Theories of Accident Causation

This article attempts to deliver explanation s of why accidents occur by analyzing the fundamental and developmental predecessors to accidental events. Accidents, events that injure people, damage property and equipment don't just happen. They are not random acts of fate that occur out of the blue. Rather accidents are the combination of events that come together to create a flow of process where a progression of events leads to a negative outcome, an accident.
The need for a theory reflects the difficulties in providing logical and rationale explanations as to actually why certain events, people, equipment interacted to generate a usually predictable negative outcome.

Over the years many academics of the safety profession have tried to bring logic to create an understanding of the underlying and contributory factors that when collide from a series of events produce the environment for an injury to occur.

A theory is: "systematically organized knowledge applicable in a wide variety of circumstances; especially, a system of assumptions, accepted principles, and rules of procedure devised to analyze, predict, or otherwise explain the nature or behavior of a specified set of phenomena."[3]

Accidents (defined) are unintended and unplanned single or multiple event sequences that are caused by unsafe acts and/or unsafe conditions and may result in immediate or delayed undesirable effects to workers.

Risk is defined as the chance of injury, damage or loss relative to the failure potential and the consequences of injuries.

3. Hazards are defined as unsafe conditions that have the potential for an activity, a situation or circumstances to produce harmful effects. It is a set conditions or a changing set of circumstances that presents a potential for injury, illness or property damage. Any element that increases the chance of loss is called a hazard.

Henrich, an early contributor, to the safety profession had several ideas about how the casual affects that produce injuries aligned to generate the negative outcome. Henrich studied 75,000 accidents and sorted the accidents by conditions:

88% or 66,000 of the 75,000 accidents were from unsafe acts
10% were from unsafe conditions
2% were unpreventable causes

This review and analysis was one of the first such studies that gave insight into exactly what is the major driver of injuries. Armed with this knowledge the safety profession can better focus resources.

Domino Theory:

Henrich further contributed to the basic understanding of accident causation by developing the widely known Domino Theory. The domino Theory holds that accidents are not random acts of fate that just happen out of the blue. This theory uses the analogy of 5 Dominos standing up of the thin base side and when one falls it will push the other down all tumbling toward injury.
The theory is designed to help practitioner identify intervention points, points that , if acted on, will yield a different outcome, a more favorable outcome such as no accident or an event that does not lead to injury or property damage. If you eliminate just one, any one of the first four Domino's that have aligned then the Domino's will not complete the sequenced fall and no injury will result. Domino Theory

- Ancestry and Social Environment (negative character traits leads to unsafe behavior can be inherited, Can be acquired

- Fault of Person (the above is why people behave in unsafe manner)

- Unsafe acts (committed by people and mechanical hazards are the causes of accidents

- Accident

- Injury

If you eliminate any one of the first four factors then you will prevent the injury.
Chain of events caused by human error lead to accidents

INSET DOMINO"S WITH LABLELS ON BOTTOM

Energy Release Theory:

Another theory that has gained respect is the energy release Theory which compares the rate of release of energy and relates to the kind of and severity of injuries. This theory focuses on the prevention of allowing energy to stores up in an uncontrolled way. The first step is to prevent the marshalling of energy by reducing the amount needed and/or providing vent release mechanisms. The next step would be to install control methods that modify the release rate which can be accomplished with the use of space (distance) and time. For example, a fixed barrier guard separates space by not allowing workers or machinery to reach a point of operation. This is a separation by space. Other control techniques include strengthen the object that may release the energy to prevent such release. For example, slings used in hoisting operations are strength tested to withstand 2 times there working load.

Multiple Causation Theory:

This theory purports that multiple factors combine in random fashion (any given order) and come together at the intersection point to produce an accident. One example of a multiple causation theory is the 4 M's which stand for:

Man
Media (environment)
Machine
Management

The analysis of these contributors is used to help identify which combinations are most likely to provide the catalyst to bring conditions together for injuries to manifest. It is important to note that this theory is one of the first that recognizes the critical role (as we now know it) that management plays in providing the essential leadership and support to execute the safety mission.

