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Hazard Management and Analysis

A hazard is a situation that poses a level of threat to life, health, property, or environment. Most hazards are dormant or potential, with only a theoretical risk of harm; however, once a hazard becomes "active", it can create an emergency situation. A hazard does not exist when it is not happening. A hazardous situation that has come to pass is called an incident. Hazard and vulnerability interact together to create risk.

Modes of a Hazard

Hazards are sometimes classified into three modes:

- Dormant - The situation has the potential to be hazardous, but no people, property, or environment is currently affected by this. For instance, a hillside may be unstable, with the potential for a landslide, but there is nothing below or on the hillside that could be affected.
- Armed - People, property, or environment are in potential harm's way.
- Active - A harmful incident involving the hazard has actually occurred. Often this is referred to not as an "active hazard" but as an accident, emergency, incident, or disaster.

Classifying Hazards

By its nature, a hazard involves something that could potentially be harmful to a person's life, health, property, or the environment. One key concept in identifying a hazard is the presence of stored energy that, when released, can cause damage. Stored energy can occur in many forms: chemical, mechanical, thermal, radioactive, electrical, etc. Another class of hazard does not involve release of stored energy, rather it involves the presence of hazardous situations. Examples include confined or limited egress spaces,

oxygen-depleted atmospheres, awkward positions, repetitive motions, low-hanging or protruding objects, etc

There are several methods of classifying a hazard, but most systems use some variation on the factors of "likelihood" of the hazard turning into an incident and the "seriousness" of the incident if it were to occur. (This discussion moved away from hazard to a discussion of risk.)

A common method is to score both likelihood and seriousness on a numerical scale (with the most likely and most serious scoring highest) and multiplying one by the other in order to reach a comparative score.

Risk = Likelihood of Occurrence x *Seriousness if incident occurred*

This score can then be used to identify which hazards may need to be mitigated. A low score on likelihood of occurrence may mean that the hazard is dormant, whereas a high score would indicate that it may be an "active" hazard.

An important component of "seriousness if incident occurred" is "serious to whom?" Different populations may be affected differently by accidents. For example, an explosion will have widely differing effects on different populations depending on the distance from the explosion. These effects can range from death from overpressure or shrapnel to inhalation of noxious gases (for people downwind) to being exposed to a loud noise.

Causes of Hazards

There are many causes, but they can broadly be classified as below.

- Natural hazards include anything that is caused by a natural process, and can include obvious hazards such as volcanoes to smaller scale hazards such as loose rocks on a hillside.
- Man-made hazards are created by humans, whether long-term (such as global warming) or immediate (like the hazards present at a construction site). These include *activity related hazards* (such as flying) where cessation of the activity will negate the risk.
- Deadly force or retribution is that hazard involving any protective and responsive-ready threat of harm or punishment that becomes active in the event of a breach of security, or violation of a boundary or barrier (physical, legal, moral) intended to prevent unauthorised or unsafe access or entry or exposure to a situation, to something, or to someone. This includes the consequences that follow trespass, breach of covenant, outrage or moral panic.

Hazard (Risk)

A hazard is any biological, chemical, mechanical, or physical agent that is reasonably likely to cause harm or damage to humans, other organisms, or the environment in the absence of its control. This can include, but is not limited to: asbestos, electricity,

microbial pathogens, motor vehicles, nuclear power plants, pesticides, vaccines, and X-rays. Identification of hazards is the first step in performing a risk assessment and in some cases risk assessment may not even be necessary.

Types

Biological

A biological hazard is one originating from an organism that is foreign (in presence or concentration) to the organism being affected. Many biological hazards are associated with food, including certain viruses, parasites, fungi, bacteria, and plant and seafood toxins. Pathogenic *Campylobacter* and *Salmonella*, are common foodborne biological hazards. The hazards from these bacteria can be avoided through risk mitigation steps such as proper handling, storing, and cooking of food. Disease in humans can come from biological hazards in the form of infection by bacteria, viruses, or parasites.

There is some concern that new technologies such as genetic engineering pose biological hazards. Genetically modified organisms are relatively new man-made biological hazards and many have yet to be fully characterised. For example, corn expressing insecticidal Cry proteins from the bacterium *Bacillus thuringiensis* was first introduced in 1996 and many of its potential detrimental effects on non-target organisms have yet to be examined.

