hazards in the transitional state include active chemical reactions (e.g., fire and explosions) that produce heat, gases, and high pressure. Pressure being transferred from a location of high pressure to a location of low pressure is a form of transitional energy.

Heat energy hazards often arise from other forms of energy such as chemical reactions and electricity passing through a resistor. But the manifestation of heat energy in workplaces deserves specific recognition in a list of transitional energy states. Heat transfers from a warmer to a cooler body through conduction, convection, or radiation. These transfer processes can involve the potential to harm people, property, or the environment. For example, hot objects can burn skin through contact or ignite some flammable vapors, and work in hot environments can transfer enough heat to a person to cause a disorder such as heat exhaustion or heat stroke.

Severe weather and geological events are recognized as hazards involving multiple forms of transitional energy. Hazards of nature include storms, floods, landslides, tornados, hurricanes, drought, wildfires, earthquakes, tsunamis, and volcanic eruptions.

For the source part of the definition, the word "condition" is common. It clearly includes static situations such as a slippery spot on a floor, a stairway with riser heights that vary substantially, and a room containing flammable vapors. It may also include forms of potential energy such as a stretched spring, materials stored overhead, and

compressed gas cylinders in a laboratory. A human–machine interface so poorly designed that it invites mistakes could also be considered a condition. A work area with airborne particulates is a condition that threatens the health of those working in the area. Despite its broad scope, "condition" does not encompass everything we recognize as hazard sources; it omits, for example, active/transitional forms of energy, biological agents, flammable materials, and volcanic eruptions. Thus, the word "condition" belongs in a definition of hazard, but is not sufficiently comprehensive to describe everything commonly recognized as a hazard.

Chemical substances, although highly useful to society, are recognized as hazards because of their potentially harmful effects on humans and other living entities. Some chemicals can kill by asphyxiation. Numerous chemicals, notably fuels, are recognized as hazards because of their flammability. Many chemicals are considered hazards because of their inherent explosive, corrosive, or reactive properties. Some increase risk of cancer, genetic mutations, or birth defects in the offspring of those exposed.

Numerous biological agents are sources of occupational hazards. Infectious diseases like flu and colds are threats in all workplaces where people interact. Infectious agents like hepatitis and HIV are especially a concern to healthcare personnel. Plants like poison ivy and poison oak are recognized as sources of allergic reactions. The research and development community has created numerous biological agents capable of harming people. Wild animals, pets, and farm animals are sources of injuries and several infectious diseases.

Musculoskeletal stressors are another important source. Although the vast majority of muscular work is healthy, musculoskeletal stressors become a hazard when the level of stress approaches or exceeds the tolerance of the person's body. The most frequent workers' compensation claims are musculoskeletal injuries and disorders.[9] Events directly causing most of the musculoskeletal injuries are overexertion from excessive lifting, pushing, pulling, holding, carrying, or throwing. Many other musculoskeletal injuries are from bodily reaction to slipping or tripping without falling. Highly repetitive motion accounts for another significant proportion of the musculoskeletal claims.

In addition to hazard sources mentioned above, the violent actions of people are the source of some hazardous situations. Among these are the highly dangerous situations created when armed robbers hold up a bank, terrorists hijack an airplane, or a recently discharged employee shows up at a worksite with a gun intent on shooting a supervisor. Once initiated, these situations can turn in many directions and end with outcomes ranging from no one being hurt to multiple deaths.

The second part of the definitions found in Table 2.1 is the bridge phrase. Although expressed in several ways, the substance of this part is quite similar across all eight definitions. Read as a group, the definitions indicate the bridge phrase should indicate that the hazard exists prior to the harm, that existence of a hazard can cause harm while not going so far as to say the source will cause harm, and that the level of intensity of the hazard source needs to be sufficient to cause the harm.

The rightmost column of Table 2.1 shows different ways to describe harmful consequences. The ANSI/AIHA management systems standard sticks closely to

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harmed, then no single definition will suit
their differing values.

Fine-tuning the definition of hazard
discussion. A workable definition is us
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a hazard as any threat to harm employee
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and visitors, or damage equipment, raw
product, and the ground on which the p
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of hazard.

In conclusion, any definition of hazar
will be verbose and may not accurately r
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2.2 RISK

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people outcomes—injuries, illnesses, and death.[8] Some of the other definitions go beyond people, including damage to equipment, property, systems, and structures. The differing items identified as being harmed by a hazard reflect differences in the values and backgrounds of the various authors and committees.

