Engineering Risk Management
Lecture 2

Risk management principles

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5. Risk treatment/reduction
6. Event analysis
7. Major industrial accidents and Learning from accidents
8. Crisis management
9. Economic issues of safety
10. Risk Governance
11. Examples of practical implementation of risk management

Definitions

Risk management:

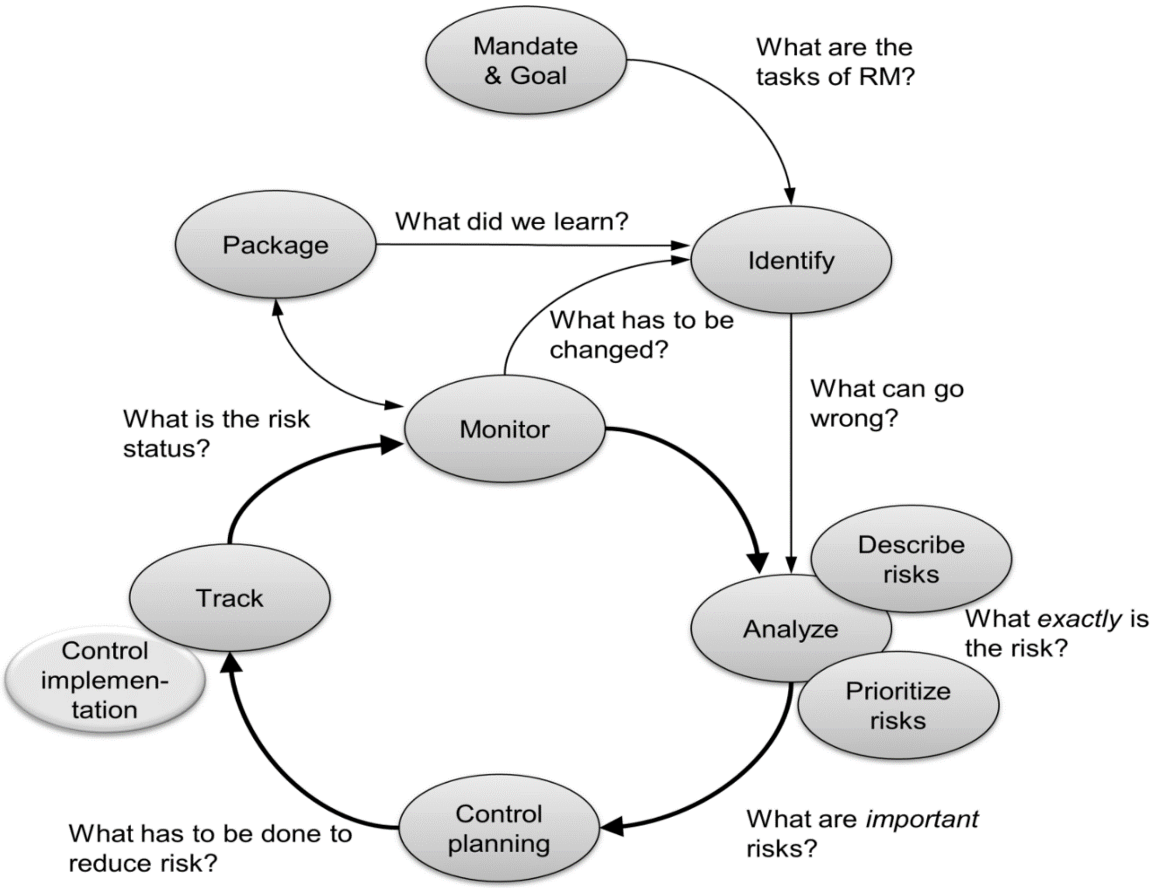
“Systematic application of management policies, procedures and practices

to the tasks of

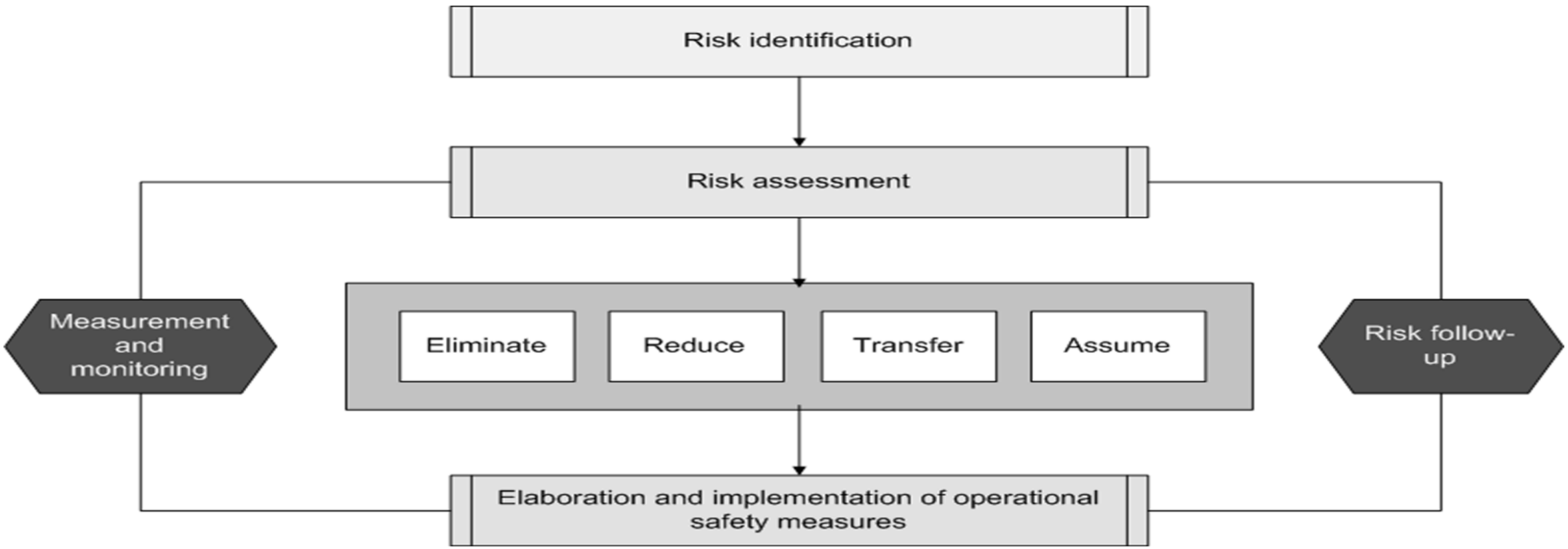
identifying, analyzing, evaluating, treating and monitoring risks.”