Another Multiple Causation Theory with emphasis on prevention of the negative event is the 3 E's:
Engineering
Education
Enforcement

Safety Engineering is the application of engineering principles to hazard recognition and control. An important part of safety engineering is the study of forces that are exerted on machines, men and control apparatus and the action of such exerted forces. The effects of force is related to material strength and it's ability (or lack of ability to deform when force pressure is applied.

Regarding the control of hazards, also known as a safety program, the acts of corporate authority are required to set the prevention ideal into motion:

1) Authorization- this is top management legitimization whereby it is sated and communicated that the company will work to identify and eliminate hazardous conditions.
2) Appropriation is the second needed element – where adequate resources are provided to fulfill the safety mission.

Hazard control begins with hazard recognition. Hazard Control is defined as any means of eliminating or reducing the risk of loss from the hazard that has been recognized. Just as with any program that management initiates and desires a favorable of, the hazard control process is:

1) Hazard recognition- you can’t begin to control it if you did not know it could cause injuries.
2) Define and select preventative measures
3) Assign responsibility for implementation of the selected control technique

Provide and effective means for measuring effectiveness

Human Factors Theory:

The Human factors theory of accident causation holds that a chain of events that is or was caused by consistent human error lead to an accident. Factors that lead to human error.

Factors that lead to human error are:
► Overload (action that exceeds the ability of component to handle the amount)
► Inappropriate Response
► Inappropriate Activities

Overload
Environmental Factors (noise, Distractions)
Internal Factors (Personal problems, stress)
Situational Factors (Instructions not clear/risk level to high)

Inappropriate Response
Know about the hazard but not doing anything about it.
Removing safeguards
Ignoring safety rules

Inappropriate Activities
Not trained to do the job that is being done. This is a lack of new worker orientation as to the appropriate, safe and efficient way to perform the task for which the person was hired.

Not judging the degree of risk correctly is another factor of the Human factors Theory that seek to give understanding to the decision when a person underestimates they level of risk that was associated with the current process

Accident/Incident Theory

Epidemiological Theory

Systems Theory of Causation

Combination Theory of Accident Causation

The actual cause may combine parts of several parts of several different models. It is important to avoid the tendency to try to apply one model to all accidents because "One Model Does Not Fit All".

Conclusion:

accident proneness, near miss, accident phenomenon, Risk responsibilities

Theories guide and shape our investigative menal thoughts and out physical activities to seek out more information so that we may better understand the root causes of what are the germinating factors that conspire to grow into an accident.

Accident Theory: Why Bother?

Professional: a calling requiring specialized knowledge and often long and intensive preparation, including instruction in skills and methods as well as in the scientific, historical or scholarly principles underlying such skills and methods, maintaining by force of organization or concerted opinion high standards of achievement and conduct, and committing its members to continued study and to a kind of work which has as its prime purpose the rendering of a public service.

widespread differences in individual perceptions of the accident phenomenon would become evident. If one were to ask when an accident begins and ends, and what the criteria are for establishing the beginning and the end of an accident, the range of view would increase. If you need further evidence of the lack of underlying principles in the field of accident investigation, try to apply scientific rigor to the investigator's jargon----words like human or pilot error, accident proneness, near miss, hazard, etc. Each example is a symptom of the lack of a sound theoretical basis of accident investigation.

The most persuasive argument for developing an accident theory for SASI members is that assumptions, principles and rules of procedure are nowhere systematically organized, and that generally accepted rules of procedure for analyzing, predicting or explaining the accident phenomenon are not available to the accident investigator. The ICAO manual contains procedures for organizing the investigation, its coordination and the reporting of investigative findings. But the contents do not address the underlying scientific principles, nor reflect scientific method. Knowledge of these principles is assumed to be the province of the investigators. Each investigator has specialized knowledge and technique which he brings to an investigation. In a large accident, where investigative groups are formed, the coordination of these individual skills compensates to some extent for the absence of professional principles and theories, because interactions among the group members generate hypotheses that are subject to vigorous debate. However, the principles governing the scope and development of the hypothesis are not well organized or documented. Accident investigation methods for establishing their validity are even less rigorous, and almost totally undocumented, in most modes of transportation. In small accident investigations, conducted by one investigator, even this compensating mechanism is absent.