To further highlight the difficulty of listing all items we wish to protect from harm, consider this contrast in perspective. A farmer with income from selling eggs would consider the chickens as valued property, and anything that could harm the chickens, like a fox, would be a hazard. In contrast, a wildlife ecologist would view the same fox as a valued part of the ecosystem deserving protection from the farmer's shotgun. Thus, if a definition of hazard incorporates a list of items that could be harmed, then no single definition will suit all authors and all organizations because of their differing values.

Fine-tuning the definition of hazard is more than a point for philosophical discussion. A workable definition is useful to an organization when trying to anticipate, recognize, and control hazards. One processing plant may wish to define a hazard as any threat to harm employees. A second processing plant in the same business as the first may choose to define hazard as any threat to harm employees and visitors, or damage equipment, raw materials, in-process materials, finished product, and the ground on which the plant sits. These examples illustrate some of the endless variations in what organizations might wish to include in a definition of hazard.

In conclusion, any definition of hazard that attempts to list each item of concern will be verbose and may not accurately reflect the values of all organizations. The preferred approach is to have a definition that is both concise enough to be easily remembered and quoted and flexible enough to allow each organization to define whatever it is they value and wish to protect.

2.2 RISK

The word risk is used in numerous ways by the public and in professional circles. Articles in the safety-related journals use risk in three basic ways.

Definition 1 says risk is a probability. Mathematicians agree that all probabilities are numerical quantities with a value in the range of zero to one, and these pure probability values have no units. Sometimes it is convenient to multiply the pure probability value by 100 in order to report it as a percentage. Books on probability and statistics use several notations for probabilities. Common notations to indicate probability of event B are P_B and $P(B)$. Using the second notation, the first definition of risk is

$$\text{Risk 1} = P(B). \tag{2.1}$$

Definition 2 says risk is the product of probability and severity. This definition is used in the insurance industry and business community to forecast expected

	SEVERITY			
Probability	Catastrophic	Serious	Slight	Minimal
Probable	*High*	*High*	*Moderate*	*Moderate*
Possible	*High*	*High*	*Moderate*	*Low*
Unlikely	*Moderate*	*Moderate*	*Low*	*Low*
Negligible	*Moderate*	*Low*	*Low*	*Low*

Figure 2.1 Example of a two-dimensional risk-assessment matrix.

monetary loss for a particular set of inputs. Expected loss may be expressed in equation form as

$$\text{Risk 2} = E(\text{loss}_B) = P(B)L_B, \tag{2.2}$$

where

$E(\text{loss}_B)$ is the expected value of financial loss from event B,

$P(B)$ is the probability of event B occurring, and

L_B is the estimated financial amount of loss if event B occurs.

This definition may be applied to forecast losses from multiple events. For example, if three events (A, B, and C) have the potential to produce losses of L_A, L_B, and L_C, respectively, then the expected loss may be calculated as

$$\text{Risk 2} = E(\text{loss}_{A,B,C}) = P(A)L_A + P(B)L_B + P(C)L_C. \tag{2.3}$$

Definition 3 says risk is the combination of probability and severity. Some authors call this the "doublet" of probability and severity. When this definition is used, most authors are visualizing a two-dimensional risk-assessment matrix such as that shown in Figure 2.1.

Some organizations add a third dimension when using risk assessment—typically frequency of exposure. If there are three levels of frequency, for example, the risk assessment will use a risk matrix for each frequency category. This could be considered a fourth definition of risk, but for this book it is considered a variation of the third definition.

Which of these three concepts of risk is
valid and useful in various situations.

Definition 1 is supported by the pu
epidemiologists. For example, risk has be
will occur (e.g., that an individual will bec
or by a certain age)."[10]

Definition 2 is a monetary definition,
the related specialty known as risk manag
relies on the ability to predict the expecte
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of claims for the specific policy. The expe
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among the many insured clients. This de
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The risk-assessment matrices such as t
The U.S. military has long used such a f
procurements. Variations and features of
in chapter 5.

2.3 RISK REDUCTION

Several terms for efforts to make systems s
section explains the rationale for choosi
describing the diverse efforts to improve t

Choosing an appropriate term involve
came from the pioneering concepts of Dr. H
the public health injury control community
events involve three phases, and each phas
The original phases were called pre-crash,
papers expanded these three phases to in
damage.[12] Today, these phases are called
Thus, a term was sought that would captu
events consist of three phases.

The second criterion came from the va
preceding section. Recall that the first d
outcome, and then defining risk as the prol
is valuable for medical research, but less us
only one way to reduce risk—reducing the
and the second and third definitions
probability of the event and the severity of

Which of these three concepts of risk is preferred? Actually, all three concepts are valid and useful in various situations.

