the American Society of Safety Engineers

vol. 1, num 2 Fall 2004

THE JOURNAL OF SH&E RESEARCH

USE OF AN INDUSTRIAL SAFETY MANAGEMENT ACCIDENT CAUSATION MODEL (ISMAC) FOR CONTROLLING OPERATIONAL PRACTICES. **Dr. Eric L. Van Fleet, Chair of the Occupational Safety and Health Program at Grand Valley State University's Center for the Health Professions-Suite 200, 301 Michigan NE, Grand Rapids, MI 49503.**

ABSTRACT

Contemporary industrial operation practices often lead to significant safety and environmental losses. These losses result from various groups involved in industrial operations and failing to understand the variables involved in accident causation. The losses resulting from the industrial accidents as well as the accidents themselves are a product of failing to apply viable conceptual models to assess safety and environmental operational issues as they influence the parties involved.

This paper addresses a conceptual model (3x3x2) designed to focus on the interrelationship between elements (workers, managers, and engineers), phases (pre-contact, contact, compounding), as they are influenced by causal factors (needless levels of human errors and human inefficiencies). This (3x3x2) matrix describes the complex interaction of the above variables and how failure to factor these variables into operational decision-making can result in significant safety and environmental losses.

USE OF AN INDUSTRIAL SAFETY MANAGEMENT ACCIDENT CAUSATION MODEL FOR CONTROLLING OPERATIONAL PRACTICES

INTRODUCTION

Basic Assumption

The Industrial Safety Management Accident Causation Model (ISMACM) is based on four basic assumptions, as follows:

1. Accidents are not naturally occurring events.
2. Humans are primarily responsible for accidents.
3. The vast majority of accidents that occur need not have taken place.
4. Accidents represent the last indicator that activities are not occurring under appropriate conditions.

Model Standards

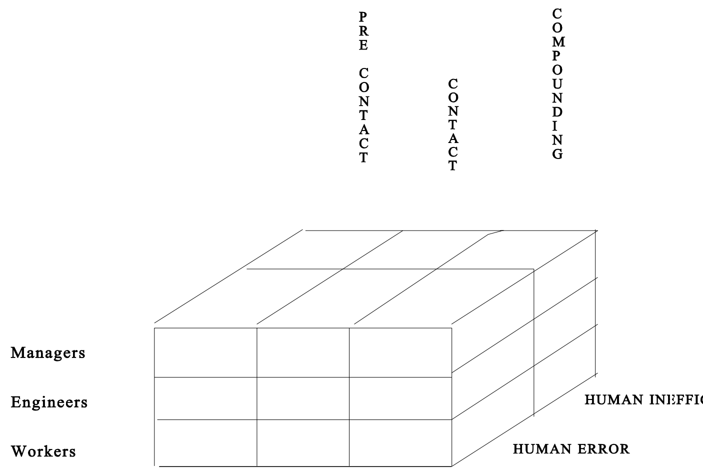
For any conceptual accident model to have value there are certain standards the model should meet. First, the model should be simple in its construction. The more complex the model, the less value it will serve in helping its user to understand accidents and apply the concepts of the model to real world situations. Secondly, the model should be general enough to apply to a wide variety of accidents in various industrial settings. Failure to conform to the second condition puts the findings of the model in jeopardy as it relates to issues of validity and reliability. If the model is not valid or reliable, application of its findings will have no value. Finally, the model should permit the user to translate its information from theory to practice. This final standard is best measured based on how it gets the user to ask questions, and how the answers to those questions translate into practices that significantly reduce the probability of future accidents and their associated losses.

It is the intent of this paper to examine the usefulness of the Industrial Safety Management Accident Causation Model (ISMACM), in meeting the aforementioned standards. To the extent that it meets those standards the model should provided its users a clearer picture of what accidents represent and what humans can do based on what accidents represent.

ISMACM

Diagram 1 depicts a 3x3x2 matrix intended to focus attention on the interrelationship between key elements (managers, engineers, and workers), phases (pre-contact, contact, and compounding phases), and causal factors (human error and human inefficiency).

Diagram 1



The role of the model is to provide the user a base from which to formulate comprehensive questions. Such a conceptual approach will provide a more comprehensive foundation from which to base decisions on what represents an accident, why accidents take place, and what humans can do to reduce the negative impact of accidents on the work environment.