The result is that the investigative effort is often inefficient, and may be incomplete, or may leave unresolved significant points of controversy. Furthermore, it usually does not provide scientifically rigorous contributions to the body of data from which future assumptions, principles or rules of procedure can be discovered and practiced by others in the profession.

To elaborate on this latter point, each accident can be viewed as an unscheduled and largely uninstrumented scientific experiment performed to test a hypothesis (or theory.) In this context, the experiment and all the costs of performing it----the injuries, damage, anguish, monetary loss, delays, disruptions----are wasted if the investigator has no hypothesis or theory to evaluate.

As an investigator, how do you establish the scope of your investigation? How far back in time must you delve----an hour, a day, a year, two years, five? What rules of procedure or what principles establish the beginning or end of the accident? How is one assured of enough facts in an investigation, and how are the facts to be reported distinguished from the facts that are not reported? What rules or principles govern these decisions?

Still other problems attributable to the lack of theory could be cited, including research difficulties, training deficiencies, inequitable litigation, popular misconceptions about the nature of accidents and others, but this would be redundant. The point is that if we are to be professional investigators of accidents, we need to organize the principles on which our work is based in a professional manner.

What Theories Exist Now?

Some rules and principles do exist now for the accident investigator. However, they are fragmented, occasionally contradictory, often privately communicated, usually not scientifically tested, and sometimes wholly without merit. Their systematic organization has not yet been achieved. When this organization is accomplished, the contradictions and fallacious assumptions will become evident, and gaps can be remedied.

A brief review of some of the most influential historical assumptions, principles and rules discloses the present state of accident theory.

The statistical work of Greenwood and Woods in 1919[4] and Newbold[5] suggested the "accident proneness" concept. Their work still influences some accident investigation, particularly in the police accident investigation field with its focus on license revocation or suspension proceedings which reflect this concept. Investigators still look for data in accidents that will support the idea that "conditions" such as attitudes, attentiveness and so forth "cause" accidents. This statistical work focused on static conditions and set the pattern for untold man years of research into "unsafe conditions" as causes of accidents. In aviation, Ames contributed much to perpetuation of this view.[6]

In 1936,' Heinrich[7] suggested the "domino" theory of accidents. His idea was that accidents are a sequence of events in a predetermined proceed/follow relationship, like a row of falling dominos. This view changed the thrust of investigations toward the events involved, rather than the conditions. It represented a redirection of the search for understanding of the accident phenomenon on the basis of a "chain--of--events" that had occurred.

An accident "reconstruction" approach emerged not long thereafter[89] which was refined extensively in the highway accident investigation field by Baker. The reconstruction focused on identification of the linear chain of events theory of the accident phenomenon.

About 1960, work at Bell Laboratories in missile system safety produced another breakthrough in the field.[10] This was the "fault tree analysis" method, generally credited to H. A. Watson.[11] This is a method for arraying events in a flow chart with a proceed! follow logic pattern. It provided an objective for the analytical effort in the sense of management by objectives, and it provided a procedure by which informed speculations about accident events sequences were organized in a visible, easily criticized and readily understood display. This work introduced a "branched events chains" concept of accidents through use of the "and/or" logic gates.

About the same time, air safety investigators contributed another milestone in the accident investigation field. The Civil Aeronautics Board published the first chart on which were plotted the flight data recorder (FDR) data.[12] This chart was the first display of the parallel events along a time scale, showing what can be viewed as a "multi-- linear events sequence" on which the findings were partially based. It appears to be the first to use the $time_o$ term, about which more will be said shortly. It also is the predecessor of the "multilinear events sequence theory" for the accident phenomenon.

In the latter 1960's, a medical doctor changed accident investigation approaches significantly with his insistence on an etiologic basis for looking at accident trauma.[13] Haddon also introduced a matrix of accident phases and components of the accident events sequence. This work was influenced by DeHaven's research in 1942, but it was Haddon who brought about the directions in accident research which now largely dominate the highway accident field at the Federal level.

Attempts by Surry[14] and others to organize these and other related concepts into a general accident model are indicated in the SASI Forum article. The concept of homeostasis is an essential theory for the understanding of accidents. The term is generally applied in medicine to a state of physiological equilibrium produced by a balance of functions and chemical composition in an organism. I propose this concept be extended to "activities," in the sense that an operational equilibrium is produced by a balancing of interrelated functions and capabilities in response to varying influences arising as the activity progresses toward its intended outcome.

The principal conclusion suggested is that an accident is not a single event, but rather an accident is the transformation process by which a homeostatic activity is interrupted with accompanying unintentional harm. The critical point is that an accident is a process involving interacting elements and certain necessary or sufficient conditions.

The objective of an accident investigation should be to isolate this process and prepare a description of the entire process by which the activity was transformed.

Expansion of some of the elements of my earlier accident process chart may be helpful. Maintenance of homeostasis during an activity requires a continuing series of adaptive responses to perturbations which arise as the activity progresses. To achieve the intended outcome, these perturbations must be accommodated without injury to any of the "actors" and without discontinuing the activity. For example, an aircraft crew makes many adaptive responses to external and internal influencing events during the course of a flight from one point to another, to maintain a stable flight activity within prescribed operational bounds. This is accomplished through a process of detecting the perturbation or indications of its presence or occurrence; of predicting the significance of the data detected; of identifying the adaptive action choices that would maintain homeostasis; of selecting the best adaptive action; of implementing the action selected; of monitoring the effects of the action implemented; and of deciding whether or not the adaptive response countered the perturbation sufficiently to maintain homeostasis without further adaptive response. Each step is an element of an accident process chart if the adaptive response is unsuccessful. Any breakdown in the adaptive process described can be used to identify the beginning (t_o) of the transformation from homeostasis into the accident being investigated.

This approach differs from the "last clear chance" doctrine in law, from the key event approach of Baker[15] and the "critical event" approach of Perchonok[16] in that they characterize different events in a linear events sequence. The last event in the process must be the last injurious event directly linked to one or more of the pre--existing actors in the activity. The problem of secondary harm can be treated by considering the impinged activity in the accident sequence.[17]

The product of the process' charting effort could take two forms. First, a detailed chart with all the actions by all the actors who acted in the specific accident would be generated, for all immediate users in need of a complete technical description of the accident. The second output could be an abbreviated, more generalized model, such as is found in an NTSB surface accident report[18] or in the hazardous materials field.[19] Criteria for entries on such a general process chart would depend on its use; reference 19 describes possible use for development of countermeasure strategies.

Applications of Accident Theory.

The accident process flow chart preparation seems most nearly available in air carrier investigations. The FDR charts, now routinely slotted, are often correlated with the cockpit voice recorder (CVR) data in a linear form[20] which could readily be converted to a multilinear events chart. Actions of others such as air traffic controllers, as indicated by the ATC tapes, could be added. Any gaps in the events sequence discovered by the application of the proceed/follow logic tests for any of the actors could be bridged by the use of logic tree analysis methods. On a linear scale, the same technique can be used in light aircraft accidents.

To provide an indication of the work effort involved, the following procedural steps are presented; they reflect the approximate order to be followed to produce the detailed chart.

1. Determine, in gross terms, the apparent events sequence that describes what happened, and sketch it in events chart form.

2. From this gross description, delineate the actors (animate and inanimate) whose probably were involved in the accident process, i.e., the pilot, an aircraft component, the controller, wind currents, passengers, etc.

3. Using the general process model described above, tentatively assign t_o to the point in the flight when the perturbation which transformed homeostasis occurred.

4. In a vertical column ahead of t_o list on a large chart each actor so the actions of each actor can be listed chronologically across the chart according to the time the action occurred (approximately, if necessary.)

5. Begin to record the "actions" of each actor for which supportable evidentiary data is developed. Add to these entries as new evidence is developed. Note that the search for evidence is guided by the gaps which become visible in the action sequence and the general process model.

6. Test each event pair entered on the chart against its temporal and spatial proceed/follow logic, both vertically for its relationship with actions of other actors and horizontally for its relationship to prior or subsequent actions (chronology) by that actor. This is the key method of validating assumed events or time/space relationships.

7. Where evidence of missing actions, suggested by the logic tests in step 6, can not be located, for whatever reason, construct a logic tree to identify possible predecessor events or actions, using the event or action to the right of the gap as the "top" event for the tree.[21] It is likely that evidence of one or more of the hypothesized events placed on the tree can be found to identify a "critical path." Alternatively, the use of simulators has helped to discover missing actions, or establish informed judgments about the comparative likelihood of alternative critical paths through the logic tree.

8. Insert the most likely events sequence for each actor and then test the vertical chronological or spatial relationships. Repeat the cycle if logic errors appear.

9. Compare the refined multilinear events sequence logic chart against the general accident process model, and verify t_0 and tend. Note that the cascading events or actions as harm cascades, either in series or parallel, may become very complex. These events usually progress naturally according to physical laws. The value of detailing this phase of the process may or may not warrant the level of detail if catastrophes are analyzed and the injury mode is repeated frequently.

10. Prepare a refined process chart of the entire accident.

11. Depending on the purpose of the investigation, a companion chart on which the path of correctable events flows is shown, and to which the necessary and sufficient conditions for the events to occur are added, can be prepared. This procedure provides an approach for identifying corrective actions which might be taken to reduce future risk.

Rules to govern the description and coding of the process charts have not yet been developed. Codes denoting precise events sequence pairs or sets or patterns seem to be feasible. The development of libraries of accident "process patterns" by professional investigators also seems feasible.

Such descriptions of accidents should help to dispel semantic difficulties in the accident investigation and safety field. For example, if the time required to adapt to a perturbation is less than the time it takes for the human organism to process the data and go through the physical motions of implementing the action selected, how should this be described? As human error, or human perception, diagnostic, or muscular limitations? A narrative is not very informative compared to a process chart which displays these relationships.

Expectations of an Accident Theory.

What can the application of this theory and the related charting procedures do for the professional accident investigator? Since both the theory and methods are essentially untested, prediction of the effects of their use is highly speculative. However, based on the author's experience, the following expectations appear reasonable.

1. The efficiency of accident investigations will be significantly enhanced. This will be accomplished by reducing the quantity of data needed to explain the accident, and by introducing "objectives" toward which the investigator is able to narrow his search for facts. No longer need the investigator "get all the facts" and then come home for the analysis, hopeful that he has all the data he needs.

2. It appears that "templates" of accident processes could be developed so each accident does not constitute a mystery for the investigator.[22] Accumulation of accident data in chart form would make available a "library" of accident processes for numerous purposes such as training, design, safety regulations, etc.

3. Development and adoption of systematically organized assumptions, principles and procedures by accident investigators would elevate their activities to professional status, if other considerations of a profession were met.

4. The availability of process charts would probably have a profound effect on safety research, and probably would permit the development of risk analyses based on the resultant data base and process research.

5. The visualization of the processes would be likely to change the public's concept of the nature of accidents, and changes in liability and tort concepts would be likely to follow as the nature of accidents is clarified.

What Can You Do?

Now, let us consider the purpose of a profession----the rendering of a public service. If you concur with the contention that the accident investigation field would benefit by the development of accident theory and systematically organized rules of procedure, then you can make some specific contributions.

One approach is to take the theory and procedures advanced in this paper, apply them in your work, and help to correct or refine them. Make an effort to identify----and chart----the t_0 and the perturbing, adaptive, stressing, injurious, cascading and subsiding events in the accident.

Secondly, review past accidents that you have investigated, as time permits, and identify these same events sequences in these accidents. Chart them, too. In other words, help to build the data base to support the process theory and methods.

Third, share the results of your experience, through the SASI FORUM or perhaps, through SASI, establish a mechanism for the exchange of professional criticism of these process `templates." This assumes you are not inhibited from such exchanges by your work or position. If you are so inhibited, start to try to change the constraints. Suppression of such exchanges seems contrary to one's professional interests.

Lastly, if the theories which have been suggested are unsatisfactory to you, propose your alternatives for testing by your fellow SASI members. In my view, air safety investigators are in a unique position to exercise leadership in this effort, because of the FDR, CVR and other records of actions by most of the actors involved in accidents. If you have the will, yours can become an outstanding contribution in the safety field.

This module introduces you to the concepts of assessment and analysis as they relate to the accident investigation process. We'll review some theories of accident causation and discuss the process of developing and analyzing the sequence of events occurring prior to, during, and immediately after an accident.

Sorting it all out...

We've collected a lot of factual data and it's strewn all over the desk. The task now is to turn that data into useful information. We've got to somehow take this data and make some sense of it. It's important to know that we are not just conducting an "assessment" to determine what actors and acts were present. More importantly, we're conducting an "analysis" to determine specifically how system weaknesses interacted with those actors and acts to cause the accident.

Analysis defined

Webster defines analysis as the, "separation of an intellectual or substantial whole into its parts for individual study."

When there is a workplace accident we need to separate or "break down" the accident process (the whole) into its component parts (events) for study to determine how they relate to the whole. Since the accident, itself, is the main event, its component "parts" may be thought of as the individual events leading up to and including the main event or the accident. The accident investigator's challenge is to effectively assess and analyze each event to determine if and how it contributed to the accident. To do this we need to makes assumptions about what causes accidents...why they happen.

Why accidents happen

Over the past century, safety professionals have tried to more effectively explain how and why accidents occur. As you will see below, their explanations were at first rather simplistic. Theorists gradually realized that it was not sufficient to explain away workplace accidents as simple cause-effect events. The developed new theories that better explained the complicated interaction among conditions, behaviors and systems that result in an accident. Let's take a look at some of these theories.

- **Single Event Theory -** "Common sense" leads us to this explanation. An accident is thought to be the result of a single, one-time easily identifiable, unusual, unexpected occurrence that results in injury or illness. Some still believe this explanation to be adequate. It's convenient to simply blame the victim when an accident occurs. For instance, if a worker cuts her hand on a sharp edge of a work surface, her lack of attentiveness may be explained as the cause of the accident. **ALL** responsibility for the accident is placed squarely on the shoulders of the employees. An accident investigator who has adopted this explanation for accidents will not produce quality investigation reports that result in long-term corrective actions.
- **The Domino Theory -** This explanation describes an accident as a series of related occurrences which lead to a final event that results in injury or illness. Like dominos, stacked in a row, the first domino falling sets off a chain reaction of related events that result in an injury or illness. The accident investigator will assume that by eliminating any one of those actions or events, the chain will be broken and future accidents prevented. In the example above, the investigator may recommend removing the sharp edge of the work surface (an engineering control) to prevent any future injuries. This explanation still ignores important underlying system weaknesses or root causes for accidents.

Multiple Cause Theory - This explanation takes us beyond the rather simplistic assumptions of the single event and domino theories. Once again, accidents are not assumed to be simple events. They are the result of a series of random related or unrelated acts/events that somehow interact to cause the accident. Unlike the domino theory, the investigator will realize that eliminating one of the events does not assure prevention of future accidents. Removing the sharp edge of a work surface does not guarantee a similar injury will be prevented at the same or other workstation. Many other factors may have contributed to an injury. An accident investigation will not only recommend corrective actions to remove the sharp surface, it will also address the underlying system weaknesses that caused it.

Developing the sequence of events

Our challenge at this point in the investigation process is to **accurately determine the sequence of events in the accident process** so that we can more effectively analyze the accident process. Once the steps in the process are developed, we can then study each event to determine related:

- **Hazardous conditions.** Things and states that directly caused the accident.
- **Unsafe behaviors.** Actions taken/not taken that contributed to the accident.
- **System weaknesses.** Underlying inadequate or missing programs, plans, policies, processes, and procedures that contributed to the accident.

We'll study these in the next module.

The final event in an unplanned process

When we understand that the accident is actually the final event in an unplanned process, we'll naturally want to know what the initial event was. When the initial event occurs, it effects the actions of others, setting in motion a potentially very complicated process eventually ending in an injury or illness. The trick is to take the information gathered and arrange so that we can accurately determine what initial condition and/or action transformed the planned work process into an unplanned accident process.

Remember, that in the multiple-cause approach to accident investigation, many events may occur, each contributing to the final event. For instance, if a supervisor ignores an unsafe behavior because doing so is not thought to be his or her responsibility, the failure to enforce behavior represents an event in the production process that may contribute to or increase the probability of an accident.

Each event in the unplanned accident process describes a unique:

- **Actor.** An individual or object that directly influenced the flow of the sequence of events. An actor may participate in the process or merely observe the process. An actor initiates a change by performing or failing to perform an action.
- **Action.** Something that is done by an actor. Actions may or may not be observable. An action may describe something that is done or not done. Failure to act should be though of as an act in itself.

It's important to understand that when describing events, first indicate the actor, then tell what the actor does. Remember, the actor is the "doer," not the person or object being acted upon or otherwise having something done ***to*** them. For instance, take a look at the statement below:

ARTICLE:

Incident Investigation: Rethinking the Chain of Events Analogy

A chain of events that leads to an incident seems like a good model to use in investigating accidents and injuries. But the logic behind the chain may be its weakest link.

by Allan T. Goldberg

The chain is both a tool and a symbol that is familiar to one and all. Almost inseparable from any thinking involving a chain is the notion that a chain will fail at its weakest link.

In the safety profession, we frequently use a chain analogy in describing incidents and their causation. This most commonly takes the form of relating an incident to a chain of events. Within this chain of events, we look for the weak link as a means of identifying what went wrong that allowed the incident to occur. We then very often go further and identify a specific human error that was made, and the person who made it. That person, and/or what they did or didn't do, is thought of as a weak link in the sense of a "performance" chain. Rigid adherence to this way of thinking can lead to some significant errors in improving safety performance. We can and should avoid them.

There are three main problems that this traditional thinking about the chain of events analogy can lead to:

1. The very notion of a chain invokes an image of a linear sequence and can lead to a failure to acknowledge the multivariable nature of outcomes in systems where people are involved. That is to say, there are, in fact, many different possible paths to an incident. A consequence of ignoring multivariable outcomes is the incorrect notion that any one change or interruption in "the chain" will prevent an incident. In reality, this wishful thinking is seldom the case.

2. The "weakest link" approach implies that there is only one "main" cause for a given incident, and that doing something directly to deal with that one cause will preclude a recurrence of the incident. This is very much at odds with modern thinking on multiple causation factors in virtually all incidents. It compounds the problem by tending to focus on what are commonly called direct or immediate causes, at the expense of getting to the root or underlying causes.

3. Looking almost exclusively at the weak link creates a focus on the point of failure and assumes that this is also the best and most effective point of control. The point of failure is often well removed from the best point of control. Not understanding this crucial concept is an error that can make it nearly impossible to seek out and deal with root causes of a problem and the system deficiencies that underlie those root causes. It also has significant implications towards overemphasis on behavioral approaches or any single-point intervention technique.

Every link in a physical chain is in fact only connected to one other on each end. The real world chain of events, however, has many more "options" in terms of inputs and outputs. Breaking a single "link" will not necessarily preclude the end event from occurring.

Human actions are a combination of attitudes, beliefs, moods, training, awareness and many other factors. The point being, we may not respond to a given situation today the same way we did yesterday. The key idea here is that many sets of inputs and outputs are possibilities in incident causation. We must be very careful to avoid thinking about causation in a purely linear manner.

It is not that hard to find what is apparently a single weak link in almost any given incident situation, whether it is a physical problem, a human error problem or some combination of both. In fact, it is almost too easy. Too easy, that is, in the sense that once we do find the weak link, we tend to stop looking for any other sources of the problem. It is vitally important to move past the notion that there is only one cause for an incident, or the almost congruent notion that only one thing needs to be corrected to preclude a recurrence. It is also important to note that any and all immediate or direct causes are but symptoms of more serious problems, the root causes. The failed link itself is a direct cause, the observable multiple factors leading to it are likewise, and until we ask why those are present, we can all too easily overlook the root (or underlying) causes.

Root causes are likely to apply to a whole series of potential incidents, not just one event. These root causes are in fact the key to prevention of future incidents. And contrary to what all too many people may think, human error is not one of them! Human error itself is a symptom that there are other problems in the management of the work that is taking place. These error problems themselves have root causes. When a worker makes an error or fails to follow a procedure, there are reasons that set up the situation. These are the root causes that must be found.

Corrective Action

When we look at the failed link in a chain, it can be very tempting to focus all attention on keeping that one link from failing again. How should we go about doing that? The most obvious immediate course of action might be to repair and/or strengthen that one link so that it is no longer the weak point. This sets us up for failure, for as was pointed out previously, the failure of the link is just a symptom. The difficulty is a failure to see the difference between the point of failure and the point of control. It is often necessary to design corrective actions for both places, but we need to base such a decision on careful analysis. Another way to think of this is that unless and until you are reasonably sure of all the factors leading to a problem, you can't make an effective decision on how to control the problem.

The leading writers in quality management disciplines point out that at least 85 percent of the factors leading to quality problems are the responsibility of management, yet we in the safety profession still deal with believers (particularly among the managers we work for) that a similar percentage of safety incidents are the sole result of "unsafe acts" of the workers. Errors or omissions on the part of executives and managers do not enter into this equation. Such thinking is then too often used as justification for over-reliance on single-point approaches to behavior-based safety (BBS), when in reality, there is no single point where the problem can be dealt with exclusively. By the way, please do not take this statement to be a denunciation of BBS; it is a proven and useful part of an overall approach to safety improvement.

What we cannot do is allow ourselves to think that the only place human error can be effectively dealt with is at the individual worker level. That approach to BBS falls prey to the problems inherent in misinterpreting the weak link problem. So where is the most effective point of control, if not at the point of failure? It is back where all aspects of the workplace are actually controlled, at the heart of the management system governing the organization.

Consider the following example. A large trucking company has a policy to fire any driver who has a "preventable" traffic accident. This in fact keeps that driver from having another accident (for that company), but does nothing to improve the performance of the company's remaining drivers. If the same company determines the root causes and points of control leading to the first accident, effective remedial actions will have a positive effect on all of the company's drivers. Which approach makes more sense? It depends on whether you want to address only the broken link, or the whole "chain system." Most of us shouldn't have much trouble making the most effective choice.

Avoiding Pitfalls

We have looked at three ways that the chain of events analogy is commonly misused. In each of these areas, we have seen that these problems can keep us from finding useful solutions to incident prevention. As in so many other situations, the very problems themselves contain the seeds of their own solutions. The chain analogy can be a useful tool in dealing with incidents, but only if we avoid the pitfalls to which its traditional interpretation can lead. There are key aspects to consider in making sure we get it right:

Recognize the multivariable nature of incident causation. Avoid the trap of thinking that there is only one path to an incident and that any change made along the way will provide adequate protection against recurrence.

Understand the Principle of Multiple Causes. Look for all the causes of an incident, not just at the failed link in the chain. Make sure you find root causes as well as direct causes, and don't mistake human error as a root cause.

Realize the point of failure and the point of control are not necessarily the same. Seek to understand the problem as part of the overall system, and identify where the system itself can be best controlled.

When incidents are looked at in this manner, great success can be achieved. Instead of misleading us, the chain analogy can be an effective component in our toolbox, joining timelines, Ishikawa (fishbone) diagrams, and various other analysis techniques as vital ways to help solve problems. Edmund Burke, the English political philosopher, said, "Experience is the school of mankind, and they will learn at no other." Almost all of us have experience in thinking about or using the chain analogy. We need not abandon or ignore this experience, but we do need to rethink how we use it in interpreting events. When we use the chain analogy properly, it will become a more useful way to help us find the solutions to new and ever more complex problems. Effective controls to the causes of incidents can and must be found. We can't afford to do less in a world of hazards ready to lead to serious workplace incidents.