Engineering risk management main steps

Main questions of engineering risk management process



Simplification of the process – looking through engineering glasses

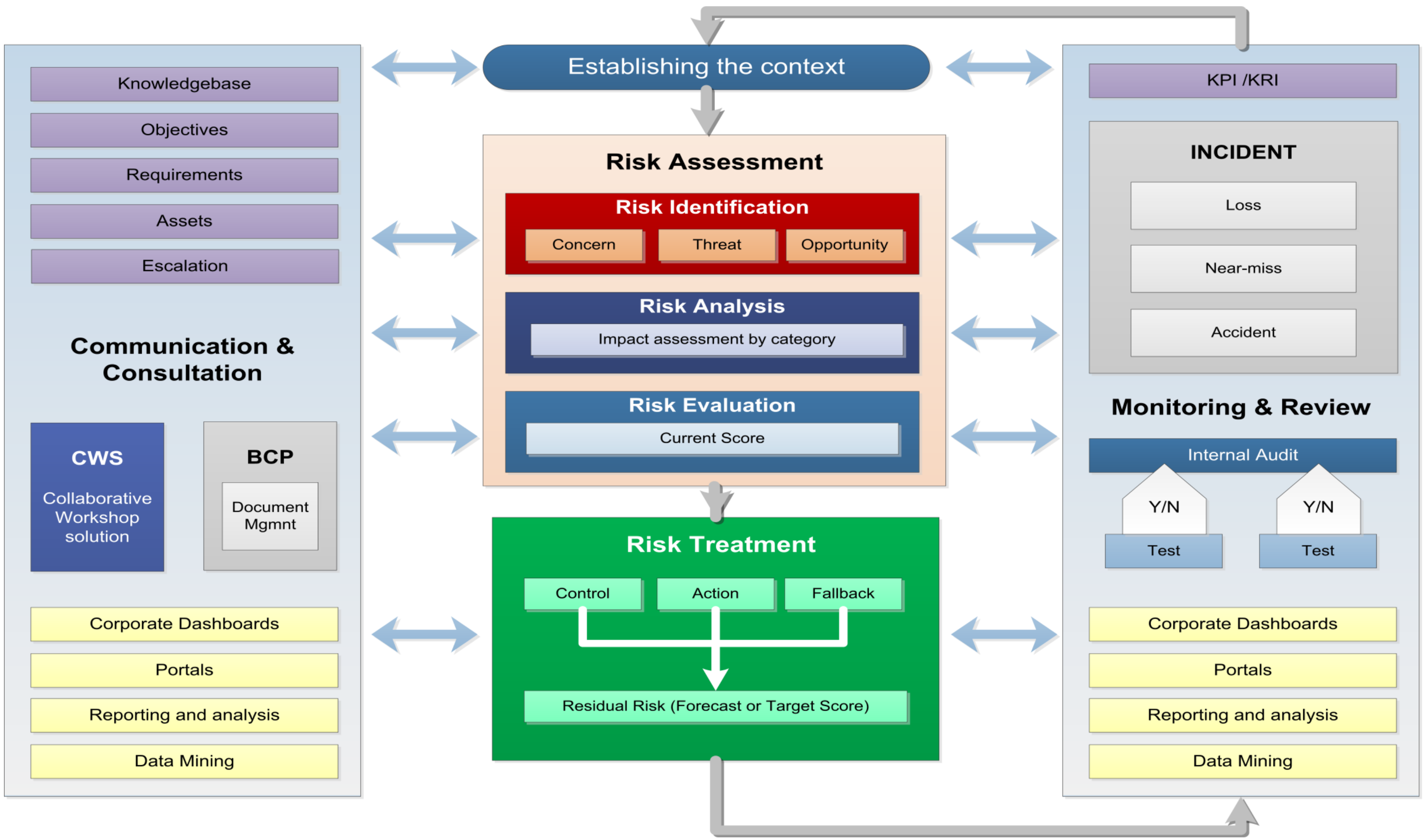


RM principles

RM:

- Is a learning process that never ends
- Creates and protects value
- Is an integral part of all organisational processes
- Is part of decision-making (or should be!)
- Explicitly addresses uncertainty
- Is systematic, structured and timely
- Is based on the best available information
- Is tailored
- Takes human and cultural factors into account
- Is transparent and inclusive
- Is dynamic, iterative and responsive to change
- Facilitates continuous improvement
- Its success depends on the effectiveness of the management framework that provide the foundations and arrangements to embed it throughout the organisation at all levels

Looking through management glasses (ISO 31000:2009)

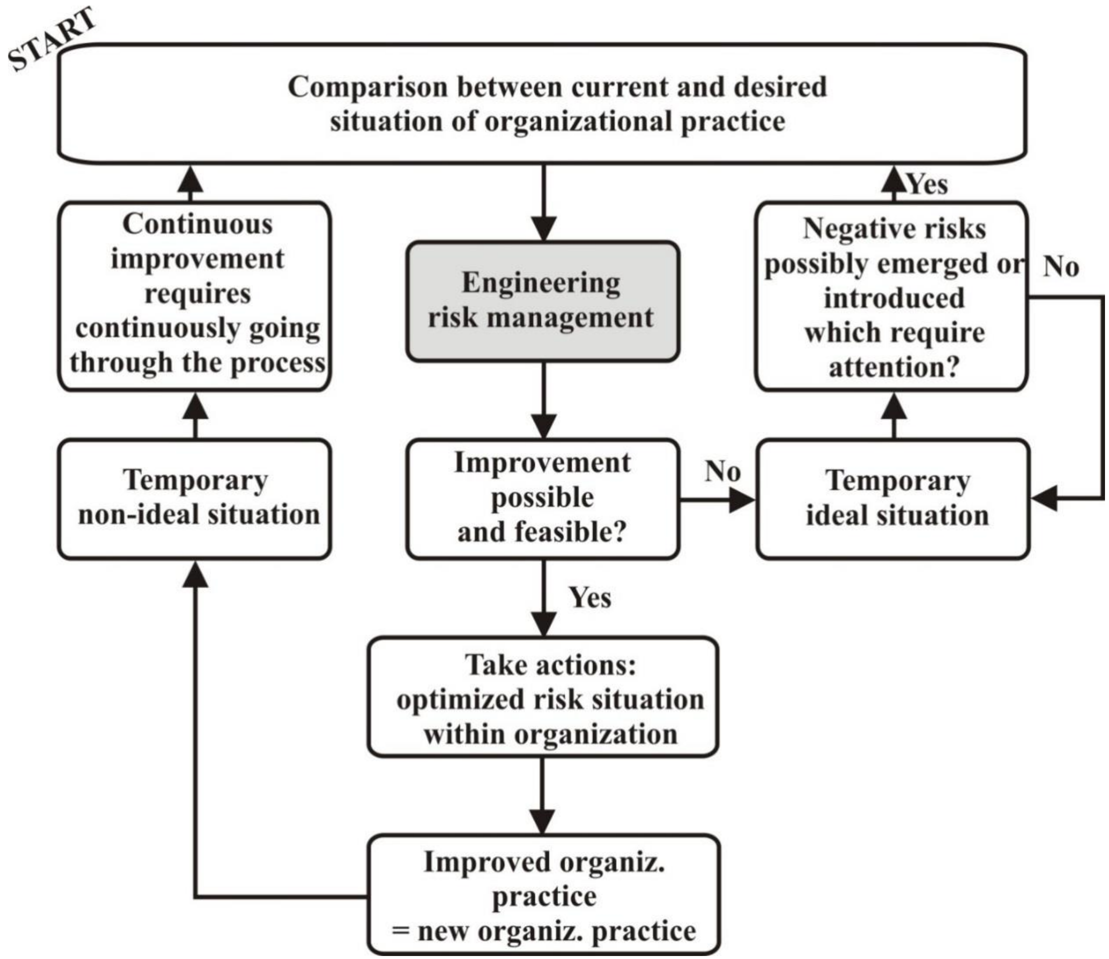


Objectives and importance of engineering risk management

- Objectives of ERM: "the early and continuous identification, assessment, and resolution of non-financial risks such that the most effective and efficient decisions can be taken to manage these risks"

- **Engineering risk management** encompasses different well-known management disciplines such as
  - **change management** (which is actually 'engineering risk management of changes'),
  - **project management** (which is actually 'engineering risk management of projects'),
  - **crisis management** (which is actually 'engineering risk management of crises'),
  - **innovation management** (which is actually 'engineering risk management of innovations'),
  - etc.

