Global Environmental Operations, Inc.

A Brief Introduction to Risk Assessment

By: David L Russell, PE, President, Global Environmental Operations, Inc. Lilburn, GA

Risk Management/Risk Assessment basics:

What is risk?

Risk is defined as anything which can harm a facility or its operations. This includes internal and internal forces such as weather, earthquake, explosion, terrorist activities, and internal causes such as leaks, spills, fire, explosions, failures, etc. Phrased in security terms, these activities are referred to as "Threats".

The threat can be from the building next door, the groundwater, a local landfill, a runaway truck, corrosion on steel piping and structures, and generally anything which can lead to failure.

We try and identify these failures and avoid them by a process called Risk Assessment. We all conduct risk assessments every day. When you are crossing a street you are performing a risk assessment. Is that car really going to stop and let me cross safely? Is the apartment house I live in a fire trap? Should I move? Is the stranger I meet on the street confrontational or passive? Should I avoid him or her or meet them head on?

What are the hazards in an industrial area? Is it safe to build a school on a specific property? What are the risks.

In some states, such as Georgia, where I live construction of public schools requires a specific threat assessment be conducted prior to the construction of the facility. This is shown in Table 1.

4797 Dean Lane, SW, Lilburn, GA, 30047
Phone: 770-923-4408: e-mail: DLR@mindspring.com

Table 1: Georgia Department of Educational Guidelines for School Siting: (POTENTIAL THREATS)

Potential hazards to an educational facility site include but are not limited to:

- ¬ Electrical transmission lines rated at 115 KV or higher
- ¬ Oil or petroleum product transmission lines and storage facilities
- ¬ Hazardous chemical pipelines
- ¬ Natural gas transmission and distribution lines larger than ten inches in diameter with a pressure of 200 psi or greater
- ¬ Propane storage facilities
- ¬ Railroads
- ¬ Major highways
- ¬ Airports, approach and departure paths
- ¬ Industrial or manufacturing facilities that:
  - Use or store hazardous substances as defined under Title 40 CFR 262
  - Emit hazardous air pollutants as defined under the Clean Air Act and/or the 1990 Clean Air Act Amendments – Risk Management Plan Section 112 (r)
  - Use or store pentachlorophenol
  - Use or store other substances that may pose a hazard to soil, water, or air.
- ¬ Lakes, rivers, dams, reservoirs, or other bodies of water
- ¬ Potential flooding because the property is located within the 100-year flood plain or dam breach zone
- ¬ Nuclear waste storage facilities
- ¬ Munitions or explosive storage or manufacturing
- ¬ Water towers adjacent to the site
- ¬ Active or abandoned mines or quarries
- ¬ Remedial hazardous waste sites
- ¬ Landfills and dumps
- ¬ Treatment plants
- ¬ Power plants
- ¬ Military installations

According to Georgia Department of Education Rules, the hazards must be reviewed, and a Risk Assessment Report issued by a Professional Engineer.

BASIC CONCEPTS OF RISK:

- ***Risk = C * L(S|A) * L(A)***
- Where ***L(A)*** is the likelihood of an attack being attempted
- ***L(S|A)*** is the likelihood of adversary success given attack
- ***C*** is the consequences following a successful attack, and

- The total risk is obtained by summing the results of the equation for all relevant scenarios
- The consequence variable ***C*** represents the ***"worst reasonable case"*** consequences given a successful attack.
- Another formulation of the risk equation is: **Risk = vulnerability * Damage or R = V*D.**
- The formulas are equivalent with the constant C being included in the Damage term
- The term L(S|A) is the probability that the attack will be successful and it is equivalent to the V in the 2nd Equation.

For an example:

If we find out that we believe that there is a 30% chance that a particular tank will leak or fail, and that there is a 50% chance that a particular structural element will fail, and the damages (consequences of the failure for each event are $1,000,000 for the tank, and $75,000 for the structural element, then with the first formula:

R_{Tank} = $1,000,000 * L(S|A) *0.30* = $300,000 L(S|A)

R_{Beam}= $75,000 * L(S|A) * 0.50 = $37,500 L(S|A)

Or

R_{Tank}= $1,000,000 * 0.30 = $300,000

R_{Beam} =$75,000 * 0.50 = $37,500

The difference is in the likelihood of the success of the attack. If we assume that for each of these elements, the success is 100% for L(S|A) then the terms are identical.

So, OK we can define risk as the possibility of a bad outcome but how do we put a number on it and discuss it in meaningful terms? We perform a risk assessment.

