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Project Report
on

RISK ANALYSIS IN CHEMICAL AND PETROLEUM INDUSTRIES

Submitted By

Gursharan Deep-40039988
Ramit Basra-40045043

Submitted To:

Dr. Fereshteh Mafakheri

Abstract

Risk can be conceived from different points of view, including technical, economic and psychological perspectives. This paper reviews some of the techniques to analyses risk in chemical and petroleum industry, both quantitative and qualitative, considering their limitations and applicability to particular scenario. There can be any event that would lead to accident, so it become important to identify such risks and eliminate them, thus avoiding major accidents.

This paper discusses the use of weighing factor, poisson distribution [2], risk exposure, Risk Matrix, HAZOP analysis [1] to analyses risk, its impact, monetary/life loss to industry based on papers presented between 1990 to 2014. Bayesian theory is used to exploit database related to industrial accidents in chemical and petroleum industries to model rate of occurrences [3]. Probability density distribution is formulated to get their causes.The chemicals have their own hazards apart from risks associated with investment. Furthermore, we have presented the alternative approach using Fault Tree Analysis (FTA), decision trees and a new technique PORT.

Keywords: Risk, Chemical Plants, Events, Consequence

1. INTRODUCTION

Most of the industrial managers rely on reactive risk management strategies i.e reacting after risk has occurred and made the damage. More cost-effective approach is pro-active. With petroleum and chemical industry, risk associated are health risks, fire risks, electrical risks investment risks and environmental risks.

2. BACKGROUND:

There have been many accidents (Flixborough, Seveso, and Bhopal) at various chemical and petroleum industry in recent years specially related to handling, storing and processing of chemicals. So these industries have attracted attention and seek to identify various type of risks involved. Several researchers are analyzing and working on incident databases to spot common trends and to estimate risks. tackle loss and ensure safety in industrial plants.

Efforts to extend the coverage of near-misses, with near-miss management audits, are initiated by Wharton Risk Management Center (Phimister, Oktem, Kleindorfer, & Kunreuther, 2003). In order to record accidents, European industries submit their data to the major accident reporting system, while a database for chemical companies in the United States is created from risk management plans (RMPs) submitted by facilities subject to the chemical accident release prevention and response regulations of the Environmental Protection Agency (EPA).

The researches have shown that risk can occur at any stage from production, supply-chain transportation, processing and distribution of chemicals/petrol. Researches on these stages is important for ensuring optimal natural resource utilization, environmental safety, reducing health risks and energy conservation. For every step there is unique decision-characteristic associated. So decision-problem-stages are also to be addressed for risk.

Major chemical disasters- Annexure-1

3. TECHNIQUES USED IN RISK ANALYSIS:

The risk assessment has been divided into two parts: Quantitative Risk Analysis Methods, and Qualitative Risk Analysis Methods.

3.1 QUALITATIVE TECHNIQUES

Qualitative analysis is a non-numerical representation and explanation based on graphic attributes, flow diagrams, graphs and data sources.

A study in 2009 show that all indirect costs of workplace safety range between two to five times of direct costs. This points toward qualitative evaluation of incident data at petrochemical industries.

3.1.1 Qualitative Weighing Factors (QF):

This is one of most widely supported qualitative technique. in some studies QFs were estimated to be two to five or between eight to eleven to calculate indirect costs on workplace safety from petrochemical incidents.

3.1.2 Hazard and Operability Analysis (HAZOP) (Risk Identification & Analysis Method)

HAZOP is well established, widely accepted and used qualitative method, first utilized in imperial chemical industries in 1963 to **identify accidents due to equipment failure**.

standard HAZOP was limited to assess hazards caused by process variables. Modified HAZOP was introduced in 1998 to study human, management, Organizational vulnerabilities.

3.1.2 Risk Matrix (Risk Assessment)

There is **not enough significant development in qualitative methods for risk assessment in the literature studied.** Only standard Risk matrices were found, which was first introduced in US Air Force at electronic system Centre [7].

Risk matrix represents risk frequency and its consequences on two axis. Product of two provides a measure of risk. Risk Matrix helps identify, prioritize and manage all major risks in chemical plant.

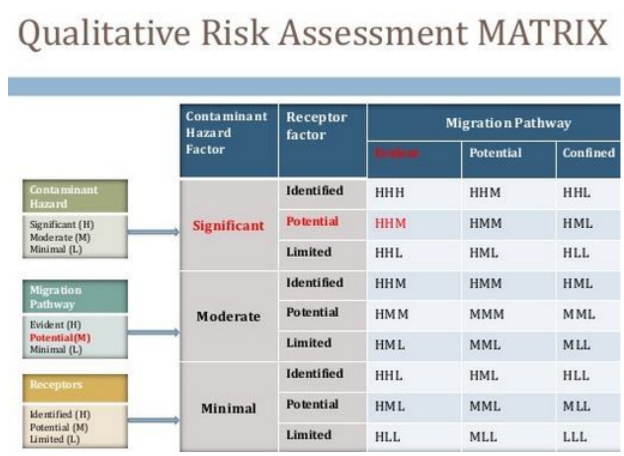


Figure-1 ***<u>Risk Matrix- Assessing Environmental & Health Risks from chemicals</u>***

Additional safety requirements will result in additional safety requirements. However quantitative methods discussed below have proved to be more beneficial and recommended for petrochemical industries than qualitative methods.

