9th Chemical Process Safety Sharing (CPSS)

Quantitative Risk Analysis (QRA) Adds Value to the Journey to Excellence in Process Safety Management

Presenter: Todd Yu
Company: DNV

Contents

1. Learn From Accidents

Learn From Accidents

There's an old saying that if you think safety is expensive, try an accident. Accidents cost a lot of money. And, not only in damage to plant and in claims for injury, but also in the loss of the company's reputation.

----Trevor Kletz

Accidents

Piper Alpha, 1988

Longford, 1998

Buncefield, 2005

Laem Chabang, Dec 1999

http://www.aparchive.com/metadata/youtube/f03b9fa65209871ff2f2cd629f5db23d

Samut Prakan, Oct 2020

https://www.thaipbsworld.com/tag/gas-pipeline-explosion/

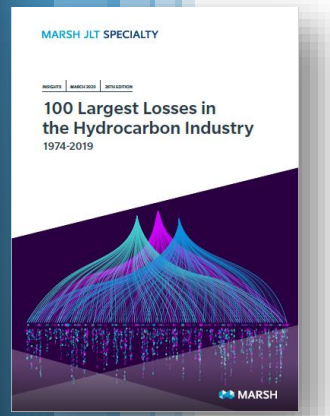
Samut Prakan, Jul 2021

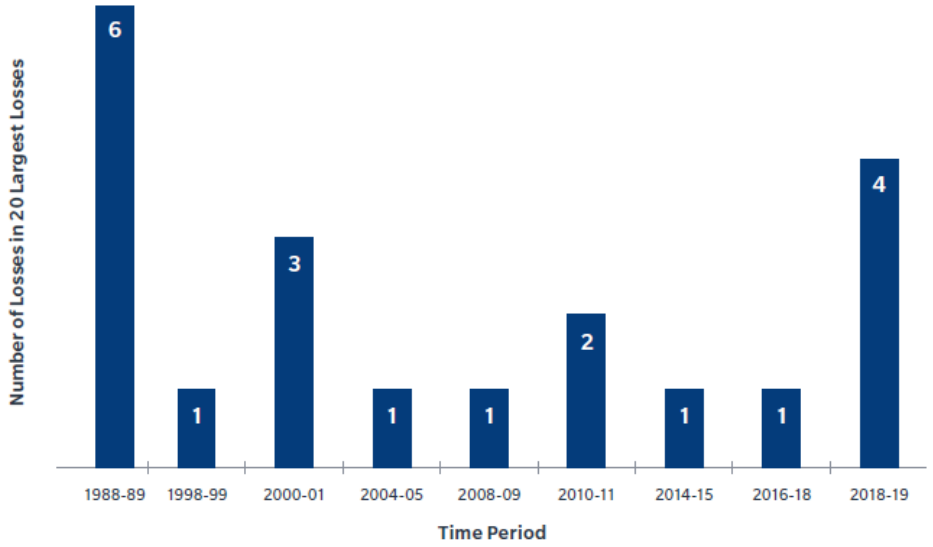
https://www.reuters.com/world/asia-pacific/residents-return-toxic-chemicals-thai-factory-dissipate-2021-07-08/

Losses in Hydrocarbon Industry

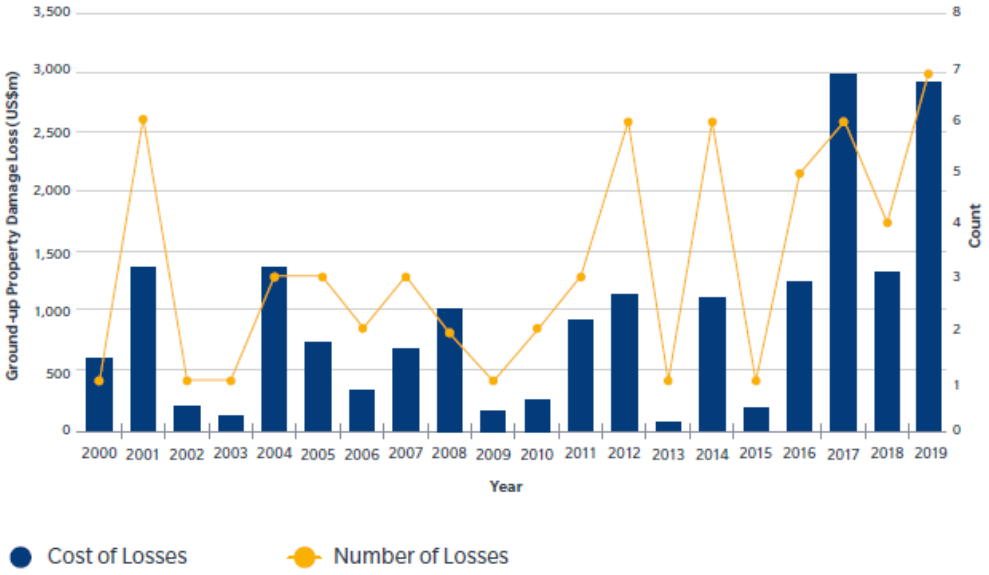
Marsh: 100 Largest Losses in the Hydrocarbon Industry 1974-2019
https://www.marsh.com/us/industries/energy-and-power/insights/100-largest-losses.html

- An unusually high number of large losses occurred in 1988-89 and 2018-19.





- The number and total cost of property damage losses have both risen in recent years.

