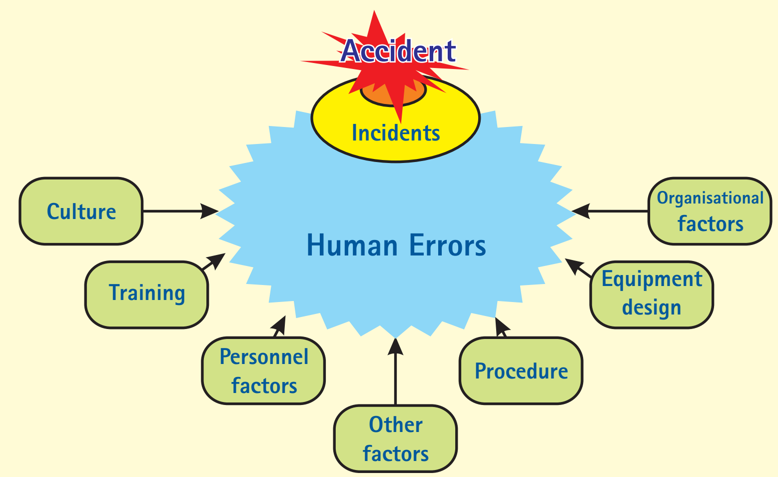
Theme – 7

Human Factors vs Accident Causation

industrial Disaster Risk Management



On behalf of
Federal Ministry
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Since inception, DMI has built vast experience in preparation of both On-site and Off-site Emergency Management Plans, Safety Audit, Risk Analysis and Risk Assessment, Hazard and Operability Studies (HAZOP), etc.
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It is a matter of pride that NDMA has selected DMI for conducting Mock Exercises on chemical (industrial) Disaster Management at key industrial locations in the country.
The Ministry of Environment and Forests, InWEnt and gtz-ASEM Germany have recognized DMI as a Nodal Training Institutes for capacity building in industrial Disaster Risk Management.

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Contents

This module helps in understanding the importance of the role of human being in industrial accidents. Module highlights how and why mistakes at human level lead to accidents and disasters. It also deals how the human errors can be reduced in reducing the possibilities of the accidents and disasters.

1. Background

"It has been estimated that up to 90% of all workplace accidents have human error as a cause" by a number of studies.
The term 'human failure' is used in this module to refer to errors and violations, newspaper headlines tend to use 'human error' as a blanket term for both.

Human error was a factor in almost all the highly publicised accidents in recent memory. The costs in terms of human life and money are high. Placing emphasis on reducing human error may help to reduce these costs. The module provides an insight view about the causes of human errors and suggests the way to reduce the errors.

2. Review of some of the accidents

Over the last few decades we have learnt much more about the origins of human failures. The industries/organisations must consider human factor as a distinct element to be assessed and managed effectively in order to control risks. Some of the following accidents of Table 1 in different sectors (blue in colour) provide clues to understand failures:

Table 1

Accident, industry and date	Consequences	Human contribution and other causes
Three Mile Island Nuclear industry 1979 (Nuclear industry)	Serious damage to core of nuclear reactor.	Operators failed to diagnose a stuck open valve due to poor design of control panel, distraction of alarms activating, inadequate operator training. Maintenance failures had occurred before, but no steps had been taken to prevent from recurring.

King's Cross Fire Transport sector 1987 (Transport sector)	A fire at this underground station in London killed 31 people.	A discarded cigarette probably set fire to grease and rubbish underneath one of the escalators. Organisational changes had resulted in poor escalator cleaning. The fire took hold because of the wooden escalator, the failure of water fog equipment and inadequate fire and emergency training of staff.
Clapham Junction 1988 (Transport sector)	35 people died and 500 were injured in a triple train crash.	Immediate cause was a signal failure caused by a technician failing to isolate and remove a wire. Contributory causes included degradation of working practices, problems with training, testing quality and communications standards, poor supervision, lessons not learnt from past incidents. No effective system for monitoring or limiting excessive working hours.
Herald of Free Enterprise 1987 (Transport sector)	This roll-on roll-off ferry sank in shallow water off Zeebrugge killing 189 passengers and crew.	Immediate cause was the failure to close the bow doors before leaving port. No effective reporting system to check the bow doors. Formal inquiry reported that the company was 'infected with the disease of sloppiness'. Commercial pressures and friction between ship and shore management had led to safety lessons not being learnt.
Union Carbide Bhopal, 1984 (Chemical Unit)	The plant released a cloud of toxic methyl isocynate. Death toll was 2500 and over one quarter of the city's population was affected by the gas.	The leak was caused by a discharge of water into a storage tank. This was the result of a combination of operator error, poor maintenance, failed safety systems and poor safety management.
Space Shuttle Challenger 1986 (Aerospace)	An explosion shortly after lift-off killed all seven astronauts on board.	An O-ring seal on one of the solid rocket boosters split after take-off releasing a jet of ignited fuel. Inadequate response to internal warnings about the faulty seal design. Decision taken to go for launch in very cold temperature despite faulty seal. Decision-making result of conflicting scheduling/safety goals, mindset, and effects of fatigue.

Piper Alpha 1988 (Offshore)	167 workers died in the North Sea after a major explosion and fire on an offshore platform.	Formal inquiry found a number of technical and organisational failures. Maintenance error that eventually led to the leak was the result of inexperience, poor maintenance procedures and poor learning by the organisation. There was a breakdown in communications and the permit-to-work system at shift changeover and safety procedures were not practiced sufficiently.
Chernobyl 1986 (Nuclear industry)	1000 MW Reactor exploded releasing radioactivity over much of Europe at environmental and human cost.	Causes are much debated but Soviet investigative team admitted 'deliberate systematic and numerous violations' of safety procedures by operators.
Texaco Refinery, 1994 (Petroleum Industry)	An explosion on the site was followed by a major hydrocarbon fire and a number of secondary fires. There was severe damage to process plant, buildings and storage tanks. 26 people sustained injuries, none serious.	The incident was caused by inflammable hydrocarbon liquid being continuously pumped into a process vessel that had its outlet closed. This was the result of a combination of: an erroneous control system reading of a valve state, modifications which had not been fully assessed, failure to provide operators with the necessary process overviews and attempts to keep the unit running when it should have been shut down.

It is all too easy to provide examples of accidents where 'human error' has given rise to a major accident with loss of life and injuries. Table 1 illustrates how the failure of people at many levels within an organisation can contribute to a major disaster. For many of these major accidents the human failure was not the sole cause but one of a number of causes, including technical and organisational failures, which led to the final outcome. Remember that many 'everyday' minor accidents and near misses also involve human failures. All major disasters lead to huge human, property and environmental losses.

We make errors, irrespective of how much training and experience we possess, or how motivated we are to do it right. Failures are more serious for jobs where the consequences of errors are not protected. However, errors can occur in all tasks, not just those which are called safety-critical.

3. Factors influencing human behaviour

In order to address human factors in workplace safety settings, people's capabilities and limitations must first be understood. The modern working environment is very different to the settings that humans have evolved to deal with. The following human characteristics that can lead to difficulties interacting with the working environment.