Table 2 Risks and Threat Assessments

In order to explain the concept of risk, we'll use the language of the security people.
RISK = THREATS
Keep in mind that the Risk or Threats may be small but the consequences can be just as devastating as a terrorist with a bomb.
You may never be asked to do a complete threat assessment, but partial ones are equally useful for processes, and you will find that the challenge is not the threat but the likelihood of occurrence. The WHEN rather than the IF.

- A **Risk or threat assessment** considers the full spectrum of threats (i.e., natural, criminal, terrorist, accidental, process, blunders, spills, lack of proper maintenance, etc.) for a given facility/location.
- The assessment should examine supporting information to evaluate the ***likelihood of occurrence*** for each threat. For natural threats, historical data concerning frequency of occurrence for given natural disasters such as tornadoes, hurricanes, floods, fire, or earthquakes can be used to determine the ***credibility of the given Risk or Threat***.

- For ***criminal threats***, the crime rates in the surrounding area provide a good indicator of the type of criminal activity that may threaten the facility.
- In addition, the ***type of assets*** and/or activity located in the facility may also increase the target attractiveness in the eyes of the aggressor.
- The type of assets and/or ***activity located in the facility*** will also relate directly to the likelihood of various types of accidents
- The threats from negligence and lack of proper supervision are often greater threats than the natural occurrences or terrorist threats because they involve people and daily activities.
- There are some good databases out there and one of the best accessible may be from the UK, Health and Safety Executive, but it is still difficult to assign the likelihood of success of a particular event.

A deeper assessment on the types of risk, failure analysis, causes, and the mitigation measures against accidents and risks is a complex and detailed science. However if we simplify the subject a bit:

There are predictable and un-predictable risks and minor and major risks.

Common Predictable Risk Examples:

Deterioration of a structure through repeated stress (ie Bridges)

Corrosive failure of materials (by test coupons)

Weathering of Concrete

Leak in a pipe

Leak in a roof

Major Risks

Airplane Disasters

Explosions

Fires

Accidents and Robberies

Bank Failures

Overfilling of a tank and leaking the contents on the ground where it is expensive to clean up and creates the possibility of fire and explosion.

We can separate major and minor risks. Here is how they are often quantified.

How do we express RISKS and THREATS?

Best expressions are in tabular form:

Risk Analysis

*A combination of the **impact of loss rating** and the **vulnerability rating** can be used to evaluate the **potential risk** to the facility from a given threat. A sample risk matrix is depicted in the Table below. **High risks** are designated by the red cells, **moderate risks** by the yellow cells, and **low risks** by the green cells*

		Criticality Rating			
ITEM DESCRIPTION	Vulnerability Rating	Very High	High	Moderate	Low
	Very High				
	High				
	Moderate				
	Low				

RISK RATING INTERPRETATION	
	These risks are very high. Counter measures recommended to mitigate
	These risks are moderate. Counter measures should be planned for future
	These risks are low. Counter measures will improve security - no urgency

Obviously, the items in red will require attention very soon. The items in green are often routine and minor representing a lower cost, and possibly a frequent occurrence.

Other versions of the above figure include potential costs and the cost and the likelihood determine where the item is placed on the table.

This is shown below:

Recognize that the **L(S|A) term is a statistical concept about the likelihood of the occurrence- so how do you analyze the likelihood of an event?**

The likelihood of a successful attack (system failure) is speculative and difficult to pin down. Most often it is as a result of minor events which have gone unnoticed or are considered too small to be important. Consider the BP refinery and Bhopal events, and look at the sequences of events for their failures. When systems fail, they occasionally do so in a spectacular fashion