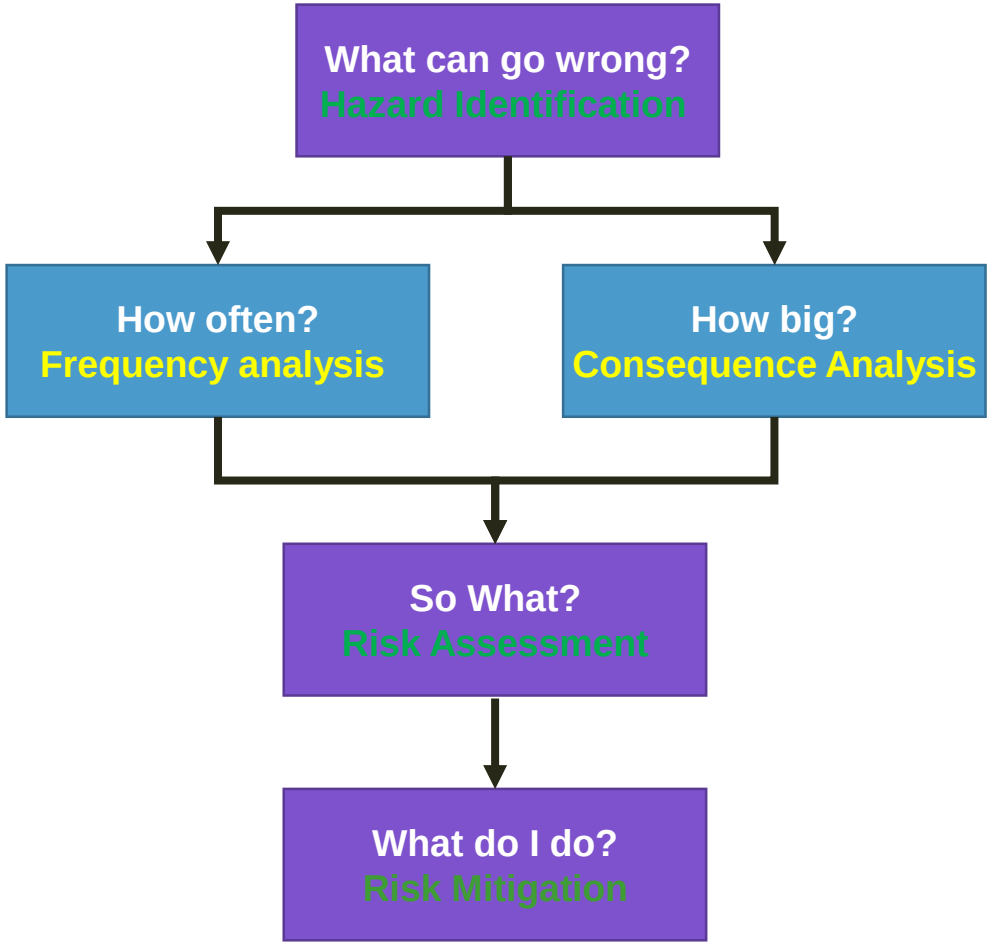


2. Risk Measures and Criteria

Risk Definition

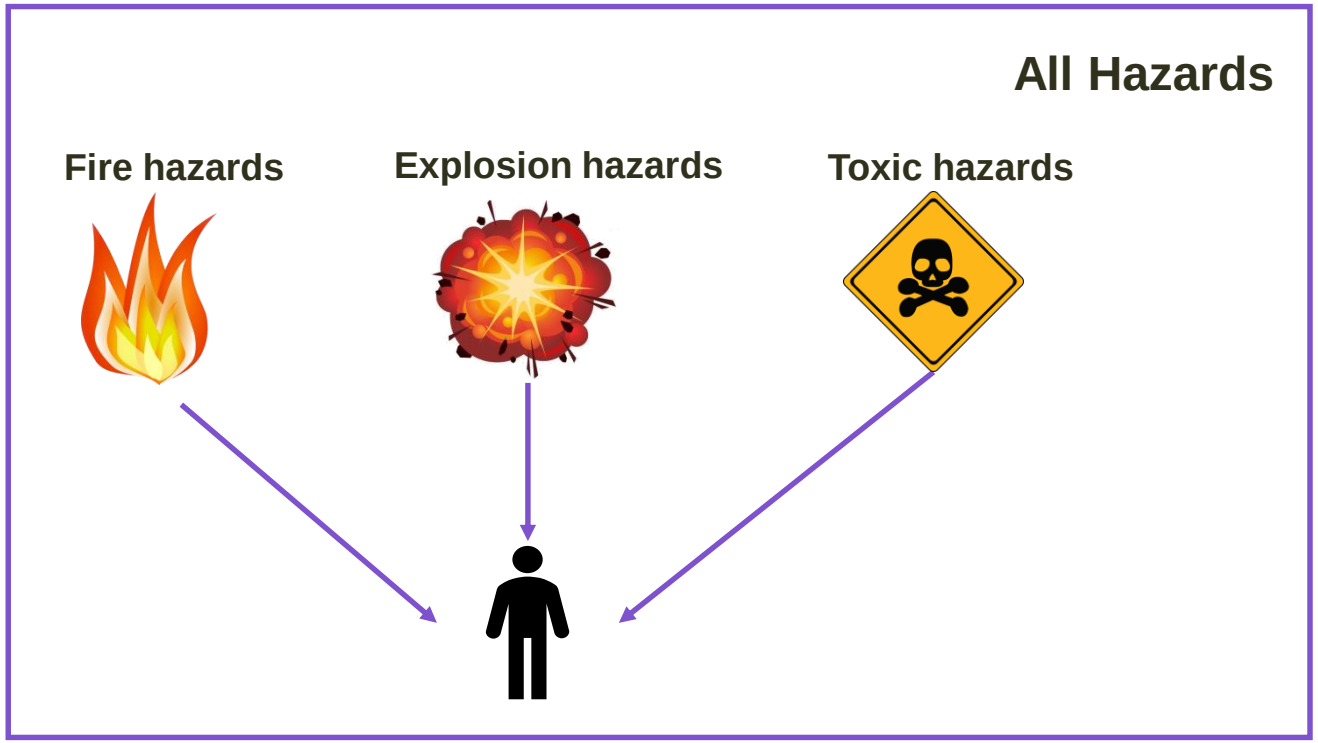
- **Risk** is the combination of likelihood and consequence of a specified undesired event occurring within a specified period or under specified circumstances
  - **Risk Value**

    Risk = Likelihood × Consequence
  - **Risk Category**



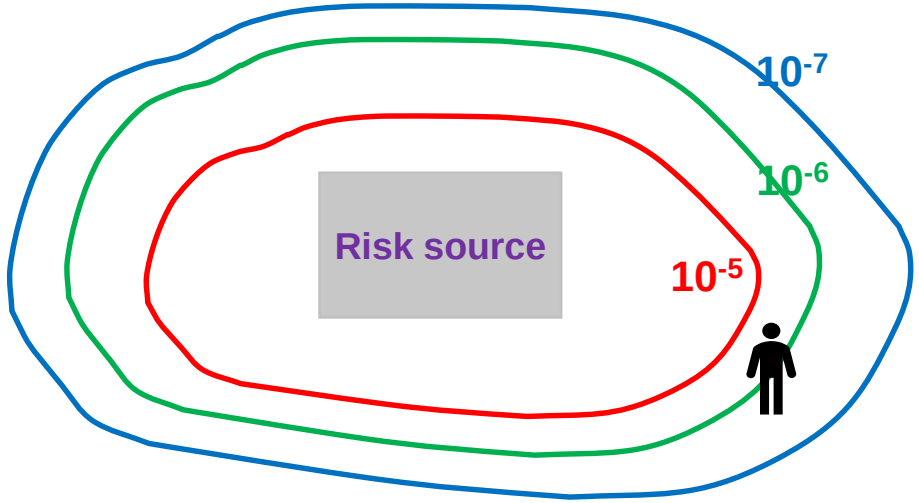
Individual Risk

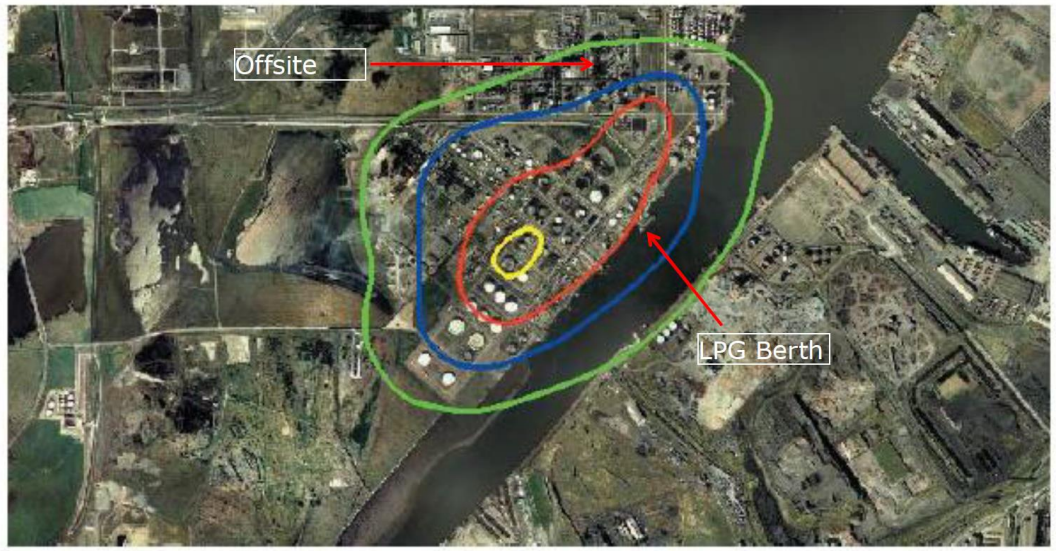
- Individual Risk represents the likelihood that a person will sustain a fatal injury by all of the hazardous events to which he or she may be exposed. Presented as a frequency number (fatalities/yr).



Location-Specific Individual Risk (LSIR)

- LSIR is the probability that an average unprotected person, permanently present at a specified location, is killed during one year due to a hazardous event at an installation.
- LSIR can be graphically displayed as iso-risk contours around a dangerous installation. LSIR does not account for actual exposure or population.





LSIR Criteria

- Risk contour criteria tend to be used for land use planning purposes, with the local planning authority left to enforce land use controls.

Canadian risk contour criteria

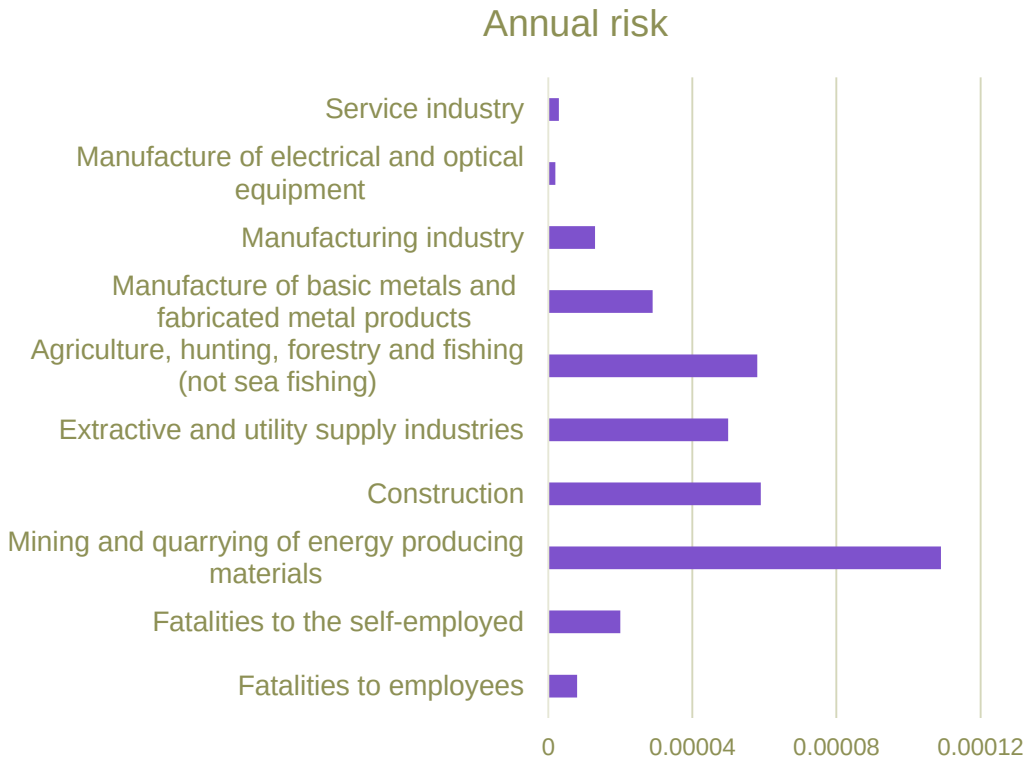
Individual Risk per Annum (IRPA)

- IRPA is the probability that a specific or hypothetical individual will be killed due to exposure to the hazards or activities a during one year.

