Chapter 3

ACCIDENT THEORIES AND ORGANISATIONAL FACTORS

3.1 INTRODCTION

Accidents are commonly regarded as intrinsically different from causal sequences that lead to disease and to any other event. As a result accident remains the only major source of morbidity and mortality which many continue to view in extra-rational terms such as 'luck', 'chance' and 'act of God'. If accidents are of such unique nature that its causation defies human understanding, control and prediction, it might be argued that it should be analysed not only by scientists and theologians and philosophers but by astrologers and soothsayers as well. On the other hand, if the causation of accidents does not differ substantially from other events, it is important that it should be subjected to rigorous and sophisticated scientific methodology. In fact, accident research is a branch of study that has evolved out of such lack of conceptual clarity (Haddon et al., 1964).

A review of literature of accident research reveals that inadequately trained professionals whose nature of work made them deal with accident phenomenon largely contributed in the early period of accident research (Anderson, 1988; Boden, 1984; Channing, 1999; Davis, 1964; Geller, 1996; Goetsch, 1993; Laitinen & Vahapassi, 1992). Consequent to this much of the accident research and theorisation are based on primitive rather than sophisticated methodology. Gradually, terms like chance, luck or act of God failed to find any mention in the accident literature and safety professionals proposed various theories and models of accident causation.

3.2 The Domino Theories of Accident Causation

Herbert W. Heinrich, is the proponent of his "Axioms of Industrial Safety" and theory of accident causation which came to be known as the Domino Theory. Heinrich's model, known as Domino Model was introduced in 1931. Subsequently, various modifications of the Domino theory are proposed by safety researchers and practitioners (Findlay & Kuhlman, 1980). Some of the those are presented here.

Domino Model describes the accident sequence as a five step series of events that "...occur in a fixed and a logical order. According to the premise of the Model, a set of 'unsafe conditions' are similar to a row of vulnerable dominos, an 'unsafe act' would start toppling. The model seeks to find out the sequential events or chain of events which in the words of Ludwig Benner, Jr. which go something like 'for want of nail the shoe was lost, for want of a shoe the horse was lost' (Benner, 1978:4).

The model takes the form of five domino bricks in a row, representing five factors in the sequence of events leading up to an accident. Chronologically, these factors can be summarised as follows (Strasser et al., 1981):

1. Ancestry and social environment: People inherit (ancestry) or learn through socialisation process certain behavioural characteristics, which are negative character traits (such as stubbornness, recklessness etc.) that might predispose them to behave in an unsafe manner.

2. Fault of person: The inherited or acquired negative character traits of people (such as recklessness, ignorance of safe practices, violent temper etc.,) make people behave in an unsafe manner and that is how hazardous conditions exist.

3. Unsafe act/mechanical or physical hazard: The direct causes of accidents lie in the unsafe acts (such as standing under suspended loads, removal of safeguards, horseplay etc.) committed by the people and the existing mechanical or physical hazards (such as unguarded gears, absence of rail guards, insufficient light etc.)

4. Accidents: Events such as falls of persons, the impact of moving objects on people etc., are typical accidents that result in injury.

5. Injuries: Injuries that result directly from accidents such as lacerations and fractures.

To summarise, Heinrich's theory of accident causation has two important parameters. First, injuries are caused by the action of preceding factors; and secondly, removal of the central factor (unsafe act/hazardous conditions) amidst the five dominoes contradicts the action of the preceding factors, and in this process prevents accidents and injuries (Heinrich, Petersen & Ross, 1980).

According to the Axioms of Accident Causation proposed by Heinrich, the 'unsafe acts of people' lead to majority of accidents. Nevertheless, the axioms, in no way absolve the management from the responsibility of creating a safe work environment for its employees. Furthermore, the role of the supervisor in the prevention of industrial accidents has been considered to be very critical.

Amongst the three important components of an organization namely, structure, technology and people, the Domino theory lays major emphasis upon the 'people' component in the causation of accidents. In fact, an analysis of the ten axioms of Heinrich's theory reveals that prime importance has been given to various factors related to 'people' in the organisation. These 'people' factors include ancestry and social factors, faults and unsafe acts of the employees and the role of supervisors as well as the responsibility of management. In Heinreich's theory, along with the 'people' factors, the structural factor like production and quality techniques, and 'technological' factors like mechanical and physical hazards are given importance for the causation of accidents.