Fundamental Relationships

ISMACM is based on a significantly different perspective of accidents and their relationship to activities. ISMACM functions on the premise that all activities proceed from a series of planned secondary events and their planned energy exchanges to a predetermined primary event. It is the intent of the activity to meet with success and be eligible for the gains and losses associated with the success of the activity. An accident, on the other hand, initiates with a primary event (which is unplanned) and proceeds through a series of secondary events until all energy associated with the contacts is dissipated. Since the accident is not planned, neither are its secondary contacts or their energy exchanges. The energy exchanges setup conditions for needless losses.

An activity, by definition, represents a task involving various hazards that is performed by one or more individuals. The intent of reaching the primary event of an activity is to be eligible for the gains and losses that come from meeting with success or failure in the activity. The activity proceeds from a series of secondary events and their planned energy exchanges to a predetermined primary event. An event, by definition, is marked by the initial contact between two or more hazards. Hazards, by definition, simply represent tangible objects (see TERM & Definitions, page 7-8). The purpose of the secondary events is to exchange energy in a predetermined way in order to proceed to the primary event. The primary event represents the final contact between hazards in the given activity and its contacts produce a final set of energy exchanges. Reaching the primary event opens the door for success/failure associated with the activity and a given set of gains and losses associated with success/failure.

Activity Example

Diagram 2 (page 9) depicts key components involved in the removal of an elevated catwalk. To be involved in such an activity important planning and execution of planning would have to occur between management, engineering, and the affected workers prior to and during the activity. If the planning and execution occurs at the level it is supposed to occur at, an accident could only occur under the conditions of chance. Accident investigations show that most accidents occur well outside the conditions of chance.

At the completion of the activity, under success conditions, the catwalk would be removed and relocated to a predetermined site under predetermined conditions. Under failure conditions, the catwalk would not be relocated to the predetermined site under the predetermined conditions.   Typical gains associated with the success of this activity would include removal of the unwanted catwalk from the selected work area, increased overhead workspace, etc. Typical losses associated with the success of this activity would include costs associated with the removal of the catwalk, materials used to remove the catwalk, etc. The activity would involve the following key hazards: Maintenance Worker One, Maintenance Worker Two, Forklift Operator, Forklift, Tines, Catwalk Components (each component represents a hazard), Pallet, and Ground (surface of storage site). The activity would have to proceed from key secondary events to the predetermined primary event. Before the activity started the planning would require knowledge of what hazards needed to contact each other, what types of energy exchanges would need to take place as a result of the contacts, what order the contacts would follow, and what the final event (primary event) would look like and what energy exchanges it would produce. The purpose of the primary event is to mark the end of a given activity. Which secondary events and primary event needs to be evaluated is based on the activity and the need to know. Interest does not require the listing of all contacts (events) only key events and their needed energy exchanges.

Accident Example

In diagram 2 conditions for catwalk removal were set. Also depicted in diagram 2 is a second primary event flowing down from the activity sequence. The second primary event is not part of the original activity and can only occur outside the conditions of chance when the level of planning and execution of the original activity does not occur at appropriate levels. In this situation, a forklift is left running unattended. Additionally, the forklift has not received proper maintenance so the automatic shutoff switch is non-operational. The unattended forklift shifts into reverse and backs into a maintenance worker pining the worker between the forklift and a wall. It can be said that at the point in which the forklift and worker make initial unplanned contact an accident has occurred. The primary event of an accident determines the label. If the contact is unplanned at the primary event it is an accident, if not, it is just a poorly planned or poorly executed activity. It is extremely important in this model to note that loss does not determine if an accident occurred. The issue is not was the energy exchange planned for. The only issue of importance is was the contact planned for. In diagram 2, the accident point is suggested between secondary event 4 and secondary event 5 of the activity. Once the unplanned contact occurs, energy must be exchanged. It is during the energy exchange phase of the accident (Compounding Phase) that actual loss is determined. Based on the losses that follow a determination of whether the accident interrupts or terminates the activity will be made.

Significant to the activity/accident examples is the fact that the accident could not have occurred if it were not for a decrease in the needed planning and execution appropriate to the activity. As such, there must have been problems with the setup or execution of the activity that opened the door for the accident and its associated losses. It is equally important to note that in the activity=s normal set of losses, injury to a worker was not a normal loss.