Another way of looking at Risk when we include financial projections

Annual Loss Expectancy

Estimated Replacement Cost

Cost expressed as $X.XX*10^{N} Rating = N

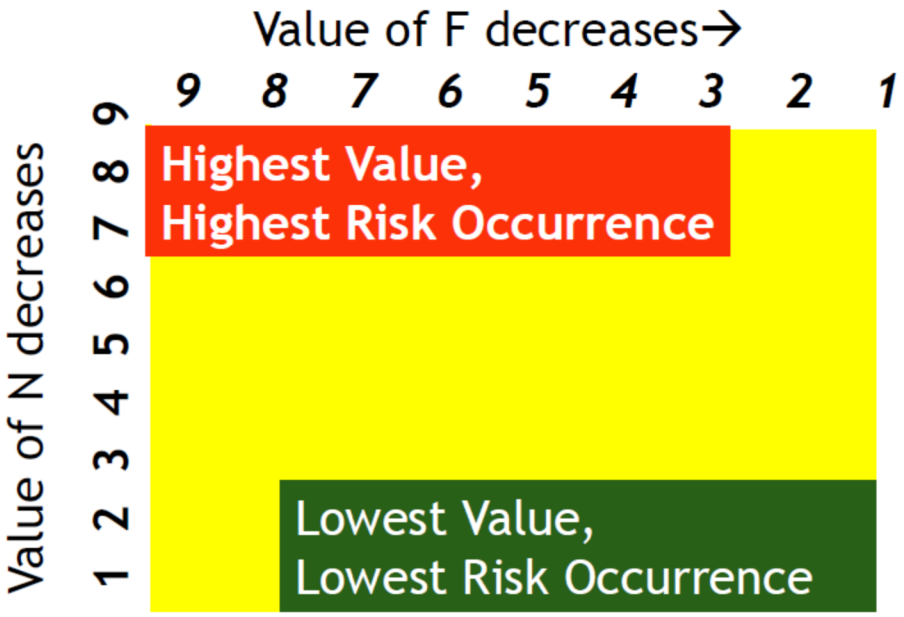
Frequency of Occurrence of undesirable event

(3 years approximates 1000 days)

1/300 years	*f=1*	*Type of event*
1/30 years	*f=2*	*Type of Event*
1/3 years	*f=3*	*Type of Event*
1/100 days	*f=4*	*etc.*
1/10 days	*f=5*	
1/day	*f=6*	
10/day	*f=7*	*etc.*

Calculated Annual Lost Expectancy = $10^{(f+N-3)}/3$

Risk Analysis by Table



Big failures or BLACK SWANS are often caused by a number of small failures cascading to catastrophe

Before 1790, all known swans were white: A discovery in Australia and New Zeeland proved otherwise. Black swans were extremely rare and hence the name. A black swan is a disaster of extreme proportion, and which is often an unanticipated event outside the normal realm of statistical thinking. Others call them unimaginable events.

The "**black swan theory"** is a metaphor that describes an event that comes as a surprise, has a major effect, and is often inappropriately rationalized after the fact with the benefit of hindsight. Nassim Nicholas Taleb, a polymath and trader on Wall Street. One such event occurred on Wall Street in 2008 when the real estate market

crashed. The Wall Street causes were also analyzed in "The Big Short: Inside the Doomsday Machine by Michael Lewis– a book which was later turned into a movie. Taleb cites the characteristics of a black swan event as the following:

1)The disproportionate role of high-profile, hard-to-predict, and rare events that are beyond the realm of normal expectations in history, science, finance, and technology;

2) The non-computability of the probability of the consequential rare events using scientific methods; — [When one has a an extremely high damage coupled with a very low probability how do you rationalize it?];

3) Most people are blind to the uncertainty and possibility of the event; —"It will never happen here!"

When you raise the possibility of a catastrophic event in your work, and someone says, "It will never happen," get out your umbrella because the rain will fall eventually.

1. Correlation is not causative
2. The improbable does happen
3. Events cascade and cause system failures.
4. Without imagination as to what could go wrong, we are sitting ducks for the improbable.
5. This carries over into personal and business history.
6. The event is a surprise (to the observer).
7. The event has a major effect.
8. After the first recorded instance of the event, it is rationalized by hindsight, as if it *could* have been expected;

9. The relevant data were often available but un-analyzed and not considered in risk mitigation programs.
10. The same is true for the personal perception of individuals.

There are a number of examples to support these ideas, drawn from practical experiences:

If you were a manager for a large city on the East Coast, and in charge of Emergency Response:

What is the likelihood of the following all occurring at one time?

1 A Major snowstorm dumping 4-8 inches of snow paralyzing the city

2 A Subway Fire 25 people trapped needing rescue and,

3 An commercial air carrier with 100 people aboard crashes on takeoff and hits a local major bridge crossing the river, river, paralyzing traffic movement on the bridges, and dumping the plane and all the passengers into the icy waters.

Highly improbable? Almost by definition, a black swan event. It can happen because it did in 1982 in Washington DC on January 13.

Other major events are shown in Youtube videos.

The first is in the US, in 2005 and deals with the Texas City, Texas, Refinery Explosion.

https://www.youtube.com/watch?v=C5mcaWRwpgg It is about 47 minutes long, and it explores the causes of the fire and explosion.

The second video is of a classic chemical accident: Bhopal, India:

https://www.youtube.com/watch?v=HsuUQzhP2Ds It is slightly longer and takes approximately one hour to watch.

