CHAPTER 31

HUMAN BEHAVIOR AND PERFORMANCE IN SAFETY

Case 1

The local newspaper reported a head-on vehicle crash that went virtually unnoticed. Robert W., the driver of an automobile, suddenly swerved into the path of an oncoming semi-trailer rig. The automobile was demolished and Robert W. was pronounced dead at the scene. The truck driver received facial injuries and two broken ribs.

Why did the accident happen? Did Robert W. suddenly become ill and lose control? Was there any icy patch on the pavement? Both were possibilities. However, only family and close friends had another theory for the accident: Robert W. had terminal cancer and had been depressed. He may have committed suicide.

Case 2

Maria B. operated a molding machine that turned out plastic parts. The machine normally operated in automatic mode. Dies came together horizontally, molten plastic was injected between the dies, and when the dies opened, the formed part fell to a parts box below. Somehow, Maria put her hand between the dies, the dies closed and crushed her hand.

Why did the accident happen? Did someone accidentally trip the machine? Why did Maria put her hand in the machine anyway? Why was the guard not in place? Would it have prevented the accident? The accident seemed unnecessary. It appeared that Maria had made a stupid mistake. Did she not read the warning sign that said, "Never reach into the machine while it is turned on"?

Maria was new on the job. In fact, it was her first day. She had been taught how to do the job just that morning and had been on her own for only 45 min. Maria did not speak English very well and could not read English. She was thrilled to have gotten the job so she could help out her poor family. Compared with previous work, this job paid well, and she wanted to do a good job for her new boss. She did not want to make a mistake.

The guard had been removed to set up a new process and the interlock, had been wired down to allow for testing by the tooling department during the morning shift. The idea was to make sure the machine operated correctly during the night shift using manual mode and then the next day to have the maintenance crew (who only worked days) replace the guard, reactivate the interlock, and return it to automatic mode.

When the machine started to malfunction, the dies opened but the part did not fall down like it was supposed to. Maria had learned nothing about that. She was trying to do

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her best. She was afraid her boss would be angry about bad parts. He was anxious when he showed her how to run the machine and was obviously under stress. As she reached into the machine to get the part loose, she accidentally bumped the foot control that tripped the machine.

To compound all the other factors, the control was the wrong one. It was designed for automatic mode. Manual operations for this machine required a hand control for protection, but the previous owners had set it up differently for automatic mode only and the hand controls were no longer on the machine. Maria's company was having trouble meeting production demands, had a large order to fill, and had just added a night shift. They purchased the machine at a bargain price because it was used and had the tooling department refurbish it and rush it into operation.

Case 3

The accident report seemed simple enough. Gary did not see the step, fell, and broke his arm. Gary came to work that morning, entered the building, and started down the hall to his office. Approximately 10 ft from the door, there was a step down into the new part of the building. Somehow he missed the step and fell forward. He put out his hand to stop the fall and broke his arm. That seemed straightforward. He made a dumb mistake; he was not paying attention.

You see, the day started terribly. Gary had not been getting along well with his wife and they were coming close to divorce proceedings. The night before, they had had another argument. In the morning, one of the children was sick and could not go to school. Gary had to find a baby sitter. A neighbor who usually helped out was gone for a couple of days, so Gary called his sister, who agreed to help out. However, she lived 30 min away. He rushed the child to his sister's and then drove to work.

That morning, there was an important meeting and Gary was scheduled to report on the performance of his production team. Already late, Gary arrived to find a delivery truck blocking his parking place, which forced him to park way in the back part of the lot.

As he ran from his car, the morning sun was virtually in line with the door of the building. He had trouble looking up as he approached the building and the sun glared into his eyes. After coming inside the entrance from the parking lot, it was somewhat dark. Gary had a lot on his mind thinking about the report, the sick child, and his strained relationship. Then he fell.

31-1 HUMAN BEHAVIOR

Why do people behave as they do? What makes them tick? Some people never seem to have a problem, whereas others seem to be accidents waiting to happen; some get along with everyone, whereas others are impossible. Human behavior is very complex and it is not fully predictable. Often, behaviors contribute to accidents. Behavior is affected by many things (see Table 31-1), including physiological condition, biochemistry, health, relationships with others, personal desires and goals, and so forth. This section looks at human behavior and important characteristics of it.