Objectives and importance of engineering risk management




DE GRUYTER
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RISK
MEDIUM
LOW


请勿
stay away

The Black Swan (type III events)

Three main features of Black swan events:

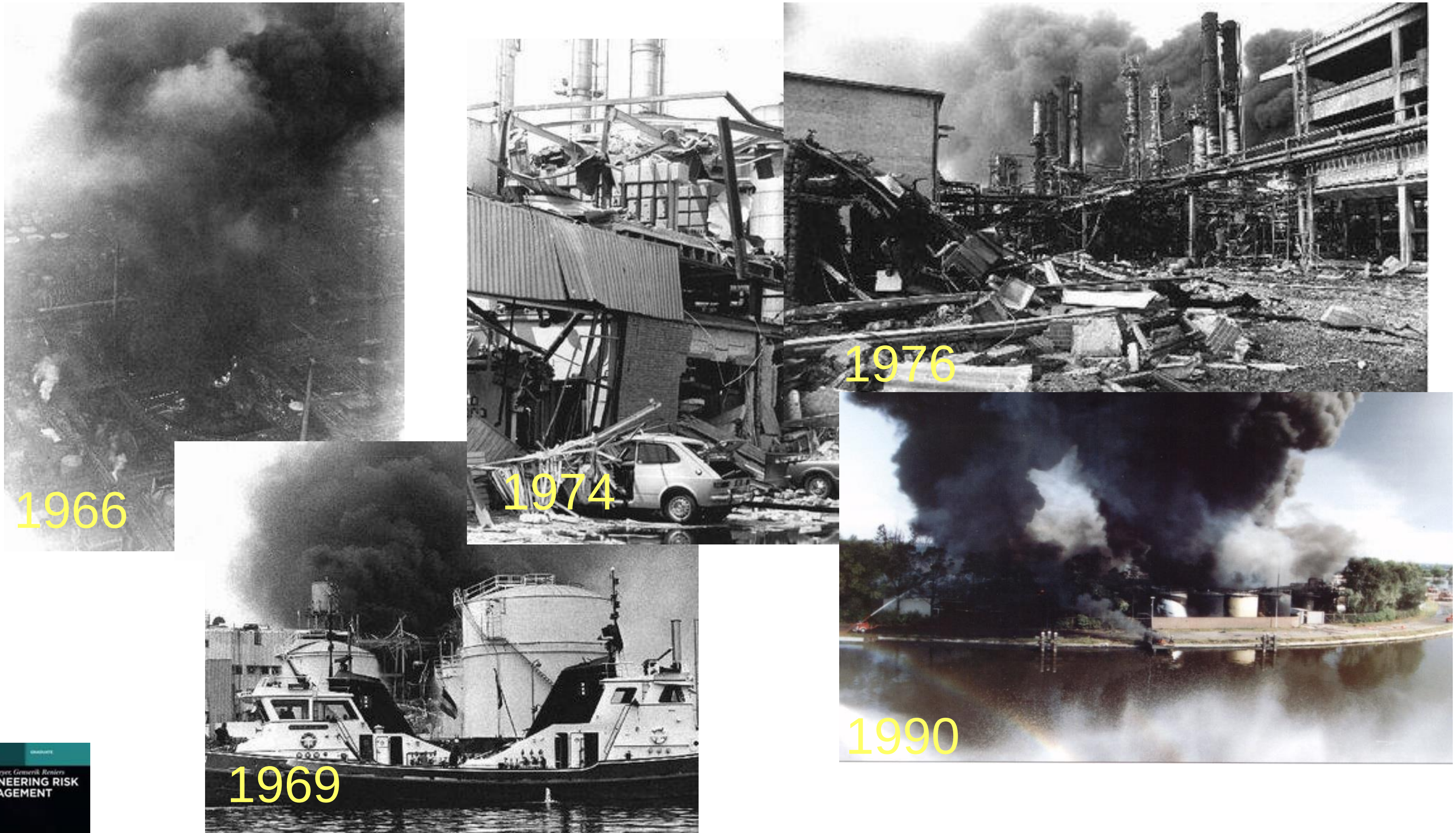
- After the occurrence of the event, explanations are formulated making it predictable or expectable
- The event has extreme or major impact
- The event is unexpected or not probable