- **Attention –** The modern workplace can 'overload' human attention with enormous amounts of information, far in excess of that encountered in the natural world. The way in which we learn information can help reduce demands on our attention, but can sometimes create further problems.
- **Perception –** In order to interact safely with the world, we must correctly perceive it and the dangers it holds. Work environments often challenge human perception systems and information can be misinterpreted.
- **Memory –** Our capacity for remembering things and the methods we impose upon ourselves to access information often put undue pressure on us. Increasing knowledge about a subject or process allows us to retain more information relating to it.
- **Logical reasoning –** Failures in reasoning and decision making can have severe implications for complex systems such as chemical plants, and for tasks like maintenance and planning.

Environmental, organisational and job factors, in brief, influence the behaviour at work in a way which can affect health and safety. A simple way to view human factors is to think about three aspects: the individual, the job and the organisation and their impact on people's health and safety-related behaviour. All three are interlinked and have mutual influence (Fig 1a-1b).

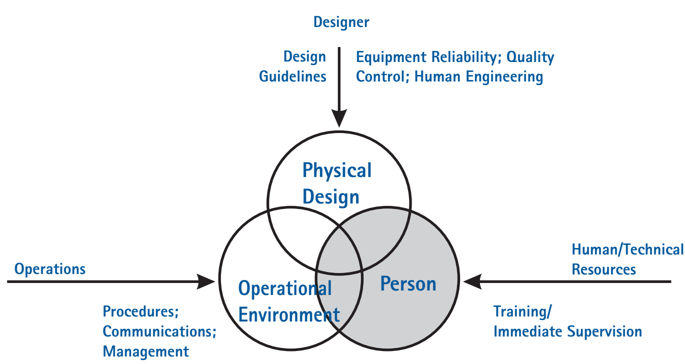


Fig-1a

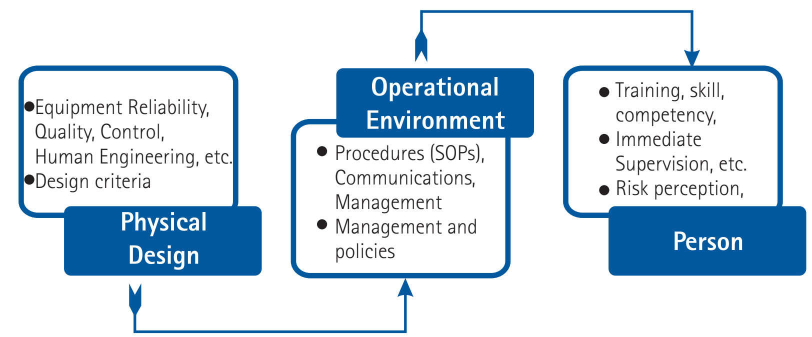


Fig-1b

The typical examples of immediate causes and contributing factors for human failures are given below:-

Individual factors

- low skill and competence levels
- tired staff
- bored or disheartened staff
- individual medical problems

Job factors

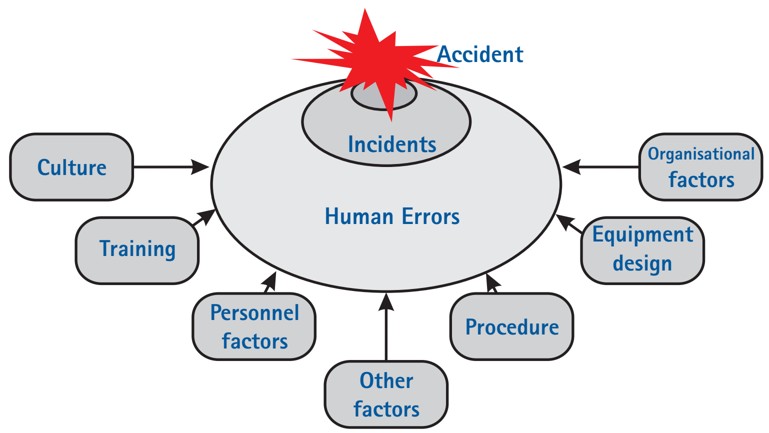
- illogical design of equipment and instruments
- constant disturbances and interruptions
- missing or unclear instructions
- poorly maintained equipment
- high workload
- noisy and unpleasant working conditions

Organisation and management factors

- poor work planning, leading to high work pressure
- poor SOPs and lack of implementation
- lack of safety systems and barriers
- inadequate responses to previous incidents
- management based on one-way communications
- deficient co-ordination and responsibilities
- poor management of health and safety
- poor health and safety culture.

All above three factors are having serious implications on each others and depends on various other factors.

It is concluded that the performance of human is being strongly influenced by organisational, regulatory, cultural and environmental factors affecting the workplace. For example, organizational processes constitute the breeding grounds for many predictable human errors, including inadequate communication facilities, ambiguous procedures, unsatisfactory scheduling, insufficient resources, and unrealistic budgeting in fact, all processes that the organisation can control. Figure 2 summarizes some of the factors contributing to human errors and to accidents.



Contributing factors to human error

Fig-2

4. Human Factors vs Accident causation

Accidents are caused by active failures or and latent conditions which can lead to human error or violations. Active failures are the acts or conditions precipitating the incident situation. They usually involve the front-line staff, the consequences are immediate and can often be prevented by design, training or operating systems.

Latent conditions are the managerial influences and social pressures that make up the culture ('the way we do things around here'), influence the design of equipment or system, and define supervisory inadequacies. They tend to be hidden until triggered by an event. Latent conditions can lead to latent failures: human error or violations. Latent failures may occur when several latent conditions combine in an unforeseen way. We all make errors irrespective of how much training and experience we possess or how motivated we are to do it right.

Considering the active failures and latent conditions in an organisation the model of accident where human error is main cause of accident can be shown as fig 3.

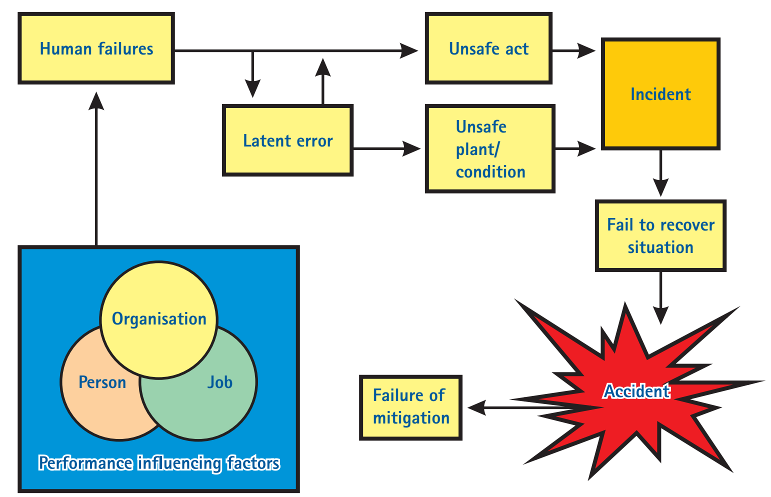


Fig-3

People can cause or contribute to accidents (or mitigate the consequences) in a number of ways:

- A failure of a person can directly cause an accident. However, people tend not to make errors deliberately. We are often 'set up to fail' by the way our brain processes information, by our training, through the design of equipment and procedures and even through the culture of the organisation we work for.