$$\text{IRPA} = \Pr(\text{Individual is killed during one year's exposure})$$

Location	LSIR (/yr)	Percentage (%)
1	10^{-5}	20
2	10^{-6}	30
3	10^{-7}	50

$$IRPA = 10^{-5} \times 20\% + 10^{-6} \times 30\% + 10^{-7} \times 50\% = 0.000235\ /year$$



- Data from "Reducing risks, protecting people" (UK HSE 2001)

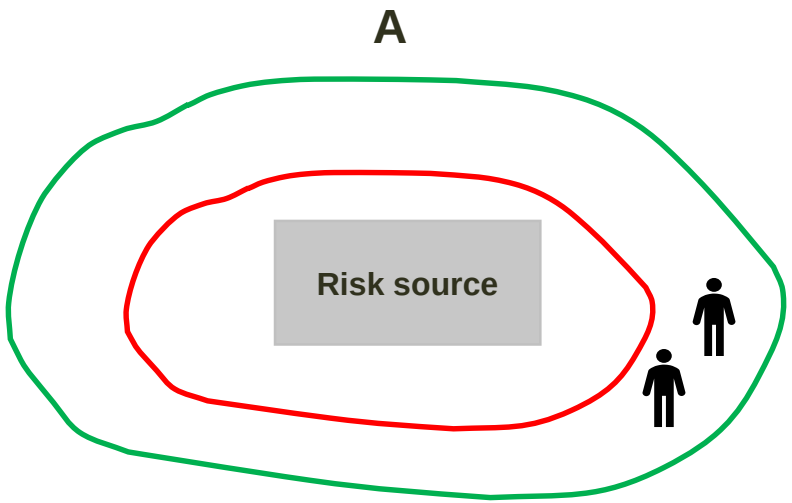
IRPA Criteria

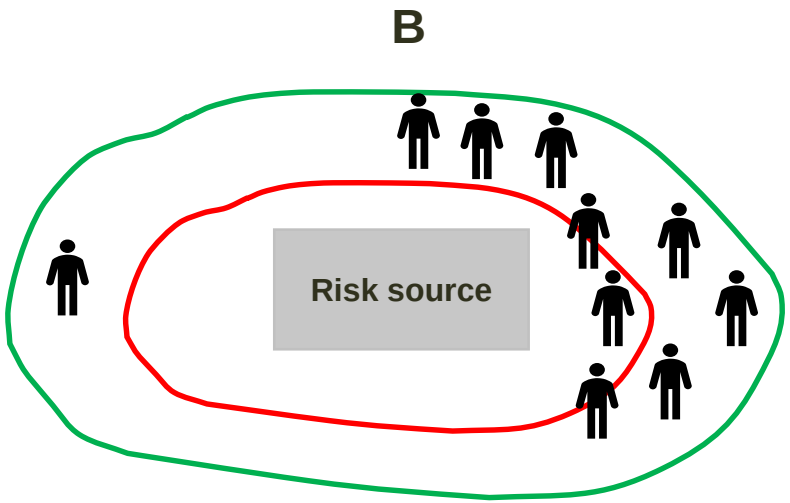
- Individual risk criteria are most commonly expressed in the form of Individual Risk Per Annum (IRPA). Today, the following IRPA values for these criteria are generally regarded internationally as applicable for hazardous industries:

	Workers (/yr)	Members of Public (/yr)
Maximum tolerable criterion	10^{-3}	10^{-4}
Broadly acceptable criterion	10^{-6}	10^{-6}

Societal Risk

- Societal Risk represents the number of people who may be killed by large, single events and how often those events might occur.





Individual Risk: A = B

Societal Risk: A < B

Societal Risk - PLL

Potential Loss of Life (PLL) is the expected number of fatalities within a specific population per

$$\mathrm{PLL}_A = \iint_A \mathrm{IRPA}(x, y)\, m(x, y)\, dx\, dy$$

- $m(x, y)$ is the population density at the location (x, y).

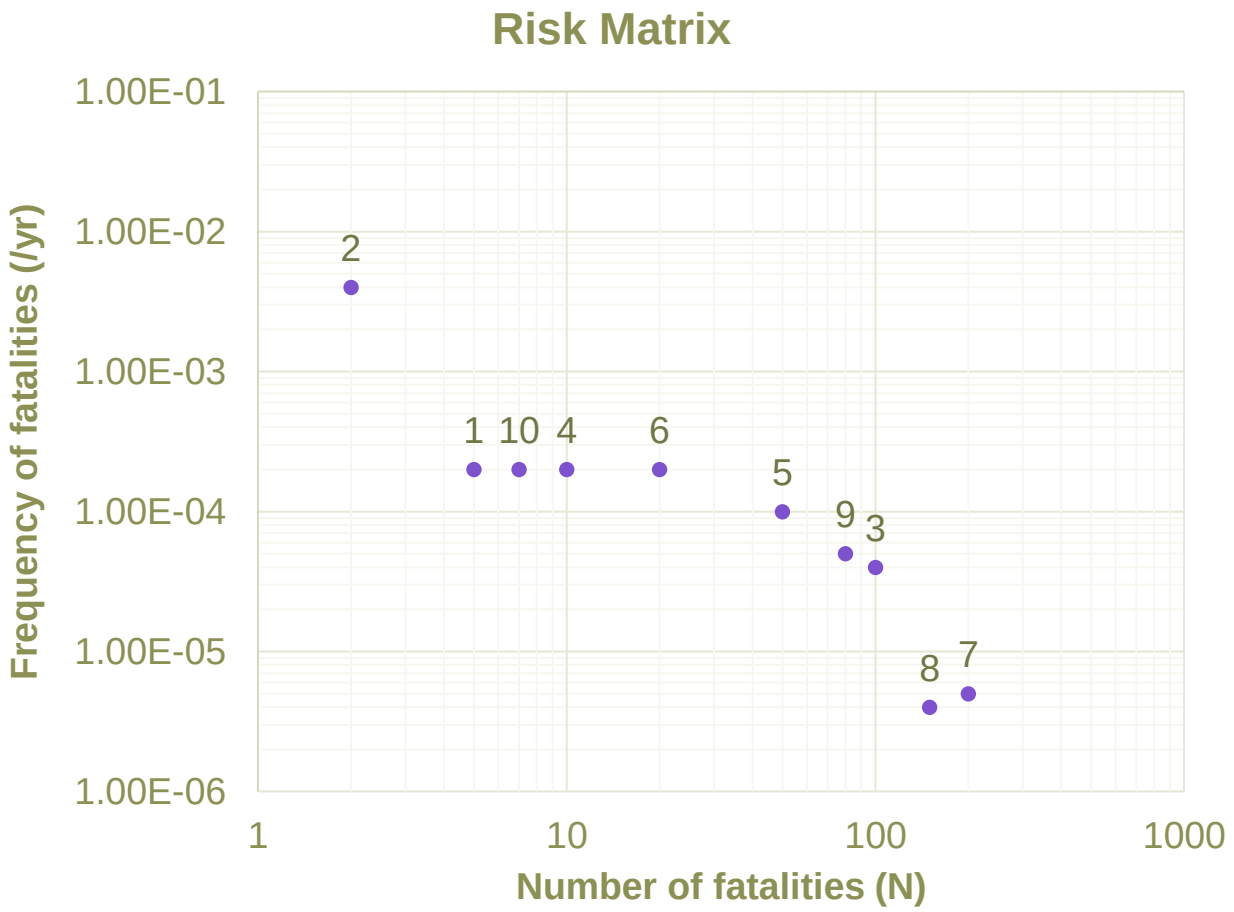
For a population where all n members of the population have the same risk per annum, we have:

$$\mathrm{PLL} = n \cdot \mathrm{IRPA}$$

Group	IRPA (/yr)	Number of people	PLL (/yr)
A	10^{-5}	10	0.0001
B	10^{-6}	20	0.00002
C	10^{-7}	30	0.00003
Total PLL			**0.000123**

Societal Risk - FN Curves

Event	Number of fatalities (N)	Frequency (F, /yr)
1	5	2.00E-04
2	2	4.00E-03
3	100	4.00E-05
4	10	2.00E-04
5	50	1.00E-04
6	20	2.00E-04
7	200	5.00E-06
8	150	4.00E-06
9	80	5.00E-05
10	7	2.00E-04