Contents

Evolution of risk management: facts and figures

- Mainly a post-1960s phenomenon

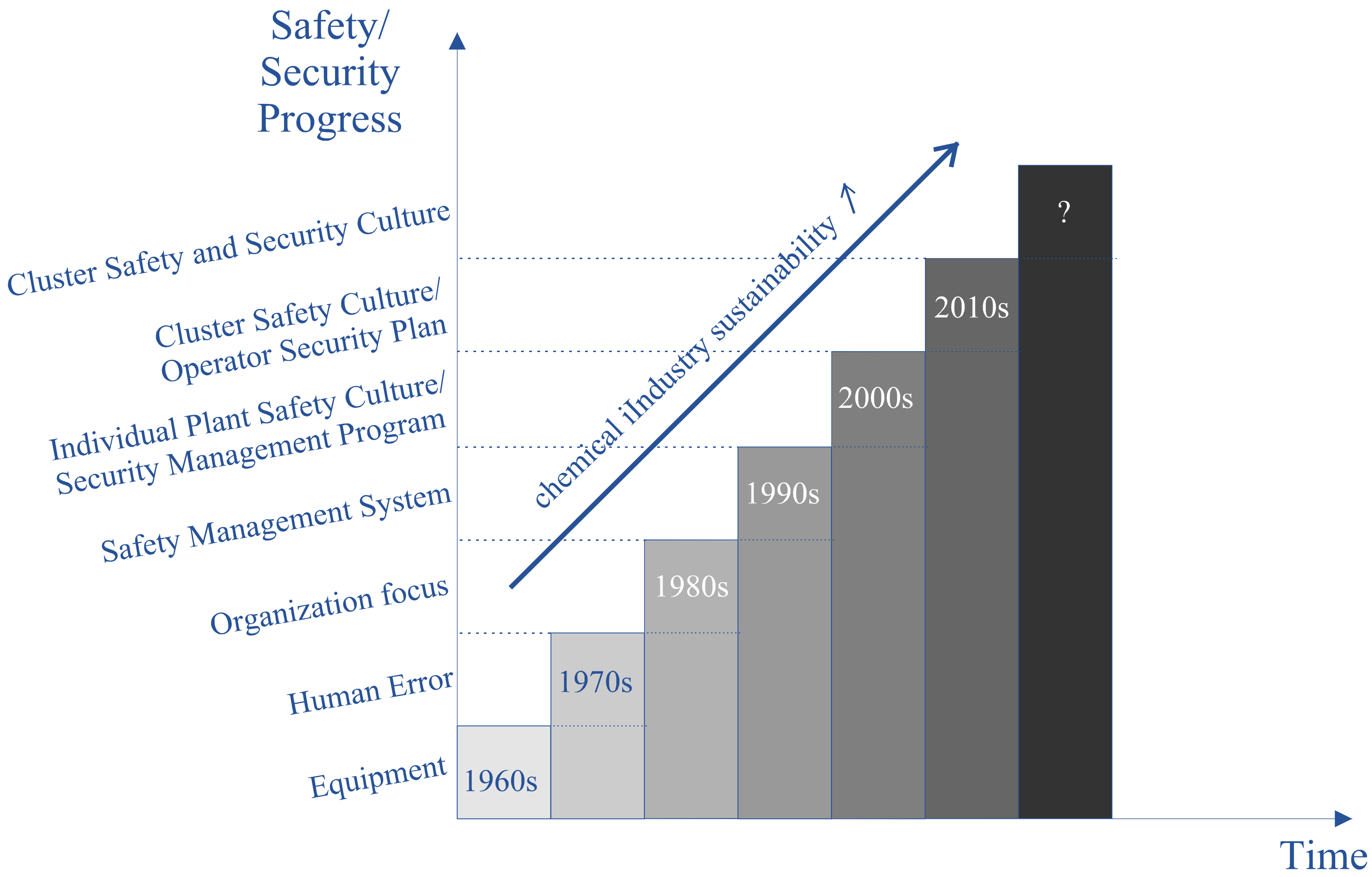
Evolution: Some pictures



Evolution: Some facts

- Mainly a post-1960s phenomenon
- “Inventors”: Nuclear industry & Chemical Process Industry