- People can make disastrous decisions even when they are aware of the risks. We can also misinterpret a situation and act inappropriately as a result.

Both of these can lead to the escalation of an incident.

- On the other hand we can intervene to stop potential accidents. Many companies have their own anecdotes about recovery from a potential incident through the timely actions of individuals. Mitigation of the possible effects of an incident can result from human resourcefulness and ingenuity.

●The degree of loss of life can be reduced by the emergency response of operators and their colleagues in a team. Emergency planning and response including appropriate training can significantly improve rescue situations.

The consequences of human failures can be immediate or delayed and the failures can be grouped into the following categories:-

- **Active failures** have an immediate consequence and are usually made by front-line people such as drivers, control room staff or machine operators. In a situation where there is no room for error these active failures have an immediate impact on health and safety.

- **Latent failures** are made by people whose tasks are removed in time and space from operational activities, e.g. designers, decision makers and managers. Latent failures are typically failures in health and safety management systems (design, implementation or monitoring).

Examples of latent failures are:

- Poor design of plant and equipment;
- Ineffective training;
- Inadequate supervision;
- Ineffective communications;
- Inadequate resources (e.g. people and equipment);
- Uncertainities in roles and responsibilities; and
- Poor SOPs.

Latent failures provide great, if not a greater, potential danger to health and safety as active failures. Latent failures are usually hidden within an organisation until they are triggered by an event likely to have serious consequences.

After an accident involving human failure the investigation into the causes and contributing factors often makes little attempt to understand why the human failures occurred. Finding out both the immediate and the underlying causes of an accident is the key in preventing similar accidents through the design of effective control measures.

4.1 Human Factors Investigation Tool (HFIT)

HFIT is based on a model of how accidents are caused which in turn is derived from a wide range of different models derived from research. The model is shown in fig 4.

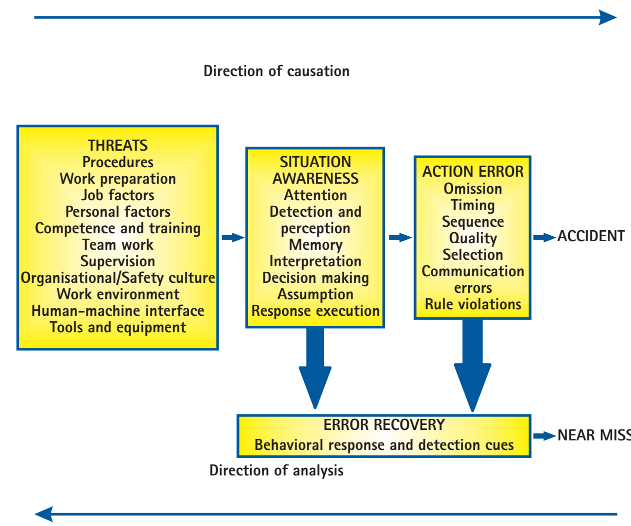


Fig-4

The model suggests that accidents occur when a person makes an 'action error', for example, omits to carry out a critical task. Action errors occur because of some fault in the person's information processing sequence, lack of attention, failure to detect information, failure of memory etc. There can be opportunities to recover situation awareness or the action error itself by detecting and correcting the problem. If this is successful, the outcome is a near miss rather than an accident. Problems with situation awareness arise because of threats such as poor procedures, competencies, communication, supervision, safety culture or other factors.

HFIT analysis is based on following four step process :-

1. Identify action errors.
2. Identify possible recovery mechanisms from those errors.
3. Identify the elements of the information processing sequence that failed.
4. Identify threats that contributed to the incident at any stage in its evolution.

4.2 Human Factors Analysis and Classification System (HFACS)

A "modernized" version of "Swiss Cheese" model describes the levels at which active failures and latent failures/conditions may occur within complex operations (Figure 5). Working backward from the mishap, the first level of model depicts those

Unsafe Acts of Operators (operator, maintainers, facility personnel, etc.) that lead to a mishap. Traditionally, this is where most mishap investigations have focused their examination of human error, and consequently where most causal factors are uncovered. After all, it is typically the actions or inactions of individuals that can be directly linked to the mishap. Still, to stop the investigation here only uncovers part of the story.

What makes Reason's model particularly useful in mishap investigation is that it forces investigators to address latent failures and conditions within the causal sequence of events. For instance, latent failures or conditions such as fatigue, complacency, illness, and the physical/technological environment all affect performance, but can be overlooked by investigators with even the best of intentions. These particular latent failures and conditions are described within the context of Reason's model as Preconditions for Unsafe Acts. Likewise, supervision can promote unsafe conditions of operators and ultimately unsafe acts will occur. For example, if an Operations Officer were to pair a below average team leader with a very junior/inexperienced crew, the result is increased risk of mission failure. Regardless, whenever a mishap does occur, the crew naturally bears a part of the responsibility and accountability. However, latent failures or conditions at the supervisory level are often equally responsible for poor hazard analysis and subsequent increased mission risk, and may ultimately cause the mishap. In this particular example, the crew was set up for the opportunity for failure.

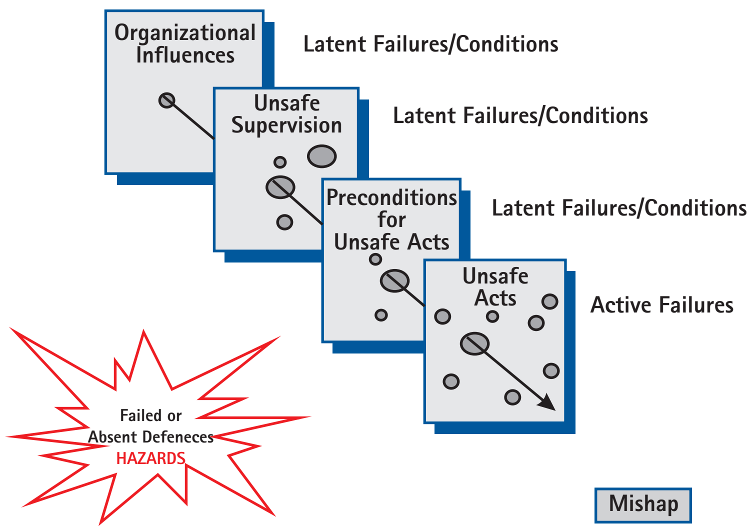


Fig-5

Reason's model does not stop at supervision; it also considers organizational Influences that can impact performance at all levels. For instance, in times of fiscal constraints, funding may be short and may lead to limited training opportunities. Supervisors are sometimes pressed to task "non-proficient" crews with complex missions. Not surprisingly, unintended and unrecognized errors may appear, and mission performance will consequently suffer. As such, hazards and risks at all levels must be addressed if any mishap investigation process is going to be effective.