Societal Risk - FN Curves

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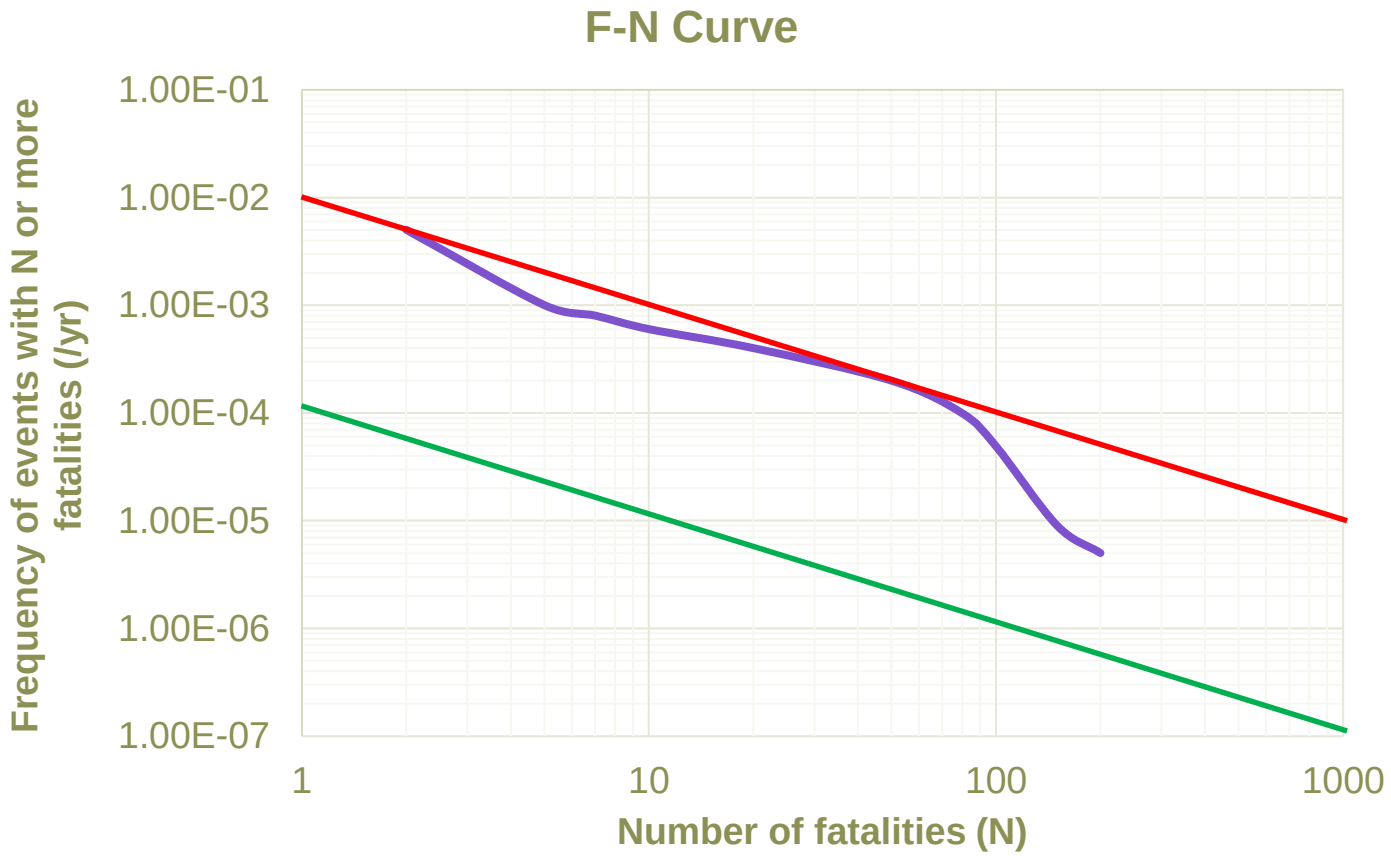
4	10	2.00E-04
5	50	1.00E-04
6	20	2.00E-04
7	200	5.00E-06
8	150	4.00E-06
9	80	5.00E-05
10	7	2.00E-04

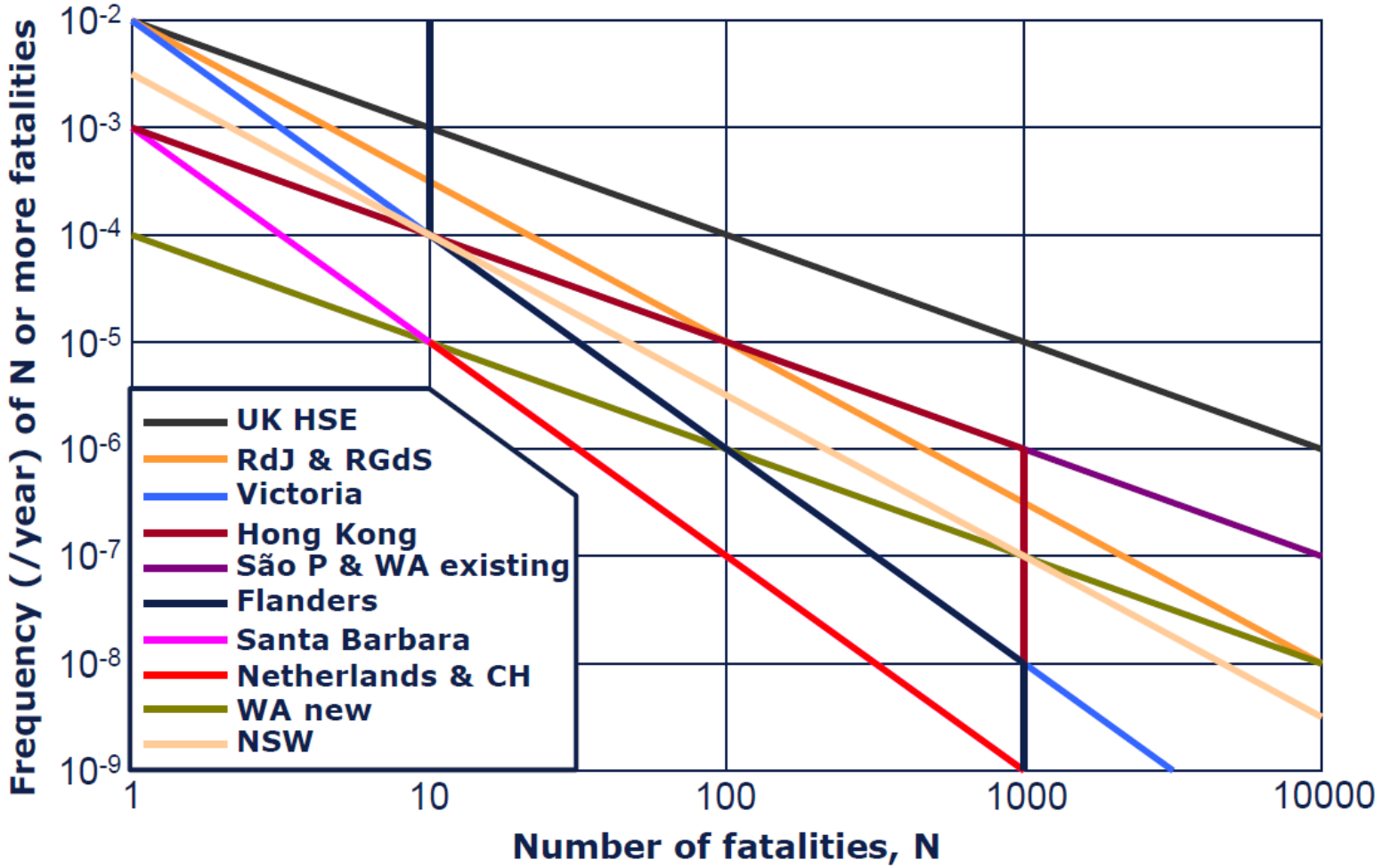
Number of fatalities (N)	Frequency (F, /yr)	Frequency of N and more (/yr)
200	5.00E-06	5.00E-06
150	4.00E-06	9.00E-06
100	4.00E-05	4.90E-05
80	5.00E-05	9.90E-05
50	1.00E-04	1.99E-04
20	2.00E-04	3.99E-04
10	2.00E-04	5.99E-04
7	2.00E-04	7.99E-04
5	2.00E-04	9.99E-04
2	4.00E-03	5.00E-03

Societal Risk - FN Curves

- FN curves clearly show the relationship between frequency and size of accident.



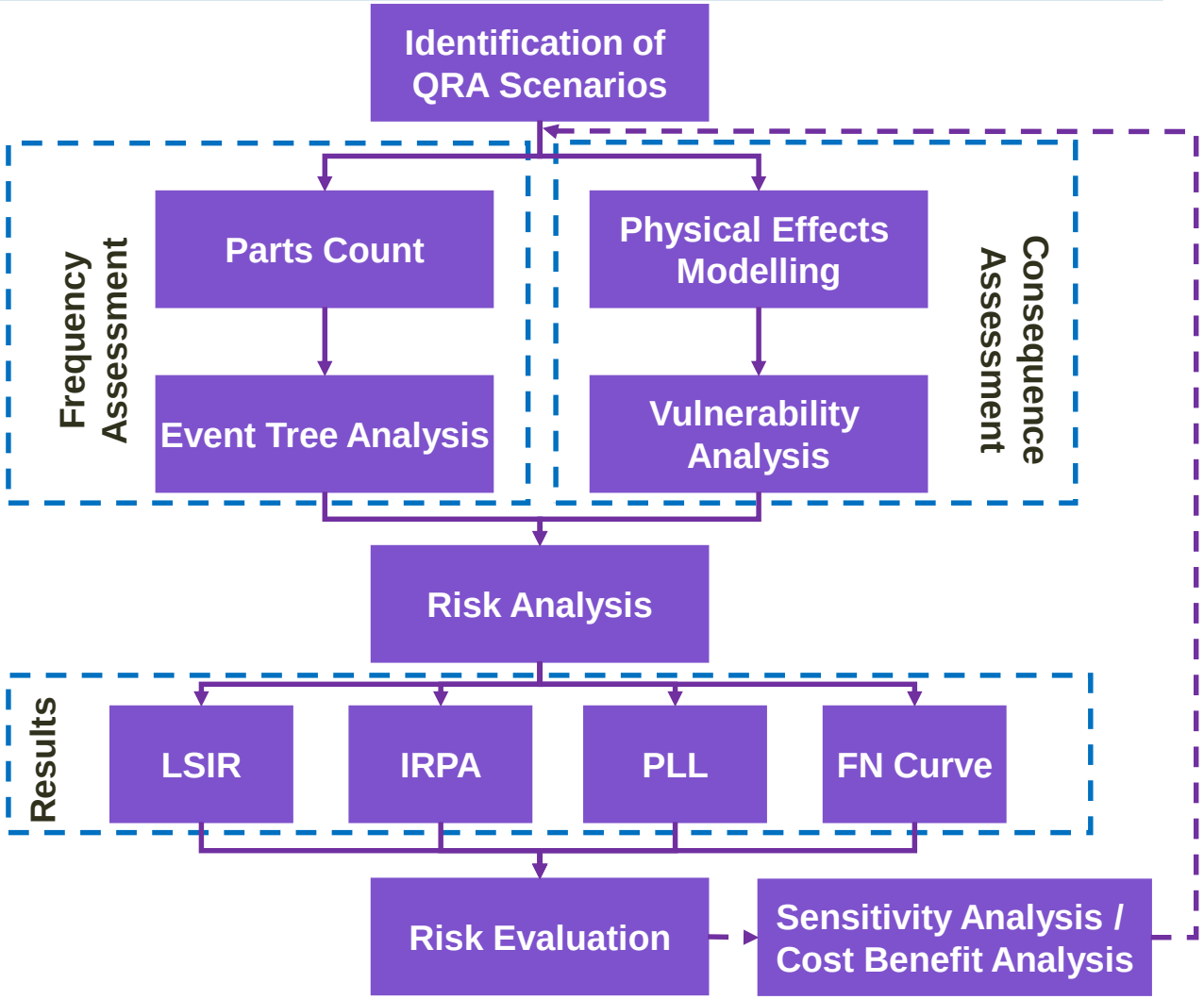
FN Curves Criteria



3. Quantitative Risk Analysis (QRA)

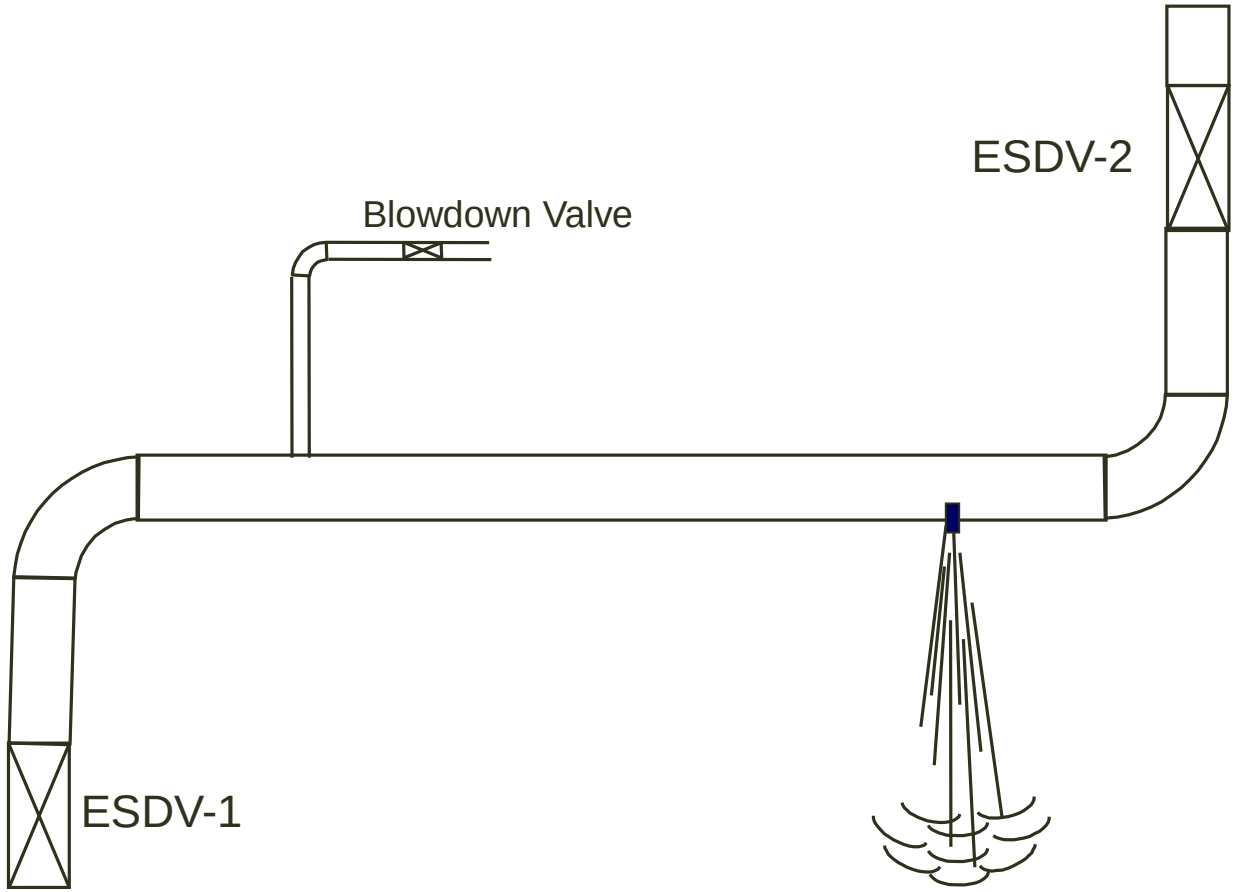
Quantitative Risk Analysis

- **Quantitative Risk Analysis** (QRA) is a risk assessment methodology that allows for numerical estimates of the level of risk associated with a certain activity or series of activities to be estimated and then assessed



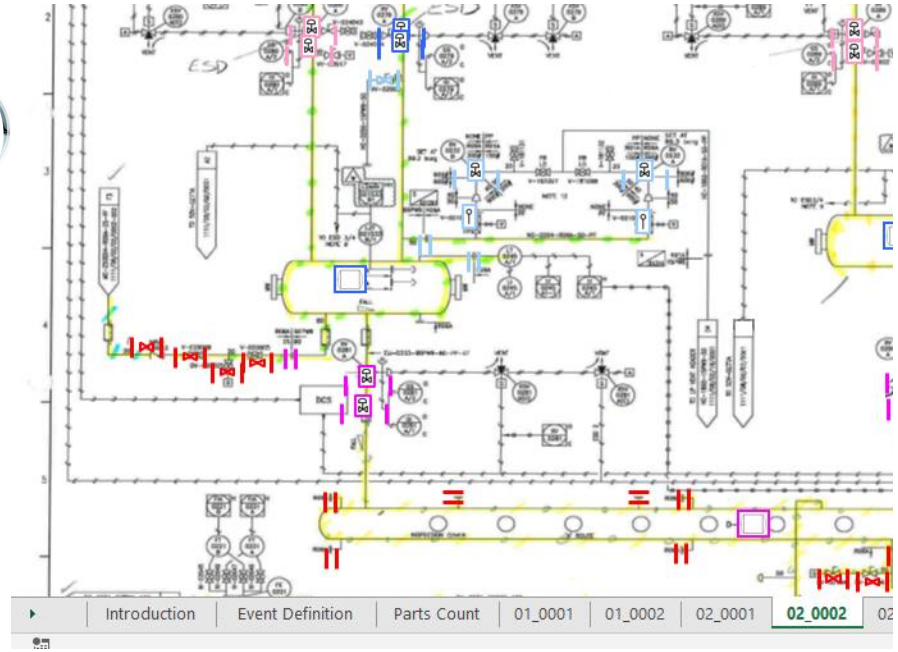
Source: RickTec

Identification of QRA scenarios



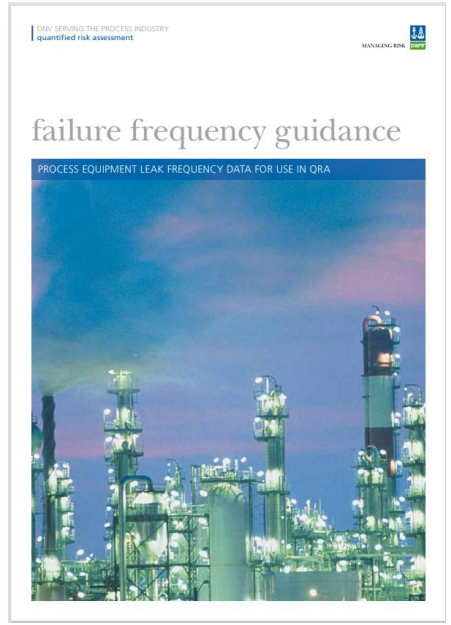
Frequency Assessment - Initial Frequency

Parts Count



Equipment	Units
6 inch pipe	20
6 inch valve	2
6 inch flange	4

Historical Leak Frequencies



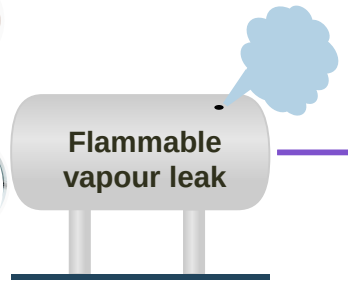
Equipment type	Small	Rupture
6 inch pipe	$1x10^{-5}$ /m/yr	$1x10^{-6}$ /m/yr
6 inch valve	$1x10^{-5}$ /yr	$1x10^{-6}$ /yr
6 inch flange	$5x10^{-5}$ /yr	$5x10^{-6}$ /yr

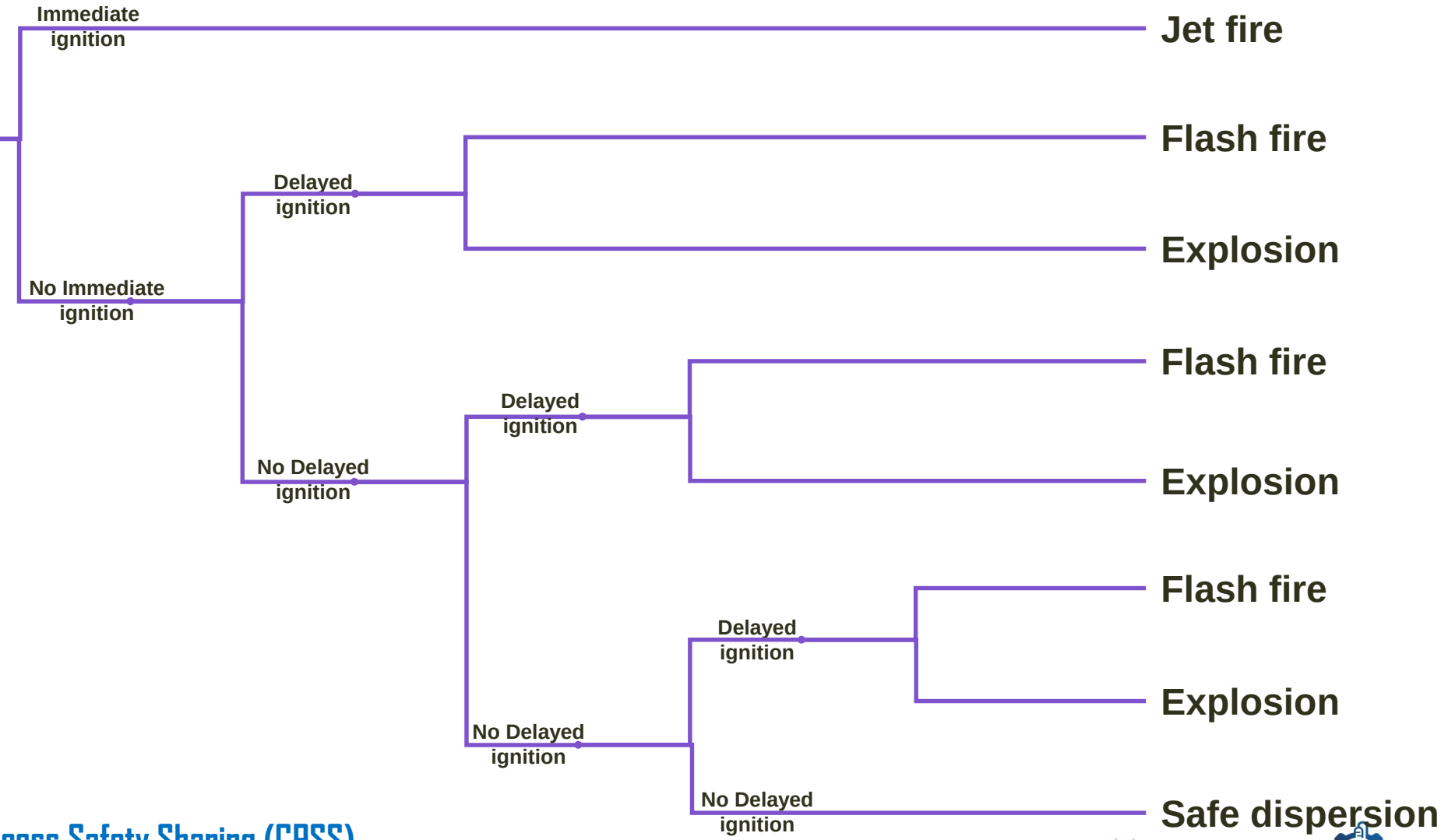
Frequency Assessment - Initial Frequency

Equipment type	Small	Rupture
6 inch pipe	$2x10^{-4}$ /yr	$2x10^{-5}$ /yr
6 inch valve	$2x10^{-5}$ /yr	$2x10^{-6}$ /yr
6 inch flange	$2x10^{-4}$ /yr	$2x10^{-5}$ /yr
TOTAL	$4.2x10^{-4}$ /yr	$4.2x10^{-5}$ /yr

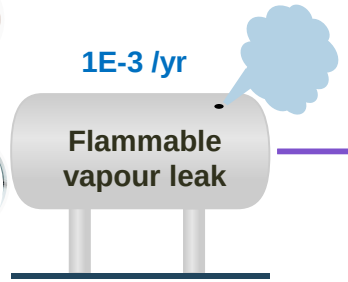
- **The leak frequencies used for the two failure cases would be:**
  - Small: 4.2×10^{-4} per year
  - Rupture: 4.2×10^{-5} per year

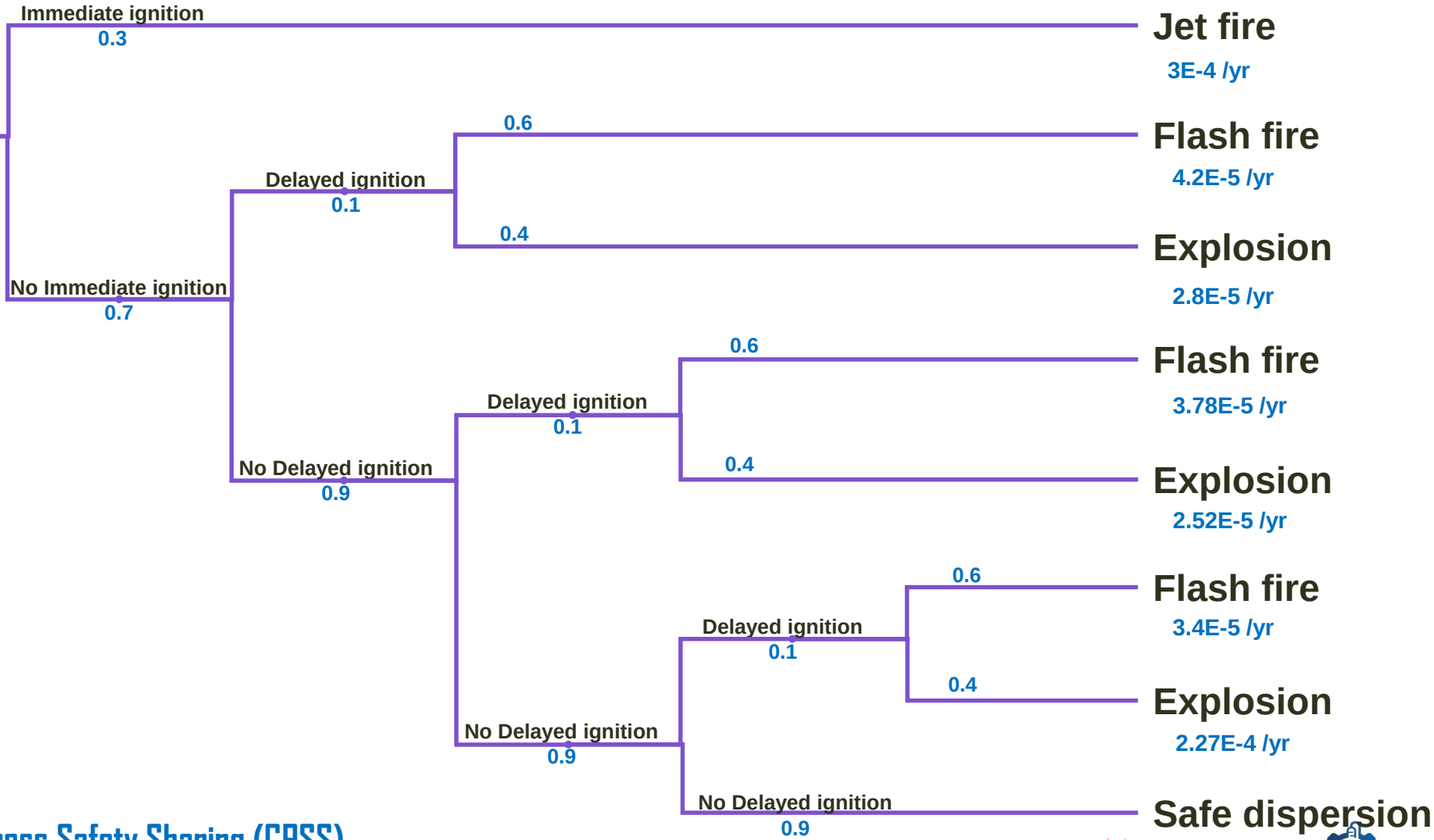
Frequency Assessment - Event Tree





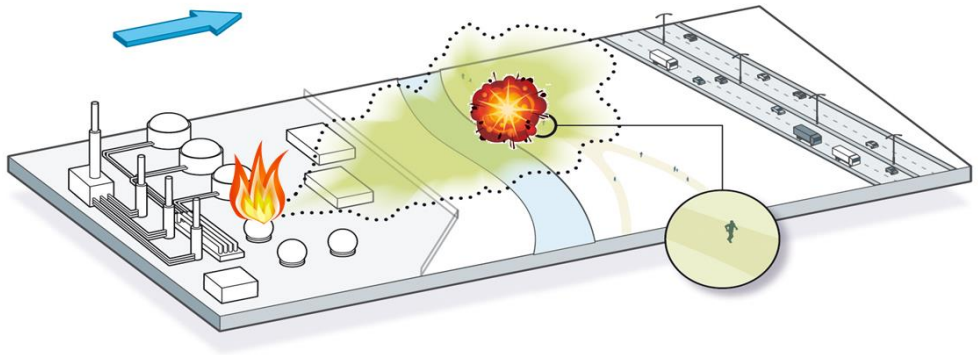
Frequency Assessment - Event Tree

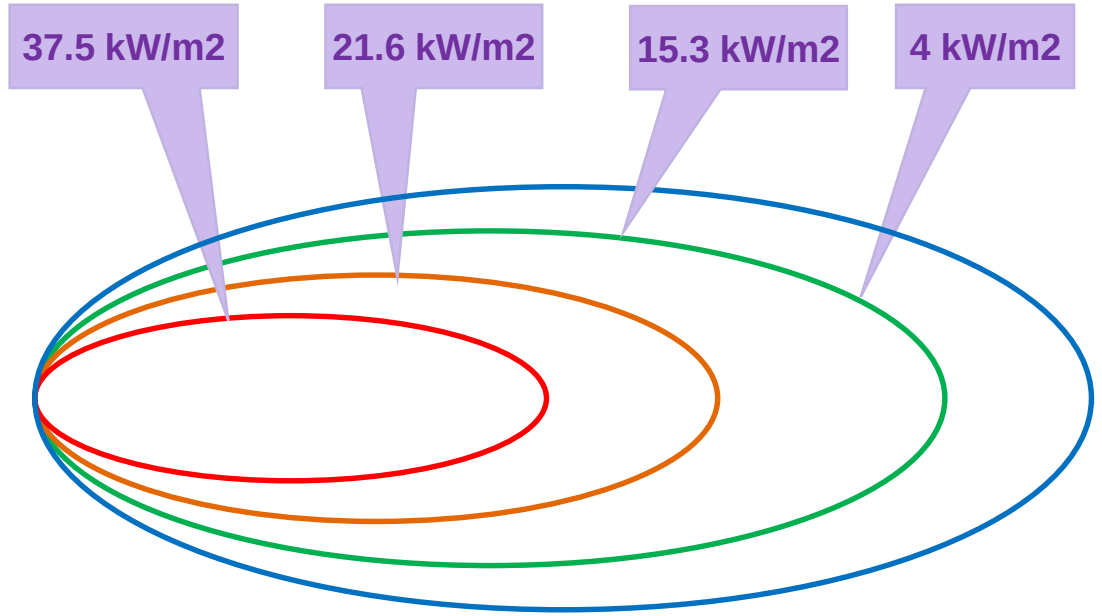




Consequence Assessment

- Modelling the physical conditions produced by toxic and flammable events



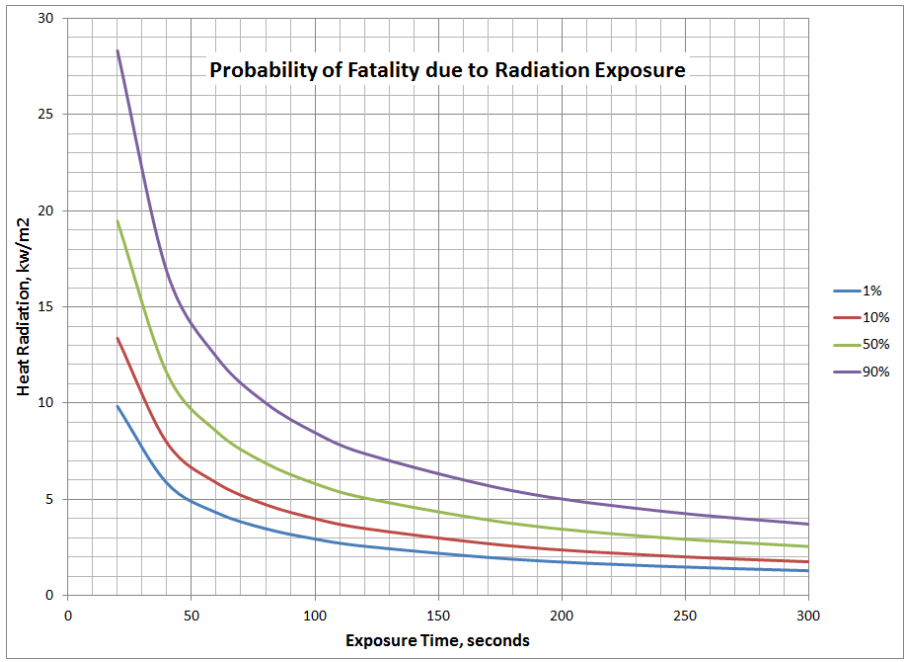


Consequence results – fire radiation

Consequence Assessment

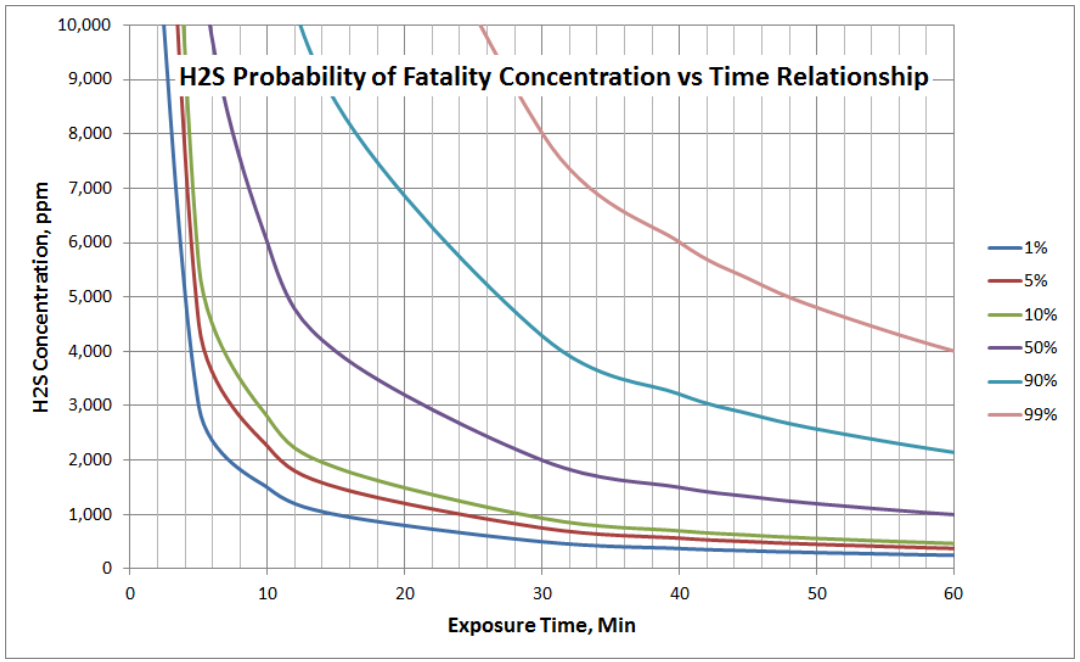
Flammables

$$P_{death} = A + Bln(Q^{4/3}t)$$



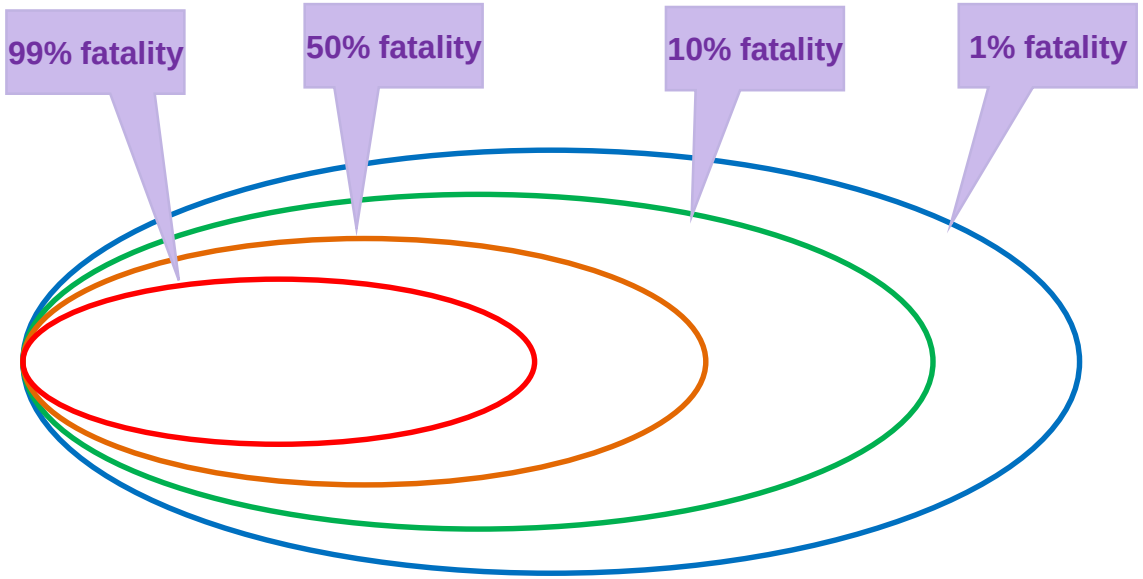
Toxics

$$P_{death} = A + Bln(C^{N}t)$$



Consequence Assessment

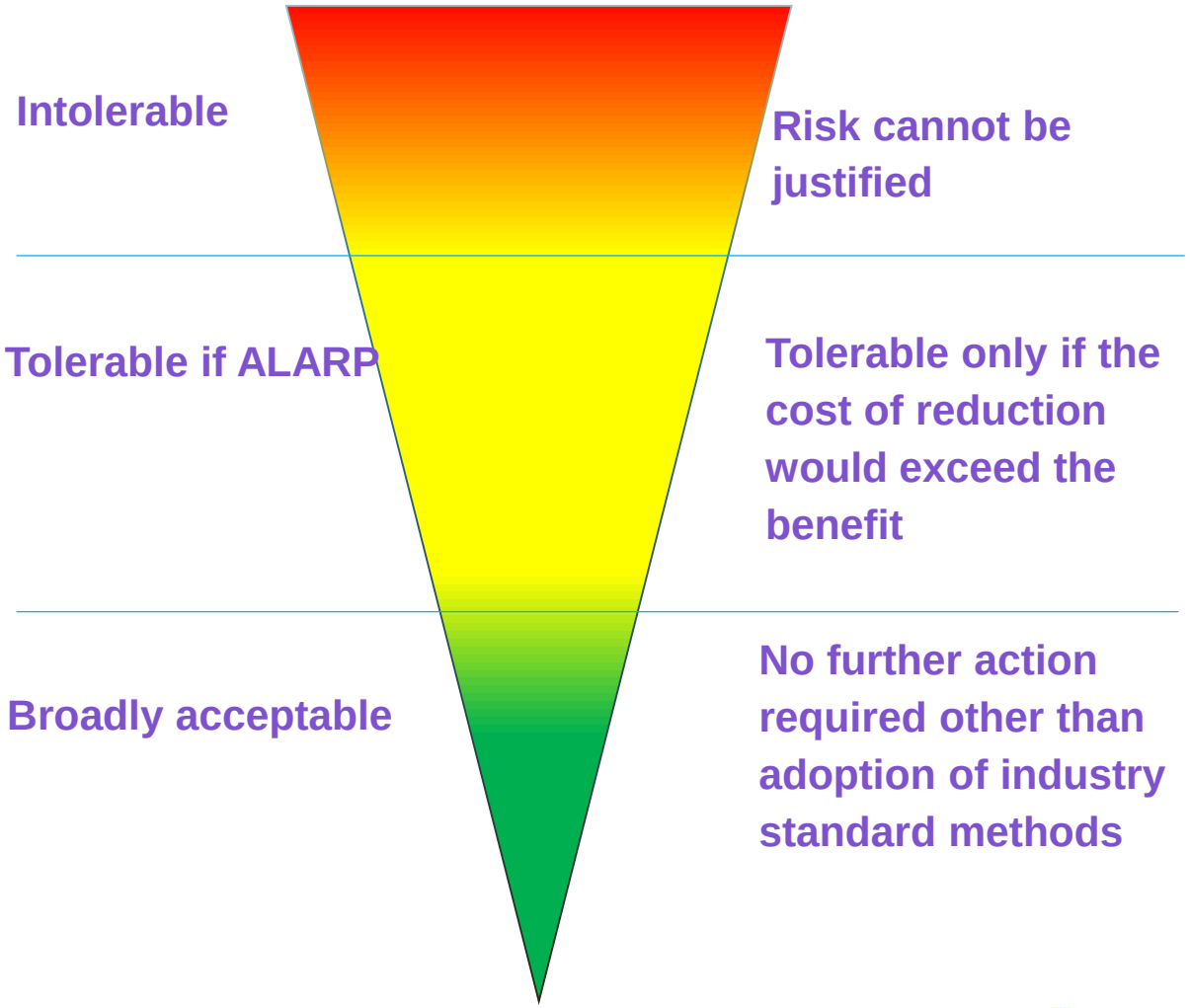
- Quantifying the impact of those conditions on personnel



Risk Analysis

Risk Evaluation

- Compare the risk levels against country and company risk criteria.
- Identify the risk contributors and find out the mitigation measures. Sensitivity Analysis may be carried out to identify the effectiveness of mitigation measures.
- Cost-Benefit Analysis (CBA) if risk is ALARP region.



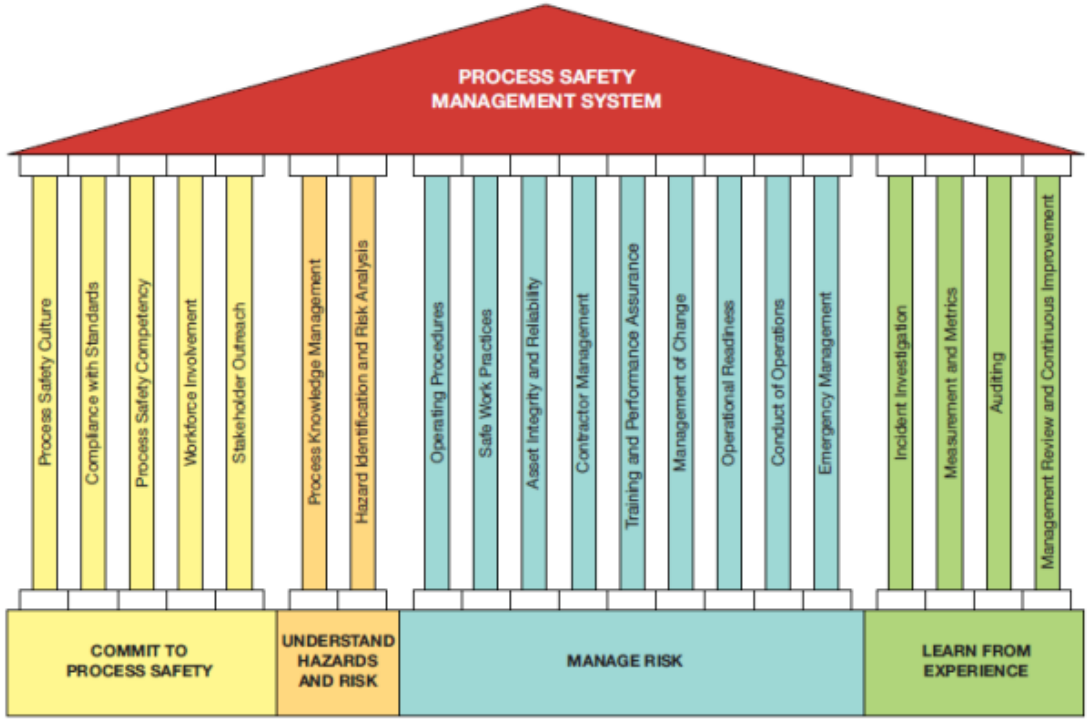
4. QRA Adds Value to PSM

Process Safety Management (PSM)

OSHA PSM

Picture source:
https://en.wikipedia.org/wiki/Process_safety_management

CCPS Risk-Based Process Safety (RBPS)



Picture source: https://www.aiche.org/sites/default/files/docs/summaries/overview-of-risk-based-06-25-14.pdf

DNV Solutions for YOUR PSM Platform

Source Information

Reporting Form field

- Audits
- 3rd Party Software
- Observation
- Workshops
- Etc

Data Capture & Storage

DNV

Process Safety Management

+

Synergi Life

Solutions

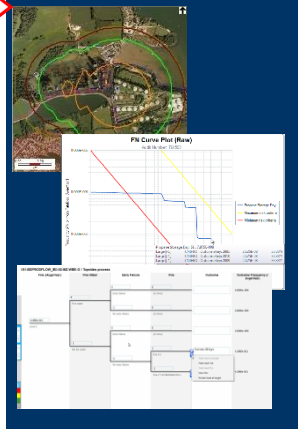
Barrier Status Current & Forecast

System | Area | Hazard

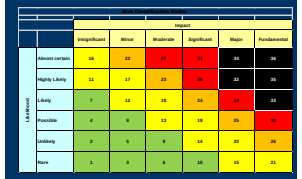
- Containment
- Gas Detection
- Escape & Evacuation
- Etc

Risk Model

Quantitative



Qualitative



Decision support

User & Associated Decision processes

5. Q&A

About DNV

DNV is an independent assurance and risk management company

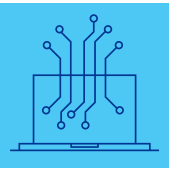
158	~12,000	100,000	100+	5% R&D
years	employees	customers	countries	of annual revenue

Ship and offshore classification and advisory

Energy advisory, certification, verification, inspection and monitoring

Management system certification, supply chain and product assurance

Software, platforms and digital solutions



Meet DNV Digital Solutions at Booth 29

- Process Hazard Analysis and QRA Software
- Reliability, Availability and Maintainability
- Asset integrity (RBI, RCM, SIL, IDMS, etc.)
- QHSE and Enterprise Risk Management
- Bow-tie and Barrier Management

Chemical Process Safety Sharing

Thank you for your attention