Evolution: a figure

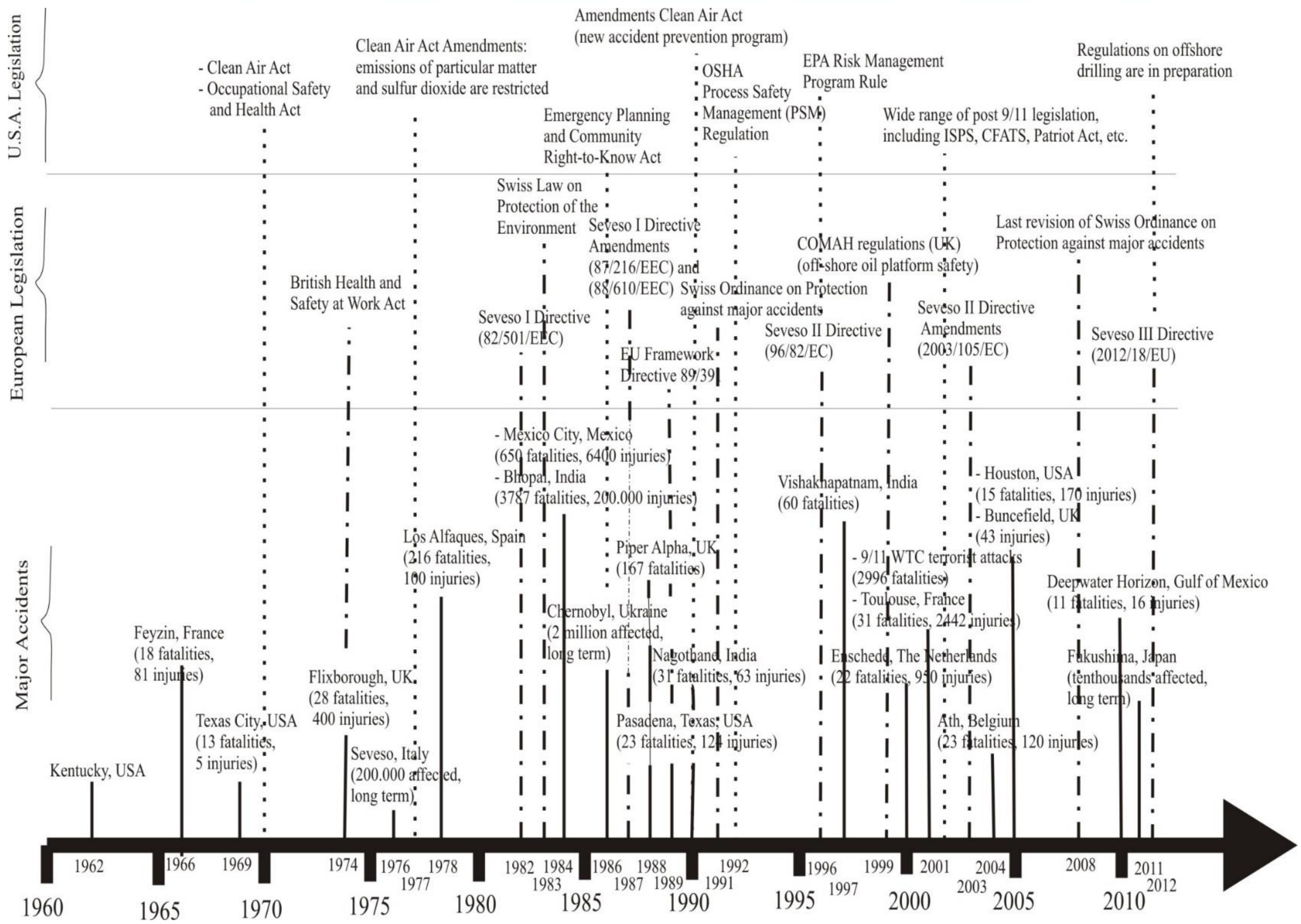


Evolution: Some facts

- Mainly a post-1960s phenomenon
- "Inventors": Nuclear industry & Chemical Process Industry