Chemical

A chemical can be considered a hazard if by virtue of its intrinsic properties it can cause harm or danger to humans, property, or the environment. Some chemicals occur naturally in certain geological formations, such as radon gas or arsenic. Other chemicals include products with commercial uses, such as agricultural and industrial chemicals, as well as products developed for home use. Pesticides, which are normally used to control unwanted insects and plants, may cause a variety of negative effects on non-target organisms.

DDT can build up, or bioaccumulate, in birds resulting in thinner-than-normal egg shells which can break in the nest. The organochlorine pesticide dieldrin has been linked to Parkinson's disease. Corrosive chemicals like sulfuric acid, which is found in car batteries and research laboratories can cause severe skin burns. Many other chemicals used in industrial and laboratory settings can cause respiratory, digestive, or nervous systems problems if they are inhaled, ingested, or absorbed through the skin.

The negative effects of other chemicals, such as alcohol and nicotine, have been well documented. Hazards associated with chemicals are dependent on the dose or amount of the chemical. For example, iodine in the form of potassium iodate is used to produce iodised salt. When applied at a rate of 20 mg of potassium iodate per 1000 mg of table salt, the chemical is beneficial in preventing goiter, while iodine intakes of 1200–9500 mg

in one dose have been known to cause death

Mechanical

A mechanical hazard is any hazard involving a machine or process. Motor vehicles, aircraft, and air bags pose mechanical hazards. Compressed gases or liquids can also be considered a mechanical hazard.

Physical

A physical hazard is a naturally occurring process that has the potential to create loss or damage. Physical hazards include, but are not limited to, earthquakes, floods, and tornadoes. Physical hazards often have both human and natural elements. Flood problems can be affected by climate fluctuations and storm frequency, both natural elements, and by land drainage and building in a flood plain, human elements. Another physical hazard, X-rays, are naturally occurring from solar radiation, but have been utilised by humans for medical purposes; however, overexposure can lead to cancer, skin burns, and tissue damage.

Hazard v. Risk

The terms hazard and risk are often used interchangeably, however, in terms of risk assessment, these are two very distinct terms. As defined above, a hazard is any biological, chemical, mechanical, or physical agent that is reasonably likely to cause harm or damage to humans or the environment with sufficient exposure or dose. Risk is defined as the probability that exposure to a hazard will lead to a negative consequence, or more simply, Risk = Hazard x Dose (Exposure). Thus, a hazard poses no risk if there is not exposure to that hazard. Consider the following example:

> Three people crossing the Atlantic in a rowboat face a hazard of drowning. (...) Three hundred people crossing the Atlantic in an ocean liner face the same hazard of drowning, (...). The risk to each individual per crossing is given by the probability of the occurrence of an accident in which he or she drowns. (...) Clearly the hazard [drowning] is the same for each individual, but the risk [probability of drowning] is greater for the individuals in the rowboat than in the ocean liner.

Hazard Identification

Mechanical and Physical Hazards

Many mechanical hazards (aircraft, motor vehicles) and physical hazards (earthquakes, floods) have already been identified and well described. Hazard identification of new machines and/or industrial processes occurs at various stages in the design of the new machine or process. These hazard identification studies focus mainly on deviations from the intended use or design and the harm that may occur as a result of these deviations and are regulated by various agencies such as the

Occupational Safety and Health Administration and the National Highway Traffic Safety Administration.

Biological Hazards

Many biological hazards have also been identified. For example, the hazards of naturally-occurring bacteria such as *Escherichia coli* and *Salmonella*, are well known as disease causing pathogens and a variety of measures have been taken to limit human exposure to these microorganisms through food safety, good personal hygiene and education. However, the potential for new biological hazards exist through the discovery of new microorganisms and through the development of new genetically modified (GM) organisms. Use of new GM organisms is regulated by various governmental agencies. The U.S. Environmental Protection Agency (EPA) controls GM plants that produce or resist pesticides (i.e. Bt corn and Roundup ready crops). The U.S. Food and Drug Administration (FDA) regulates GM plants that will be used as food or for medicinal purposes.

Chemical Hazards

A variety of chemical hazards (DDT, atrazine) have been described as well. However, every year companies produce more new chemicals to fill a new need or to take the place of an older, less effective chemical. Laws, such as the Federal Food, Drug, and Cosmetic Act and the Toxic Substances Control Act in the U.S, require protection to human health and the environment for any new chemical introduced.

In the U.S., the EPA regulates new chemicals that may have environmental impacts (i.e. pesticides or chemicals released during a manufacturing process), while the FDA regulates new chemicals used in foods or as drugs. The potential hazards of these chemicals can be identified by performing a variety of tests prior to the authorisation of usage. The amount of tests required and the extent to which they are tested varies depending on the desired usage of the chemical. Chemicals designed as new drugs must undergo more rigorous tests that those chemicals to be used as pesticides.

Hazard Analysis

A hazard analysis is used as the first step in a process used to assess risk. The result of a hazard analysis is the identification of risks. Preliminary risk levels can be provided in the hazard analysis. The validation, more precise prediction and acceptance of risk is determined in the Risk assessment (analysis). The main goal of both is to provide the best selection of means of controlling or eliminating the risk. The term is used in several engineering specialities, including avionics, chemical process safety, safety engineering, reliability engineering and food safety. Alternative definitions include:

Identification, studies and monitoring of any hazard to determine its potential,

origin, characteristics and behaviour. The process of collecting and evaluating information on hazards associated with the food under consideration to decide which are significant and must be addressed in the HACCP plan.

An analysis or identification of the hazards which could occur at each step in the process, and a description and implementation of the measures to be taken for their control.

Hazards and Risk

A hazard is defined in FAA Order 8040.4 as a "Condition, event, or circumstance that could lead to or contribute to an unplanned or undesirable event." Seldom does a single hazard cause an accident.

More often, an accident occurs as the result of a sequence of causes. A hazard analysis will consider system state, for example operating environment, as well as failures or malfunctions.

While in some cases safety risk can be eliminated, in most cases a certain degree of safety risk must be accepted. In order to quantify expected accident costs before the fact, the potential consequences of an accident, and the probability of occurrence must be considered. Assessment of risk is made by combining the severity of consequence with the likelihood of occurrence in a matrix. Risks that fall into the "unacceptable" category (e.g., high severity and high probability) must be mitigated by some means to reduce the level of safety risk.

IEEE STD-1228-1994 Software Safety Plans prescribes industry best practices for conducting software safety hazard analyses to help ensure safety requirements and attributes are defined and specified for inclusion in software that commands, controls or monitors critical functions.

When software is involved in a system, the development and design assurance of that software is often governed by DO-178B. The severity of consequence identified by the hazard analysis establishes the criticality level of the software. Software criticality levels range from A to E, corresponding to severities of Catastrophic to No Safety Effect. Higher levels of rigor are required for level A and B software and corresponding functional tasks and work products is the system safety domain are used as objective evidence of meeting safety criteria and requirements.

Recently a leading edge commercial standard was promulgated based on decades of proven system safety processes in DoD and NASA. ANSI/GEIA-STD-0010-2009 (Standard Best Practices for System Safety Program Development and Execution) is a demilitarized commercial best practice that uses proven hostistic, comprehensive and tailorable approaches for hazard prevention, elimination and control. It is centred around the hazard analysis and functional based safety process.

Severity Definitions - Safety Related

Severity	*Definition*
Catastrophic	Results in multiple fatalities and/or loss of the system
Hazardous	Reduces the capability of the system or the operator ability to cope with adverse conditions to the extent that there would be: • Large reduction in safety margin or functional capability • Crew physical distress/excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely • Serious or fatal injury to small number of occupants of aircraft (except operators) • Fatal injury to ground personnel and/or general public
Major	Reduces the capability of the system or the operators to cope with adverse operating conditions to the extent that there would be: • Significant reduction in safety margin or functional capability • Significant increase in operator workload • Conditions impairing operator efficiency or creating significant discomfort • Physical distress to occupants of aircraft (except operator) including injuries • Major occupational illness and/or major environmental damage, and/or major property damage
Minor	Does not significantly reduce system safety. Actions required by operators are well within their capabilities. Include: • Slight reduction in safety margin or functional capabilities • Slight increase in workload such as routine flight plan changes • Some physical discomfort to occupants or aircraft (except operators) • Minor occupational illness and/or minor environmental damage, and/or minor property damage
No Safety Effect	Has no effect on safety

Likelihood of Occurrence

Likelihood	*Definition*
	• Probable Qualitative : Anticipated to occur one or more times during the entire system/operational life of an item. • Quantitative: Probability of occurrence per operational hour is greater than 1×10^{-5} • Remote Qualitative: Unlikely to occur to each item during its total life. May occur several times in the life of an entire system or fleet. • Quantitative: Probability of occurrence per operational hour is less than 1×10^{-5}.