Model Component
Elements

Running down the left side of the ISMACM matrix are elements (Managers, Engineers, and Workers). Elements represent major human groupings that can introduce needless levels of human error (HE) or human inefficiency (HI) into any given activity. It is the introduction of these needless levels of HE/HI by one or more of the elements, which first leads to the degradation of the activity and, if unchecked, eventually leads to an accident. The intent of focusing on the elements is not for the purpose of assigning fault. Rather, emphasis should be placed on how each group can introduce needless levels of HE/HI into an activity. Once one understands how each element can introduce needless levels of HE/HI, countermeasures can be developed that significantly reduce such contributions.

Each element is influenced by its interactions or lack of interaction with one or more of the other elements. How one element interacts on another (in this model) is a critical issue. Each interaction among and between elements is dependent upon the phase the element is in and the needless levels of human error and human inefficiency the element is permitted to introduce into that phase of the activity.

In the past emphasis has been placed on blaming workers for accidents. Although this is a simple approach it represents a significant level of ignorance on the part of the fault seekers. Competent accident investigations over the years have consistently demonstrated that control over accidents rests primarily with existing management and engineering practices. Application of Management Oversight Risk Tree (MORT) has found that management consistently introduces conditions that eventually translate into accident conditions. Fault-Tree Analysis has been able to consistently link engineering oversights that have set up conditions for accidents. To suggest that workers are merely victims of accidents would also represent ignorance. Each group, in their area of control within an activity, often introduce needless levels of human error/human inefficiencies (HE/HI). These HE/HI=s, degrade the activity and open the door for accidents. The more the activity is degraded by these groups, the worse off the activity is and the greater the odds that an accident will occur. Each group introduces these unwanted conditions often unaware that they are doing so until faced with the unwanted or unexpected losses. It is important to note that whether an accident occurs or not, the simple needless downgrading of an activity drives up the cost of doing business.

Model Component
Phases

There are three phases running down from the top of the ISMACM matrix. The three phases are pre-contact, contact, and compounding, respectively (concepts originally suggested by William Haddon in the 60’s). The phases represent three distinct areas of impact on activities and accidents. Although the phases are not mutually exclusive (each phase flows into the other) each is mutually exclusive of the other when it comes to the application of countermeasures.

The pre-contact phase, of an accident, is that phase in which conditions are set that can either reduce the chances of an accident taking place or increase the chances of an accident taking place. The more that needless levels of human error/human inefficiency are permitted into the setup of the activity, the greater the odds the activity will fail and the greater the probability of an accident. From an accident prospectus, mistakes made in the pre-contact phase, by one or more elements, sets hazards on an unplanned collision course. The pre-contact phase is critical to the development of prevention countermeasures.

The contact phase represents that phase of an accident in which the conditions for probable loss are established. The contact phase sets the criteria for probable energy exchange between contacting hazards. It is important to note that from a conceptual point of view, the contact stage does not involve energy exchange. The contact phase is the point at which hazards make initial contact. All the energy that is to be exchanged is present, but none of the energy is released in this phase. It is also important to note that this is the phase, which determines if the label accident should be used. If the hazards make initial contact in an unplanned state, the contact can be called an accident. If the hazards make initial contact in a planned state, the label accident cannot be used. The contact phase is critical to developing severity reduction countermeasures designed to reduce probable loss.

The compounding phase represents that phase of an accident in which energy is exchanged between hazards. It is this phase that determines actual loss and sets the stage for compounded losses. Actual loss will be based on how the hazards dissipate their respective energies over time and space. The general rule is that hazards that dissipate their energy over a lot of time and space will suffer the least losses. Conversely, the hazards that dissipate their energy over a short time and space will suffer the greatest losses. The energy exchange between hazards is further influenced based on the density of the hazards involved and the initial points of contacts between hazards. The compounding phase is critical to developing cleanup countermeasures designed to return hazards back as close to their original condition as is reasonable and desirable. Additionally, this is the phase in which losses can compound as a result of failing to cleanup in a timely fashion. As such additional cleanup countermeasures must be developed and implemented which reduce the chances of compounding conditions. Example, if a worker sustains a broken arm as a result of an unplanned contact with a moving rod, the cleanup countermeasure would require setting the broken arm if the conditions of reasonable and desirable can be met. An example of a compounded loss would be waiting too long before administering competent first aid resulting in the injured party going into shock (a compounded loss). Shock can escalate into death a further compounding of the original losses. If the injured party goes into shock, it is important to note that shock was not part of the original losses. It set in afterwards and produced its own energy exchanges.