- Legislation: ad hoc & reactive

Evolution: a Figure

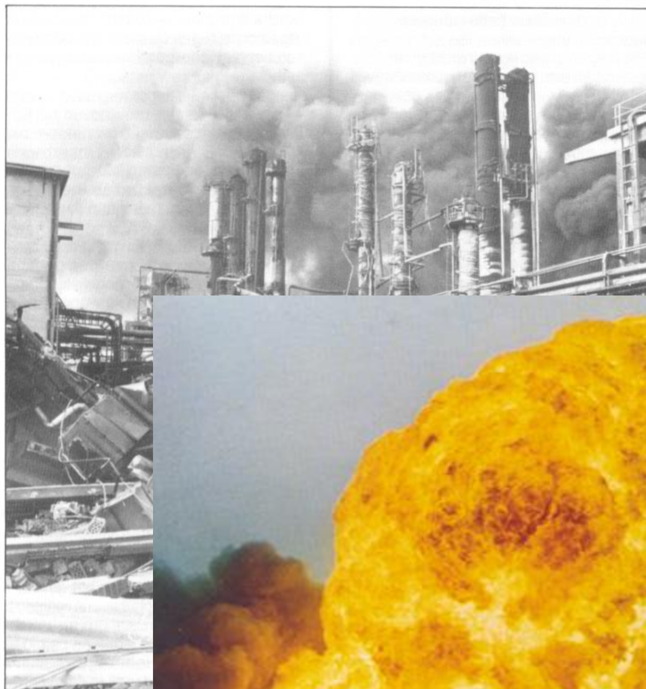


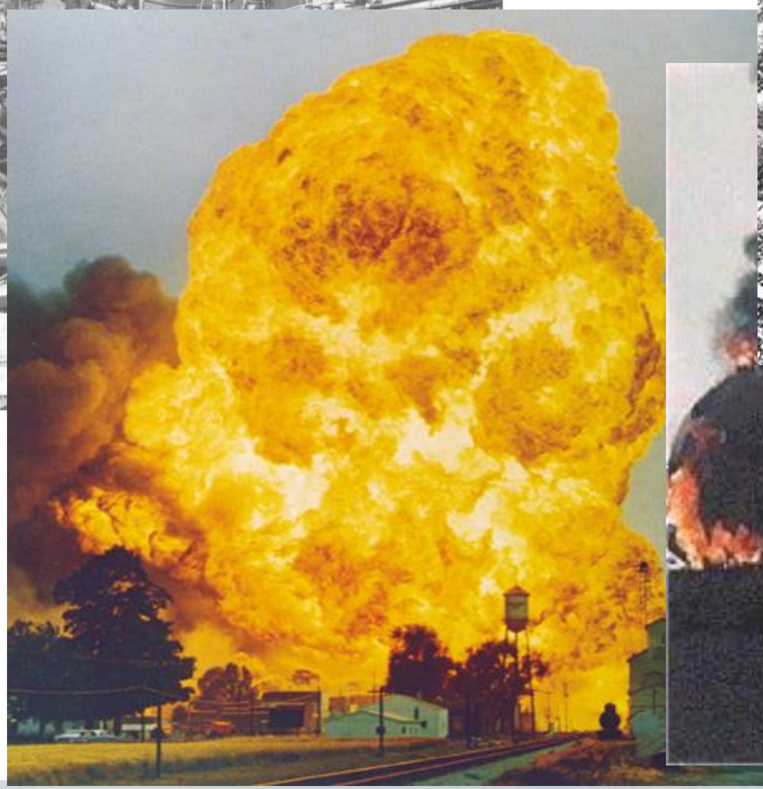
Evolution: some facts

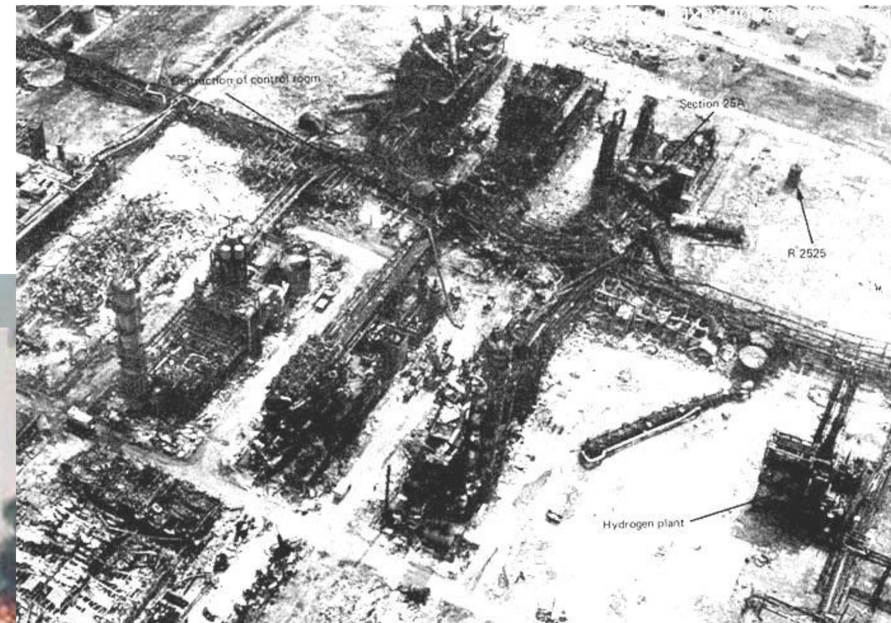
- Mainly a post-1960s phenomenon
- “Inventors”: Nuclear industry & Chemical Process Industry
- Legislation: ad hoc & reactive

- At present: widely disseminated and used by many industrial sectors

However…






Destruction of control room
Section 25A
R 2525
Hydrogen plant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RISK
MEDIUM
LOW

Remember: the importance of engineering risk management

Not all risks can (or should!) be avoided (risks also result into profits, gains, products, etc.), BUT risks should be controlled and managed!

Examples:
Adult+ fryer = small risk
Child + fryer = large risk

Trained employee with toxic product = small risk
Non-trained employee with toxic product = large risk

Computer-operated warehouse = small risk
Manually operated warehouse = large risk

→ Managing risks adequately is very important!

Types of risk management

Remember: risk management = (to put it simple) prediction of risks and the identification and implementation of control measures to maintain these risks at an acceptable level

Risk management levels:

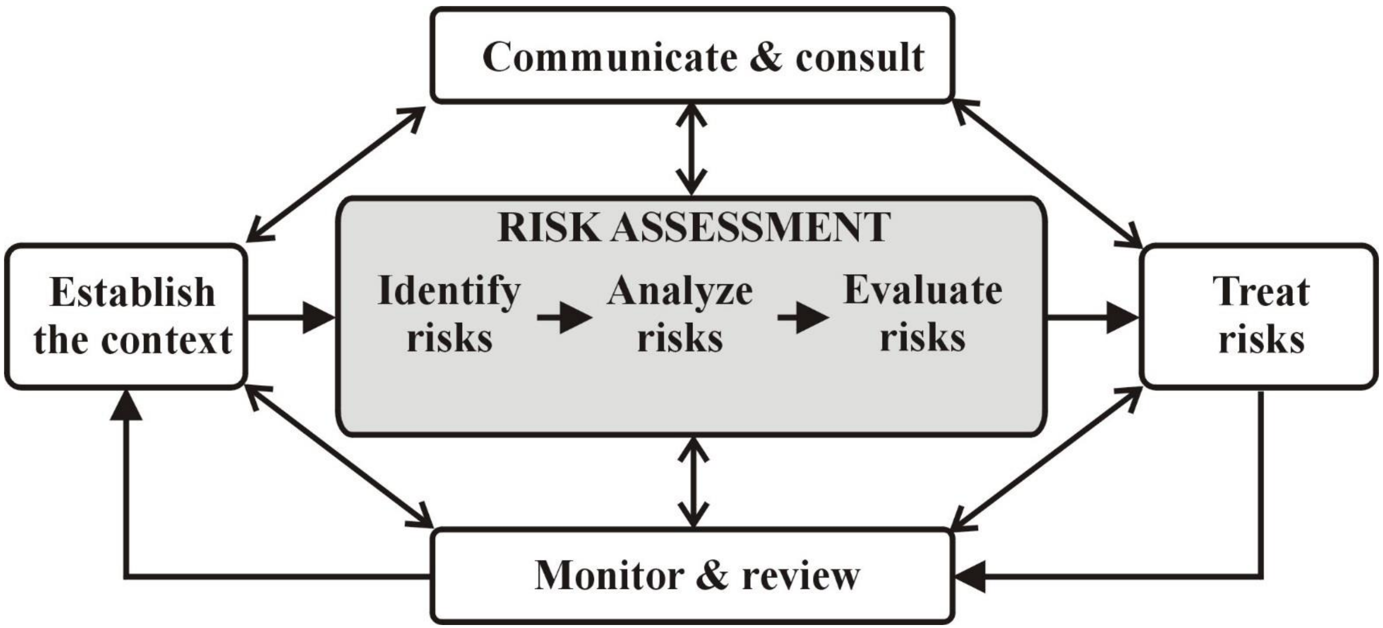
- International (ILO, UN, NAVO, etc.)
- National (H5N1-impact, homeland security, etc.)
- Regional
- Municipal
- Organisational (global, business unit, department, etc.)
- Personal

Hazard levels:

- Environment
- Technical/economic
- Social/people

Fields of knowledge/expertise within 'Engineering Risk Management'?