3.2.1. Bird's Updated Domino Sequence

Frank Bird Jr. is the first to propose an updated Domino theory of accident causation. The five key factors in this updated sequence are - (1) Lack of Control: Management; (2) Basic Causes: Origins; (3) Immediate Cause: Symptoms; (4) Accident: Contact and (5) Injury-Damage: Loss (Strasser, 1981).

(1) Lack of control – Management: Lack of management control is the most critical domino in accident causation. According to this theory, it is possible to develop a manufacturing system 99.9% reliable against accidents. Management's inability to attain this level would lead to accident occurrence

(2) Basic causes-Origins: Two basic causes of accidents are: a) personal actors, namely lack of knowledge or skill, poor motivation and a range of

physical and psychological problems and b) job-related factors, namely inadequate work standards, inadequate purchasing standards, improper usage of machines and materials, normal wearing away of machines etc. By identifying these basic causes of accidents, professional managers are expected to develop effective control system.

(3) Immediate causes-Symptoms: Traditionally, various immediate causes of accidents (e.g., poor housekeeping, operating without authority, ignoring safety procedures etc.,) are merely symptoms of the deeper underlying problems. While recognising the immediate causes of the problem and taking necessary steps for the countermeasures, professional manager is expected to identify the basic causes of accidents too in order to adopt control measures.

(4) Accident-Contact: Accident is considered as an undesired event that results in physical harm, injury, and property damage. The term 'accident' is purely descriptive and has no real etiological connotation. In the absence of the more appropriate term, Frank E. Bird chose to continue with the term because of its wide usage and acceptance.

(5) Injury-damage - Loss: Injury results in loss that terminates in a) personal physical harm of a variety of types and property damage, including fire. To optimise loss reduction, the professional is expected to adopt appropriate countermeasures.

Bird's updated Domino Sequence is highly focussed on the role of management in controlling the accident related damage, injury and resultant loss. It emphasises the importance of looking for the basic causes for the causation of accidents rather than the immediate cause. The model encompasses the three major components of organisation namely, structure, technology and people in its attempt to understand the phenomenon of accident causation. The definition of accident adopted in the model is all encompassing. The model enables one to explain not only the personal injury but also the damage to property and occupational diseases caused in the workplace.

3.2.2 Edward Adam's Domino Sequence For Accident Causation

Edward Adam, the Director of Loss Prevention for Pet. Inc. St. Louis, further updated the Domino sequence for accident causation. Except the last two dominoes namely, the accident and the injury, the rest of the three dominoes were re-titled.

In Adam's postulation of accident causation, the first domino is the Management Structure. It epitomises the values, beliefs, and objectives of the key decision-makers of the organisation. It is only at this level that the priorities, the strategies and guidelines are evolved to be carried out by the manager and in turn by the supervisor. At this level there is possibility of committing 'Tactical Errors'. The second and the third dominoes are Operational Errors and Tactical Errors, respectively. Unsafe acts on the part of the employees and unsafe conditions existing in the workplace are seen as arising from 'Operational Errors'. The second domino in the accident causation series known as Operational Errors, comprises of wrong decisions or decisions not made either by the manager or the supervisor. Such behaviour on the part of the manager or supervisor is deeply rooted in the domain of the Management Structure (Findlay & Kuhlman, 1980).

Adam's theory includes organisational factors which are the cause of accidents. These include organisational objectives, appraisal system, standards of measurement, chain of command, span of control, delegation of responsibility and authority, layout of the workstation, equipment, the process of transforming raw material into output and / or the process of providing the services.

3.2.3 Weaver' Updated Domino Theory

D. A. Weaver's update of the Domino theory of accident causation categorises three important components of the theory namely, (I) Unsafe Act and/or Unsafe Conditions, (ii) Accident and (iii) Injury. All these three components are considered as Symptoms of Operational Error. Many unplanned and undesired outcomes that occur are the symptoms of operational error that take place in an organisation (Heinrich, Petersen &

Ross, 1980).

For example, lost baggage in the air travel, contaminated batch of a product, customer badly treated etc., are all symptoms of operational error. *Such errors have the potentiality of snowballing into major event.* It is postulated that such operational errors take place because the unsafe act and/or condition are permitted to take place.