Theories of Behavior

There are many theories of behavior. Some are descriptive theories that allow characterization or classification of a person after observing that person's behavior. Some theories

TABLE 31-1 Performance-Shaping Factors[a]

Situational characteristics
- Temperature, humidity, air quality
- Noise and vibration
- Degree of general cleanliness
- Manning parameters
- Work hours/work breaks
- Availability/adequacy of supplies
- Actions by supervisors
- Actions by co-workers and peers
- Actions by union representatives
- Rewards, recognition, benefits
- Organization structure (e.g., authority, responsibility, communication channels)

Task and equipment characteristics
- Perceptual requirements
- Anticipatory requirements
- Motor requirements (speed, strength, precision)
- Interpretation and decision making
- Complexity (information load)
- Long- and short-term memory
- Frequency and repetitiveness
- Continuity (discrete versus continuous)
- Feedback (knowledge of results)
- Task criticality
- Narrowness of task
- Team structure
- Human-machine interface factors (design of equipment, job aids, tools, fixtures)

Job instructions
- Procedures required
- Verbal or written communications
- Cautions and warnings
- Work methods
- Shop practices

Psychological stresses
- Task speed
- Task load
- High jeopardy risk
- Threats (of failure, loss of job)
- Monotonous, degrading, or meaningless work
- Long, uneventful vigilance periods
- Conflicts of motives about job performance
- Reinforcement absent or negative
- Sensory deprivation
- Distractions (noise, glare, movement, flicker, color)
- Inconsistent cuing

Physiological stresses
- Fatigue
- Pain or discomfort
- Hunger or thirst
- Temperature extremes
- G-force extremes
- Atmospheric pressure extremes
- Oxygen deficiency
- Vibration
- Movement constriction
- Lack of physical exercise

Individual factors
- Previous training and experience
- State of current practice or skill
- Personality and intelligence variables
- Motivation and attitudes
- Knowledge of required performance standards
- Physical condition
- Influence of family and other persons or groups
- Group identification

[a] Derived from *Hazard Survey of the Chemical and Allied Industries*, American Insurance Association, New York, 1979. The items resulted from a questionnaire survey of failures of many plants and operations.

are predictive: they attempt to predict what a person will do given information about their past, their surroundings, or internal attributes. The information is obtained by introspective, subjective, or objective means.

Early theorists believed that behavior had biological origins. Theories related observable behavior to such things as instincts, habits, and conditioned reflexes from repeated stimuli. Later, other theorists looked to underlying elements within an individual that were not accessible through introspection by the individual. Others looked to many factors that together cause behavior: inherited traits and characteristics and environmental factors that lead to a person's behavior. The inherited traits may be both physiological and psychological. The environmental factors may be an accumulation of experiences and particular situations or conditions surrounding one at any moment.

Motivation

Motivation is that part of psychology that deals with getting someone to perform desired behaviors or actions. Motivation involves content and process theories. Content looks at the characteristics of an individual or his/her environment that stimulate performance or action and at what variables influence desired actions. Process looks at the linkages between content and specific actions and addresses the question of how to tap needs and outcomes to achieve desired actions. Although no theory of motivation is fully supported by research studies, some provide a framework for working with people toward desired actions and performance. A few theories are summarized in this section.

Maslow Maslow developed a hierarchy of needs that has been quite popular. His theory is a content theory that looks within an individual for variables that effect desired performance. His hierarchy consisted of five classes of needs. He thought that needs at the base of the hierarchy had to be satisfied first, before higher ones were very meaningful. Higher ones became more important as lower ones were satisfied. His five classes of needs in ascending order are:

1. Physiological needs, such as hunger and thirst
2. Safety needs (primary body needs)
3. Social needs, such as friendship and affiliation
4. Esteem, including self-esteem and the esteem of others
5. Self-actualization, such as reaching one's potential

Research suggests that basic needs do not diminish as they are satisfied.

Herzberg Herzberg's theory is a content theory that looks at work outcomes rather than needs. He proposed two types of outcomes that affect behavior: intrinsic factors and extrinsic factors. Intrinsic factors involve the work itself and recognition of one's work. Extrinsic factors include rewards associated with the work, such as pay, relations with co-workers and superiors, and working conditions. Whereas Herzberg believed that only attainment of intrinsic factors can sustain motivation toward organization goals, research suggests that both are important and there are significant differences among people in their preference for outcomes.

Vroom Vroom addressed the motivation process. In his expectancy theory, there are three concepts. The first is the attractiveness of outcomes (valence of outcome). The theory does not concern itself with which outcomes. The second concept is the belief a person has about the link between an action and the outcome (instrumentality perceptions). For example, one may feel that achieving some performance deserves a raise. The third concept is a person's belief about the effort required in an activity and the likelihood of successful completion of the activity (expectancy perceptions). In summary, Vroom's expectancy theory states that when a person's expectancy perceptions for an activity are high and instrumentality perceptions linking the activity to attractive outcomes are high, the person will be highly motivated to engage in the activity. Related studies suggest that desired behavior is most often achieved if rewards are given every time the behavior is achieved, rather than occasionally. It is also important to state clearly the linkage between behavior and reward.

The implication of Vroom's theory and related work is that people can be motivated to perform when there are clearly defined linkages between behaviors, and rewards, the

linkages are implemented consistently, and rewards are given regularly when a desired behavior is achieved.

Judgment

One definition for judgment is deciding or discriminating. It is the operations of the mind in which one compares information, evaluates values and formulates a decision, or reaches a conclusion. The decision or conclusion may be expressed verbally or may result in an action. Formulating judgments or reaching decisions can be deliberate or can extend over time. One may rely on information available from memory or drawn from careful compilation from various sources.

People differ in their ability to make judgments. Quick judgments and decision may be critical. In making quick decisions, one relies heavily on previous knowledge and experience available from memory. The action taken as a result of a judgment is more likely to be a desirable action when there is a rich background of knowledge, experience, and compiled information.

Emotion

People are not robots. People have feelings and emotions. Emotions may be experienced internally or exhibited through actions. Behavioral literature describes many kinds of emotions, including joy, fear, anger, grief, guilt, pride, love, hate, pity, and anxiety. Emotions may be generated by situations at home or at work and they may be associated with other people, with activities, or with conditions. Control of emotions and acceptable emotional expressions as well as control of the situations that generate them are important. Communications and management of interpersonal relations are means by which emotion-generated situations can be reduced. Emotions can be disruptive or facilitating, depending on the situation.

Attitudes, Opinions, and Beliefs

Attitudes, opinions, and beliefs are much the same thing: judgments or sentiments that the mind forms about something or someone. One also may hold attitudes about groups of people, social institutions, or issues. Attitudes may be positive or negative and are usually enduring. Attitudes an individual has can be inferred from their actions in certain situations and from verbal statements. Formal assessment of attitudes involves the use of carefully developed survey instruments. An attitude survey has many statements about situations or actions with which respondents agree or disagree. Results provide a picture of individual or group attitudes about situations covered in the survey.

Attitudes may be related to behavior. For example, one may have attitudes about another person, such as a supervisor. However, attitudes are not always a predictor of behavior. A person may know the effects of an action are bad, but continue to do it. Some call this cognitive dissonance. An example is a person who knows that smoking can lead to heart and lung disease, but continues to smoke.

Individual Differences

People are not alike. They differ in size, shape, strength, reaction time, physical condition, health, and physiological performance. They differ in ability to perform actions; in

knowledge, skills, and abilities; in the ability to form judgments and make decisions; in attitudes and beliefs; in emotion; and in social and economic ways.

The differences are not fixed; they are variable. Individuals change over time. Some differences take care of themselves. The heart and respiratory rates are elevated when people exercise, but after resting, they return to normal. In other cases, people change through various means. Performance is changed through training, knowledge is changed through education, and some physical conditions are changed through medication. The important points are that people differ and individuals differ over time.

31-2 HUMAN BEHAVIOR AND SAFETY

Safe Behavior

Chapter 4 discussed the idea there are two causes for accidents: unsafe conditions and unsafe acts. Most of this book deals with unsafe conditions, their recognition, and control. A significant part of the accident formula is unsafe acts. Why do people perform unsafe acts? How does one prevent unsafe acts from occurring? These are behavioral issues. Understanding human behavior gives clues to managing behavior. The three Es of safety (see Chapter 3) suggest ideas to prevent unsafe acts. Education, enforcement, and engineering all have a role. Enthusiasm, a fourth E, has a role, too. Other concepts apply too.

Education Most behaviors are learned. Learning may be informal. Studies suggest that by age 6 years, people have acquired half their knowledge and skills. Children learn to walk and talk by trial and error. They obtain a great deal of reinforcement from those around them. Higher concepts and abstract learning usually occur in school. Education and training provide the knowledge and skills people require to act safely.

To avoid accidents and injuries, one must first recognize dangers in a situation. Not everyone brings the same knowledge and experience to a situation; not everyone will recognize or perceive a danger that may be inherently present or may develop. For example, some workers may not recognize that a guard should be in place on a machine because they may not have experience with equipment and may not recognize a danger or know what protection is appropriate. In another case, a dangerous situation develops rapidly. A child runs into the street after a ball. A driver may recognize the danger developing after seeing the ball roll into the street and the child near the curb. In another situation, the driver may not see a danger when a child is merely playing near a curb.

After recognizing a danger, individuals must act to protect themselves against an accident and possible harm. One must know what actions are correct and safe and one must complete the action required. Knowing the appropriate action and performing it correctly requires training and practice.

Enforcement Enforcement involves formalized rules and procedures and following them. Compliance can depend on self-discipline but more often, enforcement involves someone else auditing the actions of others. With enforcement, there may be some consequence for not acting properly. For example, one company gives drivers responsibility for their vehicles. Failure to drive properly results in loss of that job. Unsatisfactory performance of tasks can lead to other management-imposed outcomes both positive and negative.

Engineering In many cases, engineers can design to prevent certain behaviors from occurring. They also can design so that certain behaviors are not likely to cause the performer harm. This role for engineers will be discussed further in subsequent sections.

Communication

Communication is an important part of education. People cannot perform correctly if they are not told what dangers to look for, what procedures to follow, or how to act safely. Communication may involve training classes, supervisor instructions and comments, training videos and computer programs, published procedures and rules, and warnings and instructions. They may even involve simulations. People cannot be expected to decide and act on their own if they do not have the knowledge, skills, and experience to recognize a dangerous condition and to know what actions are appropriate as it develops or when it occurs.

Feedback

Knowledge of results—feedback—is an essential ingredient in learning. Correct behavior must be reinforced, and performance is greatly enhanced by knowledge of results. If someone does something correctly, they need to know; if they do it incorrectly, they also need to know. Safe behavior requires feedback on performance. Feedback on wearing of personal protective equipment—a safe behavior—is important in gaining user cooperation.

Several methods are used to provide feedback. Feedback may be verbal comments from someone else or reports of measured results of actions. For example, a report may contain the number of parts produced, the number of errors, or the accident rate. Feedback may be awards or rewards.

If individual performance is important, feedback should be given to individuals; if group performance is important, it should be directed to the group. In some cases, both individual and group feedback are needed.

Immediate feedback is generally better than delayed feedback. Actions can be divided into short increments or small elements, and feedback on these small components is usually better than feedback on large components. Feedback should be precise. If there is a particular task or component of a larger action, feedback should reflect correct or incorrect performance of the individual components. Reinforcement should be as often as practically possible.

Job Safety Analysis

Job safety analysis (JSA) is one technique to help identify what behaviors in an operation are safe and correct. It is a form of task analysis that is sometimes called job hazard analysis. In the analysis, one breaks down an operation into activities of workers. The analyst identifies the hazards associated with each activity in the operation, and for each activity, the analyst describes how to perform the job correctly and safely (see Figure 31-1). People have used a variety of forms for completing a JSA analysis. The hazard analysis and recommended practices can become part of a user manual, operations manual, or training program.

A JSA can be completed concurrently with other forms of task analysis common to industrial engineering practice. Such process analyses look at work flow, motion economy, time for each job element, eye movement, and hand and foot movement. A JSA should consider abnormal activities and conditions, not just normal, routine operations. It is often under the unusual situations (when things go wrong) that accidents and injuries occur. Even activities like cleaning and maintenance are nonroutine. People often make the wrong

WORKSHEET FOR JOB SAFETY ANALYSIS	Job		JSA by
	Supervisor	Date of Analysis	Reviewed by
	Department	Work Group	Approved by
Brief description of job, its beginning and end, and desired results			
Required or recommended personal protective equipment for all tasks (Special requirements are noted with each task.)			
SEQUENCE OF TASKS OR STEPS	POTENTIAL HAZARDS AND INCIDENTS	SAFE JOB PROCEDURES	

Figure 31-1. Example of a job safety analysis worksheet.

decisions or take the wrong course of action in adverse situations. As discussed earlier, hazards during nonroutine, abnormal operations need to be protected by design.

Risk-Taking Behavior

For many activities, it is obvious that performing an action will not produce an accident or injury every time. A person will take a chance. For example, one does not get in an accident every time one rides a car. Therefore, one may reason that wearing a seat belt is not always necessary. Similar reasoning suggests that one can operate a machine without a guard in place, because one does not always become injured. People who are risk takers, are involved in accidents more frequently, and have higher absentee rates from work than those who are not risk takers.

Risk-taking behavior is greater under some circumstances than others. For example, most people will take greater risks when they have a choice, but are reluctant to take risks when it is required. Individuals are less likely to take risks when they are anxious and are more likely to take risks when they understand what is going on. For example, many people are afraid to undergo surgery. However, the more the individual knows about a surgical procedure, the less reluctance there is to undergo the surgery. Individuals are not willing to take risks when the status quo has strong value. People are reluctant to change, because there is often a fear of the unknown and they are satisfied with the way things are.

Risk taking is affected by people's perception of the risk. Table 31-2 lists risk perception factors that affect acceptance of risk situations. There are many things that affect

TABLE 31-2 Risk Perception Factors Affect Risk Acceptance[a]

More Acceptable	Less Acceptable
Voluntary	Involuntary
Natural	Human-made
Controllable	Not controllable
Delayed effect	Immediate effect
You and yours	Me and mine
Essential	Nonessential
Off-the-job	On-the-job
Misuse hazard	Proper use hazard
Affects few	Affects many
Effects reversible	Effects irreversible
Sensory perception	Unable to sense
Relates to self-worth	Does not relate to self-worth
Greater benefits	Lesser benefits
Experience	No experience
Understood	Not understood
Higher cost to fix	Lower cost to fix
Low consequence	High consequence
High probability	Low probability
No alternatives	Alternatives

[a] Buys, J. R., "Risk Perception, Evaluation, and Projection," Informal Report EGG-SHS-5975, Idaho National Engineering Laboratory, Idaho Operations Office, U.S. Department of Energy, Idaho Falls, ID, August, 1982.

people's estimates of risk. They may think that risk is greater than it really is or less than it really is. Table 31-3 lists several factors that affect the value people place on risk.

There are differences between group risk-taking behavior and individual risk-taking behavior. For example, fear tends to trigger group behavior. When fear is aroused, people choose to be together with others. Conversely, when people are anxious, they choose to be alone. Examples of groups are family, friends, work groups, command groups, or groups structured around coping with common or shared stresses or threats. Groups have informal structures, whereas organizations have formal structures.

Biorhythms

After the emergence of various behavioral theories, attempts were made to link the theoretical components to the likelihood of safe behavior or accidents. One concept that has drawn widespread attention is the use of biorhythms to predict the likelihood of accidents or other undesirable events caused or influenced by behavior or condition. Although some early studies appear to show that biorhythms affect accidents, more recent studies have not been able to show such affects.[1]

Biorhythms are not to be confused with biological rhythms. The theory of biorhythms stems from the early nineteenth century and it has so many followers that handheld biorhythm calculators are easily purchased. The concept suggests three precise, fixed rhythms that originate at birth and affect events in an individual's life. These three rhythms have 23-, 28-, and 33-day periods or cycles, respectively. The congruence of the periods is said to affect events, moods, and actions of a person.[2]

TABLE 31-3 Risk Perception Factors Affecting Risk Estimation[a]

Underestimate	Overestimate
Known	Unknown
Understood	Not understood
Common	Uncommon
Mundane	Dramatic
Little media coverage	Much media coverage
Noncontroversial	Controversial
Me in control	You in control
Voluntary	Nonvoluntary
Fun risks	Work risks
Few injuries/events	Many injuries/events
Sensory perception	Unable to sense
Benign experience	Hurtful experience
"Scientific"	Not "scientific"

[a] Buys, J. R., "Risk Perception, Evaluation, and Projection," Informal Report EGG-SHS-5975, Idaho National Engineering Laboratory, Idaho Operations Office, U.S. Department of Energy, Idaho Falls, ID, August, 1982.

Alcohol and Drugs

Alcohol and drugs do contribute to accidents and injuries. There is a strong relationship between motor vehicle deaths and blood alcohol levels of drivers and between fire deaths and blood alcohol.

Employers face problems of employees drinking on the job or coming to work with alcohol in their blood. Results of one study indicate that employees who abuse alcohol are absent 16 times more often than those who do not, receive three times more sick leave, have four times the accidents, and are five times more likely to receive worker's compensation. Both street drugs and prescription drugs can increase the likelihood of accidents. When any drug reduces physical or mental performance, the chances of error, poor judgment, and accidents increase. Many companies have programs to assist employees with alcohol and drug problems that affect their work and the loss and claims rates. Some employers use drug and alcohol screening programs during hiring or employment. For some jobs that can affect the safety of others, laws may require drug and alcohol monitoring.

31-3 DESIGNING FOR HUMAN BEHAVIOR

There are many ways to remove or reduce hazards through design. Sometimes engineers forget to consider user capabilities and limitations, user behavior, and the use environment. Understanding people and their behavior is an important element of design. For example, running a pipe along a floor surface creates a tripping hazard. It does not make any difference that the activity near the pipe is a production activity or a maintenance and repair activity. The probability for an accident may be lower for certain activities, because walking near the pipe is less frequent. However, the hazard still exists. Any person walking or working near the pipe must avoid falling over it, that is, special actions to step over it are required.

Design problems may be even more subtle. A change in surface friction properties may create a slipping hazard. During initial steps on a surface, a walker gains a feel for the resistance underfoot. When there is a sudden change in resistance to a slipperier surface and the walker is not aware of the change, the gait must be adjusted suddenly from the first to the second condition. A failure to adjust can lead to feet slipping out from under the person and a fall. Similarly, a sudden change to a high friction surface will require adjustments. Failure to adjust may lead to a fall forward because the second surface prevents any movement between the shoe and the surface.

Designing for human behavior must anticipate foreseeable activities, and defining what is foreseeable requires a knowledge of what people do in various circumstances. It is not enough, for example, to safeguard machines for normal operations or production use. The designer must protect workers involved in cleaning, setup, and maintenance. In many cases, the designer can reduce hazards by incorporating features that are less dependent on people protecting themselves.

Designing for people must anticipate a range of ages and capabilities. Will the users be normal adults? Will the users have disabilities? What might the disabilities be? Could the users also be children? Will users be large or small? The field of human factors engineering or ergonomics addresses many of the capabilities and limitations of people and how to design with them in mind. Chapter 33 discusses ergonomics.

Dealing with these design problems requires analysis to identify the potential behaviors and errors in behaviors that can lead to accidents and injuries. Techniques to identify these behaviors include JSA or some derivative of it and testing of designs with users that adequately represent the population of potential users. Other methods may also be useful.

31-4 SAFETY AND COMMON SENSE

Some people have the notion that safety is nothing more than a lot of common sense. There are many problems with this approach when one considers human behavior.

What is common sense? The dictionary says it is sound, ordinary sense or good judgment. Common means a characteristic shared by a group at large, or belonging or pertaining to the community at large. Sense means sound perception or reasoning or correct judgment, or the ability to perceive or discern. It infers sensibility or a quick reaction to actions of objects or others.

The ability to perceive and recognize hazards is important to safety. To take corrective action, people need an ability to recognize the danger in a rapidly developing situation. People need skill in making good judgments or decisions about corrective actions to be safe.

One problem with common sense as a basic premise for safety is that human capabilities for achieving safe behavior are not universal. Individuals vary in their training, experience, knowledge, skill, and ability to recognize hazards, to perceive dangerous situations in a timely manner, to make sound judgments, and to take the correct protective action without error.

Most people would agree that children do not have common sense. When does one obtain common sense? How can you tell if someone has it?

Leaving safety to common sense suggests that somehow safety in a complex society will result if people are left to their own devices. Accidents are caused. Safety is achieved by thorough analysis, good design, and solid development of knowledge and skills through training and management. It is not an innate characteristic common to society. The desire to be safe is common; the actions required to achieve it are not.

31-5 TECHNOLOGICAL ILLITERACY

Another behavioral problem facing highly technical societies is a divergence between products and environments that depend on technology to make them work and to make them safe and the limited knowledge of the users and occupants that depend on that technology. Technology tends to raise the knowledge and skill required to use or control it. As a result, fewer and fewer people have the skills and knowledge to keep things safe; more and more people lack a good understanding of technologies and their potential dangers.

The average person who is cleaning something does not understand the chemistry of soap, solvents, acids, and alkaline materials. It is not uncommon to find people mixing different cleaning agents to gain more cleaning power, and too often the result is an accident and injury.

Many people do not understand mass, moments, inertia, potential and kinetic energy, or conservation of momentum. They wonder why they were unable to stop a falling object. They fail to recognize the danger of walking under a suspended load. They fail to see the danger of bicycling on the same pavement with 3,000-lb vehicles moving only inches away at speeds three or four times faster than they are. Lobby groups push lawmakers to make trucks 20% to 30% larger, and then the same lawmakers create rules that make passenger vehicles smaller.

Two national surveys that explored the technical knowledge and skills of the American population found that technological illiteracy is significant and somewhat related to literacy in general.

Fifty percent of American industrial workers have math skills at or below the eighth-grade level. Twenty-eight percent of people cannot make correct change when given a cash register receipt. Thirty-three percent of the respondents to one survey did not know how a telephone works, even though the device is much older than they are. Nineteen percent believed they had little understanding of radiation. Forty-one percent believed that rocket launchings and other space activities have caused changes in our weather. Twenty percent believed it was not wise to plan ahead, because many things turn out to be a matter of good or bad luck anyway.

Problems are compounded by the fact that literacy, including technological literacy, is lowest among the poor and uneducated. Studies of who is most affected by disaster indicate that the poor and poorly educated suffer the greatest losses. Perhaps there is a relationship between technological literacy and loss rates.

Given this context, designers have a challenge. They must make technology and technology-based products, systems, and environments safe, even for many who have little or no understanding of them. Recognition of hazards, making judgments, and taking corrective actions cannot be left to untrained users. Moving technology to third-world countries places even greater portions of a population at risk if safety is not built in or workers and communities are not trained.

31-6 JOB AND OTHER STRESSES

Another aspect of safety related to human behavior is job stress. Physical disorders that stem from behavioral problems, such as anxiety, fear, and other forms of psychological stress, are called psychosomatic disorders. The psychological condition manifests itself in physical disorders of various kinds.

Job stress is becoming more important in safety. It seems to increase with the increase in the number of high-paced, demanding jobs. In addition, more and more claims

for job stress receive workers' compensation. Job stress is common in management positions. However, it occurs in many other kinds of positions as well.

Various conditions or situations in our lives cause our body to react. A scare causes the heart rate to increase, blood pressure to rise, and adrenalin to be secreted. Even sweating may start. Job situations may produce similar effects in the body. Certain tasks may be difficult to perform and produce similar reactions. There may be deadlines to meet, difficult social situations, difficult to handle co-workers, or presentations to make, all of which may produce similar responses. Continued stresses and chronically complex and difficult work situations may lead to more extreme health problems. Researchers identified major events in life that are related to subsequent illnesses and assigned weightings to these events. Table 31-4 contains a test for evaluating the likelihood of becoming ill from major stress events in life.

Stress may be positive or negative. The body's reactions to stress help us concentrate and perform. Some people do better under pressure. When there is no opportunity to relax or escape from the stress conditions, stress can be negative and can lead to reduced performance and health problems. The term *burnout* is closely associated with prolonged job stress. A number of factors contribute to job stress: not enough time to complete a job, lack of clear direction and goals, lack of clear instruction, absence of recognition or reward, lack of opportunity to participate, responsibility without authority, prejudice and bigotry, poor interaction with others because of differing goals and values, unpleasant or dangerous work conditions, lack of control over job performance, and job insecurity.

There are several techniques people can use to help reduce and manage stress. First, they must recognize the situations and conditions that lead to stress and they need to sense the body reactions that are symptoms of job stress. Applying one or more relaxation techniques can help reduce stress. A deep breath or simple exercises followed by relaxation can help. Another technique is getting away from certain difficult situations. Modifications in lifestyle, such as exercise, also may help.

31-7 MANAGEMENT PROCESSES

Management methods can affect how people perform or an organization performs. Management methods also affect the culture of an organization, referring to how people in the organization approach work planning, organization, and execution. The reader should refer to the wealth of literature on effective management methods. This section touches on a few concepts and approaches and how they may influence performance, including safety performance.

Total Quality Management and Six Sigma

More traditional organizational structures found in U.S. companies and organizations was a top-down approach. The organizational structure had multiple layers between the top leader of the organization and the lowest-level worker. Before the age of computers and the Internet, the layers of management provided a path for directing what was to be done down through the organization and communication up through the structure the status of what was accomplished. Many organizations continue to use such an approach.

In the 1990s, most U.S. organizations eliminated many of the layers in the top-to-bottom structure. In part, the change resulted from the use of personal computers and the Internet. Higher levels did not need many of the intermediate layers to analyze and process

TABLE 31-4 Life Stress Scale[a]

Event	Value	Score
Death of spouse	100	—
Divorce	73	—
Marital separation from mate	65	—
Detention in jail or other institution	63	—
Death of a close family member	63	—
Major personal injury or illness	53	—
Marriage	50	—
Being fired at work	47	—
Marital reconciliation	45	—
Retirement from work	45	—
Major change in the health or behavior of a family member	44	—
Pregnancy	40	—
Sexual difficulties	39	—
Gaining a new family member	39	—
Major business readjustment	39	—
Major change in financial state	38	—
Death of a close friend	37	—
Changing to a different line of work	36	—
Major change in the number of arguments with spouse	35	—
Taking on a mortgage more than $10,000	31	—
Foreclosure on a mortgage or loan	30	—
Major change in responsibilities at work	29	—
Son or daughter leaving home	29	—
In-law troubles	29	—
Outstanding personal achievement	28	—
Spouse beginning or ceasing work outside the home	26	—
Beginning or ceasing formal schooling	26	—
Major change in living conditions	25	—
Revision of personal habits	24	—
Troubles with the boss	23	—
Major change in working hours or conditions	20	—
Change in residence	20	—
Changing to a new school	20	—
Major change in usual type and/or amount of recreation	19	—
Major change in church activities	19	—
Major change in social activities	18	—
Taking on a mortgage or loan less the $10,000	17	—
Major change in sleeping habits	16	—
Major change in number of family get-togethers	15	—
Vacation	13	—
Christmas	12	—
Minor violation of the law	11	—
	Total	—

[a] Holmes, T. H., and Rahe, R. H., "The Social Readjustment Rating Scale," *J Pychosomatic Res*, 2:213–218 (1967).

Note:

Instructions

1. In the table above, check those events that occurred to you in the last 12 months.
2. For each item checked, insert the value for that item in the score column.
3. Sum all entered scores.

	Total Score	*Probability of Becoming Ill*
4. Compare your score to the following:	<150	37%
	150–300	51%
	>300	80%

information into a form for the next higher level. Someone at any level could access information from a common source, and software applications provided the same analysis and reports to virtually anyone on the computer network. The change in technology impacted how organizations worked and reduced overhead costs.

The changes in management methods recognized that together, a group of people is smarter than any one person alone. The changes required a collaborative environment.

Another change was the emphasis on quality to be competitive in the marketplace. Many organizations rediscovered the work of Juran and Deming on quality and methods for achieving it. A national award was established called the Malcolm Baldridge Award that recognized the quality improvements of companies.

One of the basic elements of total quality management (referred to as TQM or quality improvement) involves listening to the customer to identify opportunities to improve. Another basic element was recognizing that organizational performance was tied to management processes given to workers and realizing that workers can perform not better than the process allows. Making individual performance the point of change could not be effective. In contrast, the approach sought participation of everyone in a work group. The group would review the processes it used. The group would identifying the opportunities for change that would contribute to meeting customer expectations and needs.

With this approach, the metrics for assessing performance changed. Some reduce the metrics to two basic ones: process time and errors. Process time refers to how long it takes to complete some function. Process time varies with specific settings.

Delivery time of mail is an example. One may write a letter, put it in an envelope with postage, and drop it in an out box on the desk. The addressee may see it several days later. Various steps in the process can affect the total delivery time. One may be affected by how frequently someone picks up mail from the out box. Another step may be how long it sits in the mail room before transfer to the post office. Then there are steps in the postal service handling and delivery. Suppose the daily pickup from the outbox occurs at 9 AM each morning at the same time that incoming mail is delivered. If the letter was completed at 10 AM on a Friday and the office is closed all weekend, the letter will not be picked up until Monday and will not move internally in the organization for nearly 3 days. Walking to the mail room and dropping the letter in the postal pickup box after completing the letter will reduce the delivery time potentially by more than 2 days. It would be easy for people to find opportunities to reduce the cycle time and increase the satisfaction of the recipient customer.

Errors, too, can have many definitions, depending on what is meaningful to a work process. In total quality management, the goal is to reduce errors. Errors produce “scrap” or end products or results that are not useable or do not meet standards acceptable to customers. Errors cause rework that elevates cost. By focusing on the management processes, identifying opportunities for improvement and incorporating quality enhancing steps into the processes, the error rates are reduced. The goal is for all participants to become involved in identifying and implementing changes and achieving results. The greater the focus on continuous improvement and the more frequently the process is reviewed, the faster the organization achieves new levels of quality.

Six sigma refers to six standard deviations out on the normal distribution and achieving one error in one million opportunities. Six sigma has emerged as the name for programs devoted to learning quality improvement techniques and implementing them.

Total quality management and six sigma also apply to safety management. Errors can refer to incidents, accidents, and damage-causing events. Incidents, accidents, and damage-causing events add to process times. A key to reducing incidents, accidents, and

damage-causing events is incorporating hazard recognition, evaluation, and control into efforts to improve quality, of which safety is a component. To be successful, it is essential to train those in a work group on the essentials of hazard recognition, evaluation, and control relevant to their processes.

Use of a total quality management approach requires a change in how work is planned, organized, and accomplished. Everyone in the work group can contribute to improving results, including safety. Effectiveness results from broad participation.

Shared Leadership

Another management strategy that reflects the change from a top-down management approach is shared leadership. In a top-down setting, the individual at the top of an organization or an organization unit is the leader. The leader plans, organizes, and directs. Because the work to be accomplished is so complex, no one person has sufficient knowledge to be able to master all of the details of a process. The idea of shared leadership invites others in a group to contribute ideas for improvement by the entire group and to take responsibility for leading the rest of the group in certain aspects of the work. As a result, the roles of people in the group vary, depending on who is leading a particular activity. In one activity, a person my have a leadership responsibility and in the next be a participant. Leadership is not limited to only one person.

31-8 BEHAVIOR-BASED SAFETY

With these changes in management methods and the success that they achieved, safety management methods derived from or related to the general methods emerged that can be summarized as behavior-based safety methods. Much has been written about this aspect of safety management. Just as with the general shift in management methods, some organizations are more successful than others in implementing behavior-based safety. As a result, the work group and organization experiences a cultural change and safer work records.

Different authors have defined behavior-based safety somewhat differently. In general, behavior-based safety techniques focus on work processes. In analyzing work processes, the workgroup identifies behaviors that are critical to safe process performance. They measure how well the group completes safe behaviors. Measurement typically requires observation. Analysis of performance provides feedback to the participants. Participants also identify and resolve other process elements that impact the ability to perform safely as part of the continuous improvement process.

To be effective, those in the workgroup need training on hazard recognition, evaluation, and control as well as learning how behaviors that are part of the process can contribute to the safety of the work. The participants may need to change their approach to how safety is handled in the process. It requires a shift from a top-down management style. It requires broad participation and collaboration among members of a work group. It requires shared leadership within a work team. Instead of placing blame for wrong behavior, it works to change the process and to ensure that those engaged in the process understand the role that their behavior plays in the success of the process. It works in concert with other safety methods, which all contribute to continuous improvement of the processes.

EXERCISES

1. Contact a local hospital or clinic. Find out what employee assistance programs they provide for employers. These may include programs to deal with personal problems off the job, alcohol and drugs, stress management, and other subjects.
2. Obtain several accident reports or liability lawsuit reviews. Analyze the findings for unsafe acts and conditions. Evaluate the cases to determine if designs could have incorporated features that would have eliminated the unsafe acts or removed the harm from such acts.
3. Work with an organizational unit to apply quality methods to its processes and identify how to incorporate safety into the processes.

REVIEW QUESTIONS

1. To what factors did early behavioral theorists link behavior?
2. Briefly explain the following motivation theories:
   (a) Maslow
   (b) Herzberg
   (c) Vroom
3. Briefly characterize the following:
   (a) judgment
   (b) emotion
   (c) attitudes, opinions, and beliefs
   (d) individual differences
4. Name three things that can help prevent unsafe behaviors.
5. Why is communication important for safe behavior?
6. Why is feedback important for safe behavior?
7. How should feedback on performance be provided?
8. Explain job safety analysis.
9. Identify three factors that affect:
   (a) perception of risk
   (b) estimates of risk
10. What are biorhythms? Are they predictors of accidents?
11. How are alcohol and drugs related to accidents and unsafe acts?
12. What role can engineers play in preventing unsafe acts?
13. What is common sense? Is it the basis for safe behavior? Explain.
14. What is technological illiteracy? How is it related to safe behavior?
15. What is job stress? How is it controlled?
16. Explain how management methods have changed and how safety methods are an integral part of those changes.
17. What is behavior-based safety and how is it tied to process improvement?

NOTES

1 Wolcott, J., McKeeken, R., Burgin, R., and Yanowitch, R., "Correlation of General Aviation Accidents with Biorhythm Theory," *Human Factors*, 19:283–284 (1977).

2 Thommen, G., *Is This Your Day?*, Crown Publishers, Inc., New York, 1964.

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