3.2 QUANTITATIVE TECHNIQUES

Chemical and petroleum industries are using many sophisticated quantitative techniques to identify high level risks events and prevent them, thus reducing various industrial accidents. These techniques, commonly known as QRA, translate risk into measurables numbers and can be computed mathematically through application of various calculations. Data is either set of historic values or an estimate, so it itself is uncertain. These techniques require large amount of time and money.

Adapted primarily from probabilistic risk assessment approaches developed in other industries, the use of QRA is spreading rapidly through the US chemical industry [4]. Somewhere, legislators are also making it mandatory to make QRA a part of accident prevention measures.

3.2.1 Frequency of Incidents

(a) Poisson distribution

The annual number of occurrences of an abnormal event is a non-negative, integer-valued outcome that can be estimated using the Poisson distribution for y [2]:

$$y \sim p(y = y_i) = \left\{ \frac{\lambda^{y_i} e^{-\lambda}}{y_i!} \right\}, \quad y_i \in \{I^1\}, y_i \geq 0, \lambda > 0$$

……………. (1a)

where yi- number of abnormal events in year i, λ- annual average number of abnormal events, with the expected value, E(y), and variance, V(y), equal to λ.

Previous distribution is assumed to be:

$$p(\lambda) \propto \lambda^{\alpha-1} e^{-\beta\lambda}, \quad \alpha > 0, \quad \beta > 0.$$ ……… (1b)

due to uncertainty.

(b) Negative Binomial distribution

The annual number of incidents of an abnormal event is a non-negative, integrated result, which can be estimated using the Negative Binomial distribution for y [2]:

$$y \sim (q)^{\mu}(1-q)^{y_i} \quad y_i \in \{I^1\}, y_i \geq 0, \mu > 0, q \geq 0$$

………………….. (1c)

yi- no of incidents in year i.
V(y)-expected variance

Previous distribution is assumed to be:

$$p(\mu) \propto \mu^{\alpha-1} e^{-\beta\mu}, \quad \alpha > 0, \quad \beta > 0,$$ ….. (d)

3.2.2 Incident Forecasting

a) Incident probabilities

Table 1 shows the number of incidents (N Total) for the 7 companies extracted from the NRC database (from 1991-2002).

Company	Type	N_{Total}
A	Petrochemical	688
B	Petrochemical	568
C	Speciality chemical	401
D	Petrochemical	220
E	Speciality chemical	119
F	Speciality chemical	83
G	Speciality chemical	18

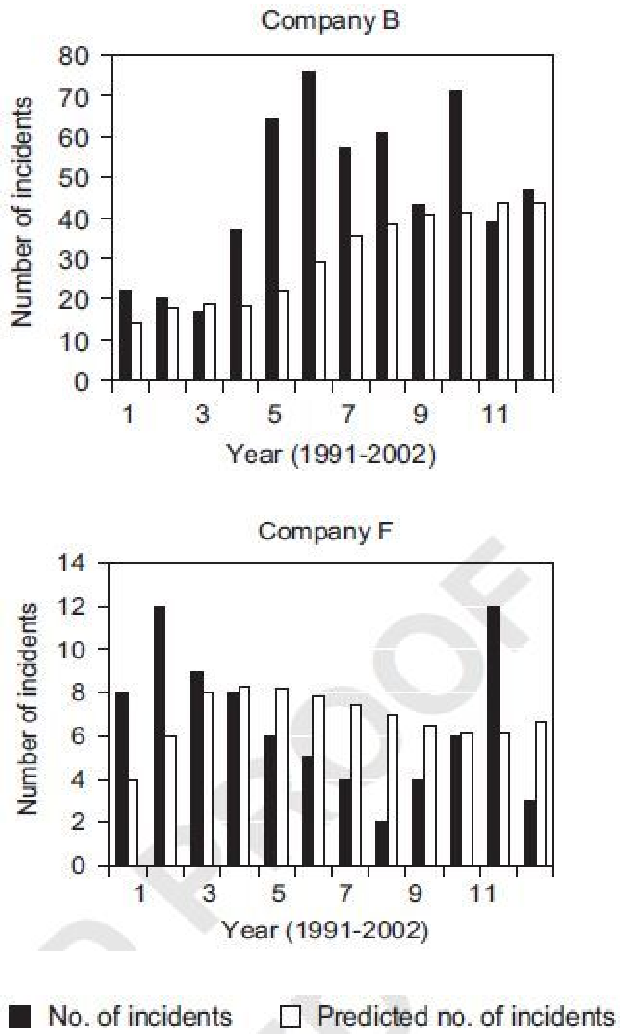


Figure-2 ***Predictions - Number of incidents with Poisson Distributions - Company B & F***