Definition 1 is supported by the public health community, particularly the epidemiologists. For example, risk has been defined as "A probability that an event will occur (e.g., that an individual will become ill or die within a stated period of time or by a certain age)."[10]

Definition 2 is a monetary definition, supported by the business community and the related specialty known as risk management. The entire basis for underwriting relies on the ability to predict the expected value of claims for each policy. Underwriters do this by using past experience to estimate the probability and monetary value of claims for the specific policy. The expected loss, or risk, is a summation of all the foreseeable losses using an extension of Equation 2.3. An insurance policy transfers the monetary risk from the insured to the insurer, and the insurer spreads the risk among the many insured clients. This definition is also used in the system safety community. Although Definition 2 is useful when the loss can be expressed in monetary units, it presents problems if the monetary value of an event is controversial. For example, what value should an employer put on an incident that causes an employee's death, brain damage, or paralysis?

The risk-assessment matrices such as the one in Figure 2.1 illustrate Definition 3. The U.S. military has long used such a framework for risk assessments of major procurements. Variations and features of these tables are discussed in more detail in chapter 5.

2.3 RISK REDUCTION

Several terms for efforts to make systems safer are found in the OSH literature. This section explains the rationale for choosing *risk reduction* as the best term for describing the diverse efforts to improve the safety of systems.

Choosing an appropriate term involved trying to satisfy two criteria. The first came from the pioneering concepts of Dr. Haddon, concepts still highly regarded in the public health injury control community. His simple idea was that vehicle crash events involve three phases, and each phase affords opportunities to reduce losses. The original phases were called pre-crash, crash, and post-crash.[11] Haddon's later papers expanded these three phases to include all forms of trauma from energy exchange.[12] Today, these phases are called pre-event, during event, and post-event. Thus, a term was sought that would capture the fundamental concept that harmful events consist of three phases.

The second criterion came from the various definitions of risk discussed in the preceding section. Recall that the first definition involves specifying a medical outcome, and then defining risk as the probability of that outcome. This definition is valuable for medical research, but less useful for OSH because it implies there is only one way to reduce risk—reducing the probability of the event occurring. More useful are the second and third definitions of risk because they include both the probability of the event and the severity of the harmful consequences. A term was

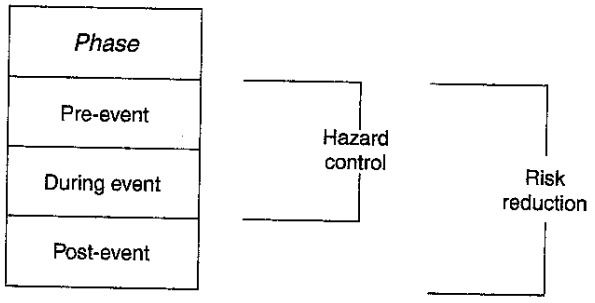

Figure 2.2 Incident phases keyed to the terms "hazard control" and "risk reduction."

sought that would apply to all these definitions. In the process of looking for the best term, some competing terms were considered.

The term *hazard control* was considered because it is used extensively in the safety literature. It implies existence of a hazard and one or more ways to control that hazard. However, it does not encompass any efforts involving post-event response, rehabilitation, or restoration. Figure 2.2 depicts the distinction between the terms hazard control and risk reduction. Using the Haddon phases, the graphic indicates that hazard control is appropriate for efforts (or countermeasures) aimed at the first and second phase. However, it is an inappropriate term if the third phase is included.

Another possible term is the one used by Dr. Haddon—loss reduction. Although this term encompasses the efforts in all three phases, it remains problematic due to its association with monetary losses. Thus, an alternative word was sought. The word risk was chosen because it embodies the concept of harmful outcomes, including but not limited to monetary losses.

Based on the above rationale, risk reduction means to lessen risk, and risk means any of the three definitions discussed in the previous section. Thus, we can reduce risk by

- Reducing the probability of a specified undesired outcome,
- Reducing the severity of the harm,
- Reducing the exposure to a harmful agent, or
- Combining two or more of the above.

The three terms discussed in this chapter figure heavily in the concepts addressed in the five major parts of this book. The chapters in part II address methods for analyzing hazards and assessing risks. Part III contains chapters on program management approaches for reducing risks; and parts IV and V contain chapters on risk-reduction strategies and tactics applicable to each of the hazard sources introduced in this chapter.