According to the Weaver's model, the existing management practices are responsible for any unsafe act like using defective equipment, failure to use personal protective equipment, improper lifting of materials etc. It is postulated that such management practices emanates from the organisational safety policy, priorities, organisational structure, decision-making, the prevailing management system of control, evaluation and administration. Another postulation of Weaver's model is the lack of knowledge of the management regarding the prevention of accident. It is important to explore why knowledge is not effectively sought or not effectively applied by the management. In fact, the Weaver's model asserts that any operational error exposes the vulnerability of the management policy, line of authority, line and staff relationships, accountability, rules, initiatives etc.

3.2.4 Zabetakai's Updated Domino

According to this theory proposed by Dr. Michael Zabetakis, accidents are caused by the unplanned transfer, or release of excessive amount of energy (mechanical, electrical, chemical, thermal, ionising radiation) or of hazardous materials (such as carbon monoxide, carbon dioxide, hydrogen sulphide, methane and water). Unsafe act or an unsafe condition may trigger the release of large amounts of energy or of hazardous material which in turn causes the accidents (Heinrich, Petersen & Ross, 1980).

According to this theory, contrary to the popular belief, the unsafe act and unsafe conditions are merely symptoms of failure. There are three basic causes of accidents. These are a) the poor management policies and decisions b) personal factors and c) environmental factors.

Factors that contribute to the poor management policies and decisions are safety policy, management's commitment to safety, production and safety goals, staffing procedures, use of records, span of authority and responsibility, accountability, communications, selection of personnel, inspection procedures, standard and emergency job procedures, housekeeping, purchase and maintenance procedures, design of equipment and workstation design etc.

Personal factors that play important role in accident causation are many. These are: ability, knowledge, motivation, safety awareness, physical and mental state, level of performance etc.

Environmental factors in the causation of accident include thermal conditions, humidity, vibration, dust gases, vapours, ventilation, slippery surfaces, inadequate supports, hazardous objects etc.

3.3 The Star Step Model

Hugh Douglas, Safety Director of the Imperial Oil Company, proposed the Star Step Cause and Effect Sequence Model in his book titled 'Effective Loss Prevention'. This model follows a logical series of steps (Douglas & Crowe, 1976)

Step I: This step comprises of formation of Purpose, Objective and Goal.

Step II: In accomplishing the objectives resources are to be organised and administered in such a way that desired objective is attained.

Step III: As far as resources are concerned, there is an upper level beyond which it is too costly to undertake or continue any activity. Exercise is undertaken to determine that upper limit.

Step IV: Likewise, it is necessary to decide the lower limit beyond which the costs of loss would be very high. In the context of the safety management it is crucial to decide what are the bare minimum goals need to be achieved

Step V: The acceptable limit is a range within which tasks and conditions can be blended together in a variety of ways so that acceptable level of performance is attained. The upper limit and the lower limits of the resources determine the standard.

Step VI: The acceptable range and the Lower acceptable limit or standard will vary in accordance with the criticality of the inherent hazards, and the *potential consequences for not setting and meeting a high enough* standard.

Step VII: Lower acceptable limit is the lowest standard which individuals or an organisation is expected to accept as satisfactory. In addition to this there is another standard known as the Lowest Acceptable Standard, set by law. It has been evidenced that in some cases the lower acceptable limit and the lowest acceptable standard are the same.

Factors that determine the lower acceptable limit for the activities and conditions of any organisation are: a) Personal judgement; b) Consensus decision; c) The forces of the market place; d) The socio-political values of the community interface and e) Legal requirements (Findlay & Kuhlman, 1980).

To summarise, the stair step sequence model emphasises upon process of making decision regarding the range within which purpose, goals and objectives or in other words standards are to be fixed after giving due consideration to the upper and lower acceptable limits in terms of the cost and risk involved. In this decision-making process several organisational factors such as management practices, tasks and technology, resource availability, systems elements are to be accounted for. The model points out criticality of the attitudinal component namely, 'zeal for excellence' in deciding the lower acceptable limit. In other words it hints at the importance of existing organisational values to work towards excellence. Extra organisational factors like legal requirements, demands of the market forces, the prevailing socio-political values can exert influence in deciding the lower and upper acceptable limit. These limits would define the space and scope within which the organization could formulate the standards, objectives and goals to achieve its purpose for the safety management system to prevent loss due to injury and damage.

3.4 Accident Proneness Theory

The idea that some individuals or groups of people are especially vulnerable or invulnerable to misfortune is very old. In 1919, during World War

I, Major Greenwood and Hilda M. Woods carried out extensive studies on accidents among workers in a British munitions factory. They found that accidents were not evenly distributed but that a relatively small proportion of the workers had most of the accidents. To explain this phenomenon, they did not describe some workers as "prone" to accidents but developed the theory of unequal initial liability. According to this theory, a small minority of individuals has greater numbers of accidents than would be expected on the basis of chance alone. Taking the accident records of a large number of work groups, they compared the observed frequencies with three alternative hypothetical distributions. Further checks on consecutive time periods led them to propose that the presence of individuals with unequal liabilities best explained all the facts (Haight, 2001).

In 1926, E.M.Newbold, followed-up the preliminary work of Greenwood and Woods. They studied the accident records of a large group of workers in 13 factories. Her result largely substantiated those of Greenwood and Woods. She was careful to point out, "It is not possible in a mass examination of this kind to find out how much of this may be due to individual differences in the conditions of work or how much to personal tendency, but there are many indications that some part, at any rate, is due to personal tendency". (In Haddon et al., 1964: 397). Despite Newbold's caveat and her careful phrasing with respect to "personal tendency", her work has been widely cited as offering definite proof of the existence of individuals who are psychologically prone to accidents. Partially as the result of her research, the idea of accident proneness together with the belief that the best attack on industrial accidents is the detection and elimination of accident-prone workers was to dominate industrial psychology for some time.

Finally, in 1939, using motor vehicle accident records, E. Farmer and E.G. Chambers substantiated the fact that accidents do not distribute themselves at random. They then administered psychological tests to accident-free and accident–repeating groups in an attempt to determine personal characteristics that might explain the differences observed (Goetsch, 1993).

However, in 1951 one of the most decisive critiques of the accident-proneness concept appeared in a long article by A.G. Arbous and J.E.Kerrich of the South African Council for Scientific and Industrial Research. Thereafter, in many research studies, the concept of accident proneness has been criticised on statistical, methodological and theoretical grounds.

Methodologically, the most important aspect is the failure to control an environmental exposure or risk as some individuals are more likely to be exposed to hazardous occupations or environments and thus to incur more accidents. From the theoretical point of view, there is some reason to doubt the existence of any identifiable personality type that could be labelled as the accident-prone personality. Most of the studies have shown that individuals with higher number of accident in one year do not continue to experience the same in succeeding years. Therefore, today safety professionals think less in terms of proneness as a causative agent and look for other theories to explain the reason for accident repeaters (Heinrich, Petersen & Ross, 1980).

3.5 Human Factors Models of Accident Causation

Human factors models of accident causation refer to distracting influences upon the worker by either internal or external factors. Such distracting influences are of temporary rather than permanent nature. Therefore, if care is taken to eliminate such distracting factor there is a possibility of preventing the causation of accidents. Basically, such models state that whenever human beings are overloaded due to a mismatch between the capacity of the individual and the external demand made upon him, the individual becomes more susceptible to accident. Among various Human Factors Models Ferrell's Human Error Theory and the Petersen Accident-Incident Causation Model will be discussed here.

3.5.1 The Ferrell's Human Error Theory

Russell Ferrell, Professor of Human Factors at the University of Arizona is the proponent of the theory. According to this theory accident causation is attributed to a chain of events ultimately caused by human error. Human error is in turn caused by one of the three situations: overload, inappropriate response and inappropriate activities (Reason, 1990).

Overload: It amounts to an imbalance between a person's capacity at a given time and the load that person is carrying in a given state. A person's capacity is the product of such factors as his or her natural ability, training, state of mind, fatigue, stress, and physical condition. The load a person is carrying consists of tasks for which he or she is responsible and added burden resulting from a) environmental factors (such as noise, heat, cold, vibration etc.); b) internal factors (personal problems, emotional stress, anxiety etc.) and c) situational factors (e.g., level of risk, unclear instructions, etc.)

Inappropriate Response/Incompatibility: The manner in which an individual responds to a given situation can cause or prevent an accident. If a person removes a machine-guard from a machine in an effort to increase output, he or she has responded inappropriately. If a person disregards an established safety procedure, he or she has responded inappropriately. Such responses can lead to accidents. In addition to inappropriate responses this component includes workstation incompatibility. The incompatibility of a person's workstation with regard to size, force reach, feels and similar factors can lead to accidents and injuries.

Inappropriate Activities: Human error can be the result of inappropriate activities. For example, a person undertakes a task but does not know how to do it. Or, a person misjudges the degree of risk involved in a given task and attempts to carryout the job on the basis of that misjudgement. Such inappropriate activities may lead to accidents and injuries (Reason, 1990).

3.5.2 The Petersen Accident-Incident Causation Model

In 1982, Dan Petersen, a safety consultant proposed this model in his book titled Human Error Reduction. This model suggests human error is caused by three broad factors namely a) overload; b) Ergonomic traps and c) decision to err.

a) Overload is 'a mismatch of capacity with load in a state. An individual's capacity is dependent upon that person's natural endowment, physical condition, state of mind, knowledge and skill, habit of indulging into drug or alcohol abuse, fatigue or pressure, motivational state, attitudinal attributes, arousal level and biorhythm. Load arising out of the tasks one has to perform, challenges individual's capacity and in the event of any mismatch between the load and the capacity there is the possibility of overload. Tasks may include information processing, environmental demands, worry and stress arising out of Life Change Events (measured in terms of LCUs or Life Change Units), situational hazards etc.

b) Decision to err suggests that very often employees are found to commit 'human error' as they take certain decisions consciously or unconsciously. There are many occasions when workers choose to perform a task unsafely because according to them it is much more logical in their situation to perform it unsafely than it is to perform safely. Such things happen due to peer pressure, appraisal of the boss, priorities of the management and personal values. It may also happen as they perceive a low probability of an accident happening to them or because they perceive a low potential cost to them of the accident (Lawton & Parker, 1998).

c) Ergonomic Traps occur due to faulty workstation design and incompatible displays or controls. Thus, human error is the outcome of overload, decision to err and ergonomic trap (Reason, 1990).

In the causation of accidents human error and system failure play major role. There are many potential systems failures which are basically organisational factors related. Management fails to establish a comprehensive safety policy. Responsibility and authority with regard to safety are not clearly defined. Safety procedures such as measurement, inspection, correction and investigation are ignored or given insufficient attention. Employees do not receive a proper orientation. Employees are not given sufficient safety training. These are some examples of many types of systems failures that might occur according to Petersen's Accident-Incident Causation Model.

3.6 The Epidemiological Theory of Accident Causation

This theoretical framework in very general terms explains causal association between diseases or other biologic processes (accidents) and specific environmental experiences. In medicine and epidemiology, concepts corresponding to Heinrich's first three dominoes would be Host (human), Agent (hazard), and Environment. All kinds of illness including injury are considered as results of interactions between these three categories. The science of epidemiology was developed from the perspective of infectious diseases, which is also reflected in its vocabulary. Diseases were generally seen as results of impacts from external 'agents', such as bacteria or virus, affecting the 'host' and environmental conditions could either convey or restrain this process (Anderson, 1998). From the perspective of epidemiological model an accident is defined as 'the unexpected, unavoidable unintentional act resulting from the interaction of host, agent, and environmental factors within situations which involve risk taking and perception of danger' (Suchman, In Heinrich et al., 1980)

In this model two important components namely, predisposition characteristics and situational characteristics, are instrumental in the accident conditions and accident effects. Accident effects are the injuries and damages inflicted upon the people or the property. These effects are the measurable indices of the accident. Conditions under which accident takes place are unexpected, unavoidable and unintentional act resulting from the predisposition characteristics and situational characteristics. Predisposition characteristics include the susceptibility of the people (host), hazardous environment, injury producing agent etc. Situational characteristics are risk assessment by individual, peer pressure, priorities of the supervisor and prevailing attitude. For example, if an employee who is particularly susceptible to pressure from the people in the position of power (predisposition characteristic) were pressured by his supervisor (situational characteristic) to speed up his operation, the result would be increased probability of an accident.

Dr. William Haddon Jr., known as the father of modern injury epidemiology, proposed a framework for describing the causes of accidents and directing countermeasures in road safety. He introduces three phases of interaction, namely Pre Crash (pre-event), Crash (event) and Post Crash (post-event) as well as three groups of factors involved in each of the phases of interaction that lead to end-results of losses namely human, vehicle and equipment and Environment. By combining the phases (in the rows) with the factor (in the columns) a 3X3 matrix (known as Haddon Matrix) is constructed for categorising road losses, countermeasures and program efficiency. Later, Haddon refined the model to its current form listing the columns as Human (or Host); Vehicles (or Agents) and equipment; physical environment and socioeconomic environment (Runyan, 2003).

The model is mostly used to conceptualise etiologic factors for traffic injury and to identify potential preventive strategies for effective safety interventions (Sadauskas, 2003). Wider application of Haddon's Matrix and application of 10 point countermeasure in preventing hazard in the industries will bring into focus people, technology and structure related organisational and factors.

3.7 The Systems Theory of Causation

The very concept of 'systems' provide a general framework for modelling mutual and complex interactions in virtually all types of applications, from technology and biology, to economy, psychology, and sociology. By means of systems theory, it is possible to describe the dynamics of such circumstances in more detail and to understand under which circumstances a given system transform into new, and perhaps unwanted, stages or modes of operation. In the late 1960s, Surry explored the nature of man-environment interactions from a behavioural and systems-oriented view, in order to better understanding why such interactions give rise to accident risks, and why latent risks are transformed into accidents and injuries. Surry's model consists of two sequences. The first one analyses the risk build-up from normal man-machine-environment interaction, and the second one describes the dynamics of accidents and what makes some result in injury and some not(Surry, 1969).

In the mid 1970s, a Swedish research group, concurrently active with a project on occupational accidents in the city of Malmo, performed an evaluation of Surry's model based on the authentic material collected through the project. In spite of its clear merits the model was found to include some important limitations, mainly biases towards the behaviour of the individual The model was found to pay no attention to the technical and environmental circumstances and their origin. Many accidents occur in disturbed and deviated situations, which demand corrective and improvising actions from the individual. In such situations, it is important to analyse the background of these deviations, rather than focus on why the individual did not manage the upcoming situation properly (Anderson et al., 1978).

The most widely used systems model is that developed by R.J. Firenzie (Firenzie, 1978). The model has three important blocks. First block consists of interaction among man-machine-environment. The second block comprises of the process of collection of information, weighing of risks and decision making. The third block is the task to be performed as the outcome of the processes involved in the previous two blocks. The feedback loop connects the third and the first block. It is evident from this model that as the person interacts with a machine within an environment to perform a task, three activities namely collection of information, weighing of risks and decision making to perform the task take place. Based on the information that has been collected by observing and mentally noting the current circumstances, the person weighs the risks and decides whether or not to perform the task under existing circumstances. For example, a machine operator is working on a rush order against a fast approaching deadline. An important safety device has malfunctioned on his machine. To simply take it off will interrupt work for only five minutes, but it will also increase the probability of an accident. However, to replace it could take up to an hour. Should the operator remove the safety guard and proceed with the task or take the time to replace it? The operator and his supervisor might assess the situation (collect information), weigh the risks and make a decision to perform the task. For this reason Firenzie recommends the five factors be considered before beginning the process of collecting information, weighing risks and making decision. These factors are: a) Job requirements; b) The worker's abilities and limitations; c) What is gained if the task is successfully accomplished; d) What is lost if the task is attempted but fails and e) What is lost if the task is not attempted. It is particularly important to consider these factors when stressors such as noise, time, constraints, or pressure from a supervisor might tend to cloud one's judgement (Firenzie, 1978).

One of the basic concepts in systems theory is homeostasis or equilibrium (balance). A system is stable when it runs according to the intentions of its creator. When exposed to perturbations (disturbances), it should have a built-in capacity to regain balance, like a pedestrian being pushed, a car and its driver skidding, and so on. In more complex settings, analogous examples could include the regaining of stability in a nuclear power plant or an aircraft subjected to perturbations, either automatically or by proper actions taken by the staff. When a system is exposed to perturbations beyond its recovery capacities, an unstable process is initiated which, depending on contextual factors, may result in an accident with manifest human or material damage, sometime even cascading accidental processes with major loses (Benner, 1975).

3.8 The Sociological Theory of Accident Causation

An eminent organisational sociologist Charles Perrow of the University of Wisconsin, in USA is the proponent of this theory. He has been shaping his theory for more than two decades since the publication of his foundational work titled "Normal accidents: Living with high-risk technologies" in 1984. In his book Perrow is the first to propose the framework for characterising complex technologies such as air traffic, marine traffic, chemical plants, dams and specially nuclear power plants according to their risk vulnerability. 'Normal' accidents are the events that seem to start with something ordinary or that happens all the time and almost always without causing great harm. But, such apparently trivial events cascade through the organisational system in *unpredictable ways to cause a large event with severe consequences.* This book is a classic analysis of complex organisational systems and their risk vulnerability from the point of view of a social scientist.