The investigation process then endeavours to detect and identify the "holes (hazards) in the cheese" (see Figure 5). So how do we identify these hazards? Aren't they really too numerous to define? After all, every mishap is unique, so the hazards will always be different for each mishap ... right? Well, it turns out that each mishap is not unique from its predecessors. In fact, most mishaps have very similar causes. They are due to the same holes in the cheese, so to speak. The hazards identified in each new mishap are not unique to that mishap. Therefore, if you know what these system failures/ hazards or "holes" are, you can better identify their roles in mishaps - or better yet, detect their presence and develop a risk mitigation strategy correcting them before a mishap occurs.

HFACS describes four main tiers of failures/conditions: (A) Acts, (B) Preconditions, (C) Supervision, and (D) Organizational Influences. A brief description of the major tiers with associated categories and sub-categories follows, beginning with the tier most closely tied to the mishap.

A. Acts

Acts are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situation. We have identified these active failures or actions as Errors and Violations (Figure 6).

(i) Errors: Errors are factors in a mishap when mental or physical activities of the operator fail to achieve their intended outcome as a result of skill-based, perceptual, or judgment and decision making errors, leading to an unsafe situation. Errors are unintended. We classified Errors into two types:

(a) Skill-based Errors: When people are performing familiar work under normal conditions, they know by heart what to do. They react almost automatically to the situation and do not really have to think about what to do next. For instance, when a skilled automobile driver is proceeding along a road, little conscious effort is required to stay in the lane and control the car. The driver is able to perform other tasks such as adjusting the radio or engaging in conversation without sacrificing control. Errors committed at this level of performance are called slips or lapses.

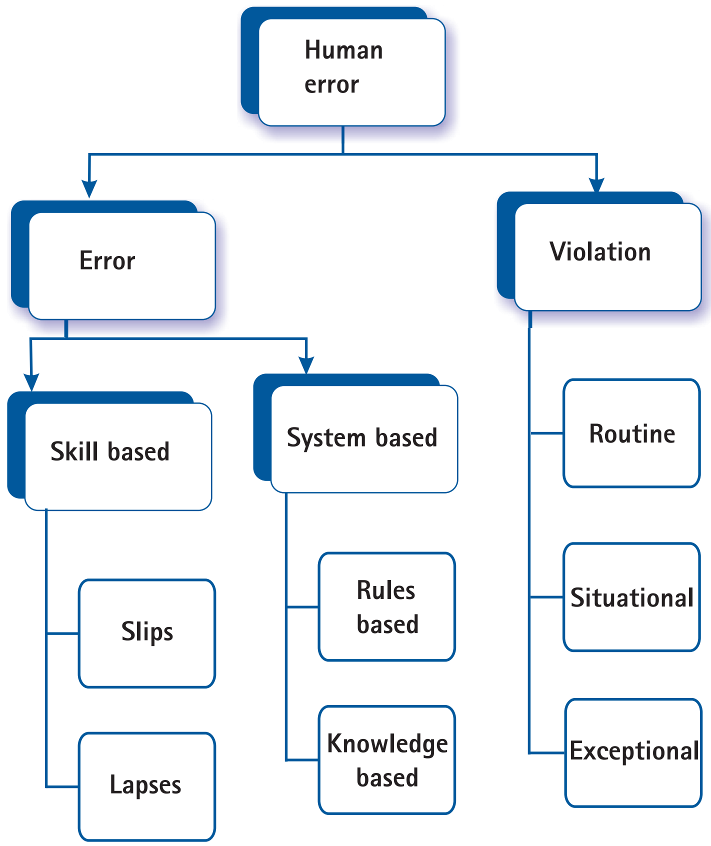


Fig-6

- **Slips** are failures in carrying out the actions of a task. They are described as 'actions-not-as-planned'. Examples would be: picking up the wrong component from a mixed box, operating the wrong switch, transposing digits when copying out numbers and misordering steps in a procedure. Typical slips might include:

- performing an action too soon in a procedure or leaving it too late;
- omitting a step or series of steps from a task;
- carrying out an action with too much or too little strength (e.g. over-torquing a nut bolt);

- performing the action in the wrong direction (e.g. turning a control knob to the right rather than the left, or moving a switch up rather than down);
- doing the right thing but on the wrong object (e.g. switching on/off the wrong switch); and
- carrying out the wrong check on the right item (e.g. checking a dial but for the wrong valve).

An example of slip: Two similarly named chemicals were manufactured at a chemical works in batch reactions. Each required the presence of an inorganic base to maintain alkalinity to prevent exothermic side reactions. Development work was in progress which involved altering the various ratios of chemicals in each reaction. A chemist, in calculating the quantities of inorganic base required, inadvertently transposed the figures (a typical slip). As a result one reaction was carried out with only 70% of the required base present and an exothermic side reaction resulted. The subsequent explosion destroyed the plant. The system was not designed to cope with a runaway exothermic reaction. There was no system for checking the calculations.

-Lapses cause us to forget to carry out an action, to lose our place in a task or even to forget what we had intended to do. They can be reduced by minimising distractions and interruptions to tasks and by providing effective reminders especially for tasks which take some time to complete or involve periods of waiting. A useful reminder could be as simple as a partially completed checklist placed in a clearly visible location for the person doing the task. We may be able to eliminate some of these lapses through better design of equipment or tasks.

An example of lapse: An experienced road tanker driver had virtually completed the filling of his vehicle from a bulk tank of inflammable liquid when a nearby telephone rang. After ignoring it for some five minutes he closed the various valves on the installation and went to answer it. On returning to the vehicle he drove away having forgotten that he had not disconnected the tanker hose from the installation. Fixed pipework from the installation fractured and approximately one tonne of material was lost. The installation was not fitted with a drive-away protection device.

(b) System based: are a more complex type of human error where we do the wrong thing believing it to be right. The failure involves our mental processes which control how we plan, assess information, make intentions and judge consequences. Two types of mistakes exist, rules-based and knowledge-based

- **Rules-based** mistakes occur when our behaviour is based on remembered rules or familiar procedures. We have a strong tendency to use familiar rules or solutions even when these are not the most convenient or efficient.
An example of rules based mistake: An operator was very familiar with the task of filling

a tank. He expected the filling procedure to take about 30 minutes. However, on this occasion the diameter of the pipe entering the tank had been enlarged and the tank was filling much more rapidly than he anticipated. He ignored the high level alarms on the grounds that the tank could not be filled so quickly. The tank overflowed. Improved communications would have alerted the operator to the changes that had been made to the pipe.

In unfamiliar circumstances we have to revert to consciously making goals, developing plans and procedures. Misdiagnoses and miscalculations can result when we use this **knowledge-based** reasoning.

An example of knowledge-based reasoning: The investigation following a major collapse of a tunnel found that the organisation had relied on the experience of one person as a control measure. However, the nature of the method of working meant that this person had no reliable instrumentation for detecting when the tunnel was becoming unstable. Relying on 'experience' was actually relying on knowledge-based reasoning of the 'expert' and was not an effective control method to prevent a serious collapse given the unpredictable nature of the event. The expert needed more reliable instruments to carry out this work.

It can be concluded that errors are Judgement and Decision Making Errors.
Mis perception of an object, threat or situation (such as visual, auditory, proprioceptive, or vestibular illusions, cognitive or attention failures). Systems as whole failure is also a part of such type failure where we fails to understand the possible causes for errors.

(ii) Violations: Violations are any deliberate deviations from rules, procedures, instructions and regulations. The breaching or violating of health and safety rules or procedures is a significant cause of many accidents and injuries at work. Removing the guard on dangerous machinery or driving too fast will clearly increase the risk of an accident. Health risks are also increased by breaking rules. For example, a worker in a noisy workplace who breaks the site rules about wearing ear defenders increases his/her risk of occupational deafness. Our knowledge of why people break rules can help us to assess the potential risks from violations and to develop control strategies to manage these risks effectively. In the workplace rules are broken for many different reasons. Most violations are motivated by a desire to carry out the job despite the prevailing constraints, goals and expectations. Very rarely they are willful acts of sabotage or vandalism. Violations are divided into three categories: routine, situational and exceptional.

a) **With a routine violation**, breaking the rule or procedure has become a normal way of working within the work group. This can be due to:

-the desire to cut corners to save time and energy;
-the perception that the rules are too restrictive;

-the belief that the rules no longer apply;
-lack of enforcement of the rule; and
-new workers starting a job where routine violations are the norm and not realising that this is not the correct way of working.

(b) In the case of **situational violations** breaking the rule is due to pressures from the job such as being under time pressure, insufficient staff for the workload, the right equipment not being available, or even extreme weather conditions. It may be very difficult to comply with the rule in a particular situation or staff may think that the rule is unsafe under the circumstances. Risk assessments may help to identify the potential for such violations. Encouraging reporting of job pressures through open communication will also be helpful.

(c) **Exceptional violations** rarely happen and only then when something has gone wrong. To solve a new problem you feel you need to break a rule even though you are aware that you will be 'taking a risk'. You believe, falsely, that the benefits outweigh the risks.

B. Preconditions

Preconditions are factors in a mishap if active and/or latent preconditions such as conditions of the operators, environmental or personnel factors affect practices, conditions or actions of individuals and result in human error or an unsafe situation (Figure 7). In this error analysis model preconditions include Environmental Factors, Condition of the Individuals and Personnel Factors.

(i) Environmental Factors: Environmental factors are factors in a mishap if physical or technological factors affect practices, conditions and actions of individual and result in human error or an unsafe situation. Environmental factors include:

Physical Environment: Physical environment are factors in a mishap if environmental phenomena such as weather, climate, white-out or dust-out conditions affect the actions of individuals and result in human error or an unsafe situation.

Technological Environment: Technological environment are factors in a mishap when cockpit/vehicle/workspace design factors or automation affect the actions of individuals and result in human error or an unsafe situation.

(ii) Condition of the Individual: Condition of the individual are factors in a mishap if cognitive, psycho-behavioral, adverse physical state, or physical/mental limitations affect practices, conditions or actions of individuals and result in human error or an unsafe situation. Condition of the Individuals include:

Cognitive Factors: Cognitive factors are factors in a mishap if cognitive or attention management conditions affect the perception or performance of individuals and result in human error or an unsafe situation.

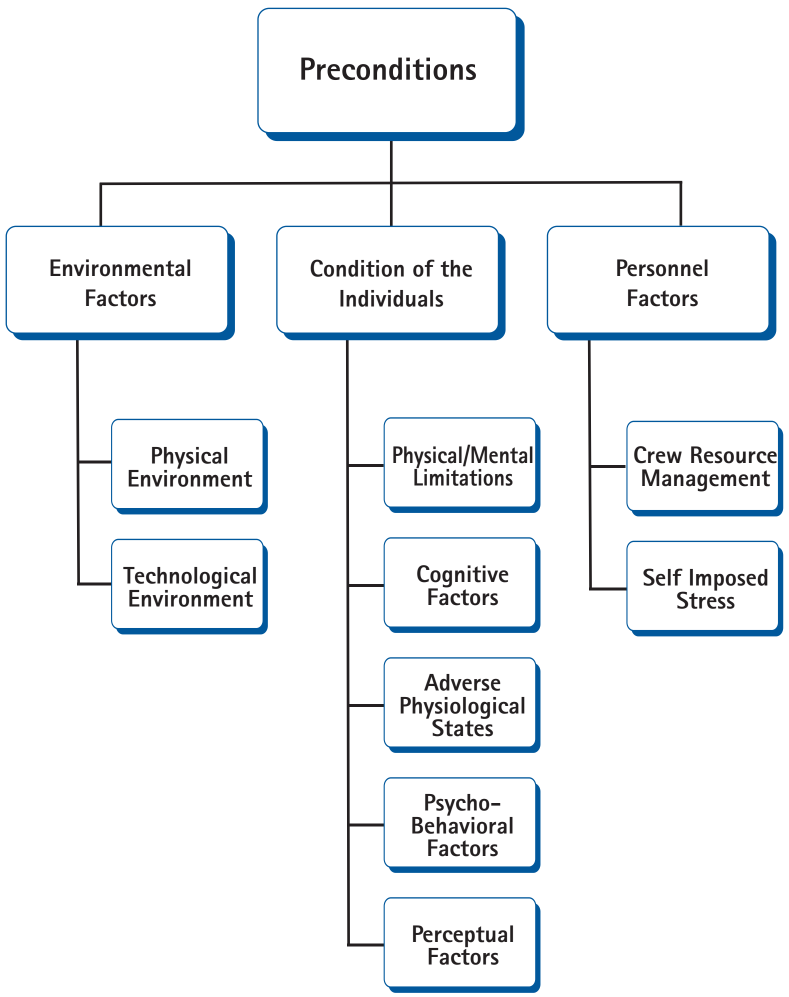


Fig-7

Psycho-Behavioral Factors: Psycho-Behavioral factors are factors when an individual's personality traits, psycho-social problems, psychological disorders or inappropriate motivation creates an unsafe situation.

Adverse Physiological States: Adverse physiological states are factors when an individual experiences a physiologic event that compromises human performance and this decreases performance resulting in an unsafe situation.

Physical/Mental Limitations: Physical/mental limitations are factors in a mishap when an individual lacks the physical or mental capabilities to cope with a situation, and this insufficiency causes an unsafe situation. This often, but not always, indicates an individual who does not possess the physical or mental capabilities expected in order to perform the required duties safely.

Perceptual Factors: Perceptual factors are factors in a mishap when misperception of an object, threat or situation (visual, auditory, proprioceptive, or vestibular conditions) creates an unsafe situation. If investigators identify spatial disorientation (SD) in a mishap, the preceding causal illusion should also be identified. Vice versa, if an illusion is identified as a factor in a mishap then the investigator should identify the resultant type of SD.

(iii) Personnel Factors: Personnel factors are factors in a mishap if self-imposed stressors or resource management affects practices, conditions or actions of individuals, and result in human error or an unsafe situation. Personnel factors include:

Crew Resource Management: Coordination/communication/planning are factors in a mishap where interactions among individuals and teams are involved with the preparation and execution of a mission that resulted in human error or an unsafe situation.

Self-Imposed Stress: Self-imposed stress are factors in a mishap if the operator demonstrates disregard for rules and instructions that govern the individuals readiness to perform, or exhibits poor judgment when it comes to readiness and results in human error or an unsafe situation. These are often violations of established rules that are in place to protect people from themselves and a subsequent unsafe condition. One example of self-imposed stress is drinking alcohol prior to operating a motor vehicle.

C. Supervision

It was determined that a mishap event can often be traced back to the supervisory chain of command. As such, there are four major categories of Unsafe Supervision: Inadequate Supervision, Planned Inappropriate Operations, Failed to Correct a Known

Problem, and Supervisory Violations (Figure 8).

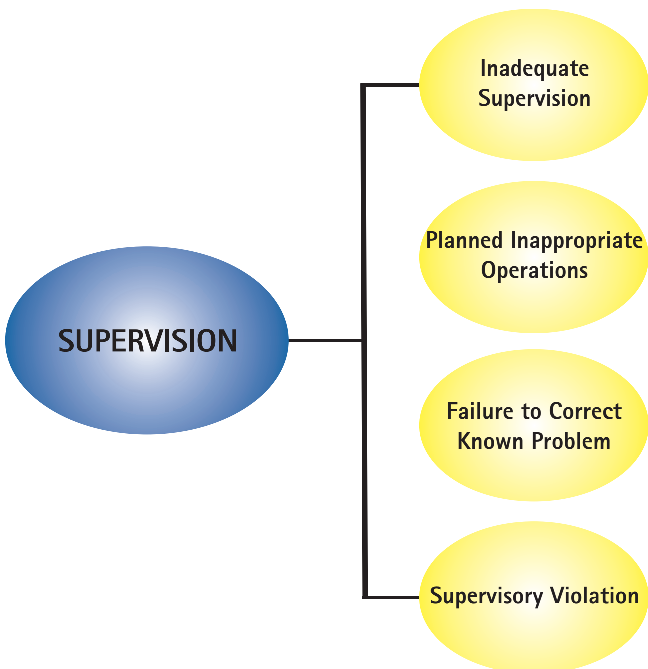


Fig-8

(i) Inadequate Supervision: The role of supervisors is to provide their personnel with the opportunity to succeed. To do this, supervisors must provide guidance, training opportunities, leadership, motivation, and the proper role model, regardless of their supervisory level. Unfortunately, this is not always the case. It is easy to imagine a situation where adequate training was not provided to an operator or team member. Conceivably, the operator's coordination skills would be compromised, and if put into a non-routine situation (e.g., emergency), would be at risk for errors that might lead to a mishap. Therefore, the category Inadequate Supervision accounts for those times when supervision proves inappropriate, improper, or may not occur at all. Inadequate supervision is a factor in a mishap when supervision proves inappropriate or improper and fails to identify a hazard, recognize and control risk, provide guidance, training and/or oversight and results in human error or an unsafe situation.

(ii)Planned Inappropriate Operations: Occasionally, the operational tempo or schedule is planned such that individuals are put at unacceptable risk, crew rest is jeopardized, and ultimately performance is adversely affected. Such Planned Inappropriate Operations, though arguably inevitable during emergency situations, are not acceptable during normal operations. Included in this category are issues of crew pairing and improper manning. For example, it is not surprising to anyone that problems can arise when two individuals with marginal skills are paired together. During a period of downsizing and/or increased levels of operational committment, it is often more difficult to manage crews. However, pairing weak or inexperienced operators together on the most difficult missions may not be prudent. Planned Inappropriate Operation is a factor in a mishap when supervision fails to adequately assess the hazards associated with an operation and allows for unnecessary risk. It is also a factor when supervision allows non-proficient or inexperienced personnel to attempt missions beyond their capability or when crew or flight makeup is inappropriate for the task or mission.

(iii)Failure to Correct a Known Problem: Failure to Correct a Known Problem refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are "known" to the supervisor, yet are allowed to continue uncorrected. For example, the failure to consistently correct or discipline inappropriate behavior certainly fosters an unsafe atmosphere and poor command climate. Failure to Correct a Known Problem is a factor in a mishap when supervision fails to correct known deficiencies in documents, processes or procedures, or fails to correct inappropriate or unsafe actions of individuals, and this lack of supervisory action creates an unsafe situation.

(iv)Supervisory Violations: Supervisory Violations, on the other hand, are reserved for those instances when supervisors willfully disregard existing rules and regulations. For instance, permitting an individual to operate an aircraft without current qualifications is a flagrant violation that invariably sets the stage for the tragic sequence of events that predictably follow. Supervisory Violations is a factor in a mishap when supervision, while managing organizational assets, willfully disregards instructions, guidance, rules, or operating instructions and this lack of supervisory responsibility creates an unsafe situation.

D. Organizational influences

Fallible decisions of upper-level management directly affect supervisory practices, as well as the conditions and actions of operators. These latent conditions generally involve issues related to Resource/Acquisition Management, Organizational Climate, and Organizational Processes (see Figure 9). Organizational Influences are factors in a mishap if the communications, actions, omissions or policies of upper-level management directly or indirectly affect supervisory practices, conditions or actions of the operator(s) and result in system failure, human error or an unsafe situation.

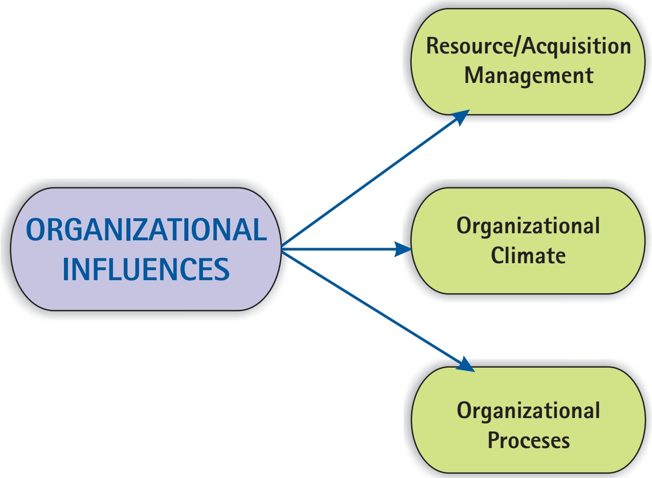


Fig-9

(i) Resource / Acquisition Management: This category refers to the management, allocation, and maintenance of organizational resources–human, monetary, and equipment/facilities. The term "human" refers to the management of operators, staff, and maintenance personnel. Issues that directly influence safety include selection (including background checks), training, and staffing/manning. "Monetary" issues refer to the management of non-human resources, primarily monetary resources. For example, excessive cost cutting and lack of funding for proper equipment have adverse effects on operator performance and safety. Finally, "equipment/facilities" refers to issues related to equipment design, including the purchasing of unsuitable equipment, inadequate design of workspaces, and failures to correct known design flaws. Management should ensure that human-factors as engineering principles are known and utilized and that existing specifications for equipment and workspace design are identified and met. Resource / Acquisition Management is a factor in a mishap if resource management and/or acquisition processes or policies, directly or indirectly, influence system's safety and results in poor error management or creates an unsafe situation.