LEARNING EXERCISES

1. The definitions of hazard in Table 2.1 are only a sample of many definitions. Review other OSH books or standards to find another definition. Respond to items a, b, and c below.
   (a) Provide the definition.
   (b) Give the reference to it.
   (c) Explain how it might be brok
   definitions in Table 2.1.
2. In the *2001 ASSE Dictionary of* contains the word risk. This sa combined probability and severit as a consequence of exposure to o hazard in Table 2.1, substitute th
   (a) With the substitution, how w
   (b) What are your thoughts abo
3. Ericson advocates a three-part h a hazardous element, (2) an init threat. Compare these three eleme (i.e., source, mechanism of trans
   (a) What are their similarities?
   (b) What are their differences?
4. This chapter discusses three defin standards to find another definitic
   (a) Provide the definition.
   (b) Give the reference to it.
   (c) Indicate which of the three definition you found. If there
5. The psychology literature contain public's perceptions of risk and examine how the public views ri traveling by commercial air, drivin these surveys often disclose discr objective measures of risk.
   (a) Do you think risk perception s definition?
   (b) What is your rationale?
6. Measures of risk are not uniform ac injury statistics, which generally me number of person-hours worked d which traditionally report a ratio of nu traveled in miles or kilometers. In bot a constant to make the ratio values m use of a constant multiplier, comm reporting differently in the occupatio
7. In the occupational domain, some used a ratio of number of injuries to you think labor unions strongly opp

(a) Provide the definition.
(b) Give the reference to it.
(c) Explain how it might be broken down into three parts as was done with the definitions in Table 2.1.

2. In the *2001 ASSE Dictionary of Terms* (see Ref. 1), the definition of hazard contains the word risk. This same book defines risk as "a measure of the combined probability and severity of potential harm to one or more resources as a consequence of exposure to one or more hazards." In the first definition of hazard in Table 2.1, substitute the foregoing definition for the word "risk."
   (a) With the substitution, how would hazard be defined?
   (b) What are your thoughts about this?
3. Ericson advocates a three-part hazard description.[13] The three parts are (1) a hazardous element, (2) an initiating mechanism, and (3) the target and threat. Compare these three elements with the three elements used in Table 2.1 (i.e., source, mechanism of transfer, and harmful consequence).
   (a) What are their similarities?
   (b) What are their differences?
4. This chapter discusses three definitions of risk. Review other OSH books or standards to find another definition. Respond to items a, b, and c below.
   (a) Provide the definition.
   (b) Give the reference to it.
   (c) Indicate which of the three definitions of risk aligns best with the definition you found. If there seems to be no good fit, explain.
5. The psychology literature contains many papers reporting surveys about the public's perceptions of risk and risk-acceptance decisions. These surveys examine how the public views risks such as living near a chemical plant, traveling by commercial air, driving a car, and smoking cigarettes. Results of these surveys often disclose discrepancies between public perception and objective measures of risk.
   (a) Do you think risk perception should be included as a fourth type of risk definition?
   (b) What is your rationale?
6. Measures of risk are not uniform across industries. Compare the occupational injury statistics, which generally measure risk as a ratio of number of cases to number of person-hours worked during a year, to transportation industries, which traditionally report a ratio of number of deaths (or other events) to distance traveled in miles or kilometers. In both domains, the raw ratios are multiplied by a constant to make the ratio values more convenient for reporting. Ignoring the use of a constant multiplier, comment on what you think is the reason for reporting differently in the occupational domain and the transportation domain.
7. In the occupational domain, some older reports about safety performance used a ratio of number of injuries to number of items produced. Explain why you think labor unions strongly opposed this approach.

8. Two very different indicators of safety find use of the specialties focused on transportation safety. One uses fatalities per million kilometers or miles traveled. A second uses fatalities per 200 000 person-hours worked. Which ratio would be most relevant to each of the following? State your reasons.
   (a) Someone planning a trip from Paris to Munich with options for traveling by plane, bus, train, or personal car.
   (b) Someone contemplating a career as a flight attendant versus another occupation.

TECHNICAL TERMS

Harmful consequences	An organization-specific enumeration of whatever is to be avoided.
Hazard	A source with potential for causing harmful consequences.
Hazard controls	For a specified hazard, various approaches intended to prevent the hazard from causing harm or to reduce the severity; similar to risk reduction but not including post-incident efforts to reduce consequences. See Figure 2.2.
Potential for causing	Phrase meaning the source is sufficient to bring about at least one harmful consequence. Sufficient in this sense considers both the source (e.g., concentration, level, energy level, etc.) and tolerance of whatever might be harmed.
Risk	A general term acknowledging the possibility of an undesirable event. Three definitions are used in the OSH community: (1) probability of a specified event, (2) expected loss, and (3) combined consideration of probability and severity using a risk-assessment matrix.
Risk reduction	Term for any effective means of lessening risk.
Source	When used in the definition of hazard, a source may be a form of energy, weather or geological event, condition, chemical, biological agent, musculoskeletal stressor, or the violent actions of people.

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