In sharp contrast to Person Theory or System Theory wherein focus is on isolated errors of individual human operators or design flaws in individual components, Perrow's framework focuses on explanation of serious accidents in terms of structural factors and combinations of problems. Perrow's framework of the organisational system in explaining catastrophies has two dimensions namely, interactive complexity (high to low non-linear interaction) and coupling (tight to loose spatial, temporal and other patterns of buffering among components). *According to him ' no matter how hard we try,* certain kinds of systems – those that had many non-linear interactions (interactive complexity) and those that were also tightly coupled- were bound to fail eventually. If thy also had catastrophic potential, we had better shut them down (or agree to live and die with them if they were that unique and valuable) or massively redesign them to be more linear and loosely coupled' (Perrow, 2004: p-10). The loosest and least complex situations are routine bureaucracies like the Post Office while the tightest and most complex are the nuclear power plants and the nation's nuclear defence missiles, radars, and retaliation protocols. It is this sociological perspective that illuminates the structural underpinnings of high-risk organisational systems and the often intricate, unanticipated causes of system failure (Jermier, 2004). Perrow believed that it is unexpected, unpredictable, unintentional but normal that "complex systems threaten to bring us down" (Perrow, 1999: p. VII).

Perrow developed his theoretical framework and published the book "Normal accidents: Living with high-risk technologies" based on his analysis of the Three Mile Island (TMI) nuclear reactor accident documents in the Harrisburg, Pennsylvania areas of the USA in 1979. In fact, he was prompted to write the book to document his objections to the Kemeny report on TMI as the report primarily blamed the plant operators for the accident. He observed that accidents such as TML and number of others, all began with a mechanical or other technical mishap and then spun out of control through a series of technical cause-effect chains because the operators involved could not stop the cascade or unwittingly did things that made it worse. Perrow's contention is that serious accidents and catastrophic events alike are the result of simultaneous and interactive failure among various system components including equipment, procedures, operators, supplies and material, environment, and design (Perrow, 1999). He found that in such cases of multiple failures, each small and insignificant on its own, engender catastrophes when they occur in combination that are not well buffered. Large-scale system failure results from the interaction of small failures; "great events have small beginnings" (Perrow, 1999: p. 9).

Perrow's framework has influenced number of important studies by social scientists in the risk and disaster area (Jermier, 2004; Perrow, 2004) nevertheless, it was not beyond criticism. First, Perrow is considered as a technological pessimist as he insists that nuclear power plants cannot be improved and even if those are improved, nothing will succeed in eliminating accidents. His dire predictions of more TMIs have not come true. Secondly, Perrow is alleged to be somewhat politically motivated. He seems to be convinced that we have technologically accident-prone and dangerous systems because certain "elites" (refereed 27 times in 411 pages) have imposed these systems on us for their own gain (Whitney,2003).Thirdly, his arguments are based on some examples rather than quantitative analysis which he acknowledges in the 'afterword' of his book (Perrow,1999).

3.9 OVERVIEW

The primary purpose of this chapter is to review the extent to which accident theories have given emphasis upon the organisational factors in the causation of accidents. It is found that in the domino theories of accident causation, organisational factors have been given importance in varying degrees. Heinrich's Domino theory is not at all explicit about the role of organisational factors in the accident causation. Instead, the emphasis is on the psycho-social factors of the individual and the mechanical or physical hazards. Nevertheless, in Heinrich's formulation of the 'axioms of industrial safety' which accompanies his Domino theory of accident causation, important roles of management and supervisors in the prevention of accident prevention have been categorically stated.

Interestingly, in the updated domino sequence, Frank Bird is very explicit about the role of organisational factors in the causation or prevention of accidents. According to his theory, lack of management control is the source of accidents, injuries or damage and influences the basic causes and immediate causes of accident. Frank Bird's theorisation of accident causation emphasises upon various aspects of management control in the areas of personnel selection and placement, design engineering, job analysis, training, employee communication, safety inspection, benchmarking, monitoring and continuous up gradation of performance at all levels of activities to attain a desired level of system reliability.

Similarly, in Edward Adam's Domino Sequence for Accident Causation, organisational factors have been given primary importance. It emphasises upon organisational structural characteristics, which include organisational objectives, appraisal system, workstation designing, delegation of responsibility and authority, appraisal system, manufacturing system, system of providing services etc. Organisational structure also epitomises the organisational core values and defines the attitudes of the people in the organisation. According to this theory, management structure is basically responsible for any operational error, tactical errors, accidents and injury or damage. In Weaver's model of accident causation any unsafe act, unsafe condition, accident and injury are nothing but symptoms of operational error for which the existing management practices are made responsible. In this theory, primary importance has been given to the management's intent and knowledge about safety. Weaver's model raises the pertinent issue, why the knowledge about safety is not effectively applied by the management. This question probes into various aspects of the organisational factors such as management policy, responsibility, use of authority, line and staff relationships, accountability, rules initiative and much more. In Zabetakis's theory of accident causation organisational factors have been given primary importance along with personal and environmental factors, in identifying and correcting the basic causes of accidents. The organisational factors include safety policy, management's intent for safety; production and safety goals; assignment of responsibility and authority; employee selection, communication procedures, training and placement; formulation of standard operating system and emergency job procedures etc.

A review of the Star Step theory proposed by Hugh Douglas reveals that there are few organisational factors, which are of critical importance in the theory. Foremost among these factors are management's safety policy containing a clear-cut statement of objectives and goals. The core values of the organisation which are adhered to by the management do play important role in determining the 'upper limit' and 'acceptable lower limit' of resources to arrive at the safety and performance standards to be followed in the organisation.

In the Human Factors models of accident causation man-machine interface in the accident causation has been deliberated upon. These models focus on such broad factors like a) Ovorload; b) Inappropriate response or incompatibility, c) inappropriate activities; d) Ergonomic trap e) Decision to err etc. Interestingly, at the micro-level, these factors are individual centric as those focus on human error in information processing. Nevertheless, such human errors are regarded by the Human Factors theorists as the out-come of potential systems failures that occur in the macro-level in the organisation. Consequently, any remedial measure related to human error need to be taken at the organisational level i.e., in matters related to the formulation of safety policy, allocation of responsibility and authority, formulation of safety procedure, periodic monitoring system with adequate provision for adopting corrective measures at various levels, training of employees in developing competency etc.

The Epidemiological theory of accident causation has a strong influence in safety management as it equates any accident with the concept of disease, which is caused by an external agent and in a particular situation. This theory has been successful in pulling-out the concept of accident from the domain of an act of God, or chance or luck to the arena of scientific enquiry. As it is evident from this theorisation that accidents or injuries are caused to the host or the individual due to certain predisposing and situational characteristics. Similarly, the effective remedial measures to prevent future occurrence of injury involves the role played by various organisational factors. In the organisational context, some of the predisposing characteristics and all the situational characteristics are nothing but the organisational characteristics contributing to the causation of accidents. These characteristics include the workstation design, physical conditions of the workplace (thermal conditions, dust, noise, toxic, engineering hazards etc.), management policies and actions, organisational policies, peer pressure etc.

In the systems theory of accident causation, man-machine interaction takes place to perform a task through a process of collection of information, weighing of risks and decision-making. Any disturbance or incompatibility in this process leads to lack of homeostasis or disequilibrium in the system that may lead to accident or injury. At the organisational level, the process of collection of information and weighing risk leads to various management functions involving formulation of system to ensure systems homeostasis or equilibrium. It connotes taking care of various organisational factors mentioned above ranging from job analysis, selection and placement of personnel and management of stressors that may affect the information processing decision-making at various levels of organisational functioning to maintain the homeostasis in the man-machine systemic interaction.

The sociological theory of accident causation proposed by Charles Perrow is focussed on the complicated dynamics of high-risk organisational system including its system of political power structure as well as the organisational structure that facilitates or inhibits organisational decision making leading to potential catastrophic incident. In this framework, explanation of serious accidents focuses on structural factors and combinations of problems. Unlike most other theories, it does not dwell upon isolated errors of individual human operators or design flaws in individual components. In this perspective the structural underpinnings of high risk organisations are highlighted.

Most of theories of accident causation reviewed here are explicit about the importance of organisational factors in ensuring safety behaviour in the organisations. Only exception is the accident proneness theory which did not mention about any organisational factors except emphasising upon adopting personnel selection procedure to weed-out the accident prone individuals. Few of the theories although not so explicit about the organisational factors, while elaborating on specific measures organisation could adopt to prevent accidents and injuries implied the importance of organisational factors. These organisational factors range from core values of the organisation, organisational structure best suited for ensuring safety, the organisational safety policy, personnel selection and placement, safety training, management and supervisory style, priorities given to safety and productivity, roles and responsibilities of employees to the management of stress for accurate information processing and decision making.

Next chapter will deal with organisational factors, which are found to have critical impact on organisational safety behaviour.