Looking through management glasses (ISO 31000:2009) from an engineering perspective



Integrated Risk Management

Dependent on the sources, risks management needs and policies can differ:

- Environmental risks
- Financial risks
- Quality risks
- Recreational risks
- Health risks
- Occupational health and safety risks
- Security risks

→ Risk managers in specific domains with their own risk management strategies and acceptability levels

Integrated risk management

Comparing a specific mgt system with an integrated mgt system, 5 ***common aspects*** can be noticed:

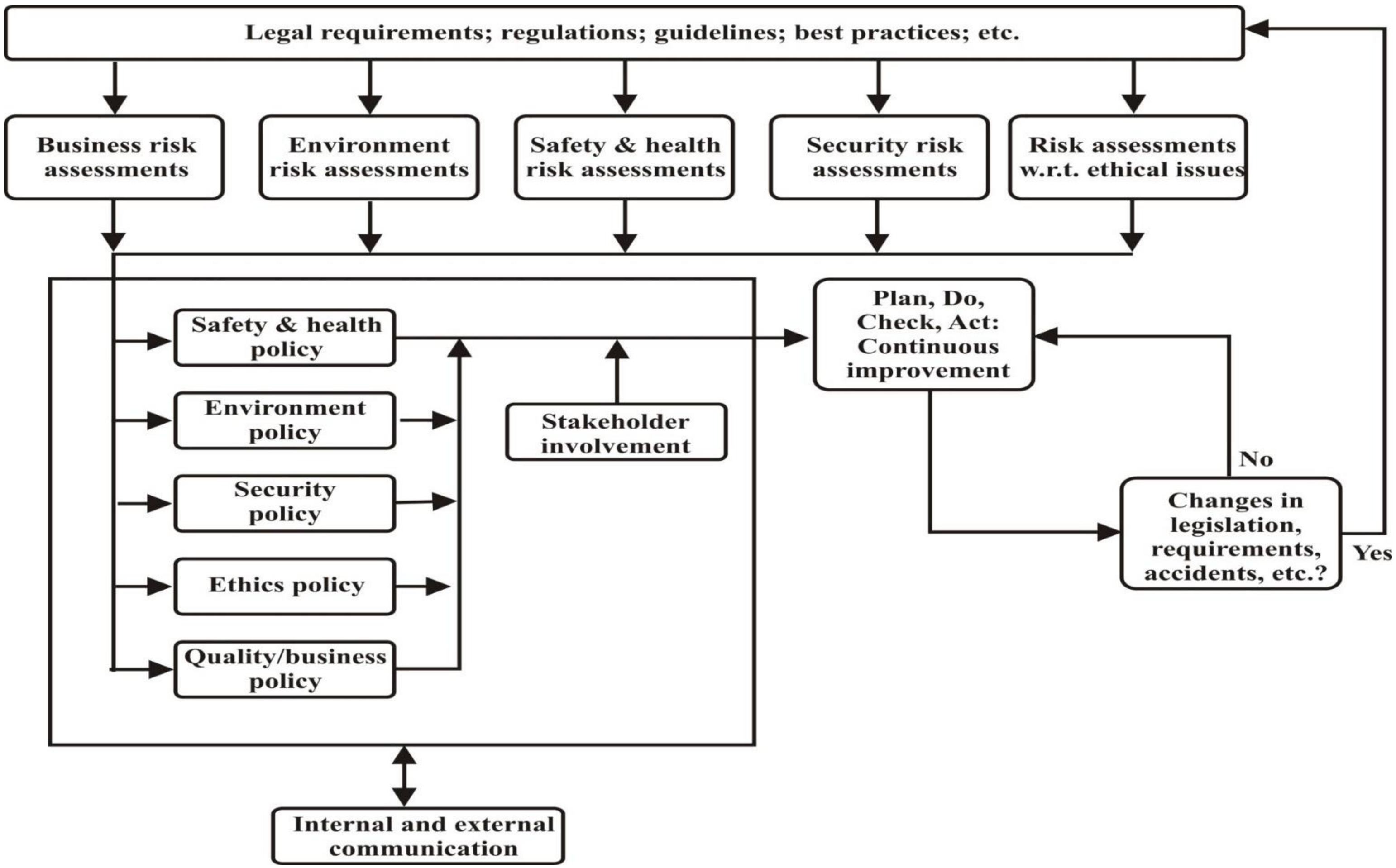
1. Both systems provide guidelines on how to develop management systems without explicitly prescribing the how-exercise in details.
2. They consider a risk management system to be an integral part of the overall company management system. This approach guarantees the focus and ability to realize the company's general and strategic objectives.
3. They all have two common aims: (i) to realize the organization's objectives taking compