Federal Railroad Administration
Office of Railroad Safety

Collaborative Incident Analysis
and
Human Performance
Handbook

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Foreword

The mission of the Federal Railroad Administration is to enable the safe, reliable, and efficient movement of people and goods for a strong America, now and in the future. This statement should guide everything we do to serve the American public and drive continuous safety improvement.

In this handbook you will learn about "Question Zero" and the important role it plays in decisionmaking. Question Zero is: "What exactly am I trying to accomplish?" If you know the answer to this question and the answer supports our mission statement, then you are on the right track.

Our first priority is safety. However, we must also have a reliable and efficient rail system. To accomplish this, we must have innovative employees who think critically and use the tools that science and technology offer us.

This handbook covers many topics such as human behavior, organizational behavior, accident/incident investigations, and learning organizations. It weaves these topics together into a scientifically based set of investigative tools that are practical and relatively easy to use. The concepts and philosophies are not difficult, but you may need to think differently and be open to new problem-solving techniques.

Remember to ask yourself Question Zero:

"What exactly am I trying to accomplish?"

Joseph C. Szabo
Administrator

Preface

"Most people do not really want freedom, because freedom involves responsibility, and most people are frightened of responsibility." – Sigmund Freud

The modern study of human error can be traced to Sigmund Freud, whose work in psychology in the late 1800s led him to conclude that human error was the product of a person's subconscious drives. Freud considered people who made errors to be less effective and, in theory, defective. Freud's theories have had a broad influence on how our society views errors and how we respond to people who make them.

More recent research into human error and error mechanisms has dispelled many of Freud's concepts, but the impacts of his original theories have persevered. These theories have become part of the societal belief that causes our culture to seek out the defective person or persons and attempt to remove them from the system. Whenever an error or incident occurs, society's first instinct is to place blame on an individual or group of individuals.

In the 1930s, industrial safety pioneer Herbert W. Heinrich published his book *Industrial Accident Prevention, A Scientific Approach*. This book was the result of years spent studying industrial accidents. Heinrich observed that 88 percent of all workplace accidents and injuries/illnesses are caused by "man-failure," but his book actually encouraged employers to control hazards, not merely focus on worker behaviors. Heinrich wrote, "No matter how strongly the statistical records emphasize personal faults or how imperatively the need for educational activity is shown, no safety procedure is complete or satisfactory that does not provide for the . . . correction or elimination of . . . physical hazards."

Unfortunately, the influence of Freud's theories caused most industrial safety professionals and managers to focus on the conclusion that 88 percent of all workplace accidents and injuries/illnesses are caused by "man-failure." The "man" in the system was the problem. This exclusive interpretation of Heinrich's conclusions served to reinforce the Freudian theory of defective people.

More recently, work by Donald Norman, Sidney Dekker, E. Scott Geller, Charles Perrow, Robert Helmrich, and James Reason, and others, has served to disprove many of Freud's theories. Modern researchers realize that behaviors are the result of drivers which exist in workplace environments, organizations, and systems. These drivers, called antecedents, precede and trigger behaviors and can predict consequences. Environmental, organizational, and system antecedents cause humans to behave in predictable ways.

Within any system, the human is the most flexible and adaptable component, able to adjust and control the system in an ever-changing operational environment. Yet, this favorable human trait is the very characteristic that can potentially lead to human error. System flaws can place the human in the position of contributing to undesired outcomes.

Every system has rules that govern how that system should function and be operated. Without such rules the system would collapse resulting in catastrophe and chaos. Obedience to the rules of the system is very important, yet rules cannot be written to cover every possible condition that may arise in a dynamic world. This is where the human's ability to adapt and be flexible must intervene in order to save the system. Humans are actually the heroes whose interventions frequently save the system from collapse.

These interventions are usually based on a predictable sequence of events:

- sensory inputs (perceiving the environment),
- analyzing the situation,
- placing the perceived situation into context with their knowledge of the system,
- using logic and reasoning to develop courses of action,
- comparing these courses of action,
- through a decision-making process, selecting what they perceive to be the best course of action, and finally,
- performing an action.

Often, these decisions must be made very quickly and with incomplete or misperceived information. Sometimes these decisions are incorrect, resulting in an error. Occasionally, an error will combine with other factors and result in unintended consequences such as an incident or accident.

With this in mind, to adequately address human error we must identify and address the antecedents, or precursors, to the behaviors that lead to the decision-making process. We can analyze accidents to determine these antecedents, but available data is scarce because these events occur relatively infrequently.

To broaden the available data of these antecedent or precursor events we are now analyzing close calls. When analyzing these data it is important to identify the behaviors that lead to the close call, but these efforts will be ineffective if we don't also identify the antecedents that drove the behavior. Once these antecedents are identified, systemic countermeasures and/or new procedures can be developed that will prevent future occurrences of the same nature. The concepts found in this handbook can be applied to any investigatory activity that involves humans.

It should be understood that these concepts do not relieve system operators from responsibility for their actions. It does, however, often explain their actions. Furthermore, there are some humans that have psychomotor skills, attitudes, or other inherent characteristics that are inappropriate to function properly within a given system. In these rare cases the person must be removed from the system. However, this type of action should be the exception, rather than the rule.

This handbook has been developed to assist you in identifying behavioral characteristics that lead to a close call and to identify the antecedents to these behaviors. With this information you will be able to develop countermeasures and procedures that will reduce the risk to employees, railroad property, and the general public.

Introduction

The Regulator and the Influence Attempt

When attempting to influence the actions, attitudes, and behaviors of external organizations it is important for the regulator to understand, not only the organizational culture of the entity that is the target of the influence attempt, but also their own culture. Every organization has an area of operation or core process. This is the purpose or mission of the organization. Surrounding this area of interest is an area of influence. This area of influence is outside the organization and exists in some other organization's area of operations. Surrounding the area of influence is the organizations area of interest. This is an area the organization would like to influence, but does not.

Some organizations become focused on their area of operations and lose focus on the true purpose or mission of the organization. This causes the area of influence to shrink and eventually the area of influence and the area of operations become the same. At this point the organization becomes what is known as a mechanistic bureaucracy and can only achieve what is allowed by its legal authority.

When an organization or individual has to depend on their formal authority granted by a higher authority (statute, regulation, etc.) to influence external entities the influence attempt will be driven by enforcement. The highest level of influence that can be achieved using this type of influence is that of enforcement, which is below the minimum level of safety. That is to say, the regulated community will comply with the rule and regulations when the regulator is present.

As an example, an inspector routinely conducts inspection on a railroad and continually writes violation for the same issues. This is an indicator that the regulator has very little influence over the railroad and that safety is not being served. At this point the regulator has simply become a cost of doing business, like diesel fuel and toilet paper.

If an organization's area of influence is larger than its area of operation it can achieve a level higher than the enforcement level; it can achieve compliance. Many regulators are satisfied with achieving this level, but remember compliance with the regulations only achieves the minimal level of safety. At this level the regulated community generally complies with the regulations most of the time. Unfortunately, this seldom solves the safety issues facing the industry.

For example, fatigue is a major safety issue in the rail industry. The Hours of Service law and its related regulations have been in existence for over a century and the FRA has successfully enforced that law and those regulations for decades. Yet the problem still exists because the FRA does not possess the capability to influence the industry beyond its regulatory authority.

On the other hand, a health organization is always striving to expand its area of influence to match its area of interest. Healthy, growing organizations do this by leveraging relationships externally, as well as internally. By using leadership and creating a learning organization, they can raise the level of professionalism, accountability, and outcomes within the regulated community. The outcome of this influence by relationships is an increase in commitment and action.

For example, a railroad that is working in partnership in the Confidential Close Call Reporting System and taking appropriate corrective actions is reducing risk in their operation. Hence, they are increasing safety in the industry and supporting FRA's mission.

How Complex Systems Fail

The following has been adapted from How Complex Systems Fail by Richard I. Cook, MD at the Cognitive Technologies Laboratory, University of Chicago. These systemic facts are presented for your consideration while you are reading the remainder of this manual.

(1) Complex systems are intrinsically hazardous systems.

All systems (e.g. transportation, healthcare, power generation) are inherently and unavoidably hazardous by the own nature. The frequency of hazard exposure can sometimes be changed, but the processes involved in the system are themselves intrinsically and irreducibly hazardous. It is the presence of these hazards that drives the creation of defenses against hazard that characterize these systems. (See Chapter 1)

(2) Complex systems are heavily and successfully defended against failure.

Over time the high consequences of failure leads to the construction of multiple layers of defense against failure. These defenses include obvious technical components (e.g. backup systems, 'safety' features of equipment, lockout-tagout, etc.) and human components (e.g. training, knowledge), but also a variety of organizational, institutional, and regulatory defenses (e.g. policies and procedures, certification, work rules, team training). The effect of these measures is to provide a series of shields that normally divert operations away from accidents. (See Chapter 2 and 8)

(3) Catastrophe requires multiple failures – single point failures are not enough.

The array of defenses works. System operations are generally successful. Overt catastrophic failure occurs when small, apparently innocuous failures join to create opportunity for a systemic accident. Each of these small failures is necessary to cause catastrophe but only the combination is sufficient to permit failure. Put another way, there are many more failure opportunities than overt system accidents. Most initial failure trajectories are blocked by designed system safety components. Trajectories that reach the operational level are mostly blocked, usually by the operators. (See Chapters 1 and 4)

(4) Complex systems contain changing mixtures of failures latent within them.

The complexity of these systems makes it impossible for them to run without multiple flaws being present. Because these are individually insufficient to cause failure they are regarded as minor factors during operations. Eradication of all latent failures is limited primarily by economic cost but also because it is difficult before the fact to see how such failures might contribute to an accident. The failures change constantly because of changing technology, work organization, and efforts to eradicate failures. (See Chapters 1 and 4)

(5) Complex systems run in degraded mode.

A corollary to the preceding point is that complex systems run as broken systems. The system continues to function because it contains so many redundancies and because people can make it function, despite the presence of many flaws. Post-accident investigations nearly always note that the system has a history of prior close calls that nearly generated catastrophe. Arguments that these degraded conditions should have been recognized before the overt accident are usually predicated on naïve notions of system performance. System operations are dynamic, with components (organizational, human, technical) failing and being replaced continuously. (See Chapter 3 and 5)

(6) Catastrophe is always just around the corner.

Complex systems possess potential for catastrophic failure. Human operators are nearly always in close physical and temporal proximity to these potential failures – disaster can occur at any time and in nearly any place. The potential for catastrophic outcome is a hallmark of complex systems. It is impossible to eliminate the potential for such catastrophic failure; the potential for such failure is always present by the system's own nature. (See Chapter 7)

(7) Post-accident attribution accident to a 'root cause' is fundamentally wrong.

Because overt failure requires multiple faults, there is no isolated 'cause' of an accident. There are multiple contributors to accidents. Each of these is necessary insufficient in itself to create an accident. Only jointly are these causes sufficient to create an accident. Indeed, it is the linking of these causes together that creates the circumstances required for the accident. Thus, no isolation of the 'root cause' of an accident is possible. The evaluations based on such reasoning as 'root cause' do not reflect a technical understanding of the nature of failure but rather the social, cultural need to blame specific, localized forces or events for outcomes. (See Chapters 8 and 9)

(8) Hindsight biases post-accident assessments of human performance.

Knowledge of the outcome makes it seem that events leading to the outcome should have appeared more salient to operators at the time than was actually the case. This means that post accident analysis of human performance is inaccurate. The outcome knowledge poisons the ability of after-accident observers to recreate the view of the operators before the accident of those same factors. It seems that operators "should have known" that the factors would "inevitably" lead to an accident. Hindsight bias remains the primary obstacle to accident investigation, especially when expert human performance is involved. (See Chapters 3 and 11)

(9) Human operators have dual roles: as producers & as defenders against failure.

The system operators operate the system in order to produce its desired product and also work to forestall accidents. This dynamic quality of system operation, the balancing of demands for production against the possibility of incipient failure is unavoidable. Outsiders rarely acknowledge the duality of this role. In non-accident filled times, the production role is emphasized. After accidents, the defense against failure role is emphasized. At either time, the outsider's view misapprehends the operator's constant, simultaneous engagement with both roles. (See Chapter 1)

(10) All operator actions are gambles.

After accidents, the overt failure often appears to have been inevitable and the operator's actions as blunders or deliberate willful disregard of certain impending failure. But all operator actions are actually gambles, that is, acts that take place in the face of uncertain outcomes. The degree of uncertainty may change from moment to moment. That operator's actions are gambles appears clear after accidents; in general. This is not a matter of judgments, but rather of all human cognition about past events and their causes. Post-accident investigations of these gambles regard these decisions as poor ones, but conversely, successful outcomes are also a result of gambles. This fact is not widely considered or appreciated.

(11) Actions at the sharp end resolve all ambiguity.

Organizations are ambiguous, often intentionally, about the relationship between production targets, efficient use of resources, economy and costs of operations, and acceptable risks of low and high consequence accidents. All ambiguity is resolved by actions of operators at the sharp end of the system. After an accident, operator actions may be regarded as 'errors' or 'violations' but these evaluations are heavily biased by hindsight and ignore the other driving forces, especially production pressure. (See Chapter 4)

(12) Human operators are the adaptable element of complex systems.

Operators and first line management actively adapt the system to maximize production and minimize accidents. These adaptations often occur on a moment by moment basis. Some of these adaptations include:

- Restructuring the system in order to reduce exposure of vulnerable parts to failure,
- Concentrating critical resources in areas of expected high demand,
- Providing pathways for retreat or recovery from expected and unexpected faults,
- Establishing means for early detection of changed in system performance in order to allow graceful cutbacks in production or other means of increasing resiliency.

(See Chapter 1 and 2)

(13) Human expertise in complex systems is constantly changing

Complex systems require substantial human expertise in their operation and management. This expertise changes in character as technology changes, but it also changes because of the need to replace experts who leave. In every case, training and refinement of skill and expertise is one part of the function of the system itself. At any moment, therefore, a given complex system will contain operators and trainees with varying degrees of expertise. Critical issues related to expertise arise from (1) the need to use scarce expertise as a resource for the most difficult or demanding production needs and (2) the need to develop expertise for future use.

(14) Change introduces new forms of failure.

The low rate of overt accidents in reliable systems may encourage changes, especially the use of new technology, to decrease the number of low consequence, but high frequency failures. These changes maybe actually create opportunities for new, low frequency, but high consequence failures. When new technologies are used to eliminate well understood system failures or to gain high precision performance they often introduce new pathways to large scale, catastrophic failures. Not uncommonly, these new, rare catastrophes have even greater impact than those eliminated by the new technology. These new forms of failure are difficult to see before the fact; attention is paid mostly to the putative beneficial characteristics of the changes. Because these new, high consequence accidents occur at a low rate, multiple system changes may occur before an accident, making it hard to see the contribution of technology to the failure.

(15) Views of 'cause' limit the effectiveness of defenses against future events.

Post-accident remedies for "human error" are usually predicated on obstructing activities that can "cause" accidents. These end-of-the-chain measures do little to reduce the likelihood of further accidents. In fact that likelihood of an identical accident is already extraordinarily low because the pattern of latent failures changes constantly. Instead of increasing safety, post-accident remedies usually increase the coupling and complexity of the system. This increases the potential number of latent failures and also makes the detection and blocking of accident trajectories more difficult. (See Chapters 4, 8, and 9)

(16) Safety is a characteristic of systems and not of their components

Safety is an emergent property of systems; it does not reside in a person, device or department of an organization or system. Safety cannot be purchased or manufactured; it is not a feature that is separate from the other components of the system. This means that safety cannot be manipulated like a feedstock or raw material. The state of safety in any system is always dynamic; continuous systemic change insures that hazard and its management is constantly changing.

(17) People continuously create safety.

Failure free operations are the result of activities of people who work to keep the system within the boundaries of tolerable performance. These activities are, for the most part, part of normal operations and superficially straightforward. But because system operations are never trouble free, human operator's adaptations to changing conditions actually create safety from moment to moment. These adaptations often amount to just the selection of a well-rehearsed routine from a store of available responses; sometimes, however, the adaptations are novel combinations and create new approaches to production tasks. (See Chapters 1, 5, 6, and 7)

(18) Failure free operations require experience with failure.

Recognizing hazard and successfully manipulating system operations to remain inside the tolerable performance boundaries requires intimate contact with failure. More robust system performance is likely to arise in systems where operators can discern the "edge of the envelope". This is where system performance begins to deteriorate, becomes difficult to predict, or cannot be readily recovered. In intrinsically hazardous systems, operators are expected to encounter and appreciate hazards in ways that lead to overall performance that is desirable. Improved safety depends on providing operators with calibrated views of the hazards. It also depends on providing calibration about how their actions move system performance towards or away from the edge of the envelope.

Chapter 1 - Complex Systems and Human Factors

"A new catastrophe seems to occur somewhere in the world with regularity, one that is later attributed to someone doing something wrong." – Barry Strauch

Complex Systems

Over the centuries, humans have developed many systems. Systems of governance, economics, religion, etc., have all been developed by humans in order to fulfill human needs. Originally, these systems were quite simple, for example, forming a team to herd wild buffalo into a canyon so they could be killed and used as a collective food source. As human needs increased so did the complexity of the systems they designed and built. Transportation, communications, and manufacturing systems are examples of systems that continually grow in complexity.

Complex systems are characterized by many interdependent variables. The more variables, and the greater the degree of interdependence between these variables, the more complex the system becomes. Complicating the system even more is the dynamic nature of the modern world.

The great system of yesterday may be substandard today, because of the changing environment and technology within which the system exists. For example, the stagecoach system in the 19th century was a state-of-the-art means of traveling across America. The methods and subsystems used to operate and support this system were appropriate and adequate for the technology that was available and the environment in which the system operated.

The same methods were inappropriate when the railroad became the preferred means of crossing the country, and even more so with the rise of the aviation industry. Some subsystems remained similar, with way-stations becoming airport restaurants and "shotgun riders" becoming air marshals, but the nature of these subsystems became more complex.

Adding to this complexity is a feature called transparency. Unfortunately, much of the information that humans need to know in order to safely operate a system is invisible to the operator. For example, how many control rods are there in the nuclear reactor and what are their current positions? This is critical information for the operator so designers build more subsystems to monitor the control rods. These subsystems add more variables to the system and more interdependence. Systems can become very complex, very quickly.

By their very nature, the more complex the system is, the larger the possibility of a system failure. So how do we control these complex systems, monitor their performance, and make necessary adjustments to the system? We add humans to the system. The way we add the human element may be good, or it may be bad, but it is critical to the safety of the system.

For example, if we design a system we believe is perfect, and then we add the human operator, we have a system that will fail at some point, due to a subsystem or support system failure. That subsystem is the human operator. At this point, convinced that the system is perfect, organizations and leaders can easily blame the human, label them as defective, remove them from the system, and replace them with another human operator. This process is repeated many times without questioning the system itself. After all, we have already determined that the system is perfect. The failures can only be attributed to a perplexing number of defective people.

Modern railroading is an example of a very complex system. Railroad systems have many interdependent variables, many of which are transparent to the operator and the system managers.

So how do we make systems that perform their required function, and maintain the adaptability and flexibility that human beings bring to the system, when we know that human operators and managers will make errors? One method is to begin examining the systems themselves for vulnerabilities to human error, then modify or redesign the system for greater reliability. (Chapter 2)

We can do this reactively by investigating accidents, determining root causes, and making the required adjustments (Chapter 8), but this method has two significant disadvantages. The first disadvantage is that there is already a "smoking hole in the ground" with property damage and possibly loss of life. The other disadvantage is that there are so few accidents this method might never discover all the system vulnerabilities. This is not to say we should not investigate accidents, but we should understand that the information gathered using this method is limited.

Production vs. Protection

The overriding goal for most organizations is to remain financially viable (survive and avoid bankruptcy) and at the same time avoid catastrophe. Yet at the same time there are limited resources to spend on production to remain viable or on protection to avoid catastrophe. This relationship is illustrated in the graph below:

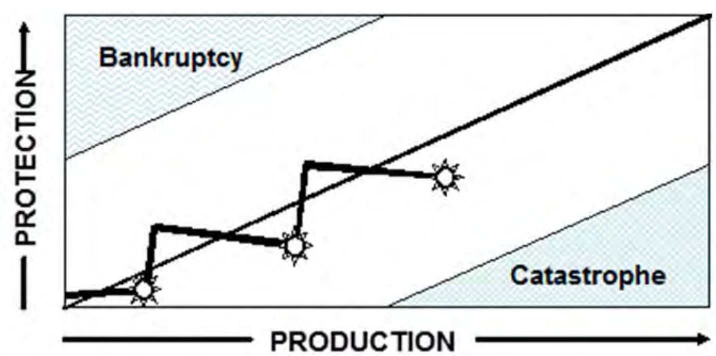


Figure 1 - Production versus Protection

As production increases the system's protection becomes strained and vulnerable to destabilization. Eventually, the operations drift to a point where they are outside the safe design envelope of the system. When an accident occurs that requires the system to be modified, increasing the level of protection brings operations back in the safe design envelope. If a level of protection is provided that cannot be supported by production the organization moves toward bankruptcy. Or if the system demands a level of production that cannot be provided adequate protection the organization moves toward catastrophic incident. This cycle is continually repeated as the organization attempts to remain in the parity zone. The model above represents the cycle of a system failure, accident, investigation, and adjustment. (We will discuss the tension between production [Quality Management Systems – QMS] and protection [Safety Management Systems – SMS] in greater depth in Chapter 12.) If we can make the system adjustments based on information from Confidential Close Call Reporting (C^3RS), or other intelligence gathering programs (Chapter 12) rather than accident investigations, we can avoid many of the accidents. In so doing we overcome the first disadvantage of relying solely on information from accident investigations and we gain this knowledge at much less cost.

As illustrated in the Heinrich Ratio (below), accidents are rare compared to the number of unsafe acts or errors that occur. Discovering these errors and analyzing them for contributing factors and root causes gives us a larger view of the system and allows adjustments to be made before the error manifests itself in the form of an accident or incident.

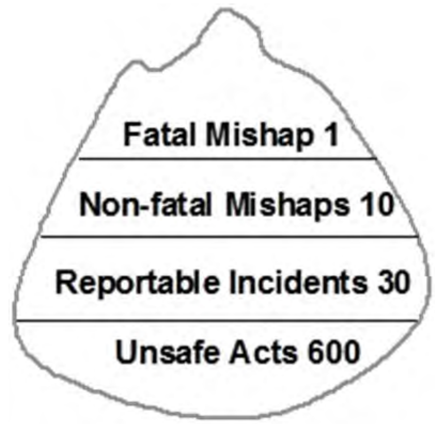


Figure 2 - Heinrich Ratio

Using C^3RS, or other data collection methods, allows us access to more information about what is going on in the real world. Furthermore, because close calls happen much more often than accidents, we can overcome the second disadvantage, which is that investigation of a relatively small number of accidents may not reveal all potential system vulnerabilities.

Operational Drift

Operational drift is where external forces are applied to a system. These pressures can cause the operations to slowly deviate from original design specification (drift) and move towards an accident or catastrophe. If no accident occurs, over time this new standard becomes the norm and the entire system is working beyond its original design. This drift to a new normal, outside the bounds of the original design, exposes the operations to new levels of risk and increased exposure to human operator errors. Leadership is responsible for detecting such drift and making cultural or process changes to protect from catastrophes. C^3RS is one means to detect Operational Drift.

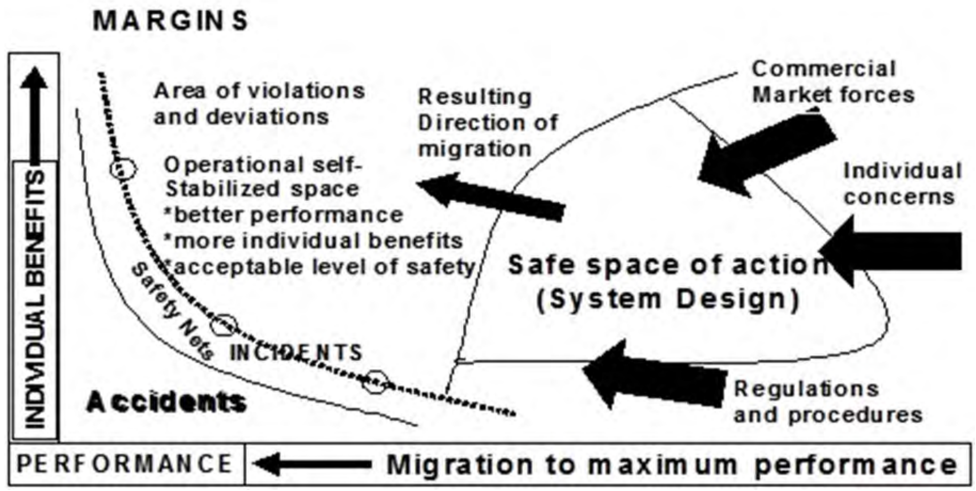


Figure 3 - Rasmussen's Drift

The Science of Human Performance

The science of human performance is the study of how human beings interact with complex systems. This can be best understood with the following model:

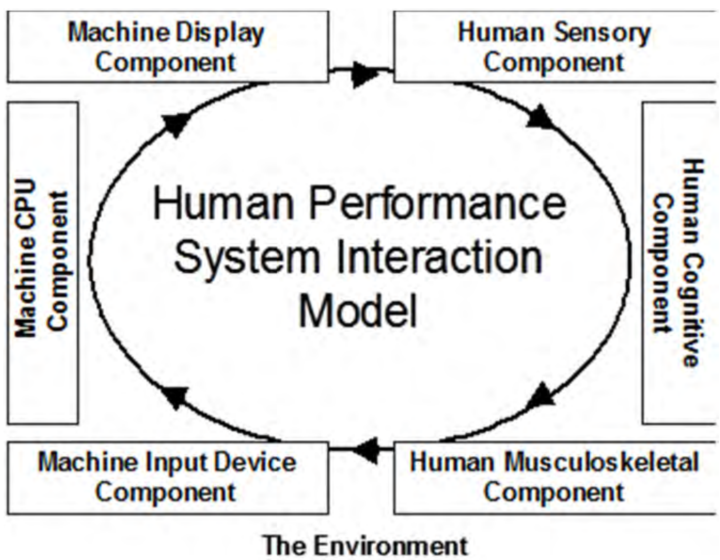


Figure 4 - Human Performance System Interaction Model

The first step in this model depicts how we, as human beings, receive information from the environment. That is to say, how people use their senses (sight, hearing, smell, taste, and touch) to receive inputs from the system they are operating and from the environment. This part of the process is referred to as *perception*.

Human Sensory Component

PERCEPTION

These inputs are processed through the brain's **sensory memory** (Chapter 3) that discards those inputs that we are not paying attention to and passes those inputs that we are attending to into **short-term (working) memory**. This part of the process is referred to as *comprehension*.

The brain then seeks to understand these inputs by drawing upon stored knowledge and experiences in **long-term memory**. Because the brain uses stored memories of past events in order to comprehend the current situation, what the brain perceives may not be exactly what is really occurring in the situation. Therefore, our comprehension of the situation is termed the *theory of the situation*. This theory of the situation is what we use as part of our decision-making process.

Human Cognitive Component

COMPREHENSION

Once we decide upon a course of action or behavior we must again interface with the system and environment using our skeletal-muscular system. These outputs are termed as *projection*, as we are projecting our desires onto the system and/or environment. We are using our *Theory of the Situation* in order to manipulate the system.

Human Musculoskeletal Component

PROJECTION

These human outputs control machine inputs to the system. Human operators use their psychomotor skills to manipulate a variety of system controls in order to maintain system operations. These controls are normally in the form of sensors, switches, levers, keyboards, mouse controls, trackballs, touch screens, etc.

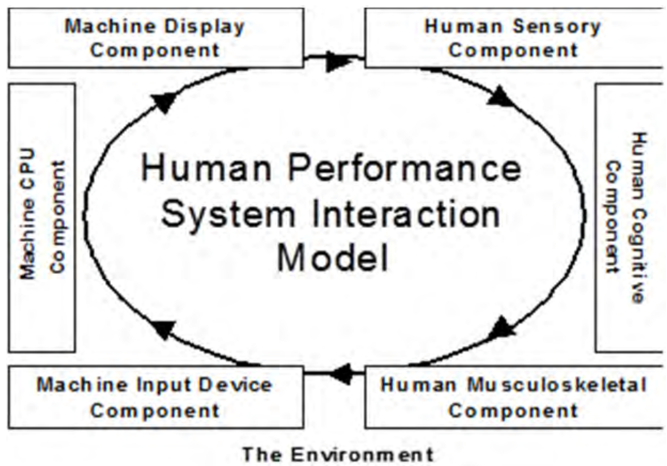
Machine Input Device Component

Once the operator has provided inputs to the system it is expected that the system will react in a predictable manner as designed.

Machine CPU Component

Various sensors monitor the system's status and provide feedback to the operator in the form of audible signals, visual displays, or other sensory mechanisms.

Again, the entire cycle looks like this:



If the system does not function as intended it is expected that the human operator will detect the malfunction or abnormality by monitoring system outputs by using their senses, understanding the situation, then making adjustments to the system inputs to correct the problem and to keep the system in a state of equilibrium - safe and efficient.

The science of ergonomics focuses primarily on human/machine interface points and works to improve system feedback mechanisms, thereby enhancing the operator's ability to perceive the system's status. It also works to improve the relationship between the operator's psychomotor capabilities and the system's control functions. The science of human performance, on the other hand, considers the entire human/machine relationship in an attempt to improve the entire human/machine system. The goal of the science of human performance is to develop highly reliable organizations through resilience engineering (Chapter 2).

Part of the problem with complex systems is their lack of transparency to system designers, system managers, and system operators. Many of the concepts that have been incorporated into this handbook are designed to bring transparency to the system so designers, managers, and operators have information available to make informed decisions. Each of these concepts is a part of an integrated safety system and an integrated safety system is part of a comprehensive Safety Management System (SMS) (Chapter 12).

Summary

Three things are evident in this discussion:

(1) Systems are complex and provide many opportunities for failure.

(2) Humans are an important part of any complex system and are the heroes that often prevent the system from failing.

(3) Humans make errors.

When attempting to understand the nature of a particular human error (or series of errors), it is imperative to look beyond the error itself. We must investigate the system or process the human was interfacing with, the controls and output/displays of the system, as well as the environment in which the human and system were operating. The Multiple Cause Incident Analysis (MCIA) (Chapter 9) tool will help you in this endeavor. The MCIA is based on the Human Factors Analysis and Classification System (HFACS) (Chapter 4).

Chapter 2 - The Highly Reliable Organization and Resilience Engineering

"In a world of finite resources, of irreducible uncertainty, and of multiple conflicting goals, safety is created through proactive resilient processes rather than through reactive barriers and defenses." – Erik Hollnagel

The previous chapter touched on highly reliable organizations, a concept that requires further examination. The design of most contemporary safety programs finds their roots in hindsight. That is, many safety managers are attempting to make adjustments to the system based on the latest safety record or last accident. Practical concerns about safety have naturally been the result of an event that has happened. The outcome is usually new demands for safety from the public and hence, from the governing body or Federal regulator, in an effort to prevent a reoccurrence of similar events. Unfortunately, this approach has had mixed results and can even lead to further undermine the safety of the system by covering, but not removing, latent conditions. This is more often true when antiquated or insufficient investigative techniques are used or hindsight bias and confirmation bias enter the equation. (More on those issues in Chapter 3.)

Not only are the remedial actions of this approach often counterproductive, they can also have a negative effect on the organization's culture. New demands for regulations are considered undesirable by management because they usually result in an increase in the cost of business, while decreasing operational efficiency. An organization's management has the fiduciary responsibility to prudently tend to the stockholders' investment, therefore management often considers these changes as intrusive and abusive. On the other hand, employees feel that they are often the target of these new demands and regulations. Furthermore, employees often think the new rules make their jobs more difficult and that control of their own work is being taken away from them. The regulator often views management as resisting change, hence placing their employees at risk, and may view employees as the cause of many of the safety violations found in the industry.

This tension between employer, employee, and regulator often serves to establish barriers between the parties and stifle communications and cooperation. The net result can be a reinforcement of a culture of conflict between the employer, the employee, and the regulator. A three-way relationship of "us versus them" cannot be a healthy and productive foundation for establishing a culture of safety.

As noted in Chapter 1, the systems that we operate in modern society are becoming ever more complex. These complex systems have more and more interdependence within the system, which leads to more unrecognized system variables, and hence the higher probability of system failures. The dichotomy of this approach seems to be that the more we attempt to design the system to prevent human error, the more complex the system becomes. The more complex the system becomes, the higher the possibility of a system error, which will need a human in the system to correct or readjust the system.

System Design

Consider the ability of the system designers and risk management owners to "see" the complex systems under their control. If it is an engineered object, then the system may be quite contained, yet if it is a railroad, the system of systems has many interfaces and few if any standard "blueprints" to understand complex normal functions. In order to begin to understand the system we must learn from the system.

So what is a highly reliable organization? A highly reliability organization (HRO) is an organization that has succeeded in avoiding catastrophes in an environment where normal accidents can be expected due to risk factors and complexity.

So, what in the world is a "normal accident" you might ask? Well, a normal accident is an "unanticipated interaction of multiple failures" in a complex system. This complexity can either be technological or organizational in origin, and often is both. A normal accident, sometimes referred to as a "system accident," can be very easy to see in hindsight, but very difficult to see in advance. Ahead of time, there are simply too many possible action pathways to seriously consider all of them; hence the latent conditions are transparent to the operator and the organization.

In designing a new system, or evaluating an existing system as part of an investigation, it is important to analyze the system for risks by identifying potential risks and designing risk management into the system. But first, what is risk? The generally accepted definition of risk is the product of probability of an undesired event multiplied by the potential consequences of the event. With this in mind the designer/investigator must consider the magnitude of the potential consequence, along with the frequency of occurrences, and then make recommendations to eliminate, trap, or mitigate the risks.

HIGH CONSEQUENCE HIGH FREQUENCY	LOW CONSEQUENCE HIGH FREQUENCY
HIGH CONSEQUENCE LOW FREQUENCY	LOW CONSEQUENCE LOW FREQUENCY

Figure 5 - Consequences and Frequency

This process of risk management is generally defined as the process of determining (and implementing) methods of minimizing and protecting against risk.

Risk management strategies can be categorized into four fundamental approaches: Inherent, Passive, Active, and Procedural.

- Inherent risk management is the elimination of hazards or the reduction in the level of hazard to a point where the potential risk is tolerable. For example, replacing steel weed cutting blades with a plastic line in a weedwacker, or the installation of a derail at an industrial siding. Derailing a car or cut of cars is tolerable, but a car or cut of cars fouling the main track is not tolerable.

- Passive risk management does not deal directly with the risk, but mitigates the risk by reducing the probability of an accident. For example, rotating blades on a lawn mower are a high level hazard; however, the risk of an accident can be reduced by enclosing the rotating blade inside a deck. The hazard (rotating blade) still exists, but the deck prevents hands and feet from encountering the hazard by its design and construction.

- Active risk management utilizes alarms, interlocks, and mitigation systems that detect changes in the system and puts the system in a safe state. This can be accomplished by either taking actions to restore the system to normal or by shutting the system down. Automatic Train Stop (ATS) systems are an example of an active risk management system.

- Procedural risk management uses standard operating procedures, operator training, safety check lists, and other management systems that involve human behaviors. Examples of procedural risk management would be safety rules and operating rules.

Normally, the order of effectiveness of these strategies is inherent, passive, active, and procedural. In most complex systems, risk management is best accomplished by using a combination of strategies to address the specific hazard.

Other Analysis/Investigation Consideration

Organizations design systems to accomplish tasks needed for the organization to provide a particular product or service and survive. These systems have an operational envelope in which operations can be safely conducted (Chapter 4, Rasmussen's Drift). However, in reality these systems function in a dynamic environment which causes variation in the system. While the system goal is stability and a safe state, these variations continually attempt to destabilize the system and move it towards an unsafe state. The purpose of the human in the system is to recognize the change in the system and take action or actions that will move the system back into a state of equilibrium and to a safe state. It should be self-evident that the earlier that the variations are detected by the human operator, the easier it is to restore the system to equilibrium. Hence the need for a well-trained, motivated, and alert operator to receive accurate and timely feedback from the system (instrumentation, alarms, and other monitoring/warning devices).

As discussed in Chapter 1, the relationship between the system and the operator is critical to safe operations. As illustrated in the Human Performance System Interaction Model a control-respond-feedback-control loop exists. The more frequently this loop is activated, the sooner the operator receives system information, and the sooner control interventions can be made. However, when designing a system, considerations must be given to the limitations of the human operator. Workload and stress (Chapter 6) are a major design consideration when developing system feedback loops.

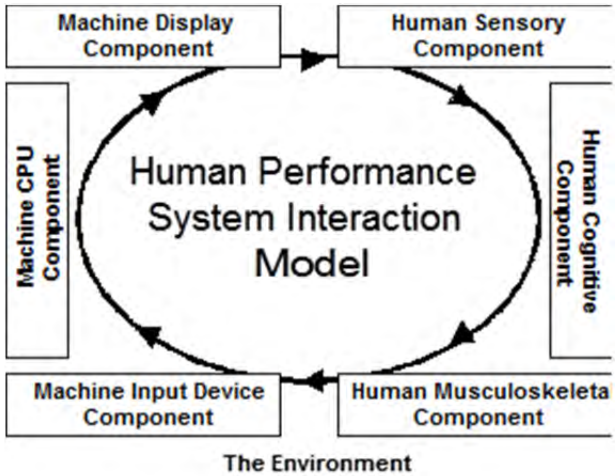


Figure 6 - Feedback-control-response-feedback loop

If the feedback loop is slow in refreshing information to the operator, the system will become more unstable before the operator is made aware of the changing situation. Slow refresh time can also lead to operator inattention, as the human mind wanders to non-task related items while waiting for new information (Chapter 5). By the same token, if the feedback system provides too much information it may cause an increase in the operator's workload. In this type of situation an operator's workload may result in missing or overlooking critical feedback information in the clutter of less urgent data.

A major short-coming in system design has been the error of designing a system that performs all the necessary functions, then attempting to plug in the human operator to control the system. A more reasonable approach would be to design the system from the onset with the human operator considered as part of the system.

Another major aspect of system design is how information is displayed to the operator. For example, if gages are used to convey system information, all gages should be calibrated such that the normal (nominal) state will result in the indicator needle being in the middle range of the gage. With this arrangement the operator does not have to read each gage, rather simply scan a row of gages to determine if there are any anomalies. This concept would also apply to controls, such as buttons or switches.

With the advent of digital technology the capability to gather information has far outreached the ability to display the information and of the human operator to receive, interpret, and analyze the data. Because of this, systems are being designed to prioritize the system data that will be provided to the operator. This allows an operator to control increasingly complex systems. The danger of this trend is that more and more system information is being withheld from the operator and the system is making decisions for itself.

In the investigation and analysis of accidents, incidents, or close calls, it is important to understand the importance of system design and how the human interfaces with the rest of the system. Is the human actively operating and controlling the system, or more passively monitoring the system for anomalies? Are the system performance feedback instruments prioritized, calibrated, and arranged properly? Are the controls positioned ergonomically and are their movements intuitive? These are but a few of the questions that should be considered.

Highly Reliable Organizations

Highly reliable organizations use a portfolio of programs to maintain continual improvement of system designs, procedure, and policies. This continuous improvement process allows the organization to recognize operational and environmental variation early and to develop countermeasures to bring the system back to stability. The goal of this continuous improvement process is to prevent errors, trap errors, and mitigate the consequences of errors at all levels of the organization. The processes that highly reliable organizations use to achieve their goals vary greatly between organizations, but they all have three basic tenets.

1. Prevent errors - Redesign systems, procedures, and operating methods in order to make it difficult, if not impossible for an error to occur. An example of this tenet would be the interlock between the locomotive throttle and the reverser control. The throttle and reverser are interlocked such that the reverser handle cannot be moved unless the throttle is in the "idle" position. This prevents an operator from increasing the engine's speed while in neutral, then engage the reverser handle and causing damage to the system.

2. Trap error - Those errors that cannot be prevented are detected and isolated or corrected. An Automatic Train Stop (ATS) system is an example of this tenet. If an operator inadvertently passes a restrictive signal and fails to take appropriate action, the system will automatically bring the train to a stop. Although the system could not prevent the error, it does trap the error.

3. Consequence mitigation - If an error cannot be prevented or trapped, procedures are in place that will mitigate the consequences of the error. Most railroads use derails on sidings to prevent rail cars from rolling out onto the main track. If a car on the siding or industry track begins to roll, it will hit the derail and derail away from the main track in order to avoid a collision with a passing train. The derail did not prevent the accident, after all the car did derail, but it mitigated the consequences of the accident.

These are just a few examples of how railroads have attempted to add resilience to their operations. Unfortunately, these attempts have often been as a result of a system failure (accident or incident), rather than a concerted effort to design a resilient system from the beginning.

Highly reliable organizations must develop and sustain a “mindful infrastructure” that is:

- Preoccupied with failure,
- Reluctant to simplify interpretations,
- Sensitive to operations,
- Committed to resilience, and
- Looks to expertise, not rank, for informed decisions.

Resilience

Few, if any systems operate in isolation without interdependency on other systems and influences for the working environment. These system interdependencies and environmental conditions are known as variables. How inputs into one system affect the performance of other interconnected systems is often unknown.

A highly reliable (resilient) organization is a learning organization (Chapter 11). Learning organizations exhibit five main characteristics: system thinking, personal mastery, mental models, a shared vision, and team learning.

Learning Organizations Characteristics

Systems thinking. The idea of the learning organization developed from a body of work called systems thinking. While you might not recognize it, much of this handbook has been an attempt to encourage system thinking. Learning organizations use this method of thinking when assessing their organizations and have information gathering systems that measure the performance of the organization as a whole and of its various components. The concept of systems thinking states that all the characteristics must be apparent at once in an organization for it to be a learning organization. If some of these characteristics are missing, then the organization will fall short of its goal. However, some authors believe that the characteristics of a learning organization are factors that are gradually acquired, rather than developed simultaneously. Recommendations in accident reports and corrective actions from close call reports should attempt to move the organization forward in one of these five characteristics.

Personal mastery. The commitment by an individual to the process of learning is known as personal mastery. There is a competitive advantage for an organization whose workforce can learn more quickly than the workforce of other organizations. Individual learning is acquired through staff training and development; however, learning cannot be forced upon an individual who is not receptive to learning. Research shows that most learning in the workplace is incidental and through on-the-job training, rather than the product of formal training. Therefore, it is important to develop a culture where personal mastery is practiced as a way of life. A learning organization has been described as the sum of individual learning, but there must be mechanisms for individual learning to be transferred into organizational learning.

Mental models. The assumptions held by individuals and organizations are called mental models (Ladder of Inference, Chapter 5). To become a learning organization, these models must be challenged. Individuals tend to espouse theories, which are what they intend to follow, but their actions, or theories-in-use, are what they actually do. Similarly, organizations tend to have "memories" which preserve certain behaviors, norms, and values. In creating a learning environment, it is important to replace confrontational attitudes with an open culture that promotes inquiry and trust. In order to achieve an open culture, the learning organization needs mechanisms for locating and assessing organizational theories of action. Close call reporting and crew resource management (Chapter 7) are two tools to achieve a more inquiring and trusting culture. Equally important for a learning organization is to identify and discard unwanted values in a process called "unlearning." As with individuals, this is very hard for organizations to accomplish and requires much patience and critical thinking (Chapter 3).

Shared vision. The development of a shared vision is important in motivating employees to learn. It creates a common focus and energy for learning. The most successful visions build on the individual visions of the employees at all levels of the organization. Thus the creation of a shared vision (similar to the shared mental model in Chapter 5) can be hindered by traditional structures where the company vision is imposed from above. Therefore, learning organizations tend to have flat, decentralized organizational structures.

Team learning. The accumulation of individual learning constitutes team learning. The benefit of team or shared learning is that employees grow more quickly, and the problem solving capacity of the organization is improved through better access to knowledge and expertise. Learning organizations have structures that facilitate team learning with features such as boundary crossing and openness. Team learning requires individuals to engage in dialogue and discussion; therefore team members must develop open communication, shared meaning, and shared understanding. Learning organizations typically have excellent knowledge management structures, allowing creation, acquisition, dissemination, and implementation of this knowledge in the organization.

So how does an organization become a resilient and learning organization? The remainder of this handbook will provide the foundation for change. Then, Chapter 11 addresses Safety Management Systems and how they can launch an organization into a new safety culture and a new way of doing business.

<u>Summary</u>

It should be the goal of every organization to become a highly reliable organization and a learning organization. In order to accomplish such a feat an organization must gather voluminous amounts of information about – ITSELF. It must learn what its values are, not printed on a poster on the board room wall, but in the street, work shop, and crew rooms everywhere on its property, in every process, policy, or procedure it employs, and in every aspect of its operation. It must look at everything it does, states, or produces critically and with a willingness to make whatever changes are necessary.

Every accident, incident, and close call is a warning signal that something is wrong in the system. Highly reliable organizations continually gather information about themselves in order to fix what is wrong (Chapter 12).

Chapter 3 - The Skill of Critical Thinking and a Scientific Approach

"Organizations learn only through individuals who learn." – Peter Senge

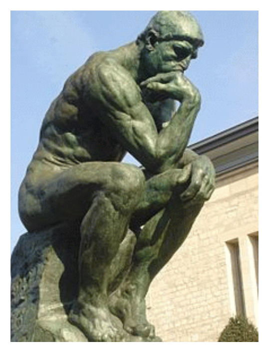
In this chapter the skill of critical thinking will be discussed within the context of incident investigation and analysis. As an investigator/analyst, critical thinking may be a very difficult thing for you to master, but it is also critical to your success.

Definition

"Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness." National Council for Excellence in Critical Thinking, 1987. That statement invites a basic question: What is thinking?

Introduction

What is thinking? Thinking generally refers to any mental or intellectual activity involving an individual's subjective consciousness. It can refer either to the act of thinking or the resulting ideas or arrangements of ideas. Thinking allows human beings to make sense of the world in different ways, and to represent or interpret it in ways that are significant to them, or which accord with their needs, attachments, objectives, plans, commitments, ends and desires. This makes thinking a very personal activity. By thinking, you sense the world and interpret the world in a unique manner. No one else in the world sees it the same way that you do.



Notice that this definition says, "...make sense of the world...interpret it in ways that are significant to them..." It does not say "...see the world as it is..." or "...recognize reality..." Thinking is a very personal process. It provides us with an interpretation of the world, but it is only our interpretation and it may or may not represent reality. The reference here is the *theory of the situation* versus the *reality of the situation*. Remember those terms?

Thinking is what drives our decision-making and much of our thinking is based on our beliefs, past experiences, and preconceived ideas (biases, see Chapter 5). It is critical that we, as investigators and analysts, recognize this fact and make a conscious effort to overcome these prejudices. So how do we accomplish this formidable task? First, remember that the word "prejudice" comes from the Latin word "praejudicium," which simply means pre + judge. So, do not prejudge! That sounds hard - and it is! But, it can be done by learning a new skill - the skill of critical thinking and bringing the use of a scientific approach to your investigation.

Scientific Approach

What is science? The word science comes from the Latin word "scientia," meaning knowledge. Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations. Modern science is the way of thinking, the disciplined way in which questions are posed and answered in order to understand events. It is the logical processes and demands for evidence that characterize science. It is an intellectual process and its ultimate goal is to understand the true nature of events. In other words, science is the search for facts and the truth.

Incident investigation is a science. Many of the tools and processes used by scientists to gather and analyze data are the same as those used by incident investigation professionals. The purpose of science and the purpose of incident investigation are to acquire knowledge.

So how, as investigators, do we gain knowledge? Psychologists recognize six methods that humans use to acquire knowledge. Keep in mind, just because we have knowledge does not mean the knowledge we have is true. The six methods of acquiring knowledge are tenacity, intuition, authority, rationalism, empiricism, and science.

- Tenacity is the willingness to accept ideas as valid knowledge because these ideas have been accepted for so long or have been repeated so often that they acquire an aura of unquestioned truth. "This is the way we've always done it!"

- Intuition operates without intellectual effort or sensory processing. It is the acceptance of an idea as valid because it feels valid. "I think" or "I believe" are words that usually lead into an intuition statement.

- Authority is acceptance of an idea as valid knowledge because some respected source claims it is valid. "It's in the book, so it must be right!"

- Rationalism is a way of thinking in which knowledge is developed through reasoning. If/then relationships, for example.

- Empiricism involves gaining knowledge through observation, or knowing by experiencing through our senses: seeing, smelling, touching, hearing, and tasting.

- Science is a process that combines the principles of rationalism and the principles of empiricism, using rationalism to develop theories and empiricism to test the theories. Science is the examination of empirical evidence using a rational approach.

Incident investigation is a science; hence it should be approached with a methodology that includes rational thinking to develop possible causal factors and empirical inquiry to validate or reject those factors. Tenacity, as defined above, has little value in an investigation. Tenacity can lead an investigator to reject, without inquiry, certain possible causal factors, or links in the causal chain.

Intuition can be of use in an investigation in developing hypotheses, but each hypothesis must be scrutinized with rational thinking and validated with empirical data. It is easy for investigators to become a victim of their own experiences, thereby developing a hypothesis prematurely, and then rejecting all facts that do not support that hypothesis. This phenomenon is known as confirmation bias (Chapter 5).

Investigators must accept information from authorities that are subject matter experts as input to their investigation. However, such input must be validated. For example, if a sleep expert provides input to an investigation that a possible causal factor is fatigue; the expert should be able to validate such an assertion using scientific methodologies.

Rational thinking allows the investigator to carefully analyze information without prejudice and to follow logical rules to arrive at acceptable conclusions. For example, consider the following:

- All crows are black (the major premise).
- This is a crow (the minor premise).
- Therefore, this crow is black (the conclusion).

However, rationalism by itself is insufficient. Take for example the following logic chain:

- All crows are black.
- This is black.
- Therefore, this is a crow.

Rationalism must be validated by empiricism to ensure that the major and minor premises are true. Empiricism will determine that the major premise (All crows are black) is true and the minor premise (This is black) is true. However, empiricism will also determine that the conclusion is false because not all black things are crows.

Science brings empirical validation to rational thinking. This scientific way of thinking is critical to accurate and thorough accident investigation.

So how does one go about thinking scientifically?

Thinking Scientifically

Rationalism is the foundation for scientific thinking. When an investigator reasons from particular factors to general conclusions, inductive reasoning is being utilized. For example, the signal was red; the train collided with an object beyond the signal; therefore, the engineer did not stop at the red signal. In this case, the investigator has taken empirical data (observable) that the signal was red and that the train collided with an object beyond the signal to inductively conclude that the engineer did not stop the train at the red signal. A couple of words of caution, regarding this example for your consideration: (1) was the signal really red? (2) perhaps the engineer stopped the train at the red signal, then started up again. Obviously, more information must be developed to validate the inductive logic.

Deductive reasoning, on the other hand, uses general ideas as the basis of making predictions regarding events and behaviors. For example, human performance can be significantly degraded after 18 hours or more of continued wakefulness. Human performance is also degraded by dips in the circadian rhythms. The engineer had been awake for more than 20 hours and the time of the event was 0500. Therefore, the engineer's performance was degraded at the time of the accident. A word of caution regarding this example: it may be true that the engineer's performance was degraded, but was it a causal factor in the accident? It may be very pertinent to the investigation, or it may be just an interesting fact that had little or nothing to do with the event.

For example, the fact that the engineer was fatigued may have little to do with the fact that the train air brake system failed to function as intended. On the other hand, a causal factor may be that the fatigued engineer failed to conduct a proper air brake test. The point is that the investigator must be a scientist-continue to ask questions and then seek valid answers to those questions. Warning: Watch out for confirmation bias, hindsight bias, and outcome bias.

The essence of modern incident investigation is the way of thinking, the disciplined way in which questions are posed and answered in order to understand events. It is the logical processes and demands for evidence that characterize incident investigation. It is an intellectual process and its ultimate goal is to understand the true nature of events.

Critical Thinking

First and foremost, critical thinking is about learning. It's about people learning! It's about organizations learning! And, most importantly, it's about you learning! When you become skilled in critical thinking the greatest things you will learn will be about yourself!

Thinking is the processing of information. The world provides us with a plethora of information. Our brain filters most of the information out - if it did not we would quickly go into overload. This is a good thing, but, as you will see in Chapter 5, this filtering also prevents us from having a "true" understanding of the world around us. Critical thinking requires a motivation to drive for the truth, even if it requires us to challenge our own belief systems (hence destroying the Ladder of Inference). Essentially, critical thinking is "a way of taking up the problems of life."

Critical thinking entails the examination of evidence, development of hypotheses, and testing of hypotheses through reasoning. It is the identification of purpose, problem, or question; making necessary assumptions; developing concepts; examining empirical evidence; using reasoning to lead to conclusions; understanding the implications and consequences; listening to objections from alternative viewpoints; and, establishing a frame of reference. Notice that nowhere in the last sentence did I mention your beliefs. Leave them out of this process.

Critical thinking incorporates a number of academic disciplines including: scientific thinking, mathematical thinking, historical thinking, anthropological thinking, economic thinking, moral thinking, and philosophical thinking. It may seem complicated, but it is really quite intuitive.

Critical thinking can be seen as having two components:

(1) a set of information gathering and processing skills, and
(2) the habit of using those skills to guide behavior.

It can be contrasted with:

(1) the mere acquisition and retention of information alone;
(2) the mere possession of a set of skills; and
(3) the mere use of those skills ("as an exercise") without acceptance of their results.

In other words, it is not enough to have information and to have the skills, or even to use the skills. To be effective at critical thinking a person needs the information, needs the skills, needs to believe the results of their analysis, and needs to be motivated to do something with the results. This is particularly crucial when dealing with self-analysis and self-improvement. It is also crucial in accident investigations. An organization's personnel may have the information they need to investigate an accident, they may possess the skills to analyze the information into meaningful intelligence, and they may believe the results of their investigation. But none of that matters if they do not have the motivation (vision), organizational capacity, and the political will to do something with what they have learned.

Critical thinking varies according to the motivation underlying it. When the motivation is based on greed or selfishness the results are typically intellectually flawed, however successful it might seem. In other words, the process may take you to a feel-good result of questionable long-term value. However, when the motivation is based on fair-mindedness and intellectual integrity the results are usually more universally accepted and have higher organizational impact. Again, it is important to recognize and reject confirmation bias.

Critical thinking of any kind is never universal in any individual or group. Everyone is subject to episodes of undisciplined or irrational thought. After all, we are all human. Its quality is therefore typically a matter of degree and dependent on the quality and depth of experience of the practitioner and the quality of questions presented. No one is a critical thinker through-and-through. We tend to overlook our own limited insights and blind spots, which can make us suffer from self-delusion. For this reason, the development of critical thinking skills and dispositions is a life-long endeavor. Then, of course, there are those people that only take a peek at themselves and refuse to see any opportunity to improve. Consider the following quotation:

"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know." – Donald Rumsfeld

It is critical that as individuals and organizations we continuously strive to reduce the number of "unknown unknowns" that exist.

Taking this to an organizational level, the collective power of an organization can take it down a path of enlightenment or darkness. Organizations consist of people and they behave as such. Organizations that utilize critical thinking are moving towards being learning organizations. Whereas, organizations that only occasionally think of themselves in a critical fashion, usually only after an emotionally significant event (catastrophe, bankruptcy, etc.), continue down a path of denial and a delusional belief that their organization and system is perfect.

The list of core critical thinking skills includes:

- observation,
- interpretation,
- analysis,
- inference,
- evaluation,
- explanation, and
- meta-cognition (that is, thinking about thinking).

An individual or group that uses strong critical thinking gives due consideration to establish:

- Evidence through observation.
- Context (defining the problem in terms of its environment).
- Relevant criteria for making the judgments.
- Applicable methods or techniques for forming the judgment, and
- Applicable theoretical constructs for understanding the problem.

In addition to possessing strong critical-thinking skills, one must engage problems and decisions using those skills. Critical thinking employs not only logic, but broad intellectual criteria such as clarity, credibility, accuracy, precision, relevance, depth, breadth, significance, and fairness. These are the same characteristics that should be considered when developing recommended corrective actions and the business case (Appendix B) supporting those recommendations.

The Result

An experienced critical thinker (investigators/analysts):

- raises vital questions and problems, formulating them clearly and precisely;
- gathers and assesses relevant information, using abstract ideas to interpret it effectively, comes to well-reasoned conclusions and solutions, tests them against relevant criteria and standards;
- thinks open-mindedly within alternative systems of thought,
- recognizes and assesses, as need be, their assumptions, implications, and practical consequences; and
- communicates effectively with others in figuring out solutions to complex problems.

In other words, they use a scientific approach, rather than a seat-of-the-pants and fill-out-the-blank form approach.

Critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. It entails effective communication and problem solving abilities. It demands a commitment to overcome our native preoccupation with one's own internal world (egocentrism) and being oriented toward or focused on one's own social group (sociocentric).

Critical thinking calls for the ability to:

- Recognize problems, to find workable means for meeting those problems.
- Understand the importance of prioritization and order of precedence in problem solving.
- Gather and marshal pertinent (relevant) information.
- Recognize unstated assumptions and values.
- Comprehend and use language with accuracy, clarity, and discernment.
- Interpret data, to appraise evidence and evaluate arguments.
- Recognize the existence (or non-existence) of logical relationships between propositions.
- Draw warranted conclusions and generalizations.
- Put to test the conclusions and generalizations at which one arrives.
- Reconstruct one's patterns of beliefs on the basis of wider experience, and
- Render accurate judgments about specific things and qualities in everyday life.

Why Critical Thinking?

Everyone thinks; it is our nature to do so. But much of our thinking, left to itself without support, is biased, distorted, partial, uninformed or down-right prejudiced. Yet the quality of our life and that of what we produce, make, or build depends precisely on the quality of our thought. Shoddy thinking is costly, both in money and in quality of life. Excellence in thought, however, must be systematically cultivated.

Becoming a critical thinker is not easy, but it can be accomplished and it is worth the effort.

How to become a critical thinker

To become a critical thinker or a good investigator/analyst you must:

- raise important questions and problems, formulating them clearly and precisely,
- gather and assess relevant information, using abstract ideas to interpret it effectively,
- come to well-reasoned conclusions and solutions, testing them against relevant criteria and standards,
- think open-mindedly within alternative systems of thought, recognizing and assessing, as need be, their assumptions, implications, and practical consequences, and
- communicate effectively with others in figuring out solutions to complex problems, without being unduly influenced by others' thinking on the topic.

<u>Summary</u>

An analyst/investigator, to be effective, must think systemically and take a scientific approach to their work. Learning to be a critical thinker and developing investigative habits that result in the development of insightful questions, posed in a thoughtful manner, and the analysis of the answers in order to understand events as close to reality as can be achieved, is the investigator's job. The effectiveness of an investigator is greatly dependent upon their ability to think critically about themselves, open their mind to possibilities outside their realm of their experience, question their biases and assumptions, and continual improvement of their communication skills. As Bertrand Russell once said, "in all affairs it's a healthy thing now and then to hang a question mark on the things you have long taken for granted."

On an organizational level, critical thinking as a corporate value is the first step toward becoming a learning organization. Learning organizations are safer, more productive, and are on the path to becoming highly reliable organizations (Chapter 11). It all starts with information gathering – people learning about themselves.

Chapter 4 - Human Factors Analysis and Classification System

"It comes as no surprise, then, that error-counting methods have different definitions, and different levels of definitions, for error, because error itself is a messy and confounded phenomenon." – Sidney W. A. Dekker

The Human Factors Analysis and Classification System (HFACS) was originally developed at the Federal Aviation Administration's Civil Aeromedical Institute by Scott Shappell and Douglas Wiegmann based on James Reason's "Swiss Cheese Model." Wiegmann and Shappell further refined HFACS in their book, A Human Error Approach to Aviation Accident Analysis (2003), in order to explore the antecedents of human error. The original model has four levels of antecedent causation: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational factors.

Unsafe Acts

Unsafe acts refer to active failures, and involve acts of omission and commission by those closest in time and physical proximity to the accident/incident. There are two primary categories of operator acts: errors and violations.

Preconditions for Unsafe Acts

These are contextual factors that foster, enable, or otherwise set up the operator or individual to err or violate a rule, policy, or procedure. Preconditions exist prior to the accident/incident. Preconditions are divided into three major categories: environmental factors, personnel factors and the condition of operators.

Unsafe Supervision

A supervisor's role is to provide operators with the opportunity to succeed. Supervisory factors consist of decisions, policies, practices, procedures, and actions by front line supervisors (i.e., shift supervisors, trainmasters, foremen, etc.) and first and second-level officers (i.e., superintendents, managers, directors) that contributed to the accident/incident by
(1) Limiting an operator's opportunity to succeed, or (2) Providing inadequate oversight and guidance.

Supervisory factors are further divided into four categories: inadequate supervision, planned inappropriate actions, failure to correct known problems, and supervisory violations.

Organizational Influences

Organizational influences include senior management and executive level decisions, practices, policies, and procedures that guide the operation and general governance of an organization and that contributed to an accident/incident. Organizational factors are further divided into four categories: resource management, organizational climate, organizational processes, and change management.

Unsafe Acts

Unsafe acts can be divided in to two primary categories: Errors and Violations. Errors are further divided into error types: Decision Errors, Skill-based Errors, and Perceptual Errors. Furthermore, violations are divided into Routine and Exceptional. Errors are physical or mental activities that deviate from intended behavior.

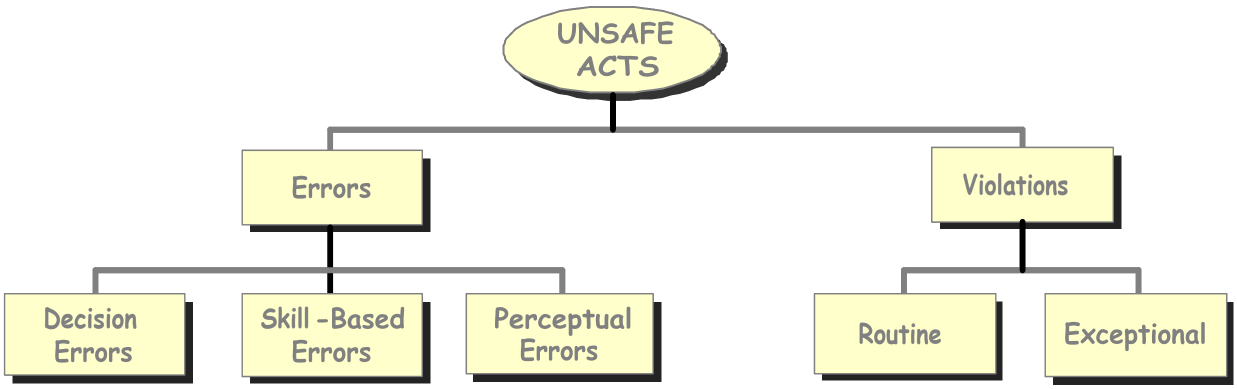


Figure 7 - Unsafe Acts

Errors

Decision errors. Decision errors are intentional behaviors that proceed as planned, yet the plan itself proves inadequate or inappropriate for the situation. Often referred to as "honest mistakes," these unsafe acts represent the actions or inactions of individuals who meant to perform correctly, but they either did not have the appropriate knowledge or made a poor choice.

Decision errors differ from skill-based errors in that decision errors involve deliberate and conscious acts while skill-based errors are a highly automated behavior. Decision errors consist of conscious decisions that are believed to be correct, but are in fact poor or erroneous. Decision errors can be divided into three types: procedural errors, poor choices, and problem-solving errors.

- **Procedural error.** Rule-based mistakes that occur during highly ordered or structured tasks, such as "if X occurs, then do Y." A procedural error may be a misapplication of a good rule or procedure, or the application of a bad rule or procedure.

- **Poor choice.** Knowledge-based mistakes. Poor choices occur when there is no explicit procedure to apply to the particular situation, and the operator must choose among several response options. These options may be explicit or implicit. This type of error is often due to insufficient knowledge or understanding of the situation, and may arise when the operator lacks sufficient training, or lacks adequate time to respond.

- **Problem-solving error.** Problem-solving errors occur when the nature of the problem is not well understood, and formal procedures or other options are not available. In situations like this, humans can develop and apply unique solutions that are wrong. In developing this solution, humans use cognitive resources that can result in loss of situational awareness and a delayed response.

Skill-based errors. Skill-based errors often occur during the execution of highly practiced actions in which there is little or no conscious thought required. Skill-based errors can be further classified into attention failures (slips), memory failures (lapses), and technique errors.

- **Attention failure.** Failures of attention typically occur when carrying out highly automated behavior. Attention failures are characterized by missed or otherwise unnoticed sensory information, and are frequently due to distractions, stress, or fatigue. Attention failures, or slips, may be manifested as delays, reversals, mis-orderings, and mis-timings in procedures and tasks.

- **Memory failure.** Memory failures, or lapses, involve a failure to remember critical information involved in a task or procedure. Memory failures are often manifested as omissions in a checklist, forgotten intentions, or losing one's place.

- **Technique error.** Technique errors involve the execution of a sequence of actions that are technically correct but that contributed to an accident/incident. Technique errors occur when an operator can carry out a task using one of several acceptable sequences. An example is train handling that, although technically adequate, leads to a break-in-two under specific environmental or operational conditions.

Perceptual errors. Perceptual errors occur when one's Theory of the Situation (perception) is different from the reality of the situation. This may be the result from degraded or unusual sensory input or poor or erroneous information displays. The error is the operator's incorrect response to the illusion or degraded sensory information. Perceptual errors include misjudging distances and misidentifying signal aspects under certain conditions (i.e., solar glare). Perceptual errors also arise from false sensations, ambiguous information, and misperception of hazards.

Violations

Violations are intentional deviations, or willful disregard, of a rule, procedure, or policy. Violations are further divided into two types: routine and exceptional.

Routine. Routine violations include habitual behaviors and actions that violate governing rules, procedures, or policies, and that are carried out with good intent. Routine violations are the result of a perceived license to bend the rules. They are often tolerated or condoned by management, and are frequently intended to save time and/or effort and negative outcomes are not intended. Examples include delays in bad ordering defective cars, or not protecting the point because it will save a few minutes of time and effort.

Exceptional. Exceptional violations include isolated actions or behaviors that are: (1) not indicative of the operator's typical actions or behaviors, and (2) not condoned by management. Exceptional violations are often extreme in nature, but like routine violations, the negative outcome was not intended (i.e., driving 100 mph in a 55 mph zone was intentional, but the crash was not). Exceptional violations are considered exceptional because they are neither typical of the individual, nor condoned by authority. An exceptional violation is a rare act that defies accepted and typical behavior.

Other Considerations

Some authors include acts of sabotage in this category. Sabotage is an intentional act and will not be used for the purposes of analysis.

Preconditions for Unsafe Acts

Preconditions for operator acts are contextual factors that fostered, enabled, or otherwise set up the operator or individual to err or violate a rule, policy, or procedure. Preconditions exist prior to the accident/incident.

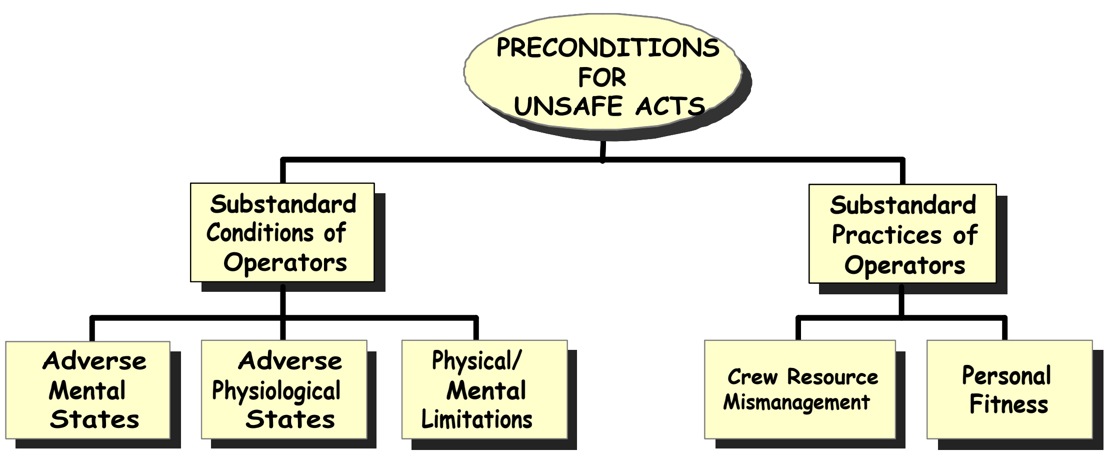


Figure 8 - Preconditions for Unsafe Acts

Preconditions for unsafe acts are subdivided between Substandard Conditions of Operators and Substandard Practices of Operators. Substandard Conditions of Operators refers to Adverse Mental States, Adverse Physiological States, and Physical/Mental Limitations. Substandard Practices of Operators refers to Crew Resource Mismanagement and Personal Fitness.

Condition of the operators

Operator conditions include an individual's mental and physiological conditions that can affect job performance, or mismatches between physical or mental abilities and job/task demands. Condition of operators is further divided into three categories: adverse mental states, adverse physiological states, and physical/mental limitations.

Adverse mental states. Adverse mental states include mental conditions, perceptions, expectations, biases, attitudes, beliefs, moods, or states that negatively affected an operator's performance. Examples include reduced situational awareness, distraction (e.g., personal problems) or preoccupation, task fixation, cognitive fatigue, poor motivation, low self-esteem, learned helplessness, boredom, job dissatisfaction, complacency, and overconfidence.

Adverse physiological states. Adverse physiological states include physiological and medical conditions that can negatively impact safe operations. These include common and serious medical illnesses or disease (e.g., diabetes), disturbed sleep patterns, intoxication, physical fatigue, hypothermia and heat stroke, and negative physiological effects of medications.

Physical/mental limitations. Physical/mental limitations occur when operational requirements exceed the capabilities of the individual. This situation can also induce stress, further reducing the human's ability to perform. This limitation may be due to sensory limitations; lack of familiarity with task requirements; inadequate training and/or limited experience, education, or knowledge of the particular task or situation; incompatible physical capabilities for the task, or any other general physical or mental incompatibility between operator capabilities and task requirements.

Practices of the operator

These personal factors include two somewhat distinct sets of issues: deficiencies in coordinating and communicating between or among individuals (crew resource mis-management), and a failure to adequately prepare mentally and physically for duty. Personal factors are further divided along these lines.

Crew resource mismanagement. Crew resource mis-management factors include conflict, poor communication, and/or poor coordination among individuals involved in the accident/incident. Examples include communication breakdowns and inadequate job briefings.

Personal fitness. Personal fitness includes behavioral factors and decisions that affect physical or mental readiness for duty. These behaviors include inadequate rest, impairment due to self-medication, poor diet, overexertion, and use of drugs and alcohol before starting work.

Other Considerations

Environmental factors. Environmental factors are further divided into the physical environment (i.e., workspace, yard, main track, office) and technological environment in which the operator works and interacts to carry out job tasks.

- **Physical environment**. Physical environment includes the tangible, visible or otherwise sensed environment in which the operator works, and includes factors in the operating environment (i.e., walking path, distance between track centers, debris and tripping hazards due to poor housekeeping, etc.) and the ambient environment (i.e., noise, vibration, temperature, lighting, etc.).

- **Technological environment.** The technological environment includes the interaction with, or operation, maintenance, and inspection of, any tools, materials, vehicles (e.g., locomotive air brakes), plant equipment (i.e., signal and track circuitry systems, switches, grade-crossing system), signage, personal protective equipment, or machines used during the accident/incident sequence. Examples include equipment or component failures, poor design of equipment (such as poor human-machine interface), or inappropriate use of equipment for the task/job.

Unsafe Supervision

Unsafe supervision has four subcategories: Inadequate Supervision, Planned Inappropriate Operations, Failed to Correct Problem, and Supervisory Violations.

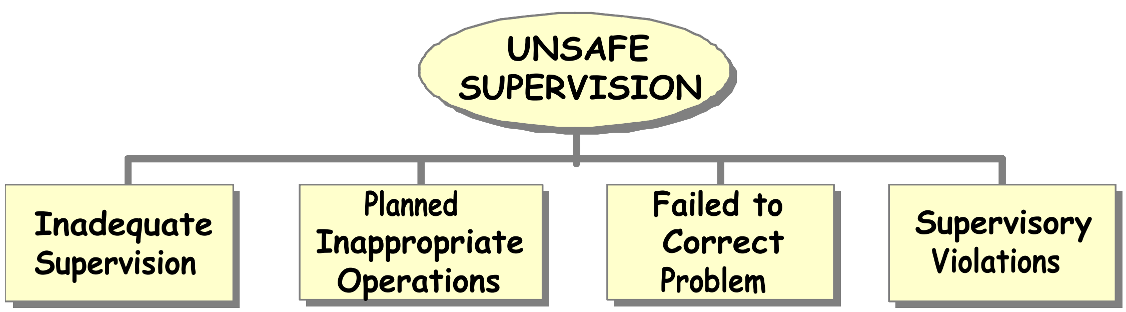


Figure 9 - Unsafe Supervision

A supervisor's role is to provide operators with the opportunity to succeed. Supervisory factors consist of decisions, policies, practices, procedures, and actions by front line supervisors (i.e., shift supervisors, trainmasters, foremen, etc.) and second-level officers (i.e. managers, superintendents, directors) that contributed to the accident/incident by (1) Limiting an operator's opportunity to succeed, or (2) Providing inadequate oversight and guidance.

Inadequate supervision. Inadequate supervision covers factors where a supervisor or manager does not provide sufficient support to operators to enable them to perform their jobs. This may be manifested as insufficient supervisory or managerial oversight, inadequate training, poor supervisory example, or otherwise not preparing an operator to perform his/her job functions safely.

Other examples of inadequate supervision include inadequate tracking of operator qualifications and/or job performance, not allowing sufficient opportunity for rest, and not providing up-to-date or current documentation and materials (i.e., bulletins, rule books, special instructions, etc.). Inadequate supervision also can include officers not knowing or understanding relevant rules and how those rules are applied, or inconsistently applying these rules.

Inadequate supervision may occur in situations where supervisors and managers are overtasked, overworked, or undertrained/qualified, to the point where the supervisor loses awareness over what is going on in the area that he/she is responsible. An example of how this can happen is when there is a transfer of administrative tasks from administrative personnel to supervisors. Administrative tasks are often easier to measure than supervisory tasks, and therefore receive priority in accomplishment.

Planned inappropriate operations. Operations that are conducted in spite of the fact that there is more than the customary risk in either the tempo or tasks associated with the operation. Planned inappropriate operations involve poor supervisory decisions that place operators at unnecessary risk. Examples include placing excessive and/or unusual workload on an operator or expecting an operator to complete a task in less than the customary amount of time.

Failure to correct problem. Failure to correct known problems refers to instances when deficiencies among individuals, equipment, training or other safety related areas are known to the supervisor, yet are allowed to continue unabated. These include failures by a supervisor or manager to correct observed or known unsafe behaviors, conditions, and hazards.

Supervisory violations. Supervisory violations include occasions when a supervisor or manager consciously violates or disregards existing rules, regulations, and policies, or allows subordinates to do the same. Examples include encouraging operators to bend or ignore rules (cutting corners), failure to enforce the rules and regulations, and permitting unqualified operators to work. This results in a degradation of the purpose and importance of the rule and can lead to routine violations.

Organizational Influences

Organizational influences have three categories: Resource Management, Organizational Climate, and Operational Process. Organizational influences include senior management and executive level decisions, practices, policies and procedures that guide the operation and general governance of an organization and that contributed to an accident/incident.

Resource management

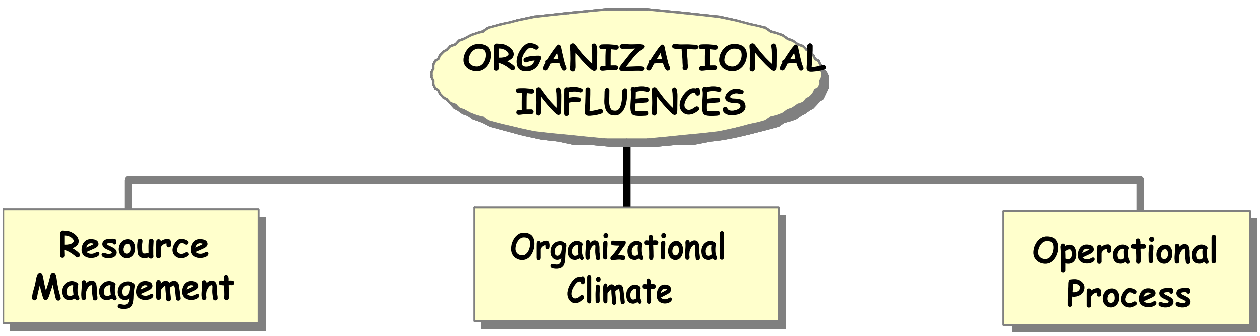


Figure 10 - Organizational Influences

Resource management factors include organizational decisions regarding the allocation and maintenance of organizational assets such as human resources, monetary assets, equipment, and facilities.

Human resources. This category includes organizational decisions, policies, etc. that govern, determine, or affect the adequacy, quality and/or amount of recruitment, selection, staffing, scheduling, training, and retention of qualified employees at all levels of the organization.

Equipment/facility resources. This category includes organizational decisions that affect the acquisition, maintenance, management, and operation of adequate equipment and facilities. Examples include:

- Unavailable, missing, or a shortage of, equipment or lack of resources needed to perform work safely and within the customary time frame.
- Acquisition of unsafe, poorly designed, or inappropriate equipment; equipment and facilities that are in poor condition; and
- Lack of formalized practices and procedures for the acquisition, maintenance, management, and/or operation of equipment and facilities.

Monetary/budget resources. This category includes the allocation of monetary assets. Examples include excessive cost-cutting and inadequate funding for safety, operational, and maintenance programs, staff, and equipment.

Organizational climate

Organizational climate includes the working environment within an organization, and may consist of formal, informal, and unwritten policies and practices. Organizational climate is further divided into three categories: organizational structure, organizational policies, and organizational culture.

Organizational structure. Organizational structure is the family tree of an organization as reflected in an organization's chain-of-command, delegation of authority [and autonomy], communication channels, and formal accountability for actions as well as access to various management levels.

Organizational policies. Organizational policies are the official guidelines that direct management's decisions about such things as hiring and firing, promotion, retention, sick leave, and a myriad of other issues important to the everyday business of the organization. Organizational policies are the institutionalized position of the organization, but not necessarily reflective of what actually occurs in the work environment. In addition to the examples above, organizational policies include health and wellness programs and fitness for duty standards/requirements.

Organizational culture. Organizational culture includes the unofficial or unspoken rules (i.e., norms, values, attitudes, beliefs, and customs) of an organization as well as the values, beliefs and attitudes employees hold toward the company.

The degree of harmony in labor relations (i.e., whether this relationship is more harmonious or adversarial) is one indicator of an organization's culture. Another indicator of organizational culture is the extent to that the organizational culture is viewed by employees as a "blame" culture or a "just" culture.

Senior and executive level managers that bend, shortcut, or otherwise violate (1) Existing organizational structures or policies, or (2) External municipal, county, state and Federal regulations, though rare, is also an indication of an organization's culture. Organizational culture provides an indication of what is truly valued by the organization.

Operational process

Operational process refers to corporate decisions and rules that govern the everyday activities within an organization, including the establishment and use of standard operating procedures and formal methods for maintaining checks and balances (oversight) between the workforce and management.

Operational process can be further organized into one of three categories: organizational operations, organizational practices and procedures, and organizational oversight.

Organizational operations. Organizational operations include work-based processes that influence the quality, quantity, pace, or style of operator performance and work. Examples include operational tempo, time pressure, competing goals (such as processes that favor presumed productivity over safety), and the inconsistent or inappropriate use of incentives or quotas.

Organizational practices and procedures. This category includes formalized activities, practices and procedures that govern or directly affect operations. Examples include a lack of, inadequate, ill-defined, poor, or inappropriate:

(1) Standard operating practices, procedures, tasks, instructions, and rules;

(2) Procedures, instructions or information dissemination about these practices, procedures, tasks, and rules; and

(3) Supporting materials, such as rule books, instructions and instruction manuals, checklists, and other job aids.

Organizational oversight. Organizational oversight includes an organization's formal approach to policy, procedure, and rule compliance. Examples include;

- Corporate safety programs.
- Risk and quality management programs.
- Hazard identification and elimination/mitigation activities, safety or defect reporting systems.
- Accident/incident investigation procedures.
- Corrective action implementation, and
- Tracking and monitoring the resources, processes, procedures, etc. that are necessary to ensure safe operations.

Other Considerations

Change management. Change management involves the formal process of managing significant changes to, or transitions within, an organization's structure, processes, and equipment/systems. Change management focuses on the impact that a change has on both the organization and its employees. This is not an original component of HFACS, but deserves consideration by the analyst if significant changes are occurring within the system or organization.

Summary

Understanding the principles underlining the HFACS will greatly assist the investigator/analyst in properly analyzing accidents and close-call reports. Without this analysis it will be difficult to develop policies, procedures, and countermeasure that will effectively address the cause(s) of human error or system failure. It is important that the investigator/analyst explore causes that are driven from above the operator level. Without that exploration, organizational and system defects will continue to be masked from detection. It is equally important for the investigator/analyst to understand the mechanics of error. These error mechanisms are both the why and how of how humans commit errors (Chapter 5).

Chapter 5 - Human Error Mechanisms

"The bombshell was that human error in medicine was conservatively estimated to account for between 44,000 and 98,000 preventable hospital deaths annually in the United States alone."
– Kim Vicente

An in-depth scientific exploration of human error mechanisms is well beyond the purpose and requirements of this handbook. Therefore, for the sake of brevity, human error mechanisms will be categorized into two broad* and often overlapping groups: internal error mechanisms and external error mechanisms. Accident investigators should be familiar with these human mechanisms in order to recognize where and how human performance issues exist in the event being investigated.

> *Note: This categorization is for simplification and the use of the investigator/analyst only and will not be found in any academic publications.

Internal error mechanisms can be considered as those errors that are a result of individuals' physiological or psychological state or limitation. In other words, those functions that occur within the human cognitive system. This would include memory function, workload, stress, and fatigue, etc.

External error mechanisms would include all the influencers and drivers that led people to make errors. This would include the system within which the person is operating and the human/system interfaces.

There are four general error mechanisms that must be considered when analyzing an incident. These are:

- Poor or mistaken decision making.
- Cognitive errors - knowledge, logic, reasoning.
- Affective thinking - attitude and mind-set, and
- Psychomotor skills - brain, hand, and eye coordination.

General Decision Making

Errors are often the result of a poor or mistaken decision-making process. Decision-making is a process that depends on cognitive thinking (knowledge, logic, and reasoning), affective thinking (attitude and mind-set), and psychomotor skills.

Cognitive decision-making is a result of several factors. How the individual perceives the environment and situation is a key factor in decision-making. Misperceiving the environment or situation can result in errors of commission or omission. Keep in mind that this misperception may be an internal error (not recognizing a hazard) or an external error (the system masked the hazard). It is not enough to say, "The employee failed to respond." The question really is "Why did the employee not respond?"

Every moment of every day our senses bombard our brains with information (sensory memory). Our brain must sort through this barrage and decide what we will pay attention to in our conscious mind. This thought process takes place in the sensory memory portion of the brain. It is constantly occurring and happens very fast.

What we decide to pay attention to is passed to the short-term or working memory of the brain. This portion of the brain is where decision-making takes place. Prior to making a decision our brain searches through our experiences (long-term memory) to see if we have faced a similar situation or environment in the past.

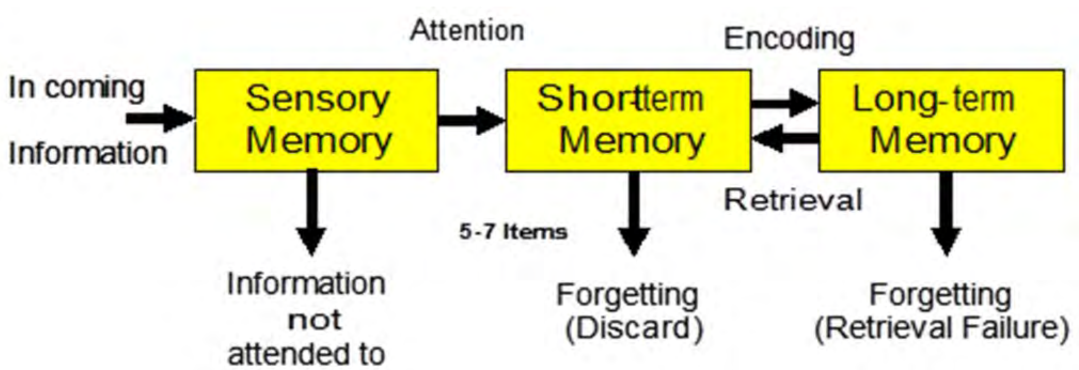


Figure 11 - Human Brain Memory Functions

While the decision-making process uses information from both short-term memory and long-term memory, before a decision is made these factors must pass through a filter of biases, preconceived ideas, and other prejudicial influencers. It should also be noted that information drawn from the long-term memory might be faulty. We may have remembered it wrong, or it may have been altered by other memories.

Tracking further back in the decision-making process to what impacts what we perceive, what we pay attention to, how we think, and our memories, we find how we perceive our responsibilities (task or job), what communications reinforcements occur, and how we relate to and work with others (communications, coordination, and cooperation). These upstream factors must also pass through the filter of our biases, preconceived ideas, and other prejudicial influencers. The diagram below illustrates this process.

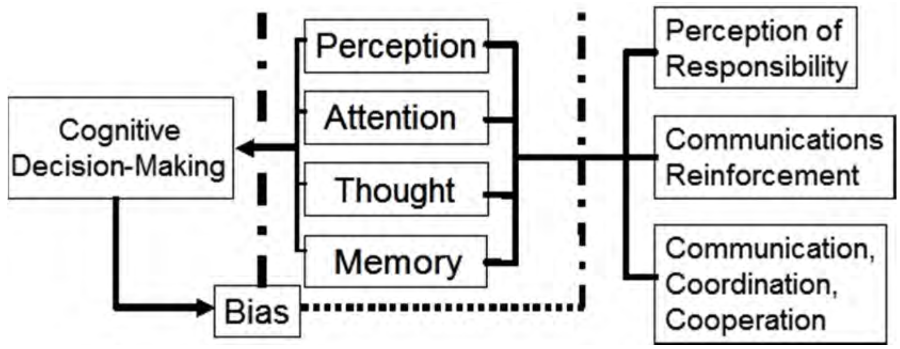


Figure 12 - Human Thought Processing

Perception of the situation is a key factor in decision-making. How we perceive the current situation and the future desired state determines what we pay attention to, how we think about the situation, and what long-term memories we access. How we perceive the situation is a combination of sensory memory and long-term memory coming together as a result of stimulation from the environment. Because perception is a combination of sensory memory and long-term memory elements, our perception may have no relevance to the current situation. Hence, we refer to this perception as the *theory of the situation* (Chapter 7). Therefore, perception is not a true reflection of the *reality of the situation*. We only try to make it that way.

It should be noted that the biases, preconceived ideas, and other prejudicial influencers mentioned above are not all bad. For example, training can influence these bias filters. If the training is appropriate and effective it will develop biases that will filter out many bad decisions. As illustrated above, the decisions we make are fed back into our biases and either reinforce or degrade that bias. For example, standardization, such as the hot water is always on the left, facilitates learning and causes good biases that reduce errors.

Attention is another key element of decision-making. We sometimes think of attention as an internal choice, but external stimuli have a significant impact on what attracts and captures our attention. Attention influencers can be categorized into four domains: Environmental, Affective, Design, and Physiological.

- The environmental domain consists of noise level, temperature, weather, etc.
- The affective domain deals with our interest level and attitude towards the task.
- The design domain lies in the area of display, controls, and alarm/warning mechanisms.
- Fitness for duty and alertness levels fall into the physiological domain.

Biases can have a significant impact on our thought and memory processes. As mentioned, we are constantly bombarded with information and we must be cautious not to use this information to begin the climb up the "Ladder of Inference." The "Ladder of Inference" takes the incoming information and filters it through our past experiences and belief system. Any information that is contrary to those experiences or beliefs is quickly discarded. We then take what is left over and affix meaning to it (interpret). From that meaning, we draw assumptions and conclusions. The conclusions then reinforce our belief system and we take action on those beliefs rather than the original information.

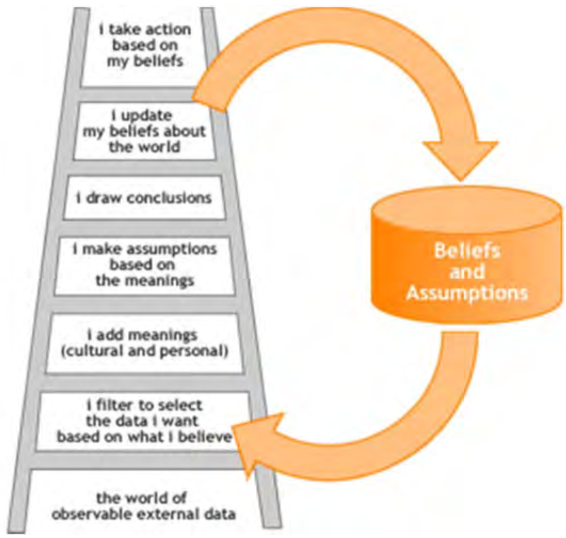


Figure 13 - Ladder of Inference

For example, you are standing before the executive team, making a presentation. They all seem engaged and alert, except for Larry, at the end of the table, who seems bored out of his mind. He turns his dark, morose eyes away from you and puts his hand to his mouth. He doesn't ask any questions until you're almost done, when he breaks in: "I think we should ask for a full report." In this culture, that typically means, "Let's move on." Everyone starts to shuffle their papers and put their notes away. Larry obviously thinks that you're incompetent -- which is a shame, because these ideas are exactly what his department needs. Now that you think of it, he's never liked your ideas. To you, Larry appears to be a power-hungry jerk. By the time you've returned to your seat, you've made a decision: You are not going to include anything in your report that Larry can use. He wouldn't read it, or, worse still, he'd just use it against you. It's too bad you have an enemy who's so prominent in the company.

You had some sensory input data – Larry's comment, which is observable data or evidence. You selected some details about Larry – he turned his eyes away and put his hand to his mouth as if he was yawning. You did not notice that a moment before he was listening intently. You then affixed meaning to these visual cues base on the culture of the group, thinking that Larry wanted to finish up the meeting. You moved quickly to the assumption that Larry was bored and drew the conclusion that Larry thought you were incompetent. The conclusion is that Larry and probably everyone that associates with him are dangerous and plotting against you. This conclusion then becomes part of your belief system. Congratulations! You've made it to the top of the ladder of inference.

This is sometimes referred to as confirmation bias (See Appendix C for other types of Cognitive Biases). Confirmation bias is where an individual searches selectively for evidence to confirm an underlying belief, discounts contradictory evidence, and stops searching once the confirming evidence is found. In the case above, you may have had a preconceived notion that Larry thought you to be incompetent. Then, in the meeting you accepted all the cues that confirmed that notion and rejected all the cues that were contrary to the preconceived notion. By the end of the meeting, your notion had become a belief that will impact all future interaction with Larry and his associates. This type of bias prevents the discovery of the influencers and drivers that caused the behaviors that resulted in the incident occurring.

Another type of bias that needs to be discussed is hindsight bias. This type of bias comes from knowing the consequence of a decision and/or behavior, hence the decision and/or behavior must have been wrong, therefore the decision-maker or operator must be to blame. In investigating and analyzing an accident, incident, or close call, you should make every attempt possible to put yourself in the place of the operator at the time of the event. The analysis should be made using only the information and knowledge that the operator had at the time of the event. The use of information and knowledge that the operator did not have at the time of the event only contaminates the investigation. The investigator or analyst must overcome these biases and attempt, to the largest degree possible, to place themself into the position of the people involved in the incident and understand what they perceived at the time of the incident and how their decision-making process led them to the behavior being analyzed.

Human error has been cited as a cause or contributing factor in disasters and accidents in industries as diverse as nuclear power, aviation space exploration, medicine, and transportation. Investigators often look at human error as incorrect behavior or a human failure. However, referencing human behavior and the dichotomy of human actions as “correct” or “incorrect,” or labeling it as “failed” or “failure,” is a harmful oversimplification of a complex phenomenon. Even FRA human factor accident cause codes are littered with the terms “failed” or “failure.” A focus on the variability of human performance and how human operators (and organizations) can manage that variability may be a more fruitful approach. This approach would focus attention on precursors that are found in organizational and technological contributing factors that can be remedied in a manner that would assist humans to avoid the same type of error.

Newer approaches such as resilience engineering (Chapter 2), highlights the positive roles that humans can play in complex systems. In resilience engineering, successes (things that go right) and failures (things that go wrong) are seen as having the same basis, namely human performance variability. It is also important to stress that “human error” mechanisms are the same as “human performance” mechanisms. Human performance is only categorized as ‘error’ in hindsight. Therefore, actions later termed “human error” are actually part of ordinary human behavior. While the term human error is firmly entrenched in the classical approaches to accident investigation and risk assessment, it has no role in newer approaches such as resilience engineering.

Stress

Stress can be defined as the quality of transactions between a person and the demands of the environment. A relationship between a person and the environment that is perceived as being relaxing and requiring little mental resources results in complacency and overconfidence. This may be great for a day at the beach, but not when interacting within a complex system. At the other end of the spectrum, if the relationship between the person and the environment is perceived to be taxing or exceeds the person's mental resources, the result is stress. High, or low, stress levels can result in irrational decision-making, loss of situational awareness, and exhaustion.

It should be noted that stress in itself is not necessarily bad. An optimal level of stress keeps us focused on the task at hand without over taxing our ability to maintain situational awareness.

Workload

Workload, like stress, can impact our decision-making process. Our brains have a certain capacity for mental processing and it likes to fill that capacity. If the workload is too light and not utilizing its full capacity for the task, the brain fills that excess capacity with other thoughts. We daydream, thinking about hobbies, other chores and tasks, or thoughts unrelated to the task at hand. We can become bored or complacent with the task, performing as if our brain was on automatic pilot.

If the workload is too high, our brain is filled to capacity, or nearly so, with the performance of the task. Again, our brains have only so much capacity. As the workload demand increases, our ability to process sensory information decreases. This results in a loss of situational awareness, fatigue, and irrational problem solving, along with other psychological and physiological problems.

Fatigue

For the purposes of this handbook, we will not discuss the aspects of physical fatigue; rather we will focus on cognitive fatigue and how fatigue impacts our situational awareness, decision-making, and mental attitude. As the brain becomes increasingly fatigued, the ability of the short-term memory to process information decreases.

As discussed in Chapter 4, there are three classes of human error: decision based, skill based, and perception based. It should be noted that each of these could also be the result of a communications error. The degradation of mental capacity due to fatigue can directly impact each of these error classes.

Some of the symptoms of fatigue are as follows:

Forgetfulness	Channelized thought process - Fixation
Poor decision-making	Apathetic
Slowed reaction time	Lethargic
Reduced vigilance	Bad mood
Reduced attention span	Nodding off
Short-term memory loss	Distraction
Poor communication	Loss of visual perception skills
Loss of situational awareness	Loss of initiative
	Poor attitude

Figure 14 - Symptoms of Fatigue

Summary

Stress, workload, and fatigue are each an example of the overlap between internal and external error mechanisms. These internal physiological and psychological influencers impact the individual's performance, but their sources are often external of the individual and originate in the environment, situation, and/or the system.

The human mind is a marvelous device, but it has limitations. Recognizing and understanding these limitations will serve the investigator/analyst well in determining systemic gaps in safety and operations.

The human ability to perform safely and efficiently within a system can be greatly affected by stress, workload, boredom, and fatigue. Each of these items will be discussed in more detail in the next chapter.

Chapter 6 - Stress, Workload, Boredom, and Fatigue

"Even if you're on the right track, you'll get run over if you just sit there." – Will Rogers

When it comes to stress, workload, boredom, and fatigue we are on the right track, but we have been sitting here too long. As discussed in the previous chapter, stress, workload, and fatigue, along with boredom are major mechanisms leading to human error. When reviewing this chapter keep in mind that these mechanisms often have their roots in the environment, the situation, supervision and/or the organization/system. For example, the lack of training or experience in performing a task may cause stress; poor job design can result in a less than optimal workload, or poor scheduling practices can lead to fatigue. These may very well be the underlying causes of many operator errors as discussed in the "Operator Error" portion of HFACS in Chapter 4.

Stress

Stress can be defined as the quality of transactions between a person and the demands of the environment. A relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being is stressful. High stress levels can result in irrational decision-making, loss of situational awareness, and exhaustion.

The absence of stress on the job can also be an unsatisfactory situation. For example, if the performance of a certain task generates little or no stress the task may become automated. That is, the individual performs the task without thinking about it and without regard for the risks involved. Such a relationship between a person and a task that is automated or is perceived as requiring limited mental resources often results in complacency, overconfidence, and loss of situational awareness. When humans interact with or within a complex system this situation can greatly increase the risk for error.

There are many sources of stress, but they can be placed into two broad categories: direct and indirect. Direct stressors are related to the particular task being performed. Lack of training or experience can be a source of direct stress while the individual attempts to cope with task requirements. An example of such a direct stressor might be attempting your first solo flight or making your first sky dive. A less dramatic, yet perhaps equally stressful, example is performing a familiar task in an unfamiliar environment, such as being a skillful mountain climber scaling an unfamiliar mountain in extreme weather conditions.

Another source of direct stress is the rate of production. As the rate of production increases beyond the physical and/or cognitive abilities of the individual, stress exceeds the person's ability to cope with the situation. Placed in this situation people will usually begin trading accuracy for speed. This often introduces errors into the production, hence increasing rework or introducing a latent unsafe condition. For example, if a track production crew is pressured to produce more completed track than they have the physical or mental capability to produce, they will begin to take short-cuts.

Short-cuts are a person's mechanism for coping with the direct stress of increased production. Such short-cuts can result in errors/defects being introduced into the track structure. These errors/defects can latently exist for years in the track structure until the right circumstances cause a derailment. Another example would be a track inspector that was expected to inspect X miles of track who is suddenly required to inspect double the number of miles of track due to personnel reductions. In making this personnel reduction, the organization has made a business decision and has accepted additional risk of error. The decision may be appropriate and justifiable, but it should be one that is carefully analyzed to insure that the organization is not unknowingly accepting more risk than is desirable or prudent.

Environmental and situational stressors are considered direct stressors if they are directly associated with the task. An example of such a stressor would be the inspection of railcars in extreme weather conditions, such as the heat in Barstow, CA in August or the cold in Minneapolis, MN in January. Another example would be working in a shop environment with a very high noise level, or performing a relatively simple task (changing a light bulb), but doing the task at the top of a 1,000 feet tall tower.

Some common sources of direct stress include:

- Effort - the total effort required to perform the task.
- Frustration - things do not go as planned.
- Performance demands - production and quality.
- Mental demands - the mental effort required to perform the task.
- Physical demands - the physical effort required to perform the task.
- Temporal demands - time constraints.

Many tasks require teamwork and communications. Stress can be induced in an individual by ill-structured information flow or a distracting rate of information flow. Standardization of procedures and forms are designed to structure information in a format that increases understandability and decreases stress. Information that is presented too fast can cause confusion, frustration, and stress. Conversely, information presented too slowly causes frustration, boredom, impatience, and lapses in attention.

Stress is not necessarily bad. As human-beings we need a certain amount of stress in order to remain focused on the task at hand and our longer term goals. Remember the mountain climber mentioned above with the unfamiliar mountain in extreme weather conditions? The additional stress may keep the mountain climber more vigilant, more engaged in the task, and more aware of the situation. Without stress in our lives, we would be totally complacent to the risks and dangers around us. Job/task design should seek to inject an optimal level of stress into the humans operating within the system without exceeding the individuals' capability to cope. Deviations from the optimum stress level should be avoided.

Indirect stressors (sometimes referred to as emotional stressors) are the issues we all have as humans during the course of our lives. They are self-referent and are truly all about the "me" in all of us. Issues such as a sick child, an argument with a spouse or friend, a broken down automobile, or a financial problem do not go away when we come to work. We may suppress the issues from our conscious mind, but they remain in our unconscious mind. Whenever the cognitive workload decreases, our thoughts return to these stressors. They continue to cause us stress even when we are not focusing on them. While we may not be focused on these issues, they interfere with our mental processing. Such cognitive interference results in a performance deficit as a result of a reallocation of attention resources, often referred to as working memory.

Referring back to Chapter 5, you will recall that the human brain has limited short-term or long-term memory capacity. This memory capacity is allocated for a variety of functions. Stress, both direct and indirect, reduces the available mental processing capability.

Workload

The modern study of workload and its relationship to stress and human performance began when N. H. Mackworth conducted research on why radar operators were missing critical signals on their displays (1948). Mackworth's study showed that an observer's ability to detect critical signals (changes in the display) declined over time. Numerous studies since then have also shown that the quality of vigilance performance is fragile and deteriorates quickly. This deterioration manifests itself in reduced accuracy and/or increased reaction time. The results of many recent studies on sustained vigilance have shown that not only does performance deteriorate, but people also find such tasks to be very demanding and stressful. Interestingly, the relationship between workload and stress is extremely close. The NASA Workload Index uses six individual sources to measure workload. Those are:

- Effort - the total effort required to perform the task.
- Frustration - things don't go as planned.
- Performance demands - production and quality.
- Mental demands - the mental effort required to perform the task.
- Physical demands - the physical effort required to perform the task.
- Temporal demands - time constraints.

From the previous page you will note that these are the same six areas that have been identified as common sources of stress. Another link between workload and stress, and the ability to maintain vigilance is the structure and rate of information flow that combine to determine how much short-term memory resources will be required to maintain focus and sensitivity to a change in the situation.

The issues of stress, workload, vigilance (situational awareness), decision-making, and performance are interrelated in such a way as to drive many human behaviors. In the analysis of close-call reports, it would serve the analysts well to ask themselves questions that explore the six areas listed above. This will greatly assist the analysts in placing themselves in the positions of the employee involved in the event. For the accident investigator, gathering data regarding these areas of workload and stress are critical to understand why the event occurred.

It is important that workload, hence stress, be optimized in order to achieve higher levels of human performance. Minor deviations in task load will have little effect on resource capacity demand and subsequent performance. Greater deviation from the optimal levels, however, requires the individual to expend additional resources. Initially, either increases or decreases in stress level beyond this normal zone results in discomfort with the situation. Further deviation can exceed the individual's range of adaptability. As this occurs, the individual's subjective perception of the workload increases and the individual begins to perceive the task as stressful. From this point on, if the workload is increased or decreased further the individual's range of adaptability has been compromised with a resulting rapid degradation in performance. This workload-to-performance relationship is illustrated below.

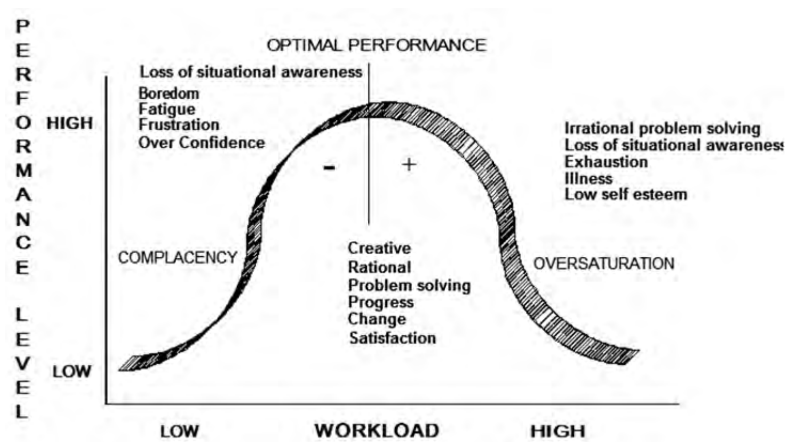


Figure 15 - Workload versus Performance

The level of workload can impact our decision-making process. As mentioned in Chapter 1, we develop our perception of the outside world through our senses. This sensory input is transferred to our short-term memory for processing. If our short-term memory is already working at or near capacity, many of these inputs will be left unattended or discarded, resulting in a loss of situational awareness. This mean the individual's internal *theory of the situation* is developed without updated information from the environment. This lack of comprehension of the environment results in the development of an erroneous *theory of the situation*. Further, this flawed *theory of the situation* is then used in the cognitive decision-making process. Once we decide upon a course of action and execute it with the best of intentions, we commit the error.

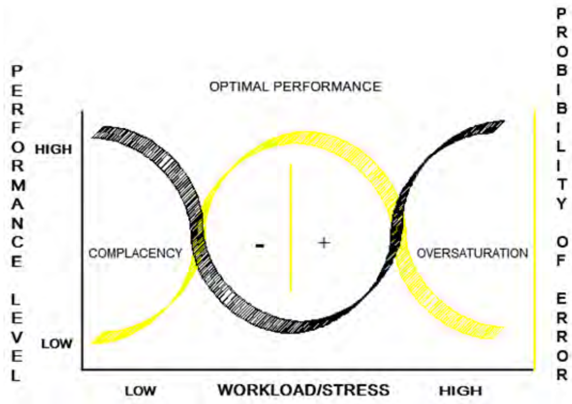


Figure 16 - Stress versus Probability of Error

As the workload/stress level deviates from the optimal level, the individual's performance level decreases. The individual's thought processes move into areas of complacency or oversaturation. As the individual's thought processes make this move, the probability of error increases.

In investigating an accident, an investigator may say, "I know how the engineer made a mistake, but why didn't the conductor catch the mistake?" Well, the conductor is required to remain vigilant in a moving environment that vibrates and rocks back-and-forth, in extreme heat or cold, at any time day or night. The conductor probably failed to catch the mistake because he was not personally engaged in the task. Certainly, conductors work within a system designed without the human in mind.

Boredom and Vigilance

Boredom is another issue that is closely related to stress and workload. Boredom can be defined as a feeling of increased constraint, repetitiveness, unpleasantness, and decreased arousal. Boredom has cognitive and affective components and perhaps psycho-physiological components as well. Boredom coupled with the need to remain vigilant often causes stress.

Vigilance is stressful because of the need to remain alert and to combat boredom over extended periods of time. Vigilance tasks typically require individuals to work in highly repetitive activities, in un-stimulating environments, and to remain attentive for intervals determined by someone else.

Have you ever gone to an airport and noticed that the TSA screeners that monitor the scanner devices are routinely rotated every 15-20 minutes. This is not done to slow down the line of passengers to be screened as many people think. Rather, it is a system that was designed with the understanding that humans can only perform that function for a finite amount of time before they begin to lose their ability to remain vigilant.

Fatigue

Fatigue is an excuse for wimping out and whining. Right? Well, perhaps not. The Department of Transportation estimates that 48 - 50 thousand transportation fatalities, millions of injuries, and $100 billion are lost every year due to fatigue related accidents. Furthermore, the situation has become so critical that the National Transportation Safety Board (NTSB) established a policy that, "Fatigue is a direct cause or contributing factor in every accident due to human error unless specifically ruled out."

Even though fatigue has been a major factor in transportation accidents for many years, our Freudian influenced society (as discussed in the introduction) is slow in recognizing the danger of having fatigued operators functioning in a complex system.

Gare Montparnasse, Paris 1895 Anding, MS 2005

Both accidents, 110 years apart with a common cause - fatigue

Fatigue is perhaps the most insidious cause of human error. The reason is that as fatigue causes our cognitive abilities to degrade we are increasingly unable to determine our own performance capability. This is a real problem because we become the worst judge of our own cognitive condition. But how bad is it in the railroad industry?

A recent study, Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, of 1,400 freight rail accidents that occurred in 2003, 2004, and the first half of 2005 revealed the seriousness of this problem. This study covered about 2,800 railroad employees involved in rail accidents. It looked at the cause or causes of the accident and the 30-day work history of the employees involved. The study determined that fatigue was a factor in approximately 25 percent of the events that had a human factors cause. As significant as this is, the study also produced a number of other findings that illustrates the seriousness of the problem, and perhaps provides us with clues to finding solutions.

In order to understand cognitive fatigue we must first understand the causes of fatigue and how sleep, or rather the lack of sleep, impacts cognitive performance. Sleep is a biological need driven by chemical changes in the brain. Studies have shown that the average person needs approximately eight hours of sleep. Prior to the invention of the light bulb, the average American slept more than 10 hours per day. Today the average American sleeps 6.7 hours per day. In our 24-hour society, fatigue has become a serious safety and health issue.

There are two major components of fatigue: (1) the time of day and (2) the individual's sleep history and continuous hours of wakefulness. The time of day refers to the natural circadian rhythm, while the sleep history and continuous hours of wakefulness refers to an acute or cumulative sleep debt. These two components determine the individual's level of alertness and cognitive performance.

The circadian rhythm is a natural change in a person's level of alertness and cognitive performance over the course of the day. Human beings are daytime creatures with a natural drive to sleep at night. This drive to sleep is caused by a change in the chemistry of the brain over time. Normally, the circadian rhythm alertness is low during the night and is reset at dawn by light. The circadian rhythm alertness rises during the morning hours, has a small dip in the afternoon, and then continues to rise in the late afternoon. This alertness level gradually declines during the evening hours and finally results in the brain signaling that it is time to sleep. The following chart represents a typical circadian rhythm pattern for an average day worker:

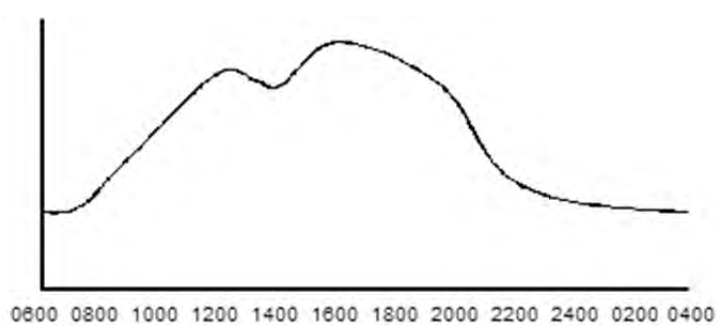


Figure 17 - Circadian Rhythm

The quality of sleep is as equally important as duration. Sleep is not a static condition; rather it is dynamic and has a well-defined architecture. This architecture includes four distinct levels of non-REM (rapid eye movement) sleep and period of REM sleep. The pattern of non-REM and REM sleep are repeated throughout the sleep episode.

One of the facts revealed in the Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules study is related to the area of acute fatigue. Acute fatigue is the result of continuous hours of wakefulness. Simply put, the longer we are awake the more fatigued we become. Performance can drop off quickly after 16 - 18 hours of continuous wakefulness. The study looked at how long the individuals involved in the accident had been awake and the frequency of accidents. The result is illustrated in the following chart.

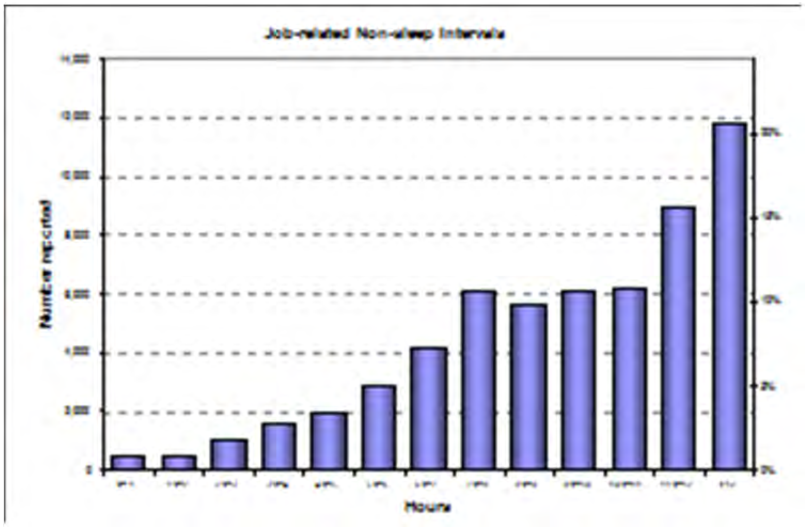


Figure 18 - Accident Rate by Total Number of Hours Worked

As you can see, the longer an individual is on duty, the higher the percentage of accidents. This has widespread implications for all crafts, whether it is a carman working a double shift, an engineering employee working a derailment, or a train crew. It should also be remembered that when these individuals finish their work they must still drive home in a fatigued state. Another fact that this study confirmed is that the time of day influences the probability of an error. The following chart illustrates the frequency of accidents by time of day.

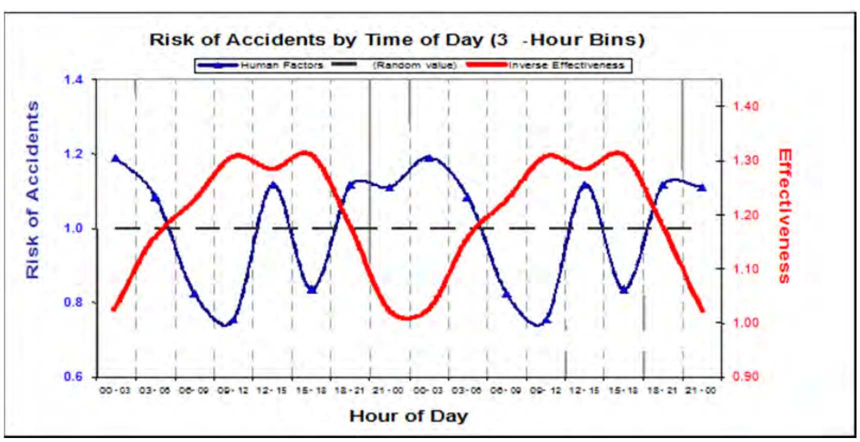


Figure 19 - Risk of Accident by Time of Day

The line with data points indicates the number of accidents occurring at that time of day. The line without data points indicated the human effectiveness level at that time of day as driven by the circadian rhythm. As you can see in the chart above, there is a strong inverse correlation between the number of accidents and the effectiveness level of the individuals involved.

Another important finding that this study revealed was that there is an increase in the probability of a person being involved in an accident as their effectiveness level decreases. These findings confirm an earlier study by the Collision Analysis Working Group. This group consisted of representatives of the FRA, rail labor, and rail management. This group studied 65 main track collisions and determined that time on-duty and time of day could be correlated to the accident rate. Notice in the chart below that the accident rate per time of day follows the circadian rhythm. Note: The circadian rhythm line has been inverted for clarity.

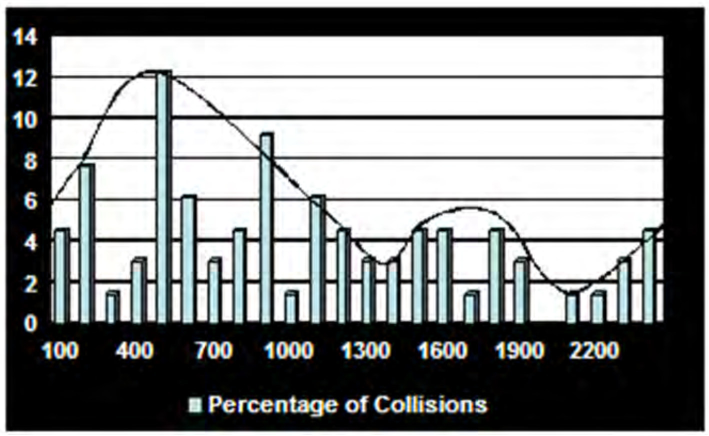


Figure 20 - Percentage of Collisions by Time of Day

Cumulative sleep loss is another important area to consider in determining performance levels. Cumulative sleep loss is where an individual loses a portion of the required sleep each night for several nights. For example, if a person needs eight hours sleep per day and they are only receiving six hours per day, after the course of a normal work week, they will have lost the equivalent of an entire night's sleep. This cumulative sleep loss can significantly affect performance.

The seriousness of cumulative sleep loss was illustrated by a recent study by the University of Denver of the operating crews on a division of a major Class 1 railroad. This study took place over a 30-day period using tests, survey instruments, questionnaires, interviews, and actigraph watches that measure when a person was awake or asleep. This study developed the following facts:

- 21.3 percent of the employees were clinically sleep deprived.
- 29.2 percent of the employees were borderline sleep deprived.
- 49.5 percent of the employees were considered "Normal."

During this study a test was conducted to measure the quality of sleep these employees were receiving. This test, the Pittsburgh Sleep Quality Index, indicated the following:

- Average score (Overall) = 8.1
- Average score (Extraboard) = 8.88
- Average score (Pool) = 7.80
- Average score (Engineers) = 8.72
- Average score (Conductors) = 7.58

Note: Scores of 5 or above indicated poor sleep quality.

The lead scientist on the study stated, "Thus, the majority of the...Engineers and Conductors would likely be considered highly fatigued in comparison to normal and even clinical populations."

So, at any given moment on this division over half of the employees on-duty were either clinically sleep deprived or borderline sleep deprived, with virtually all of them getting poor quality sleep. It should be noted that the actigraph watch detected signs of a higher than normal possibility of sleep disorders among the study group. However, because the actigraph watch was not specifically designed to detect sleep disorders, the finding was considered speculative.

Fatigue does not affect just engineers and conductors. Fatigue and circadian rhythms apply to all of us. A recent study by the Fatality Analysis of Maintenance-of-way Employees and Signalmen (FAMES) illustrates the significance that circadian rhythms can have on human performance and accident/incidents. Note how the number or fatalities spike during the afternoon circadian dip.

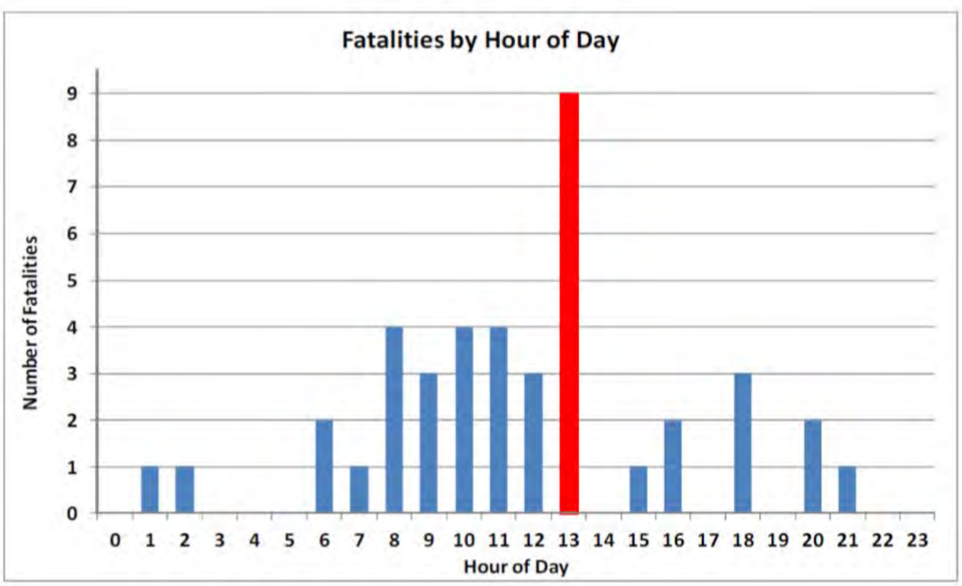


Figure 21 - Fatal Accident Pattern by Hour of Day

As mentioned in Chapter 3, the following are some of the symptoms of fatigue:

Forgetfulness	Channelized thought process - Fixation
Poor decision-making	Apathetic
Slowed reaction time	Lethargic
Reduced vigilance	Bad mood
Reduced attention span	Nodding off
Short-term memory loss	Distraction
Poor communication	Loss of visual perception skills
Loss of situational awareness	Loss of initiative
	Poor attitude

Each of these symptoms, or any combination of them, can have a significant adverse impact on operational safety and efficiency. Each one of these could be a contributing factor or root cause of the accident/incident that you are investigating.

Other Considerations

Depression

A World Health Organization study (2004) determined that there is a link between depression and fatigue. Researchers found that while fatigue and the psychological disorder of depression are not the same, and the two have different risk factors, there is considerable overlap and inter-relationship.

The study indicates that people who are depressed are more than four times as likely to develop unexplained fatigue, and those who suffer from fatigue are nearly three times as likely to become depressed. Depression and fatigue feed off each other in a vicious cycle that makes it hard to determine where one begins and the other ends.

Although researchers have long suspected that depression and unexplained fatigue are related, the nature of the relationship between the two common conditions is unclear. But studies suggest that depression and fatigue may act as independent risk factors for each other. "One can possibly understand how a fatigued person can start feeling psychologically distressed because of his or her condition, but the opposite is more difficult to explain," writes researcher Pertos Skapinakis, MD, of the University of Ioannina in Greece, and colleagues.

While depression may be difficult to detect in the workplace, there are signs and symptoms that managers and coworkers can detect. Such things as excessive absenteeism, prolonged illnesses, and attitudinal and behavioral problems may be signs of depression. Also, excessive and unexplained fatigue may be an indicator of depression.

As discussed in Chapter 5, short-term memory is critical to human performance. Anything that interferes with the memory process can significantly impact the individual's ability to successfully and safely complete tasks. Psychological disorders, such as depression and post-traumatic stress disorder, as well as significant stress, can interfere with memory.

Depression can make it difficult to concentrate, focus on details, and absorb new information. Some people who experience severe psychological trauma develop post-traumatic stress disorder and experience recurrent, intrusive, vivid memories of the traumatic event. These flashback memories are often terrifying and induce repeated acute stress responses. An acute stress response triggers the brain to release certain chemicals - otherwise known as the fight or flight response. If this occurs repeatedly, the chemicals can actually damage parts of the brain that are important for memory.

Being under constant lower levels of stress also can cause this type of harm. So it is important to obtain treatment and find ways to push back against stress. For example, through developing effective psychological coping mechanisms, engaging in vigorous physical activity, meditation, and learning relaxation techniques.

Sleep Disorders

There are more than 70 recognized sleep disorders. Of these, the most common are bruxism (teeth grinding), delayed sleep phase syndrome, narcolepsy, night terror, parasomnia, periodic limb movement disorder, REM behavior disorder, restless leg syndrome, circadian rhythm disorder, sleep paralysis, sleep walking, insomnia, and obstructed sleep apnea. Of these, obstructed sleep apnea (OSA) has the largest prevalence. But remember, there over 70 others out there working to reduce the safety and efficiencies of the operation.

According to Dr. William C. Dement, 40 percent of the population has some sort of sleep apnea with half of that subpopulation considered as needing medical treatment. Studies of over-the-road truck drivers have shown that as many as 70 percent had some form of apnea. Not only does sleep apnea add risk to operations on the job, it is linked to other health problems and diseases, such as heart disease, stroke, diabetes, high blood pressure, and more.

Sleep disorders are very dangerous, relatively easy to diagnose, and for the most part easily treatable. Yet most people never take the first step - diagnosis. There are three basic reasons for this phenomenon:

- They know they are always tired, but they think that it is normal - ignorance of the problem.
- They do not want other people to know that there is something wrong with them - stigma of seeming defective.

- They do not want their employer to find out - fear of losing their job.

Summary

It is important to understand how stress, workload, boredom, and fatigue impact human performance. It should also be noted that the effects of stress, workload, and fatigue are interrelated and cumulative.

In the early years of accident investigation, many times the cause was determined to be "operator error." While this may have answered "what" happened, it did not answer the question "why" it happened. As time moved on and we became more sophisticated in our investigation methods, the term "loss of situational awareness" was coined. While this was a positive step forward, it still did not answer the question "why."

In order to answer the "why" question, we must look at the overall system/organization to find the drivers that contributed to the error. These drivers are often difficult to find and require patience and diligence to identify, but that is where the "gold" is located. Identifying and correcting these drivers can have a significant impact on the reduction of risk and the development of a culture of safety within the organization.

Each of these issues should be considered by the analysts in analyzing close-call reports and in the development of potential countermeasures and/or corrective actions.

Chapter 7 - CRM and Highly Reliable Organizations

"It is not far-fetched to suggest that, had someone argued in those early days in favor of the importance of cultural factors, the fate reserved for such a person would have been no different from that suffered by Don Quixote, declared certifiably crazy by his contemporaries."
– Robert L. Helmreich

Organizational culture can be a driving force in safety. Crew Resource Management (CRM) is a cultural game-changer. This chapter has been added as a possible countermeasure for many of the systemic causes for human errors that occur within organizations. Many of the concepts of crew resource management can be used at all levels of an organization to improve performance.

Many individual and collective errors are the result of a person's or crew's theory of the situation not matching the *reality of the situation*. Many incidents can be traced back to the crews' inability to manage all available resources resulting in errors; for example, failed communications, poor task delegation, inability to adapt to changing situations, etc.

The old adage, "two heads are better than one," is what CRM is all about. It is a process than enhances the ability of a crew or team to develop a shared mental model of the task at hand, the potential risks involved, and the environmental situation. In other words, this process improves the performance of the crew by forming a shared mental model through the sharing of information, thereby, moving the *theory of the situation* closer to the *reality of the situation*.

Crew Resource Management

CRM employs a number of techniques to improve the management of time, knowledge, and attention. Many systems reach the level of complexity that it requires more than one person to operate it properly. Whenever this occurs it is imperative that there is an adequate level of communications and coordination between each individual in order to operate the system safely and efficiently. The final report from the Collision Analysis Working Group identified poor inter-crew communications as a possible contributing factor in 15 percent of the collisions they analyzed. If you included those events where one crewmember made an error and the other crewmember failed to detect and correct the error, the percentage would be much higher. There is also always the possibility that people other than the crew may commit a communications or coordination error that affects the crew.

This problem is not unique to the railroad industry. Many other industries suffer from communications/coordination issues. This problem was first recognized in the commercial aviation industry and was the focus of a 1979 workshop on aviation safety hosted by NASA. The NASA research presented at this meeting found that the primary cause of the majority of aviation accidents was human error, and that the main problems were failures of interpersonal communication, leadership, and decision making in the cockpit.

The output of this workshop was the development of the concept of CRM. A variety of CRM models have been successfully adapted to different types of industries and organizations, all based on the same basic concepts and principles. Examples of some of the industries that have adopted the principles and concepts of CRM are hospitals and surgical teams, nuclear power plant operators, the military, marine operations, aircraft maintenance personnel, offshore oil drilling operations, and firefighting.

CRM Concepts, Principles, and Skills

What is CRM? First, let us identify what it is not. It is not a crew calling program, a quick fix training program, or a short-term accident reduction program. It is a safety-based human factors training program, a process that addresses the entire crew and other related staff, heightens awareness of attitudes and behaviors and their impact on safety, and a process to improve crew communications and coordination. CRM can be defined as a management system that makes optimum use of all available resources—equipment, procedures and people—to promote safety and enhance the efficiency of operations. In other words, it is a tool that can be used to move an organization towards achieving a culture of safety and efficiencies.

CRM is concerned not so much with the technical knowledge and skills required in operations, but rather with the cognitive and interpersonal skills needed to manage the operations within an organized, complex system. In this context, cognitive skills are defined as the mental processes used for gaining and maintaining situational awareness, for solving problems and for making decisions. Interpersonal skills are regarded as communications and a range of behavioral activities associated with teamwork. In railroading, as in other walks of life, these skill areas often overlap with each other, and they also overlap with the required technical skills.

CRM fosters a climate or culture where the freedom to respectfully question authority and the free exchange of information is encouraged. However, the primary goal of CRM is not enhanced communication, but rather enhanced situational awareness. It recognizes that a discrepancy between what is happening and what should be happening is often the first indicator that an error is occurring. This is a delicate subject for many organizations, especially ones with traditional hierarchies, so appropriate communication techniques must be taught to supervisors and their subordinates, so that supervisors understand that the questioning of authority need not be threatening, and subordinates understand the correct way to question orders.

The intent of this dialogue is not to question or threaten authority rather it is a process where individuals within a complex system that have a disagreement in their *Theories of the Reality* can achieve a <u>shared</u> *Theory of the Situation*. This shared *Theory of the Situation*, while sharing elements of both original theories, will be closer to the actual *Reality of the Situation* than either of the originals. CRM training encompasses a wide range of knowledge, skills and attitudes including the following:

- Decision-making - A structured, mental decision-making process based on logic and reason.

- Assertiveness - Communicating your theory of the situation without being aggressive.
- Mission/Task Analysis - Gain a shared understanding of the mission or task.
- Communications - Sharing information to gain a shared *Theory of the Situation*.
- Leadership - Understanding the leadership role of all crewmembers.
- Adaptability/Flexibility - Detect changing situations and adapt to those changes.
- Situational Awareness - Acquiring and maintaining situational awareness; detect when situational awareness is being compromised and reacquire it.
- Teamwork - Work together with all the attendant sub-disciplines that each of these areas entails.

These skills are then applied in a process designed to result in a shared theory of the situation. This process includes inquiry, advocacy, conflict resolution, decision-making, critique and feedback.

Figure 22 - Crew Resource Management Loop

Each of the skills and the associated CRM process must be institutionalized into the organization through extensive training, education, coaching, mentoring, and behavior modeling. This is not a one-time training event, but rather an on-going culture changing endeavor. Once these skills have been institutionalized the full benefits of CRM can be achieved in the form of a safer and more efficient organization. This is an investment in safety and efficiency that has demonstrated success in a wide variety of industries. Many organizations have failed to achieve the many benefits of an effective CRM program because they thought CRM could be taught in a two-hour block of time during normal recurring training. The concepts of CRM are as meaningful in the boardroom as they are on the organizations' front lines. CRM, when properly trained and implemented, can change the culture of an entire organization.

The Texas Transportation Institute at Texas A&M University has recently completed three reports regarding CRM in the railroad industry. They are as follows:

Evaluation of Existing CRM Training and Railroad Team Classification
http://tti.tamu.edu/projects/project_details.htm?id=2910

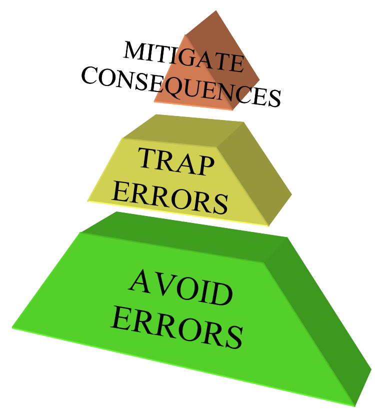
Pilot course and training materials
http://tti.tamu.edu/projects/project_details.htm?id=2911

Business Case for CRM
http://tti.tamu.edu/projects/project_details.htm?id=2912

The Highly Reliable Organization

CRM is an important component in an organization's attempt to achieve high reliability (Chapter 2), as is confidential close call reporting (C^3RS). Other programs that are characteristic of highly reliable organizations are:

- Stress, depression, and wellness programs.
- Workload management programs.
- Clear Signal for Action (CSA).
- Alertness management programs.
- Threat and Error Management Model (TEMM).



Each of these programs addresses a specific human performance issue, but it should be readily apparent that there is significant overlap and synergy between them. For example, information gathered by the CSA programs feed into the CRM training program and the TEMM. Likewise, this information can lead to modifications and improvements in the stress, depression, and wellness program.

Highly reliable organizations use this portfolio of programs to maintain continual improvement of system designs, procedure, and policies. The goal of this continuous improvement process is to prevent errors, trap errors, and mitigate the consequences of errors at all levels of the organization. Remember from Chapter 2, Highly Reliable Organizations must develop and sustain a "mindful infrastructure" that is:

- Preoccupied with failure.
- Reluctant to simplify interpretations.
- Sensitive to operations.
- Committed to resilience, and
- Looks to expertise, not rank, for informed decisions.

Prevent errors - Redesign systems, procedures, and operating methods in order to make it difficult, if not impossible for an error to occur.

Trap error - Those errors that cannot be prevented are detected and isolated or corrected.

Consequence mitigation - If an error cannot be prevented or trapped, procedures are in place that will mitigate the consequences of the error.

These processes not only increase the level of operational safety, but also improve operational efficiency. This portfolio of programs can lead to a significant change in organizational culture and move the organization toward operational excellence.

Summary

CRM is a proven process for improving operational efficiency, reducing human error, and is effective in countering fatigue. While it requires extensive training and the associated costs, studies show that CRM is cost effective with organizations that invest in the process because of the reduced property damage costs due to fewer accidents and increased efficiency due to a higher level of teamwork and coordination between employees and between departments.

CRM, C^3RS, and other human performance programs can significantly improve safety and efficiency while moving an organization toward a position of high reliability. However, in order to reap the many benefits offered by an effective CRM program the organization must be committed to changing its culture and investing in its employees.

There is more about highly reliable organizations in Chapter 2.

Chapter 8 - Incident* Investigative Techniques

"When you have eliminated the impossible, whatever remains, however improbable, must be the truth." – Sir Arthur Conan Doyle

*Note: The terms accident and incident will be used interchangeably throughout this chapter, as the investigative methodology is the same in either case.

Introduction

The concept of complex human-machine systems was introduced in Chapter 1. In Chapter 2, we discussed how complex systems needed to be made resilient to environmental changes and to variables within the system. In order to achieve resilience in a system, the organization must be able to detect or identify potential risks before they cause the system to destabilize. In order for an organization to succeed in risk identification, it must have information on how the system is functioning. Not how it was designed to function (that is easy), but how it is actually functioning in the real world. How is it responding to environmental and operational variables? What parts of the system are operating at the boundaries of the safety envelopes or even in an undesired (unsafe) state?

There are several methods that organizations can use to determine the state of a system and the results are best achieved when all these methods are integrated into a single intelligence gathering mechanism. The primary methods for monitoring the true state of a system include a confidential close-call reporting program, a peer-to-peer coaching program that reports anonymously to a central data base, and a robust incident investigation program.

Thinking about the performance of complex human-machine systems involves a conceptualization of how the system is put together, how it works, and how the various parts or components interact. Such conceptualizations are often referred to as models. In this case it is a model of the system to be investigated. A Human Performance System Interaction Model was presented in Chapter 1. This model illustrated the relationship between the system as designed and the integration of the operator into that system. This model depicts the structural separation between human and machine. In other words, that the system is comprised of humans, the machine, and the interaction between them. As technology advances these lines of separation are becoming more blurred, but for our purposes this model will be adequate.

An important aspect of system modeling is that it allows us to consider how the system can (and probably will) fail or malfunction. As discussed in Chapter 2, there are three popular risk assessment methods: event trees, fault trees, and functional resonance. Similarly, we will discuss three* general approaches to incident investigation: the sequential or domino model, the epidemiological or Swiss cheese model, and the systemic model.

*A fourth popular model, the forms based model, will not be discussed. This model is typically used in investigating high frequency, low consequence accidents, such as traffic accidents.

Sequential Accident Models

In the 1930s, Herbert W. Heinrich, an industrial safety pioneer, published his book *Industrial Accident Prevention, A Scientific Approach*. In his book, Heinrich described accidents as the result of a sequence of clearly distinguishable events that occur in a specific order. This is the classic domino model. This model depicts incidents as a set of dominos that tumble because of a unique initiating event. One domino (event) strikes the next, until the last domino representing the incident falls.

The model is deterministic because the outcome is seen as a necessary consequence of one specific event. Sequential investigation models have proven to be very useful in providing a simplistic, but somewhat scientific approach to investigations and data gathering. However, the wide-spread use of this method has served to reinforce the belief that there is a singular cause for incidents.

Furthermore, this method causes one to think that if you follow the chain of fallen dominos back until you find the first domino, future incidents could be avoided if that domino was reinforced or removed. Sequential models are popular in industry because they are easy to understand and can be easily represented graphically, but because of their simplicity, they rarely depict a complete picture of reality.

This being said, if the resources available only allow this level of investigation, it will provide some information that will lead to bringing at least one area of risk to the surface. However, it should be understood that this type of investigation has a low probability of disclosing systemic risks.

Epidemiological Accident Models

The early 1980s saw the introduction of the epidemiological model, which describes an incident as the outcome of a combination of factors. This is the basis for James Reason's model that is often referred to as the Swiss cheese model. This model views incidents as the result of interrelationships between "unsafe acts" of the operator and the latent conditions that exist in the structure of the system as described in Chapter 4. Reason describes barriers or lines of defense between hazards, people and property. Hence, accidents can be defined as a series of failures in barriers. While the sequential model identifies a single failed barrier, the epidemiological model allows for the identification of multiple failed barriers. The epidemiological model is superior to the sequential model because it allows the structure and components within the system to be possible sources of risk and causes of incidents.

In addition, the epidemiological model has the ability to identify operational functions that are approaching or operating in the boundary area between operational stability and instability. A major advantage to the epidemiological model is that it can be used relatively easily with a minimum amount of training to the practitioner. As Erik Hollnagel states, "Epidemiological models are structurally and functionally under-specified, but are valuable because they provide a basis for discussing the complexity of accidents that overcome the limitations of sequential models."

Another advantage of the epidemiological model over the sequential model is the ability to identify performance deviations (human, mechanical, or procedural), environmental conditions, barriers that were breached, and latent conditions. It is difficult, if not impossible, to identify these contributors using the sequential model.

It should be noted that the *Multiple Cause Incident Analysis* (MCIA) process is a type of epidemiological model. While it may be sufficient for most of our investigative needs, there may be events that warrant and require a more sophisticated approach to an investigation.

Systemic Accident Models

A systemic model which endeavors to describe the characteristic performance on the level of the system as a whole is an approach that looks beyond the structure and components of a system. A systemic approach depends on modeling and analyzing socio-technical systems and using information gained from a variety of intelligence gathering systems as an evaluation process. The result of this process is the ability of an organization to develop plans to recognize and respond to operational drift (positive or negative) and to develop method changes in areas of risk.

A systemic model integrates all aspects of risk, including organizational, environmental, and social aspects. The evolution of incident investigation to the systemic model represents an increased capacity in accident investigation and analysis, hazard analysis and accident prevention, risk assessment and management, and for the development of risk metrics and performance measures that allow for improved system monitoring. An important part of a systemic model is the ability of people responsible for risk management to use the model to visualize and build a shared mental model of complex system behavior.

An example of a systemic model is the Systems-Theoretic Accident Modeling and Processes (STAMP). Within a systemic model, such as STAMP, there are three fundament tenets of constraints, hierarchical levels of control, and process models. Rather than viewing an incident as an event like in the sequential and epidemiological models, the STAMP model views an incident as a violation of a system safety constraint.

First, safety related constraints specify what state system variables must be in to assume a safe relationship with other system variables. For example, if a signal is to display a proceed indication, the track that the signal governs movement over should not be occupied by another train. Or, the power must be off before the access panel to a high voltage power source is opened.

Next, the hierarchical levels of control define the constraints on the system. Changes and adaptations to safe system behaviors are limited by a process of controls that enforce system constraints. A hierarchical control structure that is designed to include the entire socio-technical system and that enforces the necessary constraints on development and operational changes are needed to prevent accidents.

Finally, the process model is a graphical representation of the mechanism for developing the hierarchy of controls needed to constrain the system.

A systemic model has, as a major advantage, the ability to analyze incidents based on knowledge of system functions, characteristics, and component interrelationships, rather than on assumptions and beliefs. In fact, properly utilized a systemic model should be able to find weaknesses in the system before an incident occurs. The process of increasing organizational resilience should be, like any other improvement process, continual.

Another significant advantage of the systemic model is that it looks beyond the sequence of events and failed barriers relating to an incident. Rather, it includes such more obscure potential factors as social norms and morals, government influence and regulators, corporate culture, management functions, and local workplace factors.

The disadvantage of the systemic model is that it can consume significant resources in terms of time and money. Therefore, most organizations utilize the systemic model only when it is perceived the information gained will be worth the resources expended.

From Error Management to Performance Variability

In Chapter 6, we discussed how organizations can increase their resiliency by controlling variability in their processes and operations.

The way we think about systems determines how we respond to the events that manifest themselves as accidents, both in direct interaction and in developing more considerate responses. (This is the case not only for technological systems, but also for social systems such as other people, organizations, etc.) Each type of accident model previously discussed has consequences for how unwanted performance outcomes are dealt with, and specifically for the measures that are taken to improve system safety during design and operation.

If a system is described by a sequential type of model, then accident analysis becomes a search for well-defined causes and equally well-defined cause-effect links. The underlying assumption is that once such causes and links have been found, they can either be eliminated or rendered ineffective by encapsulation. While the outcome of such an investigation may be less than satisfying, this level of investigation may be appropriate for organizations with limited resources and should not be discarded out of hand.

If a system is described using an epidemiological type of model, then accident analysis becomes a search for known carriers and latent conditions. The underlying assumption is that defenses and barriers can be strengthened to prevent future accidents from taking place, even though the detailed pathways may be uncertain. Since it is impractical to look for a large number of specific carriers and latent conditions, an alternative approach is to characterize reliable indications of general system health. While not encompassing the universe of destabilizing variables, the epidemiological model does provide a scientific approach that can produce multiple causes and is relatively easy and inexpensive to implement.

Finally, if a systemic type of model is used, then accident analysis becomes a search for the combinations of performance variability and unexpected dependencies that lead to system control failures and subsystem interoperability problems. This reflects the assumption that the variability in a system can be detected and controlled. A systemic approach will result in the most robust incident analysis and will provide the highest level on information, knowledge, and control regarding system stability and operational drift.

Each type of incident investigation model represents a characteristic approach to how responses to incidents should be determined. The three approaches can be called error management, performance deviation management, and performance variability management, respectively. Error management is based on the assumption that the development of an accident is deterministic or linear, as in the case of the sequential type of accident models. Consistent with that assumption, it should be possible to identify a clear root cause and therefore to prevent future accidents by eliminating or encapsulating the identified cause.

Management principle	Accident model	Nature of causes	Response type
"Error" management	Accident development is deterministic (cause-effect links)	Causes can be clearly identified (root cause assumption)	Eliminating or containing causes will exclude accidents
Performance deviation management	Accidents have both manifest and latent causes	Blunt end / sharp end deviations have clear signatures	Deviations leading to accidents must be suppressed
Performance variability management	Variability can be helpful as well as disruptive	Sources of variability can be identified and monitored	Some variability should be amplified, some reduced

Figure 23 - Three Approaches to Accident Management

The second approach, called performance deviation management, recognizes that accidents may have both manifest and latent causes, and corresponds to the epidemiological type of accident models. It is acknowledged that it may be difficult or impossible to find specific root causes, and instead the search is for traces or signatures of characteristic types of deviations. The prevention of accidents is achieved by finding ways of eliminating or suppressing the potentially harmful deviations.

While the performance deviation approach is a significant advantage over the error management approach, it still entails the view that errors or deviations are negative and therefore undesirable. As Amalberti (1996) has argued, errors or deviations have a positive side since they enable users and systems - to learn about the nature of accidents. Indeed, deviations from the norm can have a distinct positive effect and be a source not only of learning but also of innovation. This requires that the system have sufficient resilience to withstand the consequences of the uncommon action and that it is possible for the users to see what has happened and how.

Performance variability management captures this dual nature of performance deviations. This approach fully acknowledges that unwanted outcomes usually are the result of coincidences, which are the inevitable consequences of the natural variability of a system's performance. The variability can be found at every level of system description and for every kind of system from mechanical components to organizations, as well as for every level of subsystem. It is assumed that it is possible to identify the source of variability, and therefore also not only to define their characteristic "signatures" but also to monitor them in some way. The monitoring can be used either to suppress the variability that may lead to unwanted outcomes, or to enhance or amplify the variability that may lead to positive outcomes.

Performance variability management accepts the fact that accidents cannot be explained in simplistic cause-effect terms, but instead they represent the outcome of complex interactions and coincidences which are due to the normal performance variability of the system, rather than actual failure of components or functions. (One may, of course, consider actual failures as an extreme form of performance variability, i.e., the tail end of a distribution.) To prevent accidents there is a need to be able to describe the characteristic performance variability of a system, how such coincidences may build up, and how they can be detected. This reflects the practical lesson that simply finding one or more "root" causes in order to eliminate or encapsulate it is inadequate to prevent future accidents. Even in relatively simple systems new cases continue to appear, despite the best efforts to the contrary.

Summary

Of the three investigative technique models discussed in this chapter, sequential, epidemiological, and systemic, the epidemiological model provides the greatest balance between information learned and investigative costs. The epidemiological model is a scientific approach to seeking root-causes and contributing factors that can be addressed within most organizations' capacity and capability.

While the epidemiological model does not provide as much fidelity as the systemic model, it requires much less time and fewer resources to achieve a high level of detail regarding an incident. A systemic accident investigation model is normally reserved for those high consequence, high profile accidents where discovering every detail of the accident is more important than the cost of the investigation. For example, NASA uses the systemic model to investigate the loss of a payload that is worth, perhaps hundreds of millions of dollars, because the cost of a repeat of the incident would be much greater than the cost of the investigation.

An organization should tailor its incident accident methodologies to its data requirements and its resources. For example, the sequential model may be used to investigate certain derailments that are routine in nature (e.g., thermal induced rail misalignments). This less in-depth investigation model is appropriate for investigating an accident where the cause is known and the number of contributing factors and root causes are limited.

For more complex accident/incidents, an organization should use the epidemiological model. An example of where the investment in using the epidemiological model would be cost effective would be a collision where there may be many contributing factors, several root causes, and a high probability of human error involvement. In such cases, the data developed during the investigation would probably outweigh the cost of the investigation.

Whereas the sequential and epidemiological models may be routinely used by an organization, there will inevitably be those accidents that rise to a level of severity or public awareness that would justify the use of the systemic model. Accidents that may result in a regulatory rulemaking or Emergency Order should always be investigated using the systemic model to ensure that the regulation or order is, in fact, addressing the appropriate root cause of the event.

The various investigative models should be viewed as a tool box where the appropriate tool is always available to yield the appropriate data needed to take corrective actions.

Chapter 9 - Multiple Cause Incident Analysis

"To identify and resolve concerns, most industries will have to respond in a significantly different way than they have in the past." – Christopher Hart

Introduction

There are many problem-solving processes that can be of assistance in the analysis of an incident or accident. The point is not which one you use, rather that you use one of them. The FRA has selected a process called Multiple Cause Incident Analysis, or MCIA.

As discussed in Chapter 8, the MCIA process is an epidemiological investigative/problem solving process. As such, it may not be suitable as a tool for all organizations. Some organizations with greater resources and a need for a higher quality of data analysis may want to select a more robust, systemic analytical tool, such as the Systems-Theoretic Accident Modeling and Processes (STAMP), or some similar process.

Organizations with fewer resources or less vigorous data requirements may want to adopt a sequential investigative model. In any case, all organizations should adapt some type of scientific-based, evaluation/problem-solving investigation methodology.

Multiple Cause Incident Analysis

This chapter will focus on the MCIA process. In general, MCIA should fit most organizational needs for a scientific-based process that requires a moderate amount of resources. The MCIA method consists of a ten step process. Each step should be completed before moving to the next step. While the process can be modified, there are certain process steps that are critical. Taking shortcuts in these process steps does not save time. Shortcuts may actually waste time, as the results will have less meaning and value.

Step 1 - Record the incident

It is important to document the known facts and evidence in a logical and easy to understand manner. If the accident/incident is being investigated formally by the FRA, the Inspector-in-Charge (IIC) should determine how this will be accomplished to make the investigation as transparent as possible to themselves.

If this analysis is part of a Collaborative Incident Analysis Team (CIAT) (such as a C^3RS Peer Review Team) you will have much less information to handle, but it should be kept in a legible and organized manner. In either case, record the facts and evidence of the incident as accurately as possible.

At this point you may think you know everything there is to know about the incident and be tempted to draw assumptions and conclusions. Once you have drawn these conclusions your mind will accept everything that supports those conclusions and reject evidence to the contrary. Do not fall into the confirmation bias trap! Many investigations have been inaccurately reported and recorded due to confirmation bias.

If this is a field investigation, establish a "war room." This may be in a conference room at a Federal building or hotel, or simply the IIC's hotel room. Wherever it might be, the goal is to display the evidence so that the entire team can see it and mentally process it. It only takes one person to connect the dots, but that is hard to do if everybody does not have all the information.

Step 2 - Identify additional expertise required

Here is where a field investigation and the work of a CIAT momentarily diverge. If you are working on a CIAT, now is the time you use the expertise of your team to add details to help determine Contributing Factors later on in the analysis process. If you are conducting a field investigation you must stick to the facts and evidence as they are known. Do not speculate.

Once all of the preliminary facts and evidence have been gathered, the next step is to systematically develop a list of team knowledge gaps and identify further information or evidence that is required to complete the story. This information may come from expertise on the CIAT team, from specific subject matter experts (SMEs), and through other informational gathering techniques.

Step 3 - Identify stakeholders

Identify stakeholders—people who do or should care about ensuring safe performance—related to the incident as reported. This may seem like an unnecessary step and in some cases it can be abbreviated. However, keep in mind that this list will identify who has a stake in the outcome of your analysis. If someone has a stake in the outcome, that person very well may have information that will aid in your analysis.

For example, at the Cajon 1 accident, the train profile indicated that the train had 69 hopper cars weighing 60 tons each. However, the shipper that had loaded the cars had meticulously loaded 100 tons into each car. Without determining that the shipper was a stakeholder, the probable cause of the accident may not have been determined.

Step 4 - Describe actual vs. desired performance

Compare what happened to what should have happened. This step will provide you with a comparison between the actual vs. desired performance. This is not just a human performance exercise. Rather, it includes both the human performance of the individuals involved and system performance. That is, the processes, rules, regulations, procedures, hardware, and software that makes up the complex system (Chapter 1). Understanding the desired state or desired performance is critical in identifying and realizing the performance gaps and where they exist.

Once you have developed this list of performance deviations you may be tempted to determine that the cause of the accident/incident was that an individual did something wrong. Do not fall into the hindsight bias trap.

Step 5 - Develop contributing factors

Using the list of performance deviations you can now start developing a list of factors that may have contributed to the performance gap. In a team environment it is important that all team members see and understand these performance gaps. Whether they are listed on a blackboard, a whiteboard, a flip chart, or projected on a screen from a computer, everyone needs to see everything. (APPENDIX F)

Step 6 - The Five Whys

Once each performance deviation has been analyzed to develop contributing factors, the next step is to analyze the contributing factors for multiple potential root causes. The word "multiple" in the previous sentence is important. There is seldom, if ever, a single cause to an accident/incident. In this step, each contributing factor is analyzed by a process called "The Five Whys." Sometimes the root causes will manifest themselves after the question "why?" has been asked three times, whereas sometimes it will take six or seven times. The key is not how many times you ask "why," rather it is the depth of thought and investigation put into answering the question accurately.

Step 7 - Develop Corrective Actions

Once you have determined the root causes of an accident/incident the important work can begin: the development of systemic corrective actions. During this portion of the process, ask yourself, "will these solutions address only this event, or will they be used across the system to prevent similar undesired conditions?" "Will they help the organization learn?" Refer to Chapters 3 and 11 for further guidance that may help in developing more effective and systemic corrective action. It is imperative to check recommended corrective actions to ensure they do not produce unintended consequences.

Step 8 - Fact Gap Check

Review the corrective actions, root causes, and performance deviations to ensure that the corrective actions solve the issues brought forth in the process. Make sure there are no fact gaps or other informational holes in your analysis. Remember, there are many traps in the development of corrective actions, so much care, thought, and counsel must be taken!

After all, we are dealing with a complex system. A small change in one part of the system may have dire, unintended consequences in a different part of the system. When developing corrective actions, always attempt to take the highest overview of the system that your team is capable of attaining. Ask the question “What if?” as you talk through the process. Do not be afraid to be the “Devil’s advocate.”

Finally, remember this is a learning process. If your corrective action is rejected for some reason, learn why it was rejected and learn from the experience. Your knowledge of the system will grow and you will be better prepared for the next analysis.

Step 9 - Prioritize Corrective Actions

No organization has the resources to fix everything right away, even if they would like to. Every organization attempts to stay in the “Parity Zone,” courting catastrophe on one side and bankruptcy on the other (Chapter 1). Therefore, it is important to prioritize the corrective actions for implementation. There are a variety of factors that can influence how corrective actions should be prioritized. For example, immediate impact on safety, cost, time to implement, impact on the remainder of the system, etc. Within each of these categories, you should consider the overall impact of the corrective action during the prioritization process.

Consider the chart below from Chapter 6

HIGH CONSEQUENCE HIGH FREQUENCY	LOW CONSEQUENCE HIGH FREQUENCY
HIGH CONSEQUENCE LOW FREQUENCY	LOW CONSEQUENCE LOW FREQUENCY

Let’s say we have a corrective action that will impact an event that has low risk of causing death, injury, or property damage and it would seldom occur. The organization may want to protect that situation some other way and spend its resources on a different corrective action to eliminate or mitigate a high consequence – high frequency situation.

Step 10 - Communicate Corrective Action

When we communicate the incident analysis results and corrective actions to the organization it should be done in a logical and understandable manner. There are several ways to accomplish this effectively, however we currently use the business case model (Appendix B). Most decision-makers with control over the resources necessary to strategically implement corrective actions system-wide are familiar with this model and are more receptive to receiving information in this format.

Summary

This chapter has only described the MCIA process. It takes training and much practice to become proficient at analyzing accidents, incidents, or close call reports. MCIA is not the only problem-solving process that exists. It is not important what problem-solving tool an organization uses; what is important is that they have a tool and use it.

Chapter 10 - Facilitated Problem Solving

"It appears that, very early on, human beings developed a tendency to deal with problems on an ad hoc basis." – Dietrich Dörner

Introduction

While it is not the traditional role of the FRA to act as a mediator between labor and management, FRA personnel are often assigned to participate in non-traditional safety projects or programs. As such, it is important to arm yourself with a toolbox of skills needed to support FRA's number one priority: success of the program. That is our "question zero." If success of the program was not our first priority, you and others would not have been assigned to it. Although compliance with the requirements of the Code of Federal Regulations (CFR) is an important part of FRA's overall safety program, compliance with the CFR is not your number one priority when working on special projects or when working as part of an investigative team. Other personnel have those responsibilities covered. Within the context of a special program or investigation there may be times when you must act as a mediator, and it is appropriate for you to be prepared to fulfill that role.

Solving problems in a team/partnership environment

Facilitated Problem Solving (FPS) (also known as Interest-Based Negotiations) is a form of negotiation between two parties where a third party neutral assists or facilitates a settlement. The most common usage of FPS has been in negotiations during labor-management disputes. FPS is used in cases were the neutral third party is amenable to, and voluntarily accepted by, both parties. (It is assumed that in most cases the neutral party will be the FRA analyst/investigator assigned to the team). The theory of FPS is that parties are much more likely to come to a mutually satisfactory outcome when their respective interests are met rather than when one "position" wins over the other. Most negotiations ultimately involve the question of how to distribute something (e.g., money, property, benefits, or obligations) among the disputants or negotiating parties..

FPS is a preferred negotiation style in the mediation context because, in most instances, there will be a continuing relationship between the parties; an agreement satisfactory to both parties is desirable; and, for mediation to survive as a litigation alternative in the workplace, the process must be satisfying to both parties.

You may ask, "As an analyst/investigator, why do I care about labor-management negotiations and Facilitated Problem Solving?" That is a good question. Let's see if we can't satisfy your "interest" in this question.

As an analyst/investigator you will have to deal with people. Whether working as part of a partnership with the National Transportation Safety Board (NTSB), the Close Call Reporting System (C^3RS) as part of a multi-discipline team, or conducting an independent investigation of an incident or accident, you will have to work with and deal with people. That said, let's look at what FPS has to offer analysts/investigators in how to deal with people in order to gain the information you need to conduct your analysis or investigation.

Facilitated Problem Solving Skills

There are four principles of FPS that, if followed, usually produce a settlement that is mutually beneficial to the parties. These principles can also be applied to a wide variety of human relations and interactions, including team functions, individual interviews, and personal relationships. These principles are:

- Separate the people (person) from the problem.
- Focus on interests not positions.
- Invent creative options for mutual gain.
- Insist on objective criteria.

We will review each of these principles as we investigate how we can use them to enhance our personal capability to interact with others, to gather intelligence that will fill knowledge gaps in our analysis, and bring us closer to the *Reality of the Situation*.

Separate the People from the Problem

As discussed above, when analyzing or investigating an incident or accident you will have to deal with people. These persons may have a variety of interests in what the outcome of your investigation may reveal. These interests may be as diverse as, who to blame, who to sue, who to discipline, or who to protect. As an analyst/investigator, your interest is finding the truth. That is, to move, through a scientific process, from the *Theory of the Situation* to the *Reality of the Situation*.

So how do we break through the barriers of parochialism or closed-mindedness and fill our knowledge gaps? First we have to uncover what each person's *Perception of the Situation* is and what perceived risks they may feel. The analyst/investigator should attempt to "walk a mile in the other party's shoes." This will assist each party, as well as the analyst/investigator, in gaining a better understanding of the other's perception of the situation as well as assisting the parties in communicating the source of the problem. This helps the analyst/investigator uncover interests rather than positions. Once the person's interests are recognized the analyst/investigator can address that interest, hence allowing the person to share their information.

As discussed in Chapter 5, each individual views reality through their own filters, perceptions, and fears. Each individual also interprets the behaviors, words, and possible motives through their own biases and prejudices. The analyst/investigator should diffuse any negative signals, expressed by either side, as soon as possible. It should be noted that the biggest pitfall for an analyst/investigator is possibly committing the same type of error. The analyst/investigator should never assume his or her own fears are the same as those of the parties, or, that the parties' motives and perceptions are the same. To do this, the analyst/investigator must get the parties to discuss their perceptions rather than drawing assumptions.

The second component of separating people from the problem is to understand that humans are emotional beings. Following an incident/accident the emotions are generally negative, ranging from grief to fear to anger. Often the emotion of anger is used to cover other emotions. Removing the emotional component from the analysis/investigation greatly enhances the probability of reaching the *Reality of the Situation*.

Communications, or the lack thereof, can be a major contributor to the emotions that drive human behavior and the response people may have to the analyst/investigator. If you are a member of a team, you have the dual responsibility of searching for the truth, but also equally important is keeping the team focused on the goal and the scientific process of getting to that goal. The analyst/investigator must frequently ask themselves "question zero" - "What exactly am I trying to accomplish?" Remember, if you cannot answer question zero, the rest of the questions do not matter.

Faulty communications can at best be a distraction and at worst erect barriers between the parties. Furthermore, the analyst/investigator should ensure, through a rationale line of inquiry that each party or partner has a correct and clear understanding of the statements made by reporters, witnesses, or subject matter experts.

To this end, the analyst/investigator must listen carefully so as to be sure of the meaning of each statement by each party. When conducting a hearing or interview the analyst/investigator also has the responsibility of ensuring that they are speaking clearly and plainly and that their statements and questions are clearly understood by the parties. Remember, questions should follow a rationale line of inquiry and be designed to place the reporter or witness at ease and be comfortable with answering truthfully and without reservation.

Focus on interests not positions

In the course of an effort to fill knowledge gaps in an analysis or investigation, information may have to be gathered from many human sources. Each of these sources will have a position to hold or protect. Whether it is an individual or a representative of an organization, the position held will be influenced by the emotions of the moment and the biases and filters of the person. Positions are a desire for pre-determined outcomes that may not be easily satisfied, and it is the extremely rare case when a position can be fulfilled to both parties' satisfaction.

Focusing on the interests of the various parties can serve to break down the communications barriers. Interests (security) can often be met, whereas positions can seldom be fully satisfied. Interests are often based on needs (or perceived needs) whereas positions are often based on wants. It will be relevant to review some thoughts on needs at this time.

Maslow's hierarchy of needs defines the order that needs are prioritized by humans. The first and most basic of human needs are physiological, that is the need for food, drink, shelter, and relief from pain. The second level of the hierarchy is that of safety and security. Next is the need to belong, social acceptance, and love (emotions). The fourth level is the need for self-esteem and for esteem from others. The final level is self-actualization: the need to fulfill oneself by making maximum use of the individual's abilities, skills, and potential.

It is easy to see how an analysis of an event or an investigation of an incident may threaten an individual on one, or all of these levels. The reporter or witness must be reassured that you are not a threat to them and that your interest is in determining root causes and contributing factors, and not interested in placing blame.

Invent creative options for mutual gain

This particular principle is vital when working on a team or in partnership with other organizations. In these cases it is once again important to check "question zero" - "What exactly am I trying to accomplish?" The overriding interest of any participating organization should be the preservation of the process of seeking the truth, or the *Reality of the Situation*. As long as the process is serving the needs of the organization, the first priority must be preservation of the process. If the process no longer serves the needs of the organization, then the organization is wasting its time participating and should withdraw from the process.

We shall assume that all participating organizations are having their needs fulfilled or they would not be participating. This being said, when conflict within the process develops, options for mutual gain can be brainstormed. These potential solutions should attempt to address issues and concerns of each party. The neutral party (usually FRA) should not propose a solution, but should ask questions of the parties designed to elicit potential solutions.

To be successful in assisting the parties to invent options for mutual gain, the neutral party needs to be aware of the barriers that restrict option development. Such barriers may include making premature judgments, searching for a single solution and assuming that one party must win while the other must lose. The neutral party can assist the parties in brainstorming by helping them broaden the proposed options, by searching for mutual gain, and by keeping the parties from dismissing solutions as unworkable during the brainstorming phase. The neutral party should never strong-arm or pressure one party or both parties in this procedure. Further, the neutral party must remember that his/her role is to keep all options open and not to make judgments or comments regarding his/her opinion of the merits of a proposal.

Insist on objective criteria

This principle is closely related to critical thinking and a scientific approach (Chapter 3). Once the neutral party has helped the parties focus on their interests, the next step is to help the parties agree on the objective criteria that will be used to evaluate potential options. Potential criteria should be developed by each party prior to identifying particular options, and should address the interests of each party. Many times a party will know how to describe their desired outcome, but may not be able to articulate the details of how to achieve that outcome. There may be situations when a need to develop objective criteria is not necessary, if the parties readily identify options that are agreeable.

The use of objective rather than subjective criteria will allow the parties to fairly evaluate the outcome options. Objective criteria can limit the effects of reactive devaluation. In other words, having an objective criterion can reduce the cognitive bias that occurs when a proposal is devalued if it appears to have originated mainly from the antagonistic party. Moreover, parties are much more likely to comply with and carry through on terms of an agreement that they each view as legitimate, and objective criteria go a long way to providing that legitimacy. One example of the use of objective criteria is using past practice or industry standards as comparisons to the proposed agreement.

It should be noted that sometimes the objective criteria can become the vehicle for agreement. Both parties, for instance, might be willing to agree to follow industry standards or other independent criteria. Once this agreement has been reached, the only thing that remains is to research the details of the criteria.

Summary

Mediation is a form of negotiation between two parties where a third party neutral assists or facilitates a settlement, which is amenable to, and voluntarily accepted by both parties. The style of negotiation best suited for mediations is called Facilitated Problem Solving (FPS). The theory of FPS is that parties are much more likely to come to a mutually satisfactory outcome when their respective interests are met than they are when one "position" wins over the other. It is assumed that most disputes arising in an analytical/investigatory environment will be between labor and management, and the FRA representative will act as the neutral party. It is important for all parties to understand that the answer to FRA's "question zero" is the success of the program. This understanding will help keep the FRA representative focused and will work to build credibility of the process and the agency.

Chapter 11 – Systems Thinking and the Learning Organization

"Gradually, new awarenesses are assimilated into basic shifts in attitudes and beliefs. This does not happen quickly. But, when it does, it represents changes at the deepest level in an organization's culture – "the assumptions we don't see," as Edgar Schein puts it." – Peter Senge

Introduction

In earlier chapters we discussed complex systems and how humans work within those systems. We established that organizations and individuals need to understand more fully how complex systems operate and how various systems interact and influence other systems. We talked about how organizations need to use critical thinking skills to gain greater personal insight and to develop data for analysis. A scientific approach was introduced to process data into useful intelligence in order to move the organization towards the *Reality of the Situation*. Finally, a problem-solving process was offered as a means for improved decision-making.

All of these topics have been presented as components of a system that can be used to enhance an organization's performance, while simultaneously improving safety. That system is referred to as a Safety Management System (SMS) (Chapter 12). However, before an organization can take full advantage of the SMS process, it must prepare itself for the acceptance of a new culture and the destruction of its old culture. As Picasso postulated, "Every act of creation is first of all an act of destruction, because the new idea will destroy what a lot of people believe is essential to survival of their intellectual world."

Culture change for any organization can be painful and, if the organization is not really ready for change, the change attempt will probably fail. Training is critical to success, but even more important is the introduction, development, and acceptance of culture changing programs. As Dr. Jerry Weeks (NTSB) once said, "It is easier to behave yourself into a new way of thinking, than to think yourself into a new way of behaving." So, the first step in any culture changing is to prepare the organization for change through the introduction of policies, procedures, and programs that influence behaviors.

Systems

A system is a collection of parts (or subsystems) that are organized and integrated to accomplish a task or collection of tasks. The system has various inputs, which go through certain processes to produce certain outputs, which together accomplish the overall desired goal for the system.

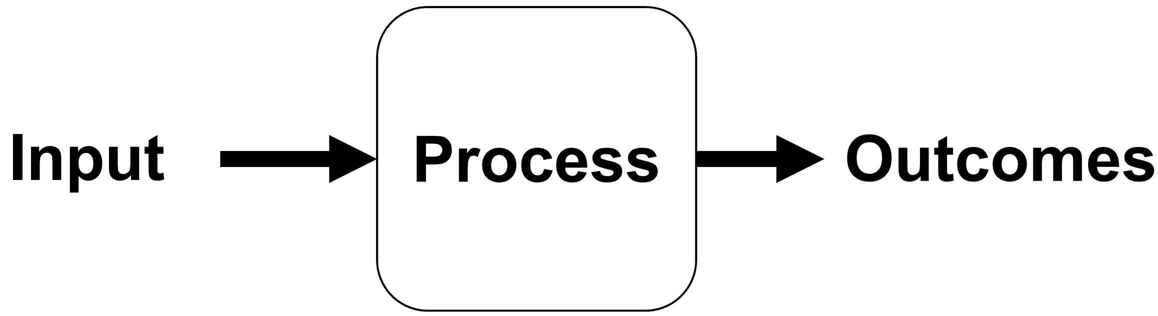


Figure 24 -Theoretical System

Systems, however, are seldom as simple as the Theoretical System illustrated above. Systems are usually made up of many smaller systems, or subsystems. For example, an organization is made up of many administrative and management functions, products, services, groups and individuals. If one part of the system is changed, the nature of the overall system is often changed, as well--by definition then, the system is systemic, meaning relating to, or affecting, the entire system. Furthermore, there are external influences as well as unrecognized internal influences.

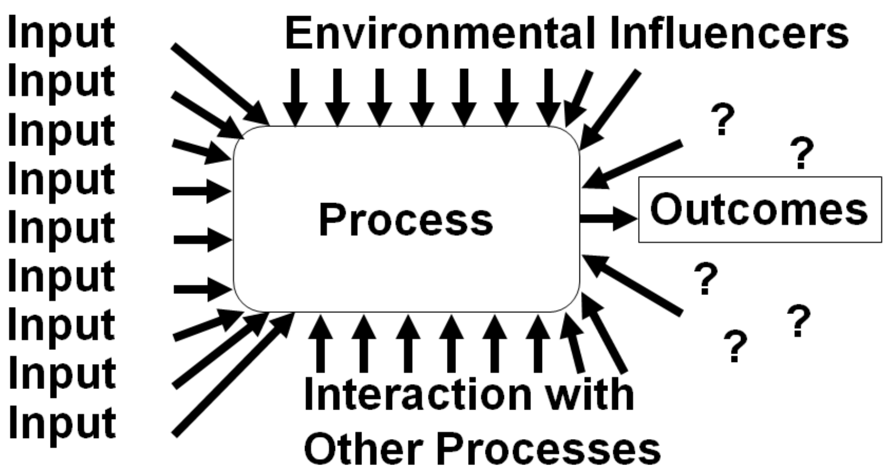


Figure 25 - Systems in the Real World

Complex systems, such as social systems, are comprised of numerous subsystems, as well. These subsystems interact with each other, and often interact with subsystems of other systems. Each subsystem has its own boundaries of sorts, and includes various inputs, processes, outputs and outcomes geared to accomplish an overall goal for the subsystem. Complex systems usually interact with their environments.

A high-functioning system continually exchanges feedback among its various parts to ensure that they remain closely aligned and focused on achieving the goal of the system. If any of the parts or activities in the system seems weakened or misaligned, the system makes necessary adjustments to more effectively achieve its goals. These adjustments are most often made by a human operator and therefore are subject to human error.

System Theory

System theory is the multi-disciplinary study of the organizations, independent of their substance, type, location, or position in time. System theory investigates both the principles common to all complex entities and the organizational models which describe them.

A system consists of four things. The first are the parts, elements, or variables within the system. Second, a system consists of attributes–the qualities or properties of the system and its elements. Third, a system has internal relationships among its elements. Fourth, systems exist in an environment. Hence, a system is a set of things that affect one another within an environment and form a larger pattern that is different from any of the parts.

A closed system does not interact with its environment. It does not take in information and therefore is likely to atrophy, that is to vanish. An open system receives information, which it uses to interact dynamically with its environment. Openness increases its likelihood to survive and prosper. Several system characteristics are:

- wholeness and interdependence (the whole is more than the sum of all parts),
- correlations,
- perceiving causes,
- chain of influence,
- hierarchy,
- subsystems,
- self-regulation and control,
- goal-oriented,
- interchange with the environment,
- inputs/outputs,
- the need for balance/homeostasis,
- change and adaptability (morphogenesis), and
- equifinality, that is, there are various ways to achieve goals.

Systems Thinking

The field of System Theory has led to the concept of systems thinking. Systems thinking is a way of thinking that assists a person to view systems from a broad perspective that includes seeing overall structures, patterns, and cycles in systems, rather than seeing only specific events in the system. This broad view allows the system operator or manager to more quickly identify the real causes of issues in organizations and know just where to work to address them. The concept of systems thinking has produced a variety of principles and tools for analyzing and changing systems.

By focusing on the entire system, operators and managers can attempt to identify solutions that address as many problems as possible within the system. Programs such as C^3RS and CSA are examples of tools that can be used to identify system problems. The positive effect of these programs is to provide solutions. Culturally, these solutions can be viewed as solution levers that not only improve the system's performance, but also demonstrate the power of the process, thereby building support for the process at all organizational levels. These solution levers are called "leverage points" in the system. This priority on the entire system and its leverage points is called whole systems thinking.

The open system model, which measures and analyzes the operational environment, recognizes the interaction between a system and its external environment. This model, in conjunction with whole systems thinking, is a powerful means for analyzing and changing systems. Systems theory has evolved to another level called chaos theory. In this context, chaos does not mean total confusion. Chaos refers to the dynamics of a system that apparently has little order, but which, in reality, has an underlying order. In these systems, small changes can cause complex changes in the overall system. Chaos theory has introduced new perspectives and tools to study complex systems, such as biological, human, groups, weather, and population growth.

The approach of systems thinking is different from that of traditional forms of analysis. Traditional analysis focuses on separating the individual pieces of what is being studied; in fact, the word "analysis" actually comes from the root meaning "to break into constituent parts."

Systems thinking, on the other hand, focuses on how the thing being studied interacts with the other parts of the system. This means that instead of drilling down deeper into an incident, as in an investigation, systems thinking works by expanding its view in order to see how possible solutions may impact the performance of the entire system. This results in sometimes strikingly different conclusions than those generated by traditional forms of analysis.

The character of systems thinking makes it extremely effective on the most difficult types of problems to solve: those involving complex issues, those that are dependent on the past or on the actions of others, and those stemming from ineffective coordination among those involved. Examples of areas in which systems thinking has proven its value include:

- Complex problems that involve helping many actors see the "big picture" and not just their part of it.
- Recurring problems or those that have been made worse by past attempts to fix them.
- Issues where an action affects (or is affected by) the environment surrounding the issue. either the natural environment or the competitive environment.
- Problems whose solutions are not obvious.

Building a resilient organization requires a nearly complete understanding of the organization, its operations, its support functions, how its employees function within the organization, and how the organization is impacted by its business, operating, and regulatory environment. The most effective way for an organization to achieve such understanding is by becoming a learning organization.

Models in science are used to simplify complex ideas, concepts, and mechanisms. The following graphical model illustrates the relationship between the *Theory of the Situation* and the *Reality of the Situation*. The arrows in this graphical model illustrate the continuous interaction between what we believe the situation to be and what is reality.

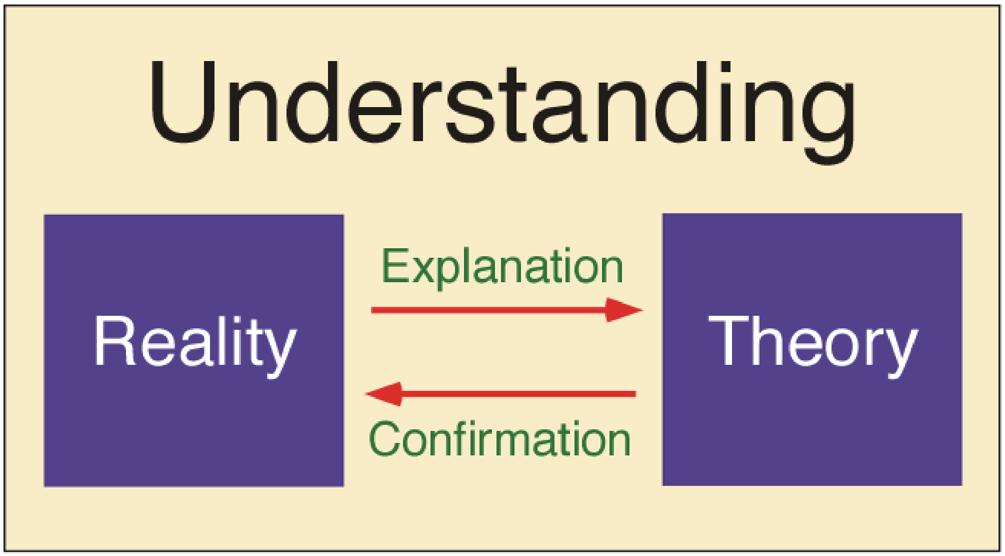


Figure 26 - Understanding Reality versus Theory

This scientific approach to understanding the realities that face an organization is the basis for organizational learning and suggests a Plan, Do, Check, Act sequence (Chapter 12) to becoming a learning organization.

Learning Organization

A learning organization is a term given to an organization that facilitates the learning of its employees and is continuously transforming itself based on feedback from its dynamic environment. Learning organizations are usually characterized by agility and adaptability, they are capable of detecting changes in the environment, and they quickly and rapidly adjust to those changes.

A learning organization has five fundamental features:

- Systems thinking.
- Personal mastery.
- Mental models.
- Shared vision.
- Team learning.

Systems thinking - The idea of the learning organization was developed from a body of work called systems thinking. Learning organizations use systems thinking when assessing their company and have information systems that measure the performance of the organization as a whole and of its various components. Systems thinking require that all the characteristics be apparent at once in an organization for it to be a learning organization. If some of these characteristics are missing, then the organization will fall short of its goal. However, more recent thinking in this area indicates that the characteristics of a learning organization are factors that are gradually acquired, rather than developed simultaneously.

Personal mastery - The commitment by an individual to the process of learning is known as personal mastery. There is a competitive advantage for an organization whose workforce can learn more quickly than the workforce of other organizations. Individual learning is acquired through staff training and development; however learning cannot be forced upon an individual who is not receptive to learning. Research shows that most learning in the workplace is incidental, rather than the product of formal training, therefore it is important to develop a culture where personal mastery is practiced in daily life. A learning organization has been described as the sum of individual learning, but there must be mechanisms for individual learning to be transferred into organizational learning. This mechanism should be a knowledgeable and available first-line supervisor.

Mental models - The assumptions held by individuals and organizations are called mental models. To become a learning organization, these models must be challenged. Individuals tend to espouse theories, which are what they intend to follow, and theories-in-use, which are what they actually do. Similarly, organizations tend to have "memories" which preserve certain behaviors, norms and values. In creating a learning environment it is important to replace confrontational attitudes with an open culture that promotes inquiry and trust. To achieve this, the learning organization needs mechanisms for locating and assessing organizational theories of action. Unwanted values need to be discarded in a process called "unlearning." This is the point where critical thinking can come into play (Chapter 3).

Shared vision - The development of a shared vision is important in motivating the staff or team to learn, as it creates a common identity that provides focus and energy for learning. The most successful visions build on the individual visions of the employees at all levels of the organization, thus the creation of a shared vision can be hindered by traditional structures where the organization's vision is imposed from above. Therefore, learning organizations tend to have flat, decentralized organizational structures.

Team learning - The accumulation of individual learning constitutes team learning. The benefit of team or shared learning is that staff learns more quickly and the problem-solving capacity of the organization is improved through better access to knowledge and expertise. Learning organizations have structures that facilitate team learning with features such as boundary crossing and openness. Team learning requires individuals to engage in dialogue and discussion; therefore team members must develop open communication, shared meaning, and shared understanding. Learning organizations typically have excellent knowledge management structures, allowing creation, acquisition, dissemination, and implementation of this knowledge in the organization.

Why is there the need for change?

So how did we get to the point where we have so many traditional organizations trying to survive in a non-traditional environment? Answering that question will go a long way in demonstrating the need for transformational change. However, to answer that question we have to go back to the pre-industrial revolution world.

Understanding the traditional perspectives of management is important because many, if not most, organizations today are still managed using these principles. This is the paradigm through which most managers still see their working world. Prior to the industrial revolution the business world consisted of many small firms that produced a single product or products with long production runs. They survived because the environment outside the organization was slow to change. In fact, in the business world, change occurred evolutionarily over generations. Employees obtained skills, usually through an apprenticeship, and then used those skills over their lifetime. Because technology was advancing so slowly there was little need for individual or organizational learning. Crafts were highly specialized and the required skills were passed down from one generation to the next. In this environment there was little need for high level business accruement or management theory.

With the advent of the industrial revolution, organizations expanded rapidly. Where a generation before had employed one or two skilled craftsmen, organizations were employing hundreds of people. Many of these employees were unskilled and only able to perform rudimentary and repetitive tasks. Many of the managers of organizations at this time were skilled engineers–able to build great machines. So it was natural for these managers to consider the human employee as just another interchangeable part in the machine. The philosophy that the organization existed to support the machine was a natural product of the industrial revolution.

The need to understand how to better manage these new mega-organizations soon became apparent. Two men entered the scene to propose new management theories. Frederic Taylor, a mechanical engineer, sought to improve industrial efficiency by proposing a scientific approach to management. Taylor's theory was based on the following principles:

- Each task has one best method.
- It is management's responsibility to find that one best method.
- It is management's responsibility to train the workers in using that best method.
- It is the workers' responsibility to perform that task using that best method and to be paid appropriately for the effort.

While Taylor was developing his scientific approach in the United States, Henri Fayol, a French mining engineer was developing what he called the general theory of business administration. Fayol's theory soon became one of the most influential concepts in modern management. Fayol's principles were:

- Develop a standard method for performing each job.
- Select the worker with the most appropriate abilities.
- Train the worker with everything needed to do the job.
- Eliminate wasted motions and steps.
- Provide wages based on performance against the standard.

While both of these theories represented a major change in organizational management, they were based on some faulty assumptions. Some of these assumptions were:

- The production environment was closed and not influenced by the outside environment,
- Mechanistic employees, machines, etc. are homogenous,
- If a part breaks, replace it with an identical part (including the human parts),
- Maximum production meant maximum efficiency.

These faulty assumptions lead to many organizational problems that are hidden in a culture that continues to exist today. These problems are:

- Closed systems focus inward, react slowly to change, and fail to adapt to change.
- Decisions are based on the historical environment, not the current environment.
- People are not machines.
- These theories treat people as if they are interchangeable parts.
- These theories lead to a "blame and punish" approach to management.

Ironically, many management problems in the 21st century can be traced back to the management problem-solvers of the 19th and 20th centuries. While their solutions may have been appropriate for their time, the environment has evolved since then and the need for change is upon us.

Learning Loops

What are the principles of a learning organization? Obviously, learning is a key principle, but how we learn is as important as what we learn. Some of the principles of learning organizations:

- Based on systems theory and triple-loop learning.
- Single, double, and triple-loop learning (effectiveness).
- Organizations function like a brain–a web.
- Information is ubiquitous.
- Employees are empowered to use double and triple-loop learning in decision-making.
- Leadership is based on developing shared vision and providing the necessary resources.
- Strategic decision-making is decentralized.

We will discuss the concepts of single, double, and triple-loop learning later in this chapter. For now let's focus on what is the purpose of a learning organization. A learning organization has the ability to scan the environment, anticipate changes in the environment, and adapt to those changes. Learning organizations develop the ability to question, challenge, and change the operating norms. They allow appropriate strategic direction and patterns to emerge from the organization at all levels and they refuse to be trapped in single-loop learning.

So, in review, organizations have many problems, professionals solve problems, today's problems are often the result of yesterday's solutions, and double-loop learning improves problem solving. There are those terms again. It's time to define learning loops.

There are four types of basic learning loops and they apply to people as well as to organizations. The first type is **zero-loop learning**. Organizations that employ zero-loop learning are most surely doomed. Organizations that function in a zero-loop learning environment fail to take corrective measures when fresh problems and imperatives arise. They are often referred to as *"disintegrators."* Employees at these organizations traditionally do not receive appropriate feedback on their performance and therefore never take corrective actions. There is no relationship between the individual's knowledge and the knowledge of the collective organization. Disintegrator organizations traditionally function in highly repetitive and routine operations.

Human resources functions in a zero-loop learning organization are characterized by:

- Selection and recruitment through unstructured interviews that focus on manual skill sets.
- Training and feedback is usually policy-based.
- Appraisal mechanisms are hierarchical in nature.

Buggy whip manufacturers and some pager companies are examples of zero-loop learning organizations.

In **single-loop learning** organizations, activities and problem-solving add knowledge to the organizations without altering the fundamental processes. Single-loop learning organizations are known as *"consolidators."* Individuals within a consolidator receive feedback and adjust accordingly, but they simply correct the problems as they occur, rather than avoiding the same challenges in the future. Learning through mistakes is a typical behavior.

Human resources functions in a consolidator organization are characterized by:

- Selection is based on technical skill and structured interviews.
- Training is based on problem-solving and communications.
- Appraisal is based on numerous performance measures and rewards stability.
- Compensation is based on performance and also tied to individual incentives.

Many government agencies fall into the consolidator category.

Figure 27 - Single-Loop Learning

Single-loop learning organizations are characterized by:

- Focusing on the parts of a problem in isolation.
- Relying heavily on what has worked in the past or elsewhere.
- Openness to solutions proposed by leaders and experts.
- Involving correction of a deficiency or completion of an action without questioning why.
- Actions leading to consequences, but the governing variables behind those actions are not addressed.

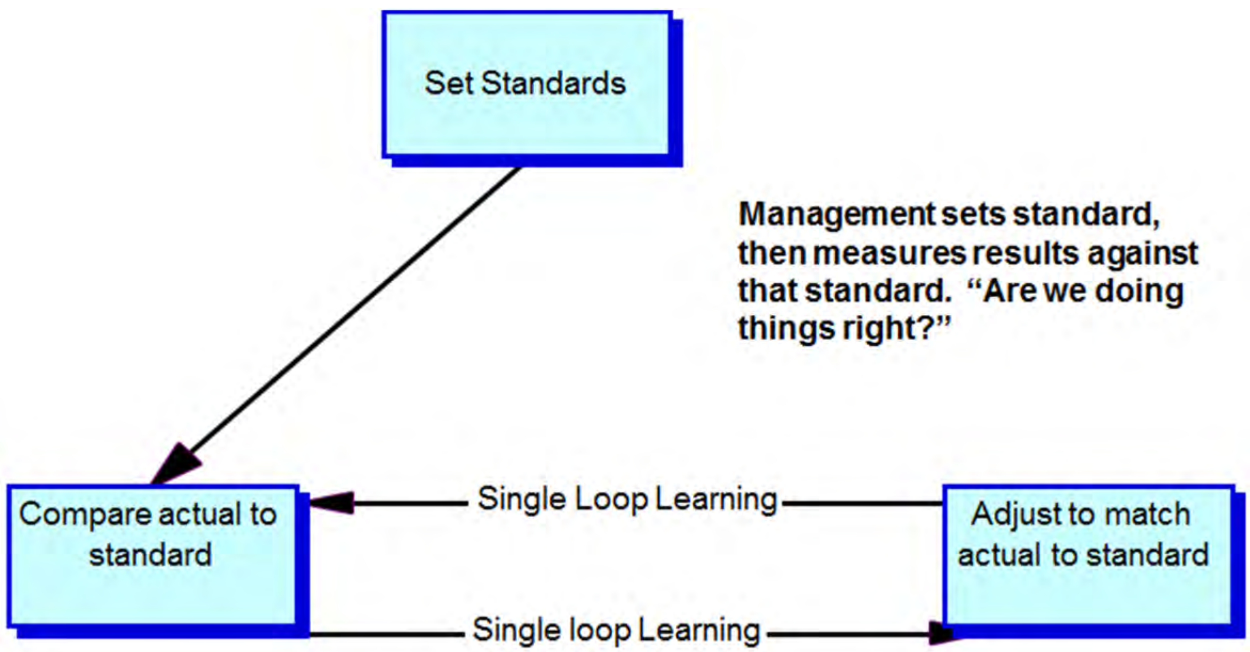


Figure 28 - Single-Loop Learning Process

An example to explain this concept is the thermostat. It operates in one mode. When it detects that the room is too cold, it turns on the furnace. When it detects that the room is too hot, it turns off the furnace. In other words, the system includes one automatic and limited type of reaction– little or no learning occurs and little or no insight is needed.

Most organizations operate according to single-loop learning–management establishes rigid strategies, policies and procedures and then management spends its time detecting and correcting deviations from the “rules.”

Double-loop learning organizations are firms whose individual employees literally change the collective knowledge base and breadth of skills available and thereby increase organizational capacity. Known as “transformers,” employees in these organizations are empowered to change the routines and processes that govern their duties. They re-frame problems, contribute to changing policies and procedures, and take risks in their work.

Human resources functions in a transformer organization are characterized by:

- Selection is based on hard and soft skills, attitudes toward learning, responsibility, teamwork and sharing.
- Training is based on personal development where employees engage in self-directed learning.
- Performance appraisal comes from above and below.
- Compensation is based on mentoring and information sharing, and on group and longer term incentive structures.

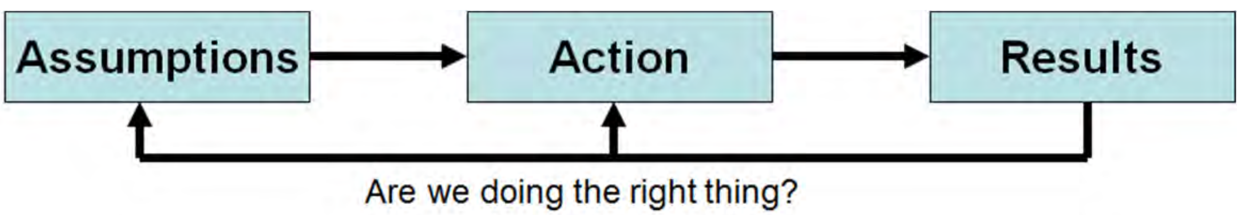


Figure 29 - Double-Loop Learning

Double-loop learning organizations are characterized by:

- Succeed in new contexts (environment).
- Make learning an integral activity within the organization.
- Ultimately to achieve better outcomes.

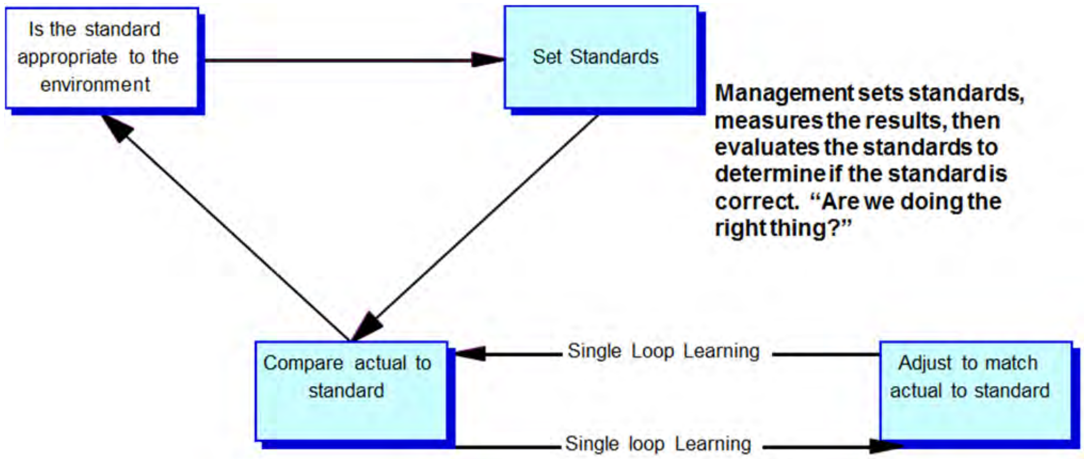


Figure 30 - Double-Loop Learning Process

In double-loop learning organizations, members are able to reflect on whether the "rules" themselves should be changed, not only on whether deviations have occurred and how to correct them. This kind of learning involves more "thinking outside the box," creativity and critical thinking (Chapter 3). This learning often helps participants understand why a particular solution works better than others to solve a problem or achieve a goal. Solutions are often systemic in nature and add resilience to the organization.

Experts assert that double-loop learning is critical to the success of an organization, especially during times of rapid change.

Triple-loop learning is the final evolution of the learning organization. These are organizations that have developed single and double-loop learning, and have moved on to learning and developing structures for how they learn. It is when an organization thinks about strategies for learning as part of its core processes that the organization has achieved this level of competency. Referred to as *"Co-Inventors,"* these organizations incorporate process evaluation into their invention of new procedures and compare success of past and present inventions/changes.

Human resources characteristics of a triple-loop learning organization are:

- Selection is based on attitude toward reflective learning, cognitive thinking. sharing ability.
- Training is based on peers teaching peers, appraisal and past performance.
- Compensation is based on profit sharing and stock option plans.
-

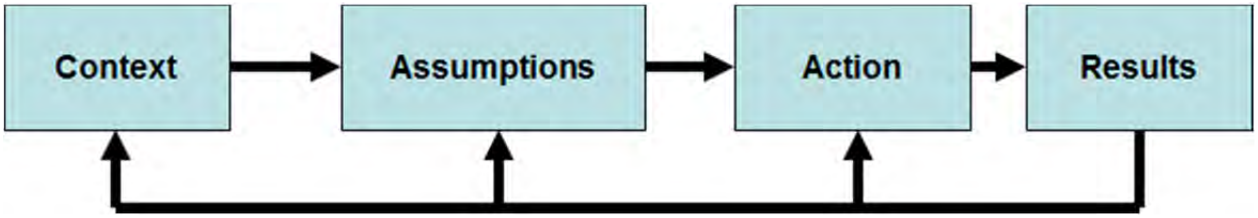


Figure 31 - Triple-Loop Learning

Triple-loop learning organizations are characterized by:

- Focus on working with all parts as a single system.
- Acceptance that solutions emerge as situations evolve.
- Involvement of the concerned people in developing the solutions.

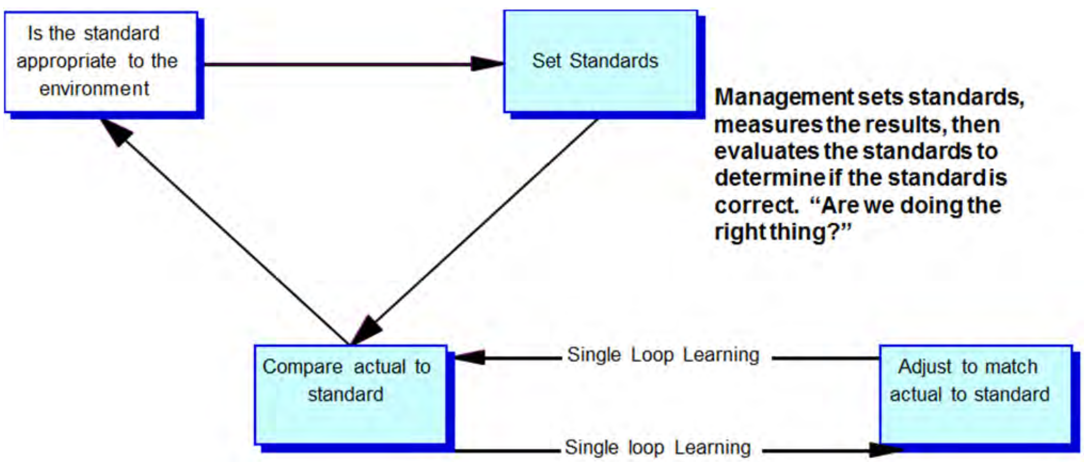


Figure 32 - Triple-Loop Learning Process

Triple-loop learning involves "learning how to learn" by reflecting on how we learn in the first place. In this situation, participants would reflect on how they think about the "rules," not only on whether the rules should be changed. This is a direct tie to critical thinking and continuous improvement. This form of learning helps us to understand a great deal more about ourselves and others regarding beliefs and perceptions.

To confront the challenges of the knowledge economy, organizations have to transform their *Human Resources Management* and *Knowledge Management* functions by removing the silos and inhibitions of the past and enabling themselves to "embrace the new roles of human capital steward, knowledge facilitator, and rapid deployment specialist." The operational branch of the organization will have a difficult time facilitating change without these critical support groups embracing the change.

In other words, the practices of human resources—Staffing, Training and Development, Performance Appraisal, Rewards and Compensation—must be the mechanism that brings employees together to share and convert tacit knowledge to explicit knowledge.

In a zero-loop learning organization, no questions are asked. In a single-loop learning organization, the question that is asked is, "Are we doing it right?" In a double-loop learning organization, the question that is asked is, "Are we doing the right thing?" In a triple-loop learning organization, the question that is asked is, "How do we decide what is right?"

Remember, organizational learning is more than just measuring and data gathering. It involves deciding what information to gather, how will it be analyzed, and what will we do with the intelligence that we learn. There are all kinds of measures of performance, but not all measures are appropriate. "Measure, measure everywhere and not a thought to think!" is an important adage to keep in mind.

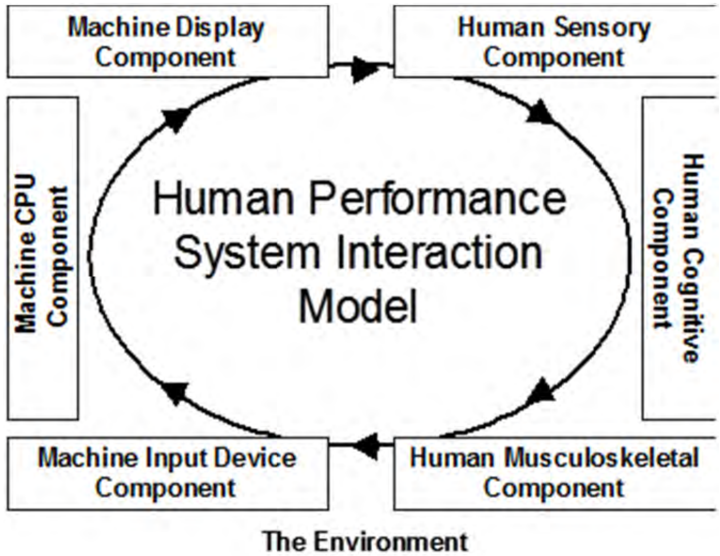
Conclusion

You may be wondering why we have spent so much time on the subject of organizations. If you remember back in Chapter 3 we discussed the Human Factors Analysis and Classification System. Many safety issues can find their root cause in the organizational level. Anyone with an interest in safety should familiarize themselves with organizational theory, structure, and behavior. Without this knowledge it would be difficult to detect root causes at the various organizational levels. Furthermore, without a clear understanding of the organization's operations and culture, recommended corrective actions may be less effective or even counter-productive.

This information is also valuable for internal decision-making and agency process improvement. What type of learning-loop does the FRA have?

Summary

Let's once again look at the Human Performance System Interaction Model to see how all of the puzzle pieces fit together.



FRA's ultimate goal is to build a network of highly reliable and resilient organizations (Chapter 2) throughout the railroad industry. To achieve this goal we must first recognize that we are dealing with a very complex system that relies heavily on humans to make the system operate (Chapter 1). We must recognize that the humans in the system will make mistakes for a variety of reasons (Chapters 4, 5, & 6). The ability of an organization to become a resilient organization will directly depend on its ability to first become a learning organization by using system thinking (Chapter 11) and critical thinking (Chapter 3) to learn from the environment and from its mistakes. Crew Resource Management, Close Call Reporting, and Clear Signal for Action (Chapter 7) all provide information regarding the environment. When mistakes are made, learning organizations use the appropriate investigative technique (Chapter 8) and then use a scientifically-based analysis technique, such as MCIA (Chapter 9) to develop actionable intelligence. They then use a problem-solving technique to develop possible corrective actions. These possible corrective actions are then evaluated to determine their impact on the overall system. If the evaluation indicates that the impact is positive, the corrective action is implemented. This process should not be a stand-alone process. Rather, it should be a process that is integrated into the organization's overall operation. This can be accomplished by developing and institutionalizing a Safety Management System (Chapter 12) that formalizes organizational learning and operational safety.

Chapter 12 - Tying It All Together

"I've got my facts pretty clear,' said Stanley Hopkins, 'All I want now is to know what they all mean." – Sir Arthur Conan Doyle

Introduction

The overriding goal, the answer to "Question Zero" is we are attempting to not only build a resilient organization, but to build a resilient industry (Chapter 2). But, we cannot do that without building resilient organizations first. To accomplish this noble goal we must all be willing to be good partners.

The key to building a resilient organization is to gather information about the organization's operation, internal and external influencers, and the operational environment. Once that information has been gathered it must be processed into usable intelligence. When the intelligence has been analyzed, effective corrective actions can be implemented. The critical step of gathering information should not be limited by hindsight bias, nor should the quality of the information be compromised by confirmation bias.

Sources of information should not be limited. The use of multiple sources of information leads to a broader and richer understanding of the *Reality of the Situation*. Personal interviews, physical evidence, documentation, close call reporting programs, Peer-to-Peer Coaching Programs, etc., are examples of where information can be gathered.

Remember Question Zero: "What exactly am I trying to accomplish?" In this case, what we are trying to accomplish is the establishment of resilient organizations.

Information Gathering

An endeavor as daunting as changing an organization's culture demands, first and foremost, an understanding of where the organization is right now. To achieve this understanding, the organization needs to examine itself with a critical eye. This requires critical thinking (Chapter 3). In order to properly analyze the current state of the organization, an immense amount of information must be gathered.

There are many ways in which an organization can gather information about itself. Programs like the Confidential Close Call Reporting System (C^3RS) and Clear Signal for Action (CSA) can provide large quantities of operational information. Also, the scientific investigation of accidents and incidents (Chapter 8) is a critical source of information. The key word in the previous sentence is "scientific." Investigative reports that only reflect "What" happened are of little value and usually end their existence in a database of questionable value. In order to make meaningful changes, organizations need to know "Why" the incident occurred.

But, gathering all the data is meaningless unless it is put into an operational and environmental context. To convert this raw data into intelligence it must be processed.

Turning Information into Intelligence

Turning information into intelligence requires an analytical process that sifts through the data, searches for root causes and contributing factors, and to some degree classifies the incident for future trending analysis. MCIA is such a tool (Chapter 9). It is an epidemiological accident/incident investigative model that is based in science.

The MCIA tool is best utilized in a team environment, where the team has been trained in the process, and has a level of expertise in the subject matter to analytically walk through the process. Collectively, the team should have the wisdom to know when the details of an analysis have gone beyond their level of knowledge and when to call on other subject matter experts.

This analytical team should be made up of members or representatives of the people doing the work as well as members of the management team. This arrangement may cause some tension during the analysis process due to the different and often competing interests of the members. Using the common interests of the parties, problems can usually be solved through the use of leadership and some facilitator problem-solving skills (Chapter 10).

However, it is not enough to have information and to have the skills of a good analyst/investigator, or even to use those skills. To be effective at improving safety, a person needs the information, needs the skills, needs to believe the results, and needs to be motivated to do something with the results.

Corrective Actions

In Chapter 1 through Chapter 6, we discussed:

- how humans interface with and operate in complex systems,
- how stress, workload, boredom, and fatigue affect human performance,
- what mechanisms operate to produce human errors, and
- how human errors can be classified and analyzed.

When conducting the analysis of an incident or close call each of these factors should be considered in determining “Why” the incident or close call occurred. Then the proposed corrective action should address that “Why” in a manner that redesigns a portion of the system to eliminate, trap, or mitigate the consequences of future occurrences. Remember that we are dealing with complex systems where a seemingly small change in one area may have significant impact on another part of the system. Careful thought and verification should go into determining whether the proposed corrective action will have an adverse impact on some other part of the system.

It should be self-evident that good people will make mistakes. Occasionally, as in any complex system, these mistakes will lead to serious consequences. Many of our current processes depend on punishment in order to attempt to control behaviors. This may be an effective means of dealing with vandals and saboteurs, but it is a highly ineffective and counterproductive method of dealing with human error.

The scientific approach to building a resilient organization dictates that we do not punish the person that made the error, rather we learn from them. As we as individuals learn, the organization learns (Chapter 3). Through learning organizations, we can produce appropriate corrective actions and move closer to becoming a resilient organization.

Safety Management Systems (Introduction)

Safety Management Systems (SMS) are rapidly becoming the new standard throughout industry. Originally conceived by the aviation industry as a means of taking aviation to a new level of safety, SMS is a mechanism to bring resilience to an organization. What is an SMS? It is a term used to refer to a comprehensive business management system designed to manage safety elements in the workplace. An SMS provides a systematic way to identify hazards and control risks while maintaining assurance that these risk controls are effective. SMS can be defined as a businesslike approach to safety. It is a systematic, explicit, and comprehensive process for managing safety risks.

As with all management systems, a safety management system provides for goal setting, planning, and measuring performance. A safety management system is woven into the fabric of an organization. It becomes part of the culture and the way people do their jobs. In this context, safety can be defined as the reduction of risk to a level that is as low as is reasonably practicable.

There are three imperatives for adopting a safety management system for a business–these are ethical (moral), legal (compliance), and financial (fiduciary responsibility). There is an implied moral obligation placed on an employer to ensure that work activities and the workplace are safe. There are legislative requirements defined in just about every jurisdiction on how this is to be achieved. Also, there is a substantial body of research which shows that effective safety management can reduce the financial exposure of an organization by reducing direct and indirect costs associated with accidents and incidents. Therefore, there are ethical, legal, and financial reasons for any organization to establish an SMS.

To address these three elements (ethical, legal and financial), an effective SMS should:

- Define how the organization is set up to manage risk.
- Identify workplace risk and implement suitable controls.
- Implement effective communications across all levels of the organization.
- Implement a process to identify and correct non-conformities (reduce variables).
- Implement a continual improvement process (learning organization).

An SMS can be created for any type of business or industry.

An SMS for companies and regulators will integrate modern safety risk management and safety assurance concepts into a repeatable, proactive system that focuses on prevention. An SMS recognizes risk and safety management as a core business process that not only provides physical security to the organization's assets, but adds value to all aspects of the operation.

A properly designed and implemented SMS provides:

- A structured means of safety risk management decision-making.
- A means of demonstrating safety management capability before system failures occur.
- Increased confidence in risk controls through a structured safety assurance process.
- An effective interface for knowledge sharing between regulator and the industry.
- A safety promotion framework to support a sound safety culture.

The primary focus of any SMS is the promulgation of safe decision-making throughout the organization. We have seen in earlier chapters how the lack of information can lead to faulty decision-making and undesired consequences. SMS is an umbrella concept that encompasses:

- How humans behave in complex systems (Chapter 1).
- A mechanism for organizations to move toward being highly reliable and resilient (Chapter 2).
- A vehicle for individuals and organizations to use science and critical thinking to maintain a posture of continual improvement (Chapter 3).
- A system that understands the human element of a given operation and works to exploit the human strengths and minimize the human weaknesses (Chapters 4, 5, & 6).
- How CRM can be used, not only to improve communications, but also to enhance the safety culture (Chapter 7).
- How improved investigative techniques and data gathering can improve operational safety and an organization's safety culture (Chapters 8 & 9).
- How processes that lead to better decision-making can improve operations and culture (Chapter 10).

Technology and system improvements have made great contributions to safety. However, part of being safe is the individual's personal belief systems and attitude. Attitude is defined by Carl Jung as "readiness of the psyche to act or react in a certain way" to outside stimuli. This is sometimes referred to as mood. It means that if you are in a bad mood or are harboring a bad attitude you have a higher level of readiness to respond badly to external stimuli, or change in the environment. Whether through data gathering methods or through direct employee input, recognizing that many opportunities exist to stop an accident from happening is the first step in moving from a reactive posture to predictive thinking, and the first step in moving from where we are today to becoming a resilient organization.

Safety begins from both the top down and the bottom up. Everyone from the clerk, carman, engineer, manager, and FRA inspector has a role to play. SMS is about decision-making. Thus, it has to be a decision-making tool, and not a traditional safety program separate and distinct from the business and operational decisions.

Hypothetical Scenario

On the floor of a locomotive manufacturing facility at the paint shop preparation ramp, a quality control inspector notices lateral hairline cracks around several handrail stanchion brackets, near the Huck fasteners. These cracks appear to be superficial, so the quality control inspector believes that they probably represent no hazard. Besides, this locomotive is finished and ready to go. Fixing this cosmetic defect would require delaying its delivery and would mean sending it back for rework. His bosses hate it when they have to send a product back for rework and they would probably criticize him for reworking a completed product for cosmetics only. It is obviously "good to go."

A loaded, time sensitive auto train is standing on the main track with a two-man train crew (engineer and conductor) on-board waiting for the mechanical forces to conduct a Class I brake test. The train consists of two new 4,300 HP state-of-the-art freight locomotives and 45 cars. Two railroad mechanical inspectors are assigned to inspect and conduct the brake test on the train. One inspector starts from the rear, the other from the head-end of the train.

As the inspector at the head-end gives the engineer the order to set the brakes, he proceeds to inspect the train working toward the rear of the train. As he passes between the two locomotives, the inspector looks up and notices a handrail stanchion cracked at the base, through the fastener bracket. He inspects the condition more closely and decides to forget the matter because the train is extremely time sensitive and they are already about 10 minutes past the call. The stanchion supports the safety chain and is located at the crossover passageway between the two locomotives.

At the same time, a first level supervisor is inspecting daily locomotive inspection records at the diesel shop. He comes across an entry on a record that indicates a cracked stanchion. He observes two initials near the entry, but does not give it a second thought and continues inspecting the daily locomotive inspection records and related maintenance records. He finishes and files the records in the filing cabinet and gets ready to meet with his boss. The supervisor thinks to himself, "so much to do and so little time."

Meanwhile the mechanical inspectors working the train meet up. The one inspector that initially noticed the cracked stanchion decided to tell his co-worker about it. The co-worker said he would take a look, but that it should be safe since railroad rules do not allow anyone on the passageway while the train is moving. About 10 minutes later, the second mechanical inspector takes a look at the cracked stanchion and decides it's much worse than the first inspector thought. He notices that the Huck fastener is nearly pulled through the bracket. At about that time, the foreman came over the radio asking the mechanical inspectors how much longer they needed to complete the inspection.

The train is given the order to release the brakes and the mechanical inspectors roll the train by as it leaves the yard.

About two hours into the trip, the engineer notices that the second locomotive was not loading properly. Both crewmembers know that they have a time sensitive train and need to make up some time because they were late getting out of the yard. The dispatcher had previously given their train priority over all opposing traffic. The engineer and conductor are brothers and anxious to get home to attend a party to celebrate their parents' 50th wedding anniversary.

Although railroad rules prohibit operating employees from exiting the cab of the locomotive while the train is moving, the brothers agreed getting home on time was important. After all, management has determined that this is a "hot" train, so they had to keep moving. The conductor exited the lead locomotive cab to check out the trailing locomotive. Train speed was about 55 mph and the train and locomotive consist was rocking slightly from side to side. The conductor used the handrails to balance himself down the passageway as he was walking toward the trailing locomotive.

As he was about to enter the crossover passageway to the trailing locomotive, the train traversed a left-hand curve causing his mid torso to come in contact with the handrail at the same location with the cracked stanchion. The pressure from his weight caused the stanchion to break in two pieces. Fortunately, the conductor regained his balance and caught himself just before falling between the two locomotives. However, in the process of catching himself, he caused injury to his right shoulder and lower back.

The conductor immediately returned to the lead locomotive and explained what happened to his brother. The train continued on to destination without incident. Upon arrival the conductor was unable to exit the cab without assistance because of severe back pain and thus felt obligated to report the injury. He was subsequently transported to the hospital where he was treated and released. Two days later, the conductor was removed from service and called for an investigation.

On the floor of a locomotive manufacturing facility at the paint shop prep ramp, a QC inspector notices lateral hairline cracks around several handrail stanchion brackets, near the Huck fasteners…and the cycle continues!

Evolution of Safety Management

Safety Management Systems (SMS) are the product of a continuing evolution in aviation safety, but the concepts can be transferred to any industry, business, or setting. However, the roots of this evolution can also be found in the rail industry. Early railroad pioneers had no safety regulation and little practical experience, or engineering knowledge to guide them. Over time, the development of more sophisticated methods of operations, operating and safety rules, safety regulations, and improvements in technology have contributed to significant gains in safety. In the next major phase of improvement to safety, a focus on individual and crew performance or "Human Factors" further reduced accidents.

Figure 33 - Evolution of Safety Thinking

Each approach has led to significant gains in safety. However, even with these significant advances, we still have opportunities to take preventative action against accidents. The question for the railroad community is, "what is the next step?"

Careful analysis typically reveals multiple opportunities for actions that could have broken the chain of events and possibly prevented an accident. These opportunities represent the organization's role in accident prevention. The term "organizational accident" was developed to describe accidents that have causal factors related to organizational decisions and attitudes. SMS is an approach to improving safety at the organizational level.

How a Safety Management System Addresses the Organization's Role in Safety

SMS requires the organization itself to examine its operations and the decisions around those operations. Accident/injury data, operations testing data, Confidential Close Call Reporting System (C^3RS) data, peer-to-peer observational data (Clear Signal for Action), and other sources can supply the organization with the needed information to begin the organization's self-examination. Using this data and the resulting analyzed intelligence allows an organization to use SMS to adapt to change, to handle increasing complexity, and to utilize limited resources efficiently. SMS will also promote the continuous improvement of safety through specific methods to predict hazards from employee reports and data collection.

Organizations will then use this information to analyze, assess, and control risk. Part of the process will also include the monitoring of controls and of the system itself for effectiveness. SMS will help organizations comply with existing regulations while predicting the need for future action by sharing knowledge and information. Finally, SMS includes requirements that will enhance the safety attitudes of an organization by changing the safety culture of leadership, management, and employees. All of these changes are designed to move the organization from the current state (reactive thinking) to that of a resilient organization (predictive thinking)

Figure 34 - Moving from Reactive Thinking to Predictive Thinking

SMS has generated wide support in the aviation community as an effective approach that can deliver real safety and financial benefits. Other industries are now beginning to explore the benefits of SMS. An SMS integrates modern safety concepts into repeatable, proactive processes in a single system, emphasizing safety management as a fundamental business process to be considered in the same manner as other aspects of business management. The structure of SMS provides organizations greater insight into their operational environment, generating process efficiencies and cost avoidance. Some participants have found that benefits begin to materialize even in the early reactive stages of implementation. This discovery of safety and operational benefits continues as organizations evolve from reactive to proactive and predictive phases.

Safety Management System (Components)

Any SMS has four key components that must be addressed:

- Safety Policy
- Safety Risk Management
- Safety Assurance
- Safety Promotion

The Four SMS Functional Components

The essential idea of any SMS is to provide for a systematic approach to achieving acceptable levels of safety risk. It recognizes that all risk cannot be removed from any operation. Risk is part of the human experience. However, SMS can move an organization from reacting to events to predicting events. In other words, SMS is a vehicle for becoming a resilient organization. SMS is comprised of four functional components, including an intangible but always critical aspect called culture.

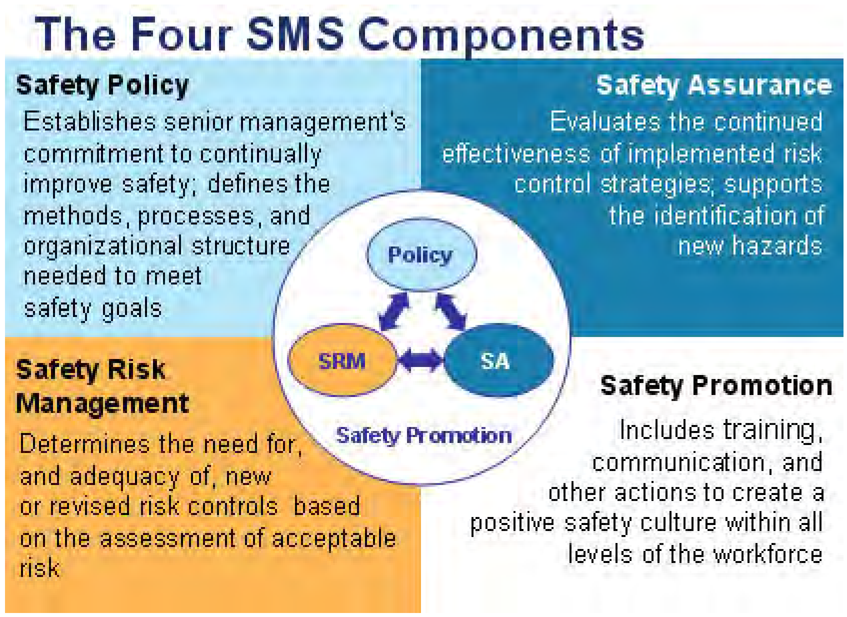


Figure 35 - The Four SMS Components

Let's explore each of these separately before we illustrate how they are interconnected.

The first component is Safety Policy. Safety Policy establishes senior management's commitment to continually improving safety by defining the methods, processes, and organizational structure needed to meet operational, financial, and safety goals as an integrated package.

- Establishes management commitment to safety performance through SMS.
- Establishes clear safety objectives and commitment to manage those objectives.
- Defines methods, processes, and organizational structure needed to meet safety goals.
- Contains fully documented policy and processes.
- Contains an employee reporting and resolution system.
- Requires accountability of management and employees.
- Establishes transparency in the management of safety.
- Builds upon the processes and procedures that already exist.

- Facilitates cross-organizational communication and cooperation.
- Establishes processes to gather information and analyze it for intelligence.

Established within the policy statements are the requirements for the organization in terms of resources, defining management commitment, and defining organizational safety targets.

The second component of an SMS is Safety Risk Management (SRM). Safety Risk Management determines the need for, and adequacy of, existing and new or revised risk controls based on the assessment of acceptable risk. An SRM is a formal process within the SMS composed of:

- Describing the system (Understanding the complexity of the system).
- Identifying the hazards (Understanding how components of the system, including the human, interrelate and interact).
- Assessing the risk (Gathering all available information on the risk).
- Analyzing the risk (Using a scientific approach to problem-solving).
- Controlling the risk (Implementing appropriate corrective actions).

Using the intelligence gained from SRM, organizations can learn engineering, managerial, and behavioral techniques to eliminate risk, trap risk, or mitigate the consequences of risk (Chapter 7).

The third component in SMS is Safety Assurance (SA). Safety Assurance evaluates the continued effectiveness of implemented risk control strategies and supports the identification of new hazards. SA is a strategy used by learning organizations to produce continuous improvement.

- SMS process management functions that systematically provide confidence that the organizational output meets or exceeds safety requirements.
- SMS is a safety partnership.
    - ➢ Management
    - ➢ Labor
    - ➢ FRA
- Ensures compliance with SMS requirements, AAR Rules, and FRA Regulations, Orders, Standards, policies, and directives.
    - Information Acquisition
        - ➢ Audits and evaluations
        - ➢ Confidential Close Call Reporting System
        - ➢ Peer-to-peer coaching (behavior-based safety)
        - ➢ Crew Resource Management feedback and training
        - ➢ Other information gathering systems
    - Data Analysis
        - ➢ Multiple Cause Incident Analysis
        - ➢ Scientific problem-solving methods

- System Assessment
- Provide insight and analysis regarding methods/opportunities for improving safety and minimizing risk.
- Existing assurance functions will continue to evaluate and improve product or service.

A learning organization will use problem-solving processes (MCIA) and statistical analysis tools (e.g., six-sigma tools) to reduce deviations in performance and behavior and to develop theories of the situation as close as possible to the reality of the situation.

The fourth component of SMS is Safety Promotion. Safety Promotion includes training, communications, and other actions to create a positive safety culture within all levels of the workforce. This is not simply the traditional on-and-off safety campaign. Rather, it is a concerted effort to communicate safety as a core value of the organization.

Safety promotion activities within the SMS framework include:

- Providing SMS training.
- Advocating/strengthening a positive safety culture.
- System and safety communication and awareness.
- Matching competency requirements to system requirements.
- Disseminating safety lessons learned.
- Everyone has a role in promoting safety.
    - ➢ A clear safety empowerment policy needs to be developed and clearly communicated to all employees.
    - ➢ The role of the supervisor in safety empowerment must be clearly communicated to all managerial/supervisory personnel.

Interface between Safety Policy and Safety Promotion

Each component of the Safety Policy must be communicated clearly and distinctly to all employees, including managers and supervisors. Each aspect of the policy must be adhered to in order to establish credibility. Conversely, if weaknesses are found in the policy, the organization needs to be agile enough to quickly make changes in the policy and communicate those changes to the workforce. The Plan-Do-Check-Act process can be used to continually improve the safety policy. The organization must develop a policy, act upon the policy, learn and improve the policy, and re-establish the policy. This process supports the learning organization and SMS.

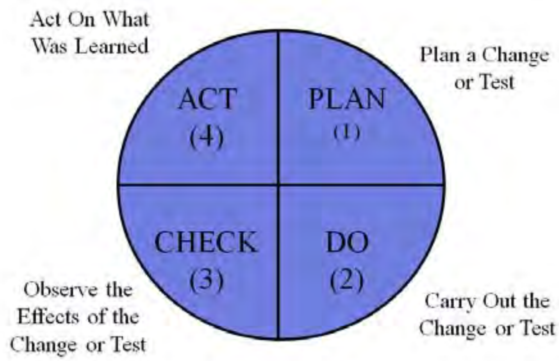


Figure 36 - Plan-Do-Check-Act

Nothing you plan or develop will be perfect, no matter how much effort and time is expended on it. This includes the development of safety policy. No one knows what the Reality of the Situation is, so the best product that can be developed is based on the Theory of Reality. Therefore, the best safety policy will have errors and holes in it. With fallibility being a given, develop the best policy that you can (Plan). Then communicate the policy to the organization (Do). Monitor each aspect of the policy, not only for compliance, but also for effectiveness and appropriateness (Check). Next, modify the policy based on what has been learned (Act), and begin the process again.

Interface between Safety Risk Management and Safety Assurance

Safety Risk Management (SRM) and Safety Assurance (SA) are the key processes of SMS. They are highly interactive. Many organizations have these two functions "stovepiped" in different departments, when in fact they should be closely related and integrated. The flowchart below may be useful to help visualize these components and their interrelationship. The interface concerns the input-output relationships between the activities in the processes. This interface is especially important where the interface is between processes involving different departments, contractors, etc. Assessments of these relationships should pay special attention to flow of authority, responsibility, and communications, as well as procedures and documentation.

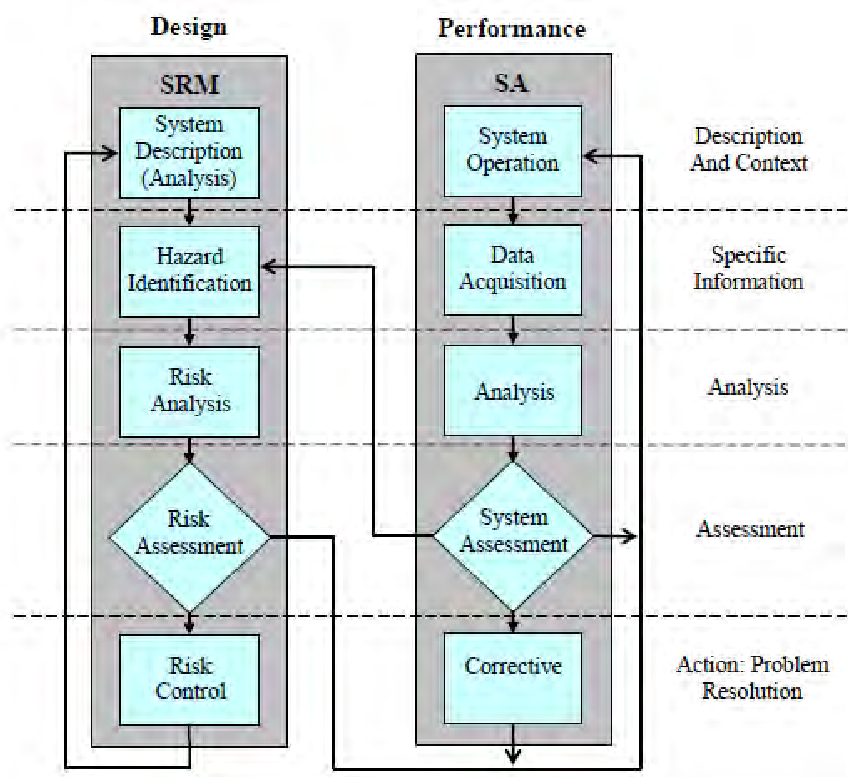


Figure 37 - Safety Risk Management and Safety Assurance

Keep in mind the roles of SRM and SA. SRM uses intelligence gleaned from various data sources to develop policies, procedures, and processes. SA, on the other hand, monitors the environment to determine the effectiveness and appropriateness of the implemented policies, procedures, and processes.

Quality and Safety Management

Quality Management Systems (QMS) are common across the spectrum of industry and business. A QMS focuses on customer satisfaction and Customer Relations Management, (this is not to be confused with Crew Resource Management discussed earlier). Most successful private organizations have some type of QMS in place. Safety Management Systems, on the other hand, focus on operational safety. The QMS and SMS must be completely compatible. Conflicts between the QMS and the SMS will result in a breakdown in the decision-making process at all levels of the organization. Such conflicts will also cause organizational values to become cloudy and middle managers, supervisors, and employees to become confused and lose confidence in senior management and the organization.

In the earlier example the mechanical inspectors may have believed that senior management's priority was on the QMS (Satisfying the Customer) and that the organization valued on-time performance over a culture of safety. They may have felt unempowered to delay the train for what they determined was a low threat risk. This behavior is the result of ambiguous or conflicting policies regarding QMS and SMS. Employees must be sure what the policies are, feel empowered to make safety decisions without fear of reprisal or reprimand, and have confidence in the validity of the policies. As you can see, SMS is not a product of just the safety department. A quality SMS requires that all departments within an organization understand their role and how that role fits into the overall operation of the business. Specifically, what is the department's role is in the SMS and how will it be held accountable for those responsibilities associated with that role.

Much of the confusion, hence the conflict between QMS and SMS, lies in the fact that they use many of the same tools, but for difference reasons and to achieve different outcomes. For example, a QMS many use six-sigma tools to detect variability in a specific product or service. SMS, on the other hand, uses six-sigma tools to detect variability in operations and human behavior. The QMS goal is to reduce that variation in order to produce a more consistent product or service.

The QMS assumes that the product design is good and safe and, therefore, quality can be improved by reducing the variability. While this is a good thing, the underlying assumption may be incorrect. Reduction in the variation of a product or service may simply result in a better, yet unsafe, product or service. For example, operational testing is designed to encourage rules compliance. This is universally understood. What is less understood is the fact that operational testing is also an opportunity to test the rule. Is it appropriate as written? Is it clear and easily understood? Is it appropriate for all operational conditions that employees may encounter?

A good SMS will focus on improving the safety performance of an organization, and therefore reduce the exposure to risks in the operation. It is not focused on the safety record per se, rather it is focused on the operational risks. Quality systems are focused on continuous improvement also, but through improving production rates. This is another source of conflict between the two systems and causes confusion and frustration among employees. For example, the safety rate is not the same as the safety performance (although some people would like to think they were the same). There are many railroads with exemplary safety records that are operating with risky behaviors, inadequate supervision, and inadequate organizational structure, and have not yet experienced an accident of significance. A good safety record does not predict an accident-free future.

Safety Management Systems are not simply the latest "buzz" word or the flavor of the month. On the contrary, SMS has evolved because of science. It is a product of scientific study in such diverse areas as human behavior, organizational behavior, psychology, business management, marketing, human resources, and more. These sciences have come together in developing a comprehensive and integrated system, which if properly implemented, monitored, and improved is a historic change of how we view safety within a complex system.

A quality SMS means we can stop reacting to the last accident, and while we will want to continue to identify hazards in a proactive manner, most of our efforts can be utilized in predicting where the potential problems are and correcting them before they manifest themselves in the safety statistics.

Safety Management System Models

There are many SMS models to choose from for incorporation into a particular business or industry. The following example is the SMS adopted as an international standard and promoted by the International Labour Organisation ILO-OSH 2001 Guidelines on Occupational Safety and Health Management Systems (see link below).

The safety management model components are:

- Policy.
- Organizing.
- Planning and implementation.
- Evaluation.
- Action for improvement.

Although other SMS models use different terminology, the process and workflow for safety management systems is always the same;

- Policy–Establish, within policy statements, the requirements for the organization in terms of resources, defining management commitment and defining Occupational Safety and Health (OSH) targets.
- Organizing–How the organization is structured; where responsibilities are; define accountabilities; who reports to whom; and, who is responsible for what.
- Planning and Implementation–What legislation and standards apply to our organization; what OSH objectives are defined and how are these reviewed; hazard prevention; and, the assessment and management of risk.
- Evaluation–How is OSH performance measured and assessed; what are the processes for the reporting of accidents and incidents and for the investigation of accidents; and, what internal and external audit processes are in place to review the system.
- Action for Improvement–How are preventative and corrective actions managed and what processes are in place to ensure the continual improvement process.

There is a significant amount of detail within each of these sections which exceeds the scope of this handbook. For further details see http://www.ilo.org/safework/info/standards-and-instruments/WCMS_107727/lang--en/index.htm

Transport Canada's Rail Safety Directorate incorporated SMS into the Canadian rail industry in 2001. The Rail Safety Management System requirements are set out in the Railway Safety Management System Regulations. The objectives of the Rail Safety Management System Regulations are to ensure that safety is given management time and corporate resources and that it is subject to performance measurement and monitoring on par with corporate financial and production goals. For more information on the SMS effort by Transport Canada see http://www.tc.gc.ca/eng/railsafety/publications-637.htm.

Myths about Railroad Safety Management Systems

SMS does not mean:

- **De-regulation**
  The railroad SMS would not eliminate existing regulatory requirements. Rather, the SMS would act as an umbrella requirement, enabling railroads to better meet the existing requirements of the rules, regulations and standards.

- **Self-regulation**
  The railroad SMS would not lead to self-regulation. The FRA has the mandate to monitor compliance with the regulations as it does with any other legislated requirement. While an SMS puts the onus on a railroad company to proactively demonstrate its management of safety, it would remain FRA's role to oversee the railroad's compliance with the regulations.

- **Eliminating inspections**
  Routine inspections, operational testing, and system assessments are an important component of FRA's regulatory oversight responsibilities, and they would continue to be used in the regulatory oversight of the railroads as part of the assessment of a company's SMS, and overall safety status.

- **Eliminating corrective action**
  Railroads will be required to comply with FRA's Risk Reduction Regulations. This includes the requirement for railroads to take corrective actions for any safety concerns and incidents of non-compliance identified by the regulator.

As the new Risk Reduction Regulations begin to go into effect, railroads should seriously consider adopting and implementing an SMS model that fits their operational environment. An SMS is a mechanism for organizations to learn. As an organization learns more and more about itself and its operational environment, actions can be taken that will allow the organization to move towards becoming a highly reliable, resilient organization.

In Closing

Changing an organization's safety culture seems complicated and difficult. It is! Changing the safety culture of an entire industry is even more daunting. Not only do the railroads need to change their culture, but the labor organizations and the FRA need to change. Such change is an overwhelming challenge, but consider the potential benefits or the alternative. Imagine railroads that operate safely and efficiently with less death and destruction, employees that go home after work to their families safe and whole, and a regulator that has a larger array of tools to use in fulfilling its mission to the American public. Or we can continue with the status quo and inevitably, as train traffic increases, we will see more and more of our fellow railroaders taken out of service, injured, or killed while performing their duty. We are at a decision point in time.

Modern science has given us the tools to make a change and to make a difference. We have the vision. We have the organizational capacity to do it. We have the political support to see it through. We merely have to decide to do it.

"The mission of the Federal Railroad Administration is to enable the safe, reliable, and efficient movement of people and goods for a strong America, now and in the future".

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APPENDIX A - Terms and Definitions

Active Conditions (Errors) - Generally associated with front line operators of complex systems (engineers, conductors, dispatchers, machine operators, etc.). The effects of active errors are felt almost immediately and are often easily identified.

Acute Sleep Loss - Occurs when an individual receives less than 6 - 7 hours of sleep in a 24-hour period. Sleep loss of one hour per night results in a cumulative sleep debt equal to an entire night's sleep per week.

Adverse Consequence - The negative impacts that may result from a human error or system failure. The primary concerns are loss of human life, economic loss (including property damage), and environmental impact.

Aggressiveness - Doing what an individual thinks will achieve their goals without regard for the opinions, feelings, or rights of others.

Antecedent - Factors that proceed, trigger, or influence behavior.

Assertiveness - A willingness to clearly express your opinion, while respecting the opinions, feelings and rights of others.

Barrier – A barrier is part of a defensive network designed to protect people and property from the risks and hazards associated with a particular process or task. Such defensive networks are designed to serve one or more of the following functions:

- To create understanding and awareness of a local hazard,
- To give clear guidance on how to operate safely,
- To provide alarms and warnings when danger is imminent,
- To restore the system to a safe state in an abnormal situation,
- To interpose safety barriers between the hazard and the potential losses,
- To contain and eliminate the hazards should barriers be breached, and
- To provide the means of escape and rescue should hazard containment fail.

Behavior - Observable actions that are measurable and based on attitude and culture.

Causal Chain (Error Chain) - A sequence of events that, if not arrested, resolved, or monitored, could relate to, involve, or cause a specific outcome.

Circadian Rhythm - The brain's sleep software. Circa meaning "about" and dia meaning "day." A biological clock that controls over 350 bodily functions (sleep/wake, performance, temperature, digestion, excretion, hormones, immune system, etc.). It operates on an approximate 25-hour cycle and is reset by light.

Cognitive Fatigue - A degradation of mental capacities in regard to decision-making, reason and judgment, and the ability to remember and process contextual information. This degradation can be caused by either acute or cumulative loss of <u>meaningful</u> sleep.

Communication - The flow of information among all team (crew) members. It includes the ability to interpret body language, tonality, and verbal cues. Also, it addresses the effective use of assertiveness in decision-making and problem solving.

Complacency - Complacency occurs when a person is in a comfort zone or has become indifferent to a situation, usually as a result of familiarity. Complacency can cause an individual to miss important situational cues.

Conflict - Conflict occurs when people who depend on each other (interdependency) express disagreement over an issue, or have a different *Theory of the Situation*.

Confusion - Confusion or ambiguity occurs when information is unclear, or when two or more pieces of information conflict.

Consequence - The outcome of a behavior or set of behaviors.

CRM - Crew Resource Management - A methodology that addresses the human element of people working together in safety sensitive conditions and interfacing with technology. In the railroad industry it can be considered as the effective use of all resources to achieve safe and efficient transportation related operations.

Cues - Hints or suggestions on which to act. Cues are consciously or unconsciously perceived, and they prompt a type of behavior.

Culture - The totality of socially transmitted behavior patterns, arts, beliefs, institutions, and all other products of human works and thought typical of a population or community at a given time. (See Safety Culture)

Cumulative Sleep Debt - Sleep need minus actual sleep equals sleep debt.

Decision Errors - Generally related to an error in selection of an appropriate solution to a problem. For example, applying the wrong rule to a given situation (rule-based) or deciding on a wrong course of action based on past experience (knowledge-based).

Effort-Performance Expectancy - Each behavior also has associated with it in the individual's mind a certain expectancy or probability of success. This expectancy represents the individual's perception of how hard it will be to achieve such behavior and the probability of successful achievement of that behavior.

Epworth Sleepiness Scale - The Epworth Sleepiness Scale is a self-diagnose, survey format test that allows for the measurement of sleepiness.

Equity Theory - The essence of the equity theory is that employees compare their efforts and rewards with those of others in similar work situations. This theory of motivation is based on the assumption that individuals are motivated by a desire to be equitably treated at work. The individual works in exchange for rewards from the organization.

Error – A deviation from accuracy or correctness; an expected variation from the organizational or group norm. An act, assertion, or belief that unintentionally deviates from what is correct, right or true.

Error Management - The process of correcting an error (or errors) before it becomes consequential.

Exchange Theory - A conceptual framework that provides a useful perspective for viewing the topic of motivation is the exchange theory. In a very general sense, exchange theory suggests that members of an organization engage in reasonably predictable give-and-take relationships (exchange) with each other.

Fatigue - Fatigue is often used as a catch-all term for a variety of different experiences such as physical discomfort from overworking a group of muscles, difficulty in concentrating and problems in staying awake.

High Reliability Organization (HRO) – An HRO is an organization that has succeeded in avoiding catastrophes in an environment where normal accidents can be expected due to risk factors and complexity.

Human Factors - A term used to describe a multi-disciplinary field devoted to optimizing human performance and reducing human error. Human factors are the applied science that studies people working together and working with machines and systems. It embraces both individual performance and the resulting influence on the team or crew performance.

Knowledge-based Behavior - Occurs when there is no pre-learned skill or rule to apply to the situation. This type of behavior is the result of the individual using whatever information and experience is available to solve the problem or respond to the situation. For example, a power operated switch is frozen in the reverse position in traffic control territory. While there are no rules governing this situation, the dispatcher solves the problem by reversing the switch at the other end of the siding and operating all trains through the siding.

Lapses - An unintentional memory (storage) error; an action that results from either forgetting or from remembering incorrectly. These errors occur during skill-based behaviors. For example, forgetting a step in a sequence or procedure.

Latent Conditions (Errors) - Most likely spawned by those whose activities are removed from the direct control interface by both time and space (designers, high-level decision-makers, construction workers, managers and maintenance personnel).

Mistakes - Occurs when there is an intentional (though incorrect) action. An unintentional planning error; these errors occur during rule-based or knowledge-based behaviors. For example, applying the wrong rule to a situation. The planned execution is correct, but the plan is incorrect.

National Culture - A nation's culture is the overarching framework within which all people behave. It is the shared values and attitudes of a national group that direct behavior.

Non-assertiveness (Passive) - An individual is unwilling to express their true opinion or question another person's opinions/actions that can result in sacrificing one individual's opinions, feelings, or rights.

Normal Accident - A normal accident, also called a "system accident," is an unanticipated interaction of multiple failures in a complex system. This complexity can either be technological or organizational, and often is both. A system accident can be very easy to see in hindsight, but very difficult to see ahead of time, there are simply too many possible action pathways to seriously consider all of them.

Organizational Culture - This level of culture is evidenced in such things as the openness of communication between management and employees, the commitment of resources to training and maintenance, and the attitudes and behaviors of critical role models. The level of teamwork among groups (i.e. dispatchers, conductors, locomotive engineers, maintenance personnel, and road crews, etc.) is also a part of this culture.

Organizational Factors - Factors within the upper levels of an organization that affect the culture and behavior throughout the entire firm. For example, factors that are promulgated by "bad parents" that results in "problem children," down-stream from the actual cause. In an environment where organizational factors have a negative impact on safety at the lower echelons, corrections of unsafe behavior at the individual level will have minimal impact on overall safety.

Organizational Level - Corporate scheduling or policy-making level; it includes division, regional, and corporate decision-makers (may not all be supervisory or management personnel).

Overload - Overload occurs when the amount of information being processed is either too much at once or the information being processed is significantly above the individual's ability to comprehend.

Pattern of Entrapment - A term used to describe the cause and effect of lapses, following procedures, decision-making errors, lack of situational awareness, and mistaking predictive cues through a chain of events heading to an undesirable situation.

Perceptual Errors - A perception of reality (Theory of the Situation) that is different than the Reality of the Situation. This can result in a mistake, slip, or lapse that in turn begins the causal chain.

Performance-Outcome Expectancy - Every behavior has associated with it, in an individual's mind, certain outcomes – either punishments or rewards. In other words, the individual believes or expects that if they behave in a certain way, they will experience certain consequences.

Pittsburgh Sleep Quality Index (PSQI) - The PSQI is an instrument used to measure the quality and patterns of sleep in older adults. It differentiates "poor" from "good" sleep by measuring seven areas: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction over the last month.

Pre-conditions for Unsafe Acts - Condition that, if not corrected, establishes an environment that enables and perhaps encourages unsafe acts. Common examples include poor communications, poor ergonomics, poor housekeeping, etc.

Professional Culture - This level of culture reflects the attitudes and values associated with an occupation. These include pride in the profession and liking the job.

Professional Level - Individual operator, team, or work group level. The "pointy end of the stick"

Reality of the Situation - The actual or accurate reality that is not influenced by human perceptions.

Rule-based Behavior - Depends on a system of rules that have been learned. These rules are then applied to new information as it is encountered. For example, when a train crew reduces train speed in response to a restricting signal, the crew is applying a previously learned rule to newly encountered information.

Safety Culture - The overall attitude towards safety as demonstrated by the compliance to safety policies and procedures. It is often influenced by the perception held by an organization.

Situational Awareness - Understanding the components in the environment at a particular moment in time and space, the comprehension of their meaning, and the projection of their status in the near future. Situational awareness is the resolution between the theory of the situation, the reality of the situation, and the theory of practice. It is the ability of each team (crew) member to maintain his/her awareness of the working environment, and their anticipation of circumstances that may require action.

Skill-based Behavior - Uses skills that have been learned and developed. For example, the action performed to apply the brakes of a train is a skill-based behavior.

Skill-based Errors - An action that exceeds the skill of the operator or is the result of an inadvertent act. For example, failure to see and avoid, or the inadvertent operation of controls.

Sleep, REM - "Dream sleep" characterized by quick eye movements, little to no muscle tone, and very active brain patterns. Mammals cannot regulate body temperature during REM sleep.

Sleep, Stage 1 - The transition from wake to sleep, characterized by a slowing of brain activity lasting approximately 5 to 10 minutes. When aroused from this stage, many people believe they were never asleep.

Sleep, Stage 2 - Slower brain activity than Stage 1; considered to be the true onset of sleep; first period lasting 10 to 15 minutes.

Sleep, Stage 3 & 4 - Deep sleep; it may be difficult to arouse a person from this stage and once aroused the person may feel sluggish for several minutes.

Slips - An unintentional execution error; an action that occurs through lack of attention or over attention. These errors occur during skill-based behaviors. For example, failing to respond to a hand signal because of preoccupation with another task or due to complacency.

Stress - A physical, chemical, or emotional reaction that causes tension in your mind and/or body.

System Level - Environment in which professional and organizational levels must operate.

Teamwork - Teamwork is the ability to work together productively toward a common goal. It involves directing individual accomplishment toward a group accomplishment.

Technical Proficiency - Technical proficiency is knowledge of the system, as well as procedural knowledge, and the execution of both. System knowledge is the familiarity with functions and types of equipment. Procedural knowledge is adherence to the procedures that govern the work process (e.g. the movement of trains).

TEMM - Threat and Error Management Model - Systematic methodology for analyzing the ability and capacity of an organization to mitigate the consequences of threats and errors.

Theory of Practice - A person's knowledge and skills (experiences) that are developed over time and are used to respond to *Theory of the Situation*.

Theory of the Situation - A set of beliefs about what is happening and what action(s) should be taken. It is based on the individual's interpretation of the available information. If a discrepancy (conflict) exists between an individual's *Theory of the Situation* and the *Reality of the Situation*, a loss of situational awareness occurs and an error chain begins.

Unsafe Acts - Acts that occur closest to the operation which are either errors or violations. Errors that result in unsafe acts are the result of improper information processing and are rooted in decision-errors, skill errors, perception errors, or a combination of these.

Unsafe Supervision - The actions or inactions of supervisors and managers. Inadequate or inappropriate supervision, planned inappropriate operations, failure to correct known problem(s), and supervisory violations.

Valance - Each outcome has a "valance" (value, worth, attractiveness) to a specific individual. Outcomes have different valances for different individuals. This comes about because valances result from individual needs and perceptions that differ because they in turn reflect other factors in the individual's life.

Violation – Deviation in behavior that, within a social context, is considered inappropriate. Deliberate deviations from those practices deemed necessary (by designers, managers, and regulatory agencies) to maintain the safe operation of a potentially hazardous system.

Violation, exceptional (non-routine) – A deliberate act that is a breach or infringement, as of a law, promise, or social norm. An unexpected variation from the norm. Unlike routine violations, exceptional violations appear as isolated departures from authority. They are neither necessarily indicative of an individual's typical behavior pattern nor condoned by management. For example, an isolated instance of driving 105 mph in a 55 mph zone is considered an exceptional violation. It is important to note that while most exceptional violations are heinous, they are not considered 'exceptional' because of their extreme nature. Rather, they are considered exceptional because they are neither typical of the individual nor condoned by authority.

Violation, routine - Habitual deviations from the norm, forming or representing part of an individual's behavioral character. Routine violations are often condoned by management or the work group. There are two generally recognized factors of routine violations: (a) The natural human tendency to take the path of least resistance, and (b) A relatively indifferent environment. For example, if the quickest and most convenient path to task completion is to violate a seemingly trivial and rarely sanctioned safety procedure, then the procedure will be routinely violated.

APPENDIX B - Sample Business Case

Confidential Close Call Reporting System
Business Case
(Corrective Action Name)

Railroad Name
Street Address
City, State Zip Code

Date Submitted

1. EXECUTIVE SUMMARY

This section should provide general information on the issues surrounding the safety problem and the proposed corrective action. Usually, this section is completed last after all other chapters of the business case have been written. This is because the executive summary is exactly that, a summary of the detail that is provided in subsequent sections of the document.

1.1 Issue

This section should briefly describe the safety issue that the proposed corrective action will address. This is where you would describe the performance gap in the system. This section should only address what the problem is and not the corrective action.

1.2 Anticipated Outcomes

This section should describe the anticipated outcome if the proposed corrective action is implemented. Describe how implementation of the corrective action will close or narrow the performance gap. It should include how the corrective action will benefit safety and describe what the end state, or desired state of the corrective action should be.

1.3 Recommendation

This section summarizes the approach for how the corrective action will address the safety problem. This section should also describe how desirable results will be achieved by moving forward with the corrective action.

1.4 Justification

This section justifies why the recommended corrective action should be implemented and why it was selected over other alternatives. Where applicable, quantitative support should be provided and the impact of not implementing the corrective action should also be stated.

2. BUSINESS CASE ANALYSIS TEAM

This section describes the roles of the team members who developed the corrective action.

3. PROBLEM DEFINITION

3.1 Problem Statement

This section describes the business problem that this project was created to address. The problem may be process, technology, or product/service oriented. This section should not include any discussion related to the solution.

3.2 Organizational Impact

This section describes how the proposed project will modify or affect the organizational processes, tools, hardware, and/or software. It should also explain any new roles which would be created or how existing roles may change as a result of the project.

4. CORRECTIVE ACTION OVERVIEW

This section describes the corrective action to include a description, goals and objectives, performance criteria, assumptions, constraints, and milestones. This section consolidates all corrective action information into one chapter and allows for an easy understanding of the corrective action since the baseline safety problem, impacts, and recommendations have already been established.

4.1. Corrective Action Description
This section describes the approach the corrective action will use to address the safety problem(s). This includes what the corrective action will consist of, a general description of how it will be executed, and the purpose of it.

4.2. Goals and Objectives
This section lists the business goals and objectives which are supported by the corrective action (if any) and how the corrective action will address them.

4.3. Corrective Action Performance
This section describes the measures that will be used to gauge the corrective action's effectiveness in correcting the problem or filling the performance gap.

4.4. Corrective Action Assumptions
This section lists the preliminary assumptions for the corrective action. For example, if the corrective action is a rules change the assumption for gaining the benefits of such a change could be that the rules change is properly communicated to the employees and that training programs are modified to incorporate the new rule.

APPENDIX C - List of Cognitive Biases

Many of these biases affect belief formation, business and economic decisions, and human behavior in general. They arise as a replicable result to a specific condition: when confronted with a specific situation, the deviation from what is normatively expected can be characterized by:

Ambiguity effect – the tendency to avoid options for which missing information makes the probability seem "unknown."

Anchoring or **focalism** – the tendency to rely too heavily, or "anchor," on a past reference or on one trait or piece of information when making decisions.

Attentional bias – the tendency to pay attention to emotionally dominant stimuli in one's environment and to neglect relevant data when making judgments of a correlation or association.

Availability heuristic – the tendency to overestimate the likelihood of events with greater "availability" in memory, which can be influenced by how recent the memories are, or how unusual or emotionally charged they may be.

Availability cascade – a self-reinforcing process in which a collective belief gains more and more plausibility through its increasing repetition in public discourse (or "repeat something long enough and it will become true").

Backfire effect – when people react to disconfirming evidence by strengthening their beliefs.

Bandwagon effect – the tendency to do (or believe) things because many other people do (or believe) the same. Related to groupthink and herd behavior.

Base rate fallacy or base rate neglect – the tendency to base judgments on specifics, ignoring general statistical information.

Belief bias – an effect where someone's evaluation of the logical strength of an argument is biased by the believability of the conclusion.

Bias blind spot – the tendency to see oneself as less biased than other people, or to be able to identify more cognitive biases in others than in oneself.

Choice-supportive bias – the tendency to remember one's choices as better than they actually were.

Clustering illusion – the tendency to over-expect small runs, streaks or clusters in large samples of random data.
Confirmation bias – the tendency to search for or interpret information or memories in a way that confirms one's preconceptions.

Congruence bias – the tendency to test hypotheses exclusively through direct testing, instead of testing possible alternative hypotheses.

Conjunction fallacy – the tendency to assume that specific conditions are more probable than general ones.

Conservatism or regressive bias – the tendency to underestimate high values and high likelihoods/probabilities/frequencies and overestimate low ones. Based on the observed evidence, estimates are not extreme enough.

Conservatism (Bayesian) – the tendency to revise belief insufficiently when presented with new evidence (estimates of conditional probabilities are conservative).

Contrast effect – the enhancement or diminishing of a weight or other measurement when compared with a recently observed contrasting object.

Curse of knowledge – when knowledge of a topic diminishes one's ability to think about it from a less-informed perspective.

Decoy effect – preferences change when there is a third option that is asymmetrically dominated.

Denomination effect – the tendency to spend more money when it is denominated in small amounts (e.g. coins) rather than large amounts (e.g. bills).

Distinction bias – the tendency to view two options as more dissimilar when evaluating them simultaneously than when evaluating them separately.

Duration neglect – the neglect of the duration of an episode in determining its value.

Empathy gap – the tendency to underestimate the influence or strength of feelings, in either oneself or others.

Endowment effect – the fact that people often demand much more to give up an object than they would be willing to pay to acquire it.

Essentialism – categorizing people and things according to their essential nature, in spite of variations.

Exaggerated expectation – based on the estimates, real-world evidence turns out to be less extreme than our expectations (conditionally inverse of the conservatism bias).

Experimenter's or expectation bias – the tendency for experimenters to believe, certify, and publish data that agree with their expectations for the outcome of an experiment, and to disbelieve, discard, or downgrade the corresponding weightings for data that appear to conflict with those expectations.

False-consensus effect - the tendency of a person to overestimate how much other people agree with him or her.

Functional fixedness - limits a person to using an object only in the way it is traditionally used.

Focusing effect – the tendency to place too much importance on one aspect of an event; causes error in accurately predicting the utility of a future outcome.

Forer effect or **Barnum effect** – the observation that individuals will give high accuracy ratings to descriptions of their personality that supposedly are tailored specifically for them, but are in fact vague and general enough to apply to a wide range of people. This effect can provide a partial explanation for the widespread acceptance of some beliefs and practices, such as astrology, fortune telling, graphology, and some types of personality tests.

Framing effect – drawing different conclusions from the same information, depending on how or by whom that information is presented.

Frequency illusion – the illusion in which a word, a name, or other thing that has recently come to one's attention suddenly appears "everywhere" with improbable frequency (see also regency illusion).

Gambler's fallacy – the tendency to think that future probabilities are altered by past events, when in reality they are unchanged. Results from an erroneous conceptualization of the law of large numbers. For example, "I have flipped heads with this coin five times consecutively, so the chance of tails coming out on the sixth flip is much greater than heads."

Hard-easy effect – based on a specific level of task difficulty, the confidence in judgments is too conservative and not extreme enough.

Hindsight bias – sometimes called the "I-knew-it-all-along" effect, the tendency to see past events as being predictable at the time those events happened. Colloquially referred to as "Hindsight is 20/20."

Hostile media effect – the tendency to see a media report as being biased, owing to one's own strong partisan views.

Hot-hand fallacy - the "hot-hand fallacy" (also known as the "hot hand phenomenon" or "hot hand") is the fallacious belief that a person who has experienced success has a greater chance of further success in additional attempts.

Hyperbolic discounting – the tendency for people to have a stronger preference for more immediate payoffs relative to later payoffs, where the tendency increases the closer to the present both payoffs are.
Illusion of control – the tendency to overestimate one's degree of influence over other external events.

Illusion of validity – when consistent but predictively weak data leads to confident predictions.

Illusory correlation – inaccurately perceiving a relationship between two unrelated events.

Impact bias – the tendency to overestimate the length or the intensity of the impact of future feeling states.

Information bias – the tendency to seek information even when it cannot affect action.

Insensitivity to sample size – the tendency to under-expect variation in small samples.

Irrational escalation – the phenomenon where people justify increased investment in a decision, based on the cumulative prior investment, despite new evidence suggesting that the decision was probably wrong.

Just-world hypothesis – the tendency for people to want to believe that the world is fundamentally just, causing them to rationalize an otherwise inexplicable injustice as deserved by the victim(s).

Less-is-better effect – a preference reversal where a dominated smaller set is preferred to a larger set.

Loss aversion – "the disutility of giving up an object is greater than the utility associated with acquiring it." (See also sunk cost effects and endowment effect).

Ludic fallacy - the misuse of games to model real-life situations.

Mere exposure effect – the tendency to express undue liking for things merely because of familiarity with them.

Money illusion – the tendency to concentrate on the nominal (face value) of money rather than its value in terms of purchasing power.

Moral credential effect – the tendency of a track record of non-prejudice to increase subsequent prejudice.

Negativity bias – the tendency to pay more attention and give more weight to negative than positive experiences or other kinds of information.

Neglect of probability – the tendency to completely disregard probability when making a decision under uncertainty.

Nonsense math effect - the tendency to judge information containing equations higher regardless the quality of them.

Normalcy bias – the refusal to plan for, or react to, a disaster which has never happened before.

Observer-expectancy effect – when a researcher expects a given result and therefore unconsciously manipulates an experiment or misinterprets data in order to find it (see also subject-expectancy effect).

Omission bias – the tendency to judge harmful actions as worse, or less moral, than equally harmful omissions (inactions).

Optimism bias – the tendency to be over-optimistic, overestimating favorable and pleasing outcomes (see also wishful thinking, valence effect, positive outcome bias).

Ostrich effect – ignoring an obvious (negative) situation.

Outcome bias – the tendency to judge a decision by its eventual outcome instead of based on the quality of the decision at the time it was made.

Overconfidence effect – excessive confidence in one's own answers to questions. For example, for certain types of questions, answers that people rate as "99% certain" turn out to be wrong 40% of the time.

Pareidolia – a vague and random stimulus (often an image or sound) is perceived as significant, e.g., seeing images of animals or faces in clouds, the man in the moon, and hearing non-existent hidden messages on records played in reverse.

Pessimism bias – the tendency for some people, especially those suffering from depression, to overestimate the likelihood of negative things happening to them.

Planning fallacy – the tendency to underestimate task-completion times.

Post-purchase rationalization – the tendency to persuade oneself through rational argument that a purchase was a good value.

Pro-innovation bias – the tendency to reflect a personal bias towards an invention/innovation, while often failing to identify limitations and weaknesses or address the possibility of failure.

Pseudo-certainty effect – the tendency to make risk-averse choices if the expected outcome is positive, but make risk-seeking choices to avoid negative outcomes.

Reactance – the urge to do the opposite of what someone wants you to do out of a need to resist a perceived attempt to constrain your freedom of choice (see also reverse psychology).

Reactive devaluation – devaluing proposals that are no longer hypothetical or purportedly originated with an adversary.

Recency bias – a cognitive bias that results from disproportionate salience attributed to recent stimuli or observations–the tendency to weigh recent events more than earlier events (see also *peak-end rule*, *recency effect*).

Recency illusion – the illusion that a phenomenon, typically a word or language usage, that one has just begun to notice is a recent innovation (see also frequency illusion).

Restraint bias – the tendency to overestimate one's ability to show restraint in the face of temptation.

Rhyme as reason effect – rhyming statements are perceived as more truthful. A famous example being used in the O.J. Simpson trial with the defenses use of the phrase "If the gloves don't fit then you must acquit."

Risk compensation / Peltzman effect – the tendency to take greater risks when perceived safety increases.

Selective perception – the tendency for expectations to affect perception.

Semmelweis reflex – the tendency to reject new evidence that contradicts a paradigm.

Selection bias - the distortion of a statistical analysis, resulting from the method of collecting samples. If the selection bias is not taken into account then certain conclusions drawn may be wrong.

Social comparison bias – the tendency, when making hiring decisions, to favor potential candidates who do not compete with one's own particular strengths.

Social desirability bias - the tendency to over-report socially desirable characteristics or behaviors and under-report socially undesirable characteristics or behaviors.

Status quo bias – the tendency to like things to stay relatively the same (see also loss aversion, endowment effect, and system justification).

Stereotyping – expecting a member of a group to have certain characteristics without having actual information about that individual.

Subadditivity effect – the tendency to estimate that the likelihood of an event is less than the sum of its (more than two) mutually exclusive components.

Subjective validation – perception that something is true if a subject's belief demands it to be true. Also assigns perceived connections between coincidences.

Survivorship bias - concentrating on the people or things that "survived" some process and inadvertently overlooking those that did not because of their lack of visibility.

Texas sharpshooter fallacy - pieces of information that have no relationship to one another are called out for their similarities, and that similarity is used for claiming the existence of a pattern.

Time-saving bias – underestimations of the time that could be saved (or lost) when increasing (or decreasing) from a relatively low speed and overestimations of the time that could be saved (or lost) when increasing (or decreasing) from a relatively high speed.

Unit bias – the tendency to want to finish a given unit of a task or an item. Strong effects on the consumption of food in particular.

Well-travelled road effect – underestimation of the duration taken to traverse oft-traveled routes and overestimation of the duration taken to traverse less familiar routes.

Zero-risk bias – preference for reducing a small risk to zero over a greater reduction in a larger risk.

Zero-sum heuristic – intuitively judging a situation to be zero-sum (i.e., that gains and losses are correlated). Derives from the zero-sum game in game theory, where wins and losses sum to zero. The frequency with which this bias occurs may be related to the social dominance orientation personality factor.

APPENDIX D – Additional Reading

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APPENDIX E – Identify Contributing Factors

Identify Contributing Factors

Review the questions listed below to dig more deeply into what occurred. What contributing factors helped trigger the incident?

Operator/Individual(s) Factors to Consider

This section looks at the many demands crew members face, working alone and with each other.

Skill Based Errors

- Was the employee distracted?
- Was there a memory lapse? Did the employee forget to take a required action?
- Did the employee attend to one part of the job and miss a different piece of task relevant information?
- Did the employee apply the wrong technique?
- Did the employee execute the correct procedure incorrectly (miss a step, skip a step?
- Did the employee execute a procedure or task that was in keeping with past practice, but inappropriate for the current situation?

Decision Errors

- Did the employee's actions misapply a rule or procedure?
- Did the employee carry out the wrong procedure correctly?
- Was the employee in a situation where there was no rule or procedure to follow or the situation about which procedure to apply was ambiguous?
- Did the employee have the knowledge, skills and abilities to carry out the job?
- Did the employee receive adequate training for the job?
- Was the crew qualified to perform the job?
- Was the work to be accomplished unclear or not well understood?
- Did the employee need to create a novel solution to complete the work?
- Was the crew experienced with this equipment, tools, and materials?

Perceptual Errors

- Did the employee fail to see, hear, or fee all the information needed to complete the job?
- Was the information needed by employee degraded, ambiguous, or incomplete?
- Did the employee misjudge the information needed to accomplish the job?

Routine Violations

- Did the employee routinely violate the rules, operating practices or procedures with good intent (e.g., to get the job done)?
- Was there meaningful enforcement of the violations involved in the event?
- Is non-compliance with the rules and procedures common?
- Did communication follow standard procedures and protocol?

Situational Violations

- Was the violation dictated by situation specific factors such as time pressure, workload, weather, or lack of equipment or resources?
- Was the employee placed in a situation where the decision involved choosing which rule to violate?

Exceptional Violations

- Was the violation an unusual or rare activity?
- Was the violation not condoned by management and vigorously enforced?
- Did something go wrong that required the employee to take an unusual step of breaking the rule?

Preconditions (Context) for operator acts

This section looks at the contextual factors that fostered, enabled, or set up the operator to make an error or violate a rule, procedure or practice.

Condition of Operators

This section addresses the individual's cognitive and physiological conditions that affect job performance.

Adverse Mental States

- Was the employee fatigued?
- Did the employee's workload impact their performance?
- Was the employee preoccupied with thoughts unrelated to the job?
- Was the employee attending to work related activities unrelated to the event?
- Was the employee's attention focused narrowly by a specific task or a warning?
- Was the employee monitoring for potential hazards?
- Did the employee's motivation or emotional state impact their ability to do the job?
- Did the employee's expectation or anticipation impact their ability to detect or attend to a potential hazard?
- Did problems outside work impact the employee's ability to focus on their job?

Adverse Physiological States

- Did the employee have any medical conditions that impacted their performance?
- Was the employee adversely impacted by heat or cold?
- Did the employee have disturbed a sleep pattern?
- Did the environment make it difficult to see, hear or feel?
- Was the employee taking any over-the-counter or prescription medication that adversely impacted them?
- Was the employee exposed to any hazardous chemicals or biological substances, during the event?

Physical/Cognitive Limitations

- Did the operational requirements exceed the physical limitations of the employees?
- Did the operational requirements exceed the cognitive limitations of the employees
- Did the employee have any visual or auditory deficits?
- Was the employee adequately trained to perform the work?
- Did they have adequate experience to operate the equipment or perform the task?

Personnel Factors

This section addresses deficiencies in coordination and communication between employees and failure to prepare for duty.

Crew Resource Management

- Did the employees conduct a job (safety) briefing?
- Did the employees coordinate effectively with each other?
- Was there a miscommunication (misunderstanding)
- Was there a breakdown in communications (equipment failure)?
- Was the message inaccurate?
- Did one or more of the employees misunderstand the communication?
- Did a member of the extended crew (dispatcher, foreman, employee-in-charge, etc.) keep information from his/her teammates?

Personal Readiness

- Was the employee adequately rested prior to performing their work?
- Was the employee impaired due to self-medication (prescription or over the counter)?
- Was the employee impacted by poor diet, drugs, alcohol or over-exertion prior to starting work?

Environmental Factors

This section looks at the physical and technological environment in which the employees work.

Physical Environment

- Was the site properly maintained (good housekeeping)?
- Did the ambient environment (temperature, lighting, space, vibration, safe paths) support the work environment
- Was the work site clean, ready for work, with safeguards in place?
- Was the site clean and free of tripping hazards?

Technology Environment

- Is the technology designed to support the work that employees need to do?
- Were safeguards in place and operable?
- Was the equipment or technology in working order?
- Were equipment inspections and audits up to date and documented?
- Was any new technology in place at this location? If so, was there proper training at this site?
- Is equipment (signage, alarms, vehicles, tools etc.) working properly?
- Did the employee have the equipment, tools, and materials they need?
- Were the limits of the equipment or technology exceeded?

Supervisory Factors to Consider

This section looks at the challenges supervisors face and the decisions they make while getting work done safely through other people.

Inadequate Supervision

- Did the supervisor provide sufficient support for the operators to do their jobs
- Did the supervisor monitor the employees' performance?
- Did the supervisor provide adequate training and resources to do the job?
- Did the supervisor track employee' qualifications to do their jobs?
- Did the supervisor allow employees to receive adequate rest?
- Did the supervisor provide current documentation (e.g., rulebooks, special instructions etc.)?
- Was the supervisor knowledgeable about how to perform the work and the procedures for doing the work?
- Was the supervisor overworked?
- Does the supervisor have time and resources to balance the competing demands to which they must respond?

Planned Inappropriate Operations

- Did the supervisor require the employee to work under excessive workload conditions?
- Did the supervisor expect the employees to complete the work in less than the customary amount of time?
- Did the supervisor enable the workload to become low enough for the employees to become complacent

Failure to Correct Problem

- Did the supervisor know about the problem?
- Did the supervisor fail to correct observed or known behaviors, conditions, or hazards?

Supervisory Violations

- Did the supervisor disregard existing operating rules, regulations or policies to allow employees to save time and/or money?
- Did the supervisor encourage employees to disregard the rules or operating practices?
- Did the supervisor fail to enforce the rules and regulations?
- Did the supervisor permit unqualified employees to work?

Organizational Factors to Consider

This section addresses senior management and executive level decisions, policies, practices, and procedures which guide railroad operations.

Resource Management

- Have organizational policies or practices impacted the recruitment, selection, staffing or scheduling of employees (including managers)?
- Have organizational policies or practices impacted training and retention of employees (craft & management employees)
- How have organizational decisions impacted the acquisition, operation and maintenance of equipment and infrastructure?
- Have organizational decisions resulted in the delay of needed equipment or infrastructure or equipment shortages?
- Have organizational decision resulted in the acquisition of equipment/infrastructure that is poorly designed or inappropriate for its intended use?
- Is there inadequate or lack of funding for safety, operational and maintenance programs?
- Do cost cutting measures impact staffing and equipment needed to perform work?
- Does senior management have time and resources to balance the competing demands to which they must respond?

Organizational Climate

- Did the organizational structure (chain of command, delegation of authority and formal accountability for actions impact the event)?
- How visible was the management presence?
- Did the frequency of management interaction with employees play a role (e.g., micromanagement or lack of supervision?
- Did the organizational policies in place support the work environment?
- How did the unofficial or unspoken rules that the employees hold about the organization impact the event?
- Are shortcuts and rule violations routinely condoned?

Organizational Processes

- Did the operational tempo, time pressure, or competing goals impact performance?
- Is the production level steady and predictable, or does it vary?
- Did pressure to meet the production level overshadow safety concerns?
- Were competing or conflicting goals involved in the event?
- How did incentives (rewards or punishment) influence people's behavior?
- Were the operational practices (rules, tasks, procedures) inadequate, ill-defined or inappropriate?
- Was the information communicated about the practices inadequate, ill-defined or inappropriate (e.g. rulebooks, paperwork, checklists, training)?
- Did the organization provide adequate oversight in the form of safety programs, hazard identification and mitigation, investigation procedures?
- Did the organization monitor the adequacy of resources and operating practices necessary for safe operation?

Change Management

- Did changes organizational structure or processes, equipment occurred?
- Has the organization recently acquired new equipment or technology?
- Is there a formal process for managing changes in organizational structure, process, technology or equipment?

Outside Influences to Consider

This section looks at how influence from outside the railroad that can affect safe railroad operations.

Regulatory Oversight

- Are the relevant regulations or laws antiquated, ambiguous?
- Are the relevant regulations or laws poorly designed or written?
- Do the relevant regulations or laws contribute to unsafe working conditions or an unsafe environment?
- Are the regulations or laws targeted at the wrong group?
- Does the regulator consistently enforce the regulation? If no, is noncompliance routine, the exception, or on purpose?

Economic/Political/Social/Legal Environment

- Did industry standards or guidelines play a role?
- Were there outside pressures, tensions, or expectations from the media, national labor management negotiations, standards setting organizations, local communities, Congress, court decisions that influenced behavior?
- How did collective bargaining agreements influence the event?
- Did passengers, shippers, suppliers or contractors contribute?
- Did the business climate impact the event?
- Did national, state, or local political figures influence the working environment or conditions
- Did media attention impact the environment in which the event occurred?
- Have changes in the workforce taken place that impacted the event?

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