Model Component
Causal Factors

Interwoven among and between the elements and phases are causal factors. Causal factors represent needless levels of human error (HE) or needless levels of human inefficiencies (HI) that are permitted to enter into an activity. These needless levels of HE/HI are introduced as a result of elements failing to properly plan and execute an activity. All activities can tolerate a certain amount of HE/HI without significantly affecting either the activity or its intended outcomes. The more complex the activity, the less HE/HI it can tolerate. A concept called the Margin of Error sets the limits by which a given activity can meet with its normal success/failure ratio. The Margin of Error also establishes the amount of HE/HI that the activity can tolerate. As the boundaries of the Margin or Error are approached, the activities success/failure rate begins to shift. This shift reduces the chance of completing the activity under desired conditions. Additionally, the shift increases the chances of unplanned contacts between hazards that can result in an accident.

There are three basic types of Human Error, they are:

1. Ignorance - One does not have the necessary knowledge to engage in the activity.
2. Pseudo Knowledge - Ones does not have the necessary knowledge to engage in the activity, but believes they have the knowledge.
3. Imprudence - One has the necessary knowledge to engage in the activity but due to faulty thinking has convinced herself or himself that he or she is the exception to the rule.

Needless human error contributions result when humans mistakenly design into or fail to design into an activity, those conditions that would keep the activity at acceptable risk levels. Once needless levels of human error are predicted or identified, countermeasures can be developed to reduce their odds of contributing to an accident or its associated losses. More importantly, identification and removal of needless human errors, prior to the initiation of an activity, can bring an activity to its appropriate functioning level. Under these conditions an accidents can only occur by chance.

Human Inefficiency (HI)

There are two basic types of Human Inefficiency, they are:

1. Mental inefficiency - A condition, short term or long term in nature, which indicates that the human element, in the activity, does not have the mental capacity to deal with the information that must be processed in the activity. Note: This is not a measure of knowledge, rather it is a measure of how much the person can absorb or process in a given situation. (i.e.: a person who cannot concentrate in a task that requires concentration because the person has a headache.)

2. Physical/biological inefficiency - A short term or long term descriptor of the human component which identifies the physical/biological incapacity to mix with the other elements involved in a given activity. (i.e.: a person with 20/200 vision suffers a sight inefficiency in all activities that require 20/20 vision.)

Needless levels of human inefficiency (HI) are reached when humans fail to consider individual or species limitations when choosing to mix with other hazards in a given activity. Needless levels of HI are reached often as a result of introducing needless levels of HE. Remember, all activities have HE and HI in them, so the goal is not their removal. The goal is to remove needless levels of HE and HI in an activity. The reason behind this is that it is the needless levels of HE/HI that consistently lead to significant alterations of an activity, which unchecked ultimately lead to accidents.

Each condition (HE or HI) can be present in a given activity on one of two levels. Level One tells the investigator that the errors or inefficiencies were characteristic only of the individual(s) directly involved in the activity. An example of this might be a person spraying a pesticide without protective clothing. If the person was trained in the use of protective clothing but thought they did not need it this time, then that person would have committed a human error. The inability for the human lungs to neutralize the impacts of the pesticide would be a Level Two human inefficiency. Level Two HEs or HIs, tell the investigator that the errors or inefficiencies would be characteristic of any individual placed in the activity. There is no such thing a as a single HE or HI degrading an activity or creating the conditions for an accident. It is the investigator's task to identify all needless levels of HE/HI present in each phase. It is also the role of the investigator to identify the different groups (elements) that introduce the needless levels of HE/HI.

Countermeasures

Countermeasures are programs, policies, procedures, tools, etc., intended to make changes within elements that will off set human errors or human inefficiencies that will cause inappropriate interactions between hazards in a particular phase of an activity. Note the focus is to alter the activity not the conditions of an accident. The reason for this focus is based on what the model already suggests. That is, that accidents are the byproduct of poorly planned or poorly executed activities. As such, improve the planning and execution of the activity and you not only reduce the chances of an accident but increase the chances of the activity occurring under the desired conditions it was suppose to occur under.