(b) Causes and Equipment Types involved in an Accident

As per our analysis Fault Tree is one of mostly picked technique to represent causes and further effects. Tree in Figure -2 displays the possible causes for each incident and the possible types of equipment for each cause. Note that the tree could alternatively show the possible types of equipment followed by the possible causes for each incident. [3]

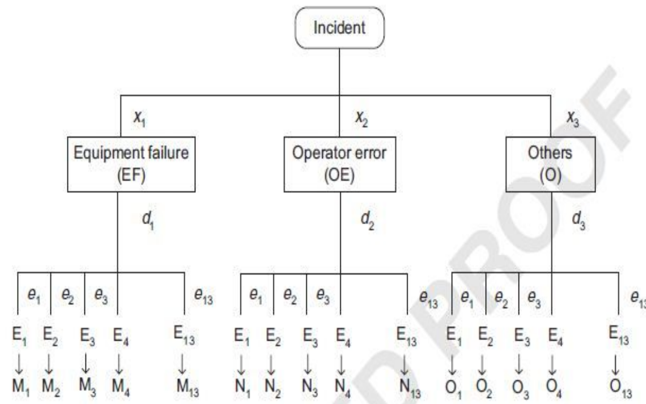


Figure-3: ***Tree- Causes and Equipment types involved in incident***

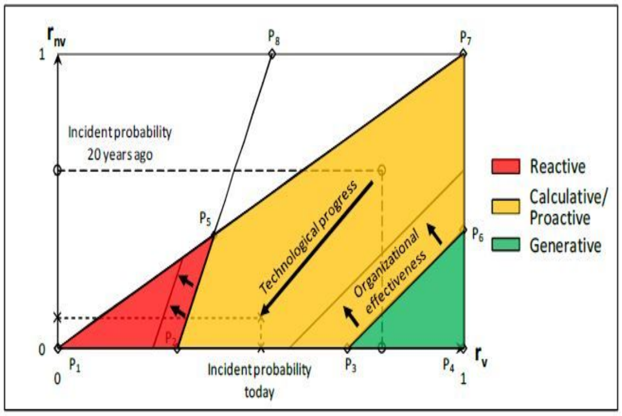
Where,

Symbol	**Meaning**
x1, x1, x3	Probabilities of causes EF, OE, O
d1, d2 , d3	Cumulative numbers of incidents at the end of each year
e1, e2,....e13	Probabilities -involvement of equipment types.
E1, E2,..E13	Incident through different causes
M+N+O	Cumulative number of incidents involved with equipment type.

As per review above mentioned Statistical models facilitates improved company-specific estimates

3.2.3 Petrochemical Organization Risk Triangle (PORT)

This is one of the latest techniques developed in risk management proposed in 2011. It is an easily understandable graphical risk management tool. It is represented as follows:



<u>Figure-3: *Petrochemical Organisation Risk Triangle (PORT)*</u>

Figure 3 shows that the type of balance and therefore the safety culture of an Petrochemical organisation, depends on the combination of the probability of an incident and the safety attitude.the probability of the incident represented by r_v and r_{nv} determines X,Y coordinates of PORT.

Where, r_v and r_{nv} are calculated as conditional probabilities:

$$r_v = p(I \mid v) = \frac{p(v \mid I) \cdot p(I)}{p(v \mid I) \cdot p(I) + p(v \mid NI) \cdot p(NI)},$$

$$r_{nv} = p(I \mid nv) = \frac{p(nv \mid I) \cdot p(I)}{p(nv \mid I) \cdot p(I) + p(nv \mid NI) \cdot p(NI)}$$

p(I)-priori probability that an incident occurs

p(NI)-priori probability that no incident occurs

p(v|I)-probability of violation in case an incident occur

p(v|NI)- probability of violation in case an incident do not occur.

p(nv|I)-probability of compliance in case an incident occur

p(nv|NI)-probability of compliance in case that an incident do not occur

The aim of PORT is to achieve a movement that enables a generative security culture, i.e. the <u>green area</u>, to be achieved.

CONCLUSION:

Risk management in the petrochemical industry has thus been strongly influenced by the findings of accident research and has continually evolved over the past fifty years.Most of old risk analysis techniques still prevails strongly in industry and used the most. Though new techniques like PORT (based on game theoretic models) are being proposed, but they catch only an approximation of reality and opens door for future research on the subject of petrochemical risk management.

Overall conclusion drawn from review of various research papers is that it is important to know an organization's accident numbers , its safety culture and application of appropriate technique to improve risk management practices to lead to safer and profitable future.

We recognize that the major problems of residual safety do not belong solely to the technical or human domains. Instead, the interactions between the technical and social aspects of the system are still little understood.

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Annexure-1