(ii) Organisational Climate: Organisational Climate refers to a broad class of organisational variables that influence worker performance. It can be defined as the situational consistencies in the organisation's treatment of individuals. In general, Organizational Climate is the prevailing atmosphere or environment within the organization. Within the present classification system, climate is broken down into

three categories--structure, policies, and culture. The term "structure" refers to the formal component of the organisation. The "form and shape" of an organisation are reflected in the chain-of-command, delegation of authority and responsibility, communication channels, and formal accountability for actions. Organizations with maladaptive structures (i.e., those that do not optimally match to their operational environment or are unwilling to change) will be more prone to mishaps. "Policies" refer to a course or method of action that guides present and future decisions. Policies may refer to hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, use of safety equipment, etc. When these policies are ill-defined, adversarial, or conflicting, safety may be reduced. Finally, "culture" refers to the unspoken or unofficial rules, values, attitudes, beliefs, and customs of an organisation ("The way things really get done around here."). Other issues related to culture include organisational justice, psychological contracts, organizational citizenship behaviour and union/management relations. All these issues affect attitudes about safety and the value of a safe working environment. Organisational Climate is a factor in a mishap if organisational variables including environment, structure, policies, and culture influence individual actions and results in human error or an unsafe situation.

(iii) Organisational Processes: This category refers to the formal process by which "things get done" in the organisation. It is subdivided into three broad categories-operations, procedures, and oversight. The term "operations" refers to the characteristics or conditions of work that have been established by management. These characteristics include operational tempo, time pressures, production quotas, incentive systems, and schedules. When set up inappropriately, these working conditions can be detrimental to safety. "Procedures" are the official or formal procedures as to how the job is to be done. Examples include performance standards, objectives, documentation, and instructions about procedures. All of these, if inadequate, can negatively impact employee supervision, performance, and safety. Finally, "oversight" refers to monitoring and checking of resources, climate, and processes to ensure a safe and productive work environment. Issues here relate to organisational self-study, risk management, and the establishment and use of safety programs. Organisational Processes is a factor in a mishap if organizational processes such as operations, procedures, operational risk management and oversight negatively influence individual, supervisory, and/or organizational performance and results in unrecognised hazards and/or uncontrolled risk and leads to human error or an unsafe situation.

5. Strategies for reducing human error

Reducing human error involves far more than taking disciplinary action against an individual. There are a range of measures which are more effective controls including the design of the equipment, job, procedures and training.

The design guidance developed consists of two forms: design principles and a three-step process for systematically addressing human errors in design. The relationships between the guidance developed, human error occurrence and consequence in system operation, and conventional engineering design and design change processes are shown in Figure 10.

The three-step process helps in the followings:-

1. Make goals and system state visible, interfaces should make accessible, information in a form so that system state can be easily related to system operational goals.

2. Provide a good conceptual model. It is important that operators must be able to develop a good conceptual model of the plant systems from training, from the design of the interface between the operator and the plant, and from observations of system operation. The information from these three sources should be consistent and complementary to reduce the possibility of operating errors.

3. Make the acceptable regions of operation visible directly indicating the acceptable, unacceptable, and desired regions of system operation in process and state. Displays can act as a visual aid. This reduces dependence on user memory recall and the need for dynamic context dependent determinations. The adequacy of plant process state can thus be judged more readily against performance targets.

4. Make process and automation behaviour predictable. Errors have a better chance of being detected if the normal behavior of plant processes and automation is predictable.

5. Employ affordances. Apply design features that visibly convey the possibilities for action.

6. Make the options for functional control visible. Errors in planning and action execution can be minimized if controls are visible so that the possibilities and limits for action are known.

7. Provide appropriate feedback. Always provide feedback for an operator's actions. Feedback can take many forms. As a minimum, feedback should convey the impact of the operator's action on the overall state of the system.

8. Ensure a close relationship between a control and its function to reduce the demand on an operator's memory, there should be a clear relationship between the location and mode of operation of a control and its function.

9. Build-in constraints. The user's actions should be limited to acceptable ranges of control possibilities to guard against errors.

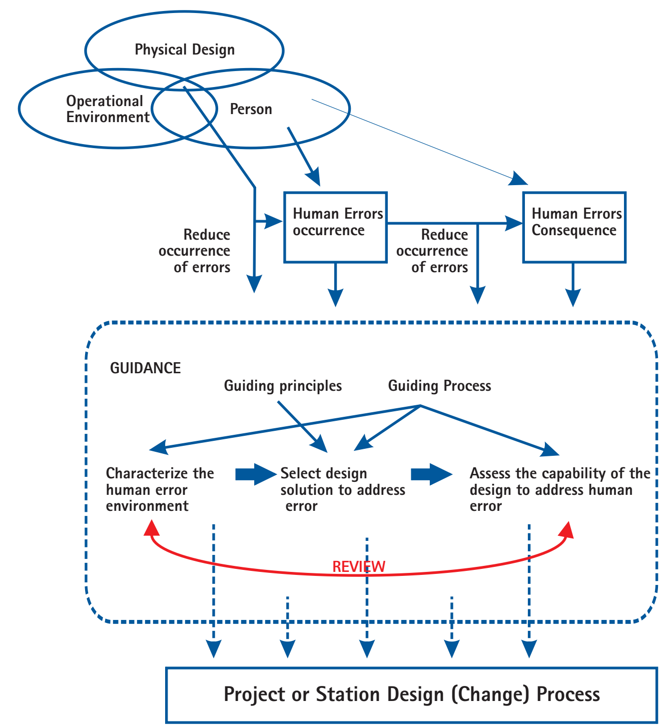


Fig-10

10. Make error recovery easy. Given that errors will occur, the system should be forgiving and allow the operator to readily detect and recover from these errors..

11. Make interfaces consistent. Consistency (and standardization) allows users to apply existing knowledge to new tasks, This reduces the burden of interface characteristics that must be learned and remembered. Minimizing the secondary tasks associated with task performance can reduce the incidence of operating error.