The extent to which any given countermeasure does its job determines the likelihood that an activity will take place within its intended design parameters. Removing or limiting the impact of needless levels of HE/HI, increases the probability of completing a given activity under its design parameters and decreases the probability of experiencing an accident. For example, a management policy (i.e.: Lockout/Tagout Policy) designed to prevent contact between the worker and an energy source such as electricity. This policy represents a pre-contact countermeasure intended to insure an appropriate interaction between the worker and the hazards the worker is suppose to contact, while removing the hazard (i.e.: electricity) the worker is not suppose to contact. Note: this countermeasure by itself will not insure appropriate work practices. Use of personal protective equipment, such as earplugs, when entering a high noise work zone, represents a contact countermeasure. The countermeasure is intended to restrict the amount of harmful noise that reaches the worker. Again, this countermeasure by itself will not reduce hearing loss from noise exposure. Providing first aid training to supervisory staff is intended to reduce the chances of shock setting in on a injured human represents a cleanup countermeasure. Again, this countermeasure by itself will not insure appropriate first aid treatment. It is the application of numerous countermeasures in each phase that offers the opportunity to return the activity back to its appropriate planning and execution levels.

Model Role

It is the intent of the model in each phase to identify those human errors/human inefficiencies (HE/HI) that will degrade the activity and to implement appropriate countermeasures that will offset the degrading of the activity. This is achieved by developing the skills to ask questions that will provide insights into what levels of HE/HI the activity can tolerate within a given phase. The questions should also provide insights as to the most typical ways the HE/HI levels can needlessly increase. This is important because accident research support the fact that it is common errors and inefficiencies that lead to accidents rather than the myth of freak levels of HE/HI.

Since the intent of each phase is to identify the critical variables that typically influence the elements of that phase, it is important to identify the types of questions that should be asked. The following questions are examples of the difference in focus between each phase.

Diagram 2 (page 9) represents an activity that resulted in an accident. The activity, as mentioned before, involved removal of an overhead catwalk. The activity required two maintenance workers (one stationed on the catwalk and one stationed on the ground) to disconnect and relocate catwalk components. It further required a forklift operator to provide a platform on which the components could be placed, lowered, and then removed for storage. During day two of the activity, the forklift operator dismounted the forklift, leaving the engine idling in park. The interlock safety switch located under the operator=s seat was designed to shut the forklift down any time the operator was not seated. The safety switch had been inoperative for several days. During one of the dismounts by the operator, the shift lever moved into reverse and the forklift began to move backwards. The maintenance worker on the ground had his back to the forklift and was unaware of it approaching. The forklift backed into the maintenance worker catching the worker between the forklift and the wall. The resulting energy exchanges caused the death of the maintenance worker.

Based on the activity/accident in diagram 3 the following Pre Contact questions could be asked.

1. What was the minimum level of knowledge each worker needed to perform his or her job correctly?
2. What practices did management have in place to see to it that each worker had the appropriate knowledge level?
3. What design components had engineers accounted for to make sure the job was performed under the appropriate work conditions?
4. What do engineers need to know to make sure the appropriate tools and equipment are available for job use?
5. What do managers need to know to make sure jobs are managed correctly?
6. What typical human inefficiencies would produce inappropriate work practices on the part of the worker?
7. What typical human inefficiencies would permit engineers to overlook inappropriate designs in equipment?
8. What typical human inefficiencies would cause managers to skip important safety practices?

The answers to these questions and others will lead to a list of additional questions to be investigated. The answers will also provide a list of desirable and undesirable conditions that will lead to probable closing. When the questioning process is complete for this phase, a ranking can be established thus permitting the conditions for appropriate risk assessment. For each set of unwanted closing conditions countermeasures must be identified, field tested, and evaluated, to determine their effectiveness in preventing such closing conditions. The need for such an approach can be illustrated in the unacceptable interactions that resulted between human, pesticide, pest, and environment when DDT was used to increase crop production in the U.S. To this day, its use still poses real threats to hazards not targeted for closings with DDT, namely humans. (Kaul et al, 1994; Kashyap et al, 1994; Jacobson et al, 1992; & Earthwatch, 1994)