A third is Chernobyl which was recently dramatized in a made for television movie on HBO. The Youtube video by National Geographic goes into the causes of the disaster and it is a lot shorter. https://www.youtube.com/watch?v=qHef2gLqqtQ

In all three videos, look for causes which led to the tragedies. This type of analysis is referred to as Root Cause Analysis. It seeks to locate the triggering event which caused the disaster.

In the case of Texas City Refinery Fire, the end of the video discusses the findings of the Chemical Safety Board (CSB). In this instance there were several minor failures which cascaded to create the fire. The probable direct source of the fire was the running truck which was unattended. But, without the flammable liquid due to the faulty maintenance and lack of adequate supervision during startup, and routine shortcuts taken during the startup, the accident would not have occurred.

The bad placement of a portable conference room-trailer caused by a poor risk analysis and a management disregard for danger based upon anticipated low occupancy was also a contributing factor to the loss of life.

In the case of Bhopal, there are several causes of the incident. Indirectly, the previous year's drought in India caused lower demand for the pesticide, and reduced the company's profits. But, the company chose to operate by reducing costs in critical elements, and allowing procedural shortcuts, delayed maintenance, and a lack of consideration of possible consequences in key safety and operations areas. It can also be argued that given the nature of the chemicals and their potential toxicity, Union Carbide, India, should not have built the plant in that location near Bhopal.

In the case of Chernobyl, the apparent root cause was a decision to continue testing a shutdown procedure on a steam turbine which could have been conducted at a similar coal fired plant at substantially lower risk[i].

However, hindsight is often perfect, and risk assessment was just coming into the US in the early 1980's.

Another type of risk is that of mal intent by people. As an example, the Ecuador Case (Aguinda vs. Chevron/Texaco, and Chevron vs. Donziger) was of the most challenging cases, but simple cases. It involves bribery, oil industry, corruption, chemistry, soil mechanics, and public health. The file is large over 121GB , but it has some supplements and video with it which make it interesting, and make it a personal perspective on the events.

https://dl.dropboxusercontent.com/u/444212/Jungle%20Fumble%20-%20Final.pptx

Examples: BP Refinery Explosion & Bhopal

Discuss causes:

- Failure to follow safety, maintenance and operating Procedures
- Shortcuts
- Poor to no supervision
- Management Failures, inadequate risk prevention considerations
- Stupidity

Large Failures don't occur in isolation but are a collection/ cascading of minor events which lead up to big events.

Examples:

Where might one be exposed to this type of activity or thinking? Consider the following:

Atlanta I-85 highway fire and failure

Contractor went bankrupt and left Polyethylene Pipe beneath elevated structure portion of highway.

Causes: Improperly stored materials (for 10 years)

Direct cause – crack addict started fire

Consequence: I-85, a major highway through Atlanta was out of service for several months.

Major traffic consequences, traffic blocked on a major N-S highway system.

Other examples: Oil black swan events include the August, 1975 Philadelphia Terminal fire. The firefighters were working in an adjacent diked area which received runoff and drainage from the oil storage tank which was on fire. The firefighters did not recognize that they were working in a pool of water covered in gasoline, and that the only thing stopping them from their personal disaster was a layer of fire foam.

Unfortunately a break occurred in the fire foam cover and the volatile materials flashed resulting in the loss of one engine and the immolation of several firefighters.

http://www.gendisasters.com/pennsylvania/6515/philadelphia-pa-refinery-fire-aug-1975

Conclusions and Considerations

Risk is ever present. Severe risk may be rare but is inevitable.

One way of reducing risk is to perform a comprehensive risk analysis which includes asking some uncomfortable questions, such as:

When you design or build: Ask yourself what can go wrong?.

The solution to good risk assessment is to be creative and imaginative with regard to risk, but temper it with reality. For example: a snowstorm on the equator is highly improbable and has a probability risk of occurrence somewhere on the order of 10^{-30} and can probably be safely ignored. There are many other events with much higher risk levels.

List your scenarios

Review them

Determine how they can be prevented—SIMPLY

Remember that when we design something to be FOOLPROOF, NATURE INVENTS A BETTER CLASS OF FOOL.

Again: Here is a listing of the recommended incident videos:

https://www.youtube.com/watch?v=C5mcaWRwpgg BP Refinery Fire in Texas.

https://www.youtube.com/watch?v=HsuUQzhP2Ds Bhopal, India disaster, and

https://www.youtube.com/watch?v=qHef2gLqqtQ Chernobyl

---

[i] **See How Good People Make Tough Choices Rev Ed: Resolving the Dilemmas of Ethical Living**

by Rushworth M. Kidder