5.1 Addressing human error in the design process

To address human errors, one first needs to characterize their potential for occurrence and consequence for the operating situations encompassing system operation. Characterizing the human error environment involves:

- Identifying operational and design requirements,
- Determining operational and functional context for system operation and possible human error occurrence,
- Understanding the operator's needs in support of task performance, and
- Evaluating the human error potential for the system operation and environment examined.
- Information for the evaluation may be based primarily on either:
  - Observation or operational experience (e.g. examination of past incidents and errors, observation of system operation, simulated system operation, walk-throughs, and talk throughs), or
  - Analytical prediction of anticipated events. Adaptation of several analytical techniques from the human reliability field can assist in assessment of human error potential. Most techniques are based on

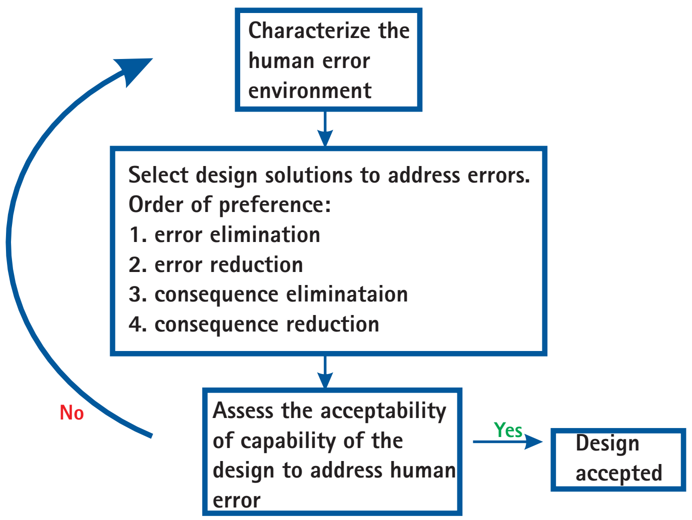


Fig-11

1. Eliminate Error Occurrence
This is the first preference, where design features known to be a source of human error are eliminated (e.g. lack of feedback, lack of differentiation, inconsistent or unnatural mappings). Design choices available for error elimination include:

- Replacement of error inducing design features (e.g. physical device separation, physical guards, application of validity and range).

- Restructuring of task so the error prevalent behaviour is no longer performed (e.g. by information filtering, only the information needed for the task is provided).
- Automate to change the role of human involvement in support of task performance.

2. Reduce Error Occurrence
Consider this approach if complete error elimination is not possible or feasible through design choices. Design features which can reduce error occurrence include:

- Identification (e.g. device labeling).
- Constraints (i.e. build in constraints to limit operation to acceptable ranges).
- Coding (i.e. aid in choice differentiation and selection).
- Consistency Feedback (i.e. convey device and system state directly in the interface).
- Predictability (i.e. design system responses so that operators can associate specific control actions with system response).

3. Eliminate Error Consequence. The third approach is to eliminate error consequences. There are three categories of design features that reflect the components of the consequence prevention strategy:

A. Error detection design features (to promote detection prior to consequence \ occurrence):

- Feedback (i.e. status information in relation to operational goals and potential side-effects of an action).
- Alert of Unacceptable Device States (e.g. visual/auditory feedback of off-normal or unacceptable device states).
- Confirmation (i.e. support of self checking and independent verification practices).
- Prediction (i.e. providing information on the outcome of an action prior to its implementation, or with sufficient time for correction).

B. Error recovery design features (to enable recovery prior to consequence occurrence):

- Undo (e.g. facilities for reversing recent control actions to allow promote error recovery).
- Guidance (i.e. alternative forms of guidance for cases where reversing a recent control action is not the preferred action).

C. Consequence Prevention Design Features
- Interlocks
- Margins and Delays (i.e. these features can provide more time to unacceptable consequence realization thus increasing the chances of error detection and recovery prior to consequence occurrence)
- Fail Safe Features

4. Reduce Error Consequence. If errors and consequences can not be completely eliminated, consider measures that enable consequence reduction. This may be achieved through application of additional design features that allow operators or automation to recognize the occurrence of an error consequence, and to take action to mitigate the consequences. Examples include:

- Margins (i.e. apply larger design margins to allow some consequences to be accommodated by normal system function and capacities).
- Engineered Mitigating Systems (e.g automatic special safety systems actions, such as Automatic Stepback and Setback). Human Intervention (i.e. operations team can readily adapt to both predefined and undefined operating situations).
- Response Teams (i.e. organisational structure is prepared and coordinated to deal with the predefined consequences).
- Consequence Prediction (e.g. aids can assist operations staff in predicting the extent of consequences of operating actions and assist in selection and execution of mitigating actions).
- Backup Replacement Function (i.e. provision of equipment and/or human intervention to mitigate consequences).

5.2 Assessment of impact of the design and track operational performance

The third stage of the process is the assessment of the impact of the selected human error defensive measures.

The scope of the plant and control center design to be assessed should be defined. Error-related issues should then be identified in the likelihood of particular error-occurring modalities, and the related design features. Error related issues can be solved by changes in designs that could lead to a change in the likelihood of human error. The analytical techniques may be applied at this stage again, to ensure that modifications in design is essential.

Assessing the impact of designs (changes) on error can assist in reducing errors and consequences. This can be proactive or reactive. Both positive (error reducing) and negative (error-increasing) characteristics should be noted.

The long term use of the system, as well as the immediate impact, should be tracked. This will help to determine new error modes that may develop, through system use, that warrant further design modification.

6. Exercise

Accidents are caused by active failures or latent conditions or failures which can lead to human error or violations.

Active failures are the acts or conditions precipitating the incident situation. They usually involve the front-line staff, the consequences are immediate and can often be prevented by design, training or operating systems.

Latent conditions are the managerial influences and social pressures that make up the culture ('the way we do things around'), influence the design of equipment or systems, and define supervisory inadequacies. They tend to be hidden until triggered by an event. Latent conditions can lead to latent failures: human error or violations.

Latent failures may occur when several latent conditions combine in an unforeseen way. We all make errors irrespective of how much training and experience we possess or how motivated we are to do it right.

Identify and list the following in your work place:

➡ **Active failures:**

➡ **Latent conditions:**

➡ **Latent failures:**

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7. Glossary

accident: any unplanned event that results in injury or ill-health to people, or damages equipments, property or materials but where there was a risk of harm.
active failure: a human error or violation the effects of which become evident almost immediately.
barrier: any measure taken to protect people or property from hazards, including physical guards but also administrative measures such as rules and procedures. Sometimes referred to as safeguards, defences or risk control systems.
hazard: anything with the potential for human injury or adverse health, damage to assets or environmental impact. See risk and risk assessment.
HPLC (event): high probability, low consequence (event). Also see LPHC
human error: system failures attributable to people but not including violations.
human failure: a term used to collectively refer to both errors and violations.
human-machine system: a system in which technology and human beings have specific functions but work together towards common goals.
immediate cause (of an incident): the most obvious reason why the incident occurred e.g. The guard is missing, the employee slips etc. There may be several immediate causes identified in one adverse event.
incident: an unplanned or uncontrolled event or sequence of events that has the potential to cause injury, ill-health or damage. Also referred to as a near miss.
lapse: when a person forgets to do something due to a failure of attention/ concentration or memory.
l**atent failure (or latent error):** a human error or violation whose effects can lie dormant in a system for a long time.
LPHC (event): low probability, high consequence (event).
major accident hazard: hazards with the potential for major accident consequences, e.g. ship collisions, dropped objects, helicopter crashes as well as process safety hazards. Major accidents are potentially catastrophic and can result in multiple injuries and fatalities, as well as substantial economic, property, and environmental damage.
occupational safety hazard: personal or occupational safety hazards give rise to incidents such as slips, falls, and vehicle accidents that primarily affect one individual worker for each occurrence(noting, of course, that they could affect many people). They contrast with process safety hazards and major accident hazards in that the latter have the potential to affect a very large number of people including those off-site.

8. References

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Notes

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