In the pre-contact phase the countermeasures= approaches used to offset undesired closing conditions are represented by the terms: elimination, modification, or containment. If elimination is selected, one or more elements must be removed from the activity or relocated some-where-else in the activity. This approach reduces the likelihood of unplanned closings. If for example, in the catwalk removal activity, conditions mandate that production workers be absent from the work area, the countermeasure would be to eliminate production workers from the work area until the catwalk removal activity was complete. When modification is selected, as an approach for reducing the changes of an unplanned contact between elements, one or more of the elements must be modified. Modification means that the element itself has been changed in some way. If an agent is added to a pesticide to give it a particular smell, to help people avoid the pesticide, it can be said that the pesticide has been modified for prevention. A third approach, called containment, requires placing a barrier around one or more of the elements to restrict unplanned closings with other elements. The storing of pesticides in puncture resistant containers significantly reduces the chance of the pesticide escaping and mixing with elements it is not intended with which to mix. In this instance, the storage container serves as the containment countermeasure. When applying a pesticide under certain environmental conditions is important (to restrict the area the pesticide covers, for example), the restrictions of application themselves become a form of containment. The use of elimination, modification or containment as an approach to prevention, permits application of any one or all these approaches to any given element.

Based on the activity/accident in diagram 2 the following Contact questions could be asked.

9. If hazards were permitted to make contact, at what points would the hazards contact each other?
10. What role would the density of a given hazard have on setting loss conditions?
11. What types of energy would be involved in the contact?
12. How much time and space would each hazard have to dissipate its energy?

The answers to these questions and others will give the investigator a picture of probable losses each element can be expected to experience. Once the probable losses have been assessed, countermeasure programs can be identified, developed, and tested to see if they significantly bring down the probable losses. The countermeasure programs will address the issues of energy, density, points of contact, time, and space. The countermeasure approach will involve the issues of elimination, modification, or containment. As in the pre-contact phase, one or more of the approaches can be applied to a given element. In the contact phase, however, the use of these approaches will be to bring down loss to a given element. An example of the approach elimination might be to remove the human element during the application of the pesticide. Here the removal of the human is intended to reduce overall loss, during the critical toxic application stage. If modification were selected, one might dilute the concentration of the pesticide to reduce loss should the chemical come into contact with non-targeted life forms. If a particular nozzle were used to concentrate the spraying of the pesticide, so that its coverage could be better controlled, the nozzle would serve as a containment barrier designed to reduce loss. As with prevention, any combination of these approaches may be used on a given element to reduce loss.

Based on the activity/accident in diagram 2 the following Compounding questions could be asked.

13. What would it take to return the hazards back close to their original conditions?
14. What countermeasures would need to be in place to keep loss to a given hazard from compounding?
15. What typical kinds of compounded losses could one expect if the original loss is not handled in a timely manner?

The answers to these questions and others will give the investigator: 1) measures necessary to cleanup the original incident properly, and 2) probable conditions for compounding. Once these conditions and the variables necessary to support them have been determined, countermeasure programs can be identified, developed and evaluated, to decide: 1) If proper cleanup can be accomplished. 2) If the conditions for compounding can be significantly reduced. The countermeasure program(s) will result in the use of the approach=s elimination, modification, or containment. (NOTE: it is important that this step not be seen as severity reduction. Severity reduction can only be applied under the conditions that set original loss. In this phase, original loss has already taken place. The effort is now focused on preventing an escalation of loss.) An example of elimination applied in this phase might be the use of a pesticide that will breakdown at a rate that significantly reduces the chances of it reaching toxic levels in the human. An example of modification might be altering the pesticide in such a way so that it cannot be absorbed in animal tissue. An example of containment might involve placing a barrier around the contaminated area until it has a chance to dissipate such that it no longer poses a problem.

All countermeasures used to address elements and phases must factor in the human error and human inefficiency portion of the equation. Failure to factor in these causal factors, in the development of countermeasures, is a guaranteed way to experience a failure in an activity and an accident.

Summary

If we have learned anything from accidents of the past, it is that the actual variables responsible for them are few and are consistent with those that will produce accidents in the present and future. The role of a model such as this is to provide the investigator tools that can be used to take what has been learned from the past and apply it to new conditions in the present. The value of such an effort is that it allows the investigator to assess what might go wrong and what losses it will produce. This information can be used to develop countermeasures to prevent such incidents or reduce their associated losses in the future. Humans can no longer permit accidents to tell them they failed to ask the right questions. Models, such as this, must help its users focus on the correct set of variables by learning to ask the correct sets of questions. They must teach users what questions to ask and how to understand the answers.

TERMS & Definitions

The following terms and definitions are provided to aid the reader in understanding ISMACM.

ACCIDENT: An incident in which two or more hazards make initial contact in an unplanned state.
ACTIVITY: A task involving various hazards that is performed by one or more individuals. Activities are planned and proceeds from a given series of planned secondary events to a predetermined, planned primary event.
AFTERMATH: The by-product resulting from the energy exchange when hazards make contact. The byproduct may be positive, negative or a combination of the two.
CAUSAL FACTOR: Any variable that contributes to an incident or its aftermath.
CLEAN-UP: A countermeasure concept which attempts to return hazards back to their original condition and attempts to keep the original loss from compounding.
CLUE: A piece of information that provides insights about the hazard, energy or activity.
CONTAINMENT: A sub-countermeasure concept that suggest that placement of a barrier around a given hazard will alter its interaction with other hazards.
COUNTERMEASURE: A process that employs policies, programs, tools, etc., intended to significantly impact, hazard(s), event(s) or its/their aftermath(s) by altering the risks levels associated with the activity.
ELIMINATION: A sub-countermeasure concept that suggests the removal of a hazard from a given environment or its relocation within the environment will alter its interaction with other hazards.
EVENT: A condition in which two or more hazards have made initial contact.
HAZARD: Any tangible object that has the potential to complement/interfere in the performance of a task. The object must posses closing and collision potential.
HUMAN ERROR An act or condition of ignorant or imprudent deviation from a code of behavior in a given task or sub-element of a task.
HUMAN INEFFICIENCY: The physical or mental inability to perform a specific task or sub-element of a task.

INCIDENT: A concept that suggests hazards have made contact but the conditions of the contact and aftermath are uncertain until investigated.
MARGIN OF ERROR: A concept that defines the degree of freedom in a task beyond which the human errors or human inefficiencies significantly increase the odds of task failure.
MODIFICATION: A sub-countermeasure concept that suggests that if a given hazard is modified a certain way it will alter that hazards interactions with other hazards.
PREVENTION: A countermeasure concept that attempts to keep given hazards from making initial contact with each other.
RISK: A quantitative expression of the probability of success/failure or gain/loss.
SEVERITY REDUCTION: A countermeasure concept that attempts to reduce probable loss when hazards exchange energy.

REFERENCES

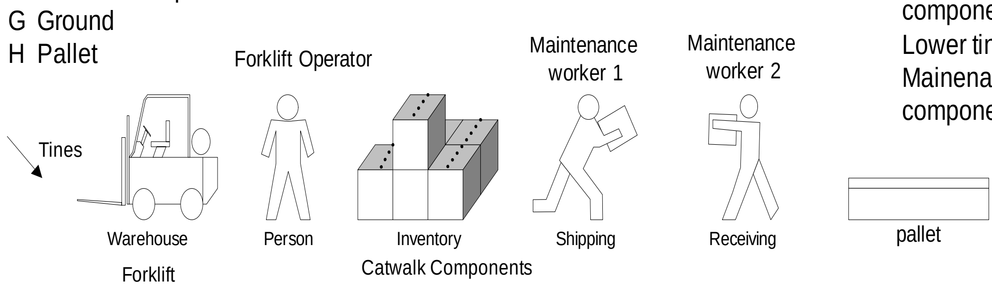
- F.E. Bird & G.L. Germain. (1996). Practical Loss Control Leadership. Det Norske Vista, U.S.A. (1-26).
- J. Suchman, et al. (1966). ABehavioral Approaches to Accident Research.@ Association for the Aid of Crippled Children. New York, New York.
- E.L. Van Fleet. (1995). AUse of an Environmental Safety Model for Dealing with Contemporary Pest Control.@ International Conference on Contemporary Pest Control Practices In Relation to Environmental Safety White Papers. Mansoura-Egypt.
- Earthwatch. (1994) Long-banned chemicals found in New England forest. Earthwatch, March-April 1994, Findings, 3.
- Jacobson, J.L.; Humphrey, H.E.; Jacobson, S.W.; Schantz, S.L.; Mullin, M.D.; & Welch, R. (1989) The American Journal of Public Health, 79(10) 1401-1405.
- Kashyap, R.; Iyer, L.R.; & Singh, M.M. (1994) Evaluation of daily dietary intake of dichloro-diphenyl-trichloroethane (DDT) and benzene hexachloride (BHC) in India. Achieves of Environmental Health, 49(1), 63-67.
- Kaul, S.M.; Sharma, R.S.; Dey, K.P.; Rai, R.N.; & Verghese, T. (1994) Impact of DDT indoor residual spraying on Phlebotomus argentipes in a kala-azar endemic village in eastern Uttar Pradesh. Bulletin of the World Health Organization, 72(1), 79-81.

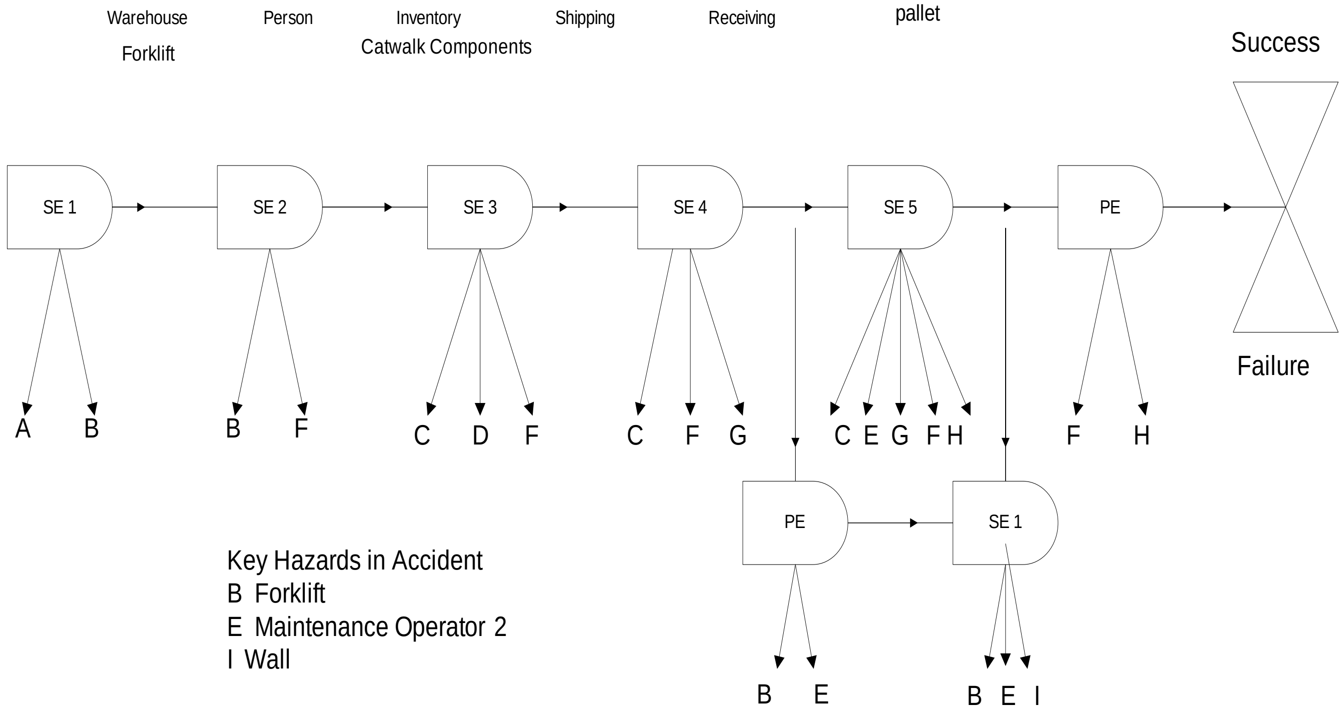
Attachment A
Diagram 2
Activity/Accident
Removal of components of an elevated catwalk.

Key Hazards
A Forklift Operator
B Forklift
C Tines
D Maintenance Worker One
E Maintenance Worker Two
F Catwalk Components
G Ground
H Pallet

GOAL: Proper removal of catwalk components

Key Tasks
Raise Forklift tines to elevated catwalk
Maintenance Worker 1 to load catwalk components onto tines
Lower tines to ground
Mainenance worker 2 to unload components onto pallets





Key Hazards in Accident
B Forklift
E Maintenance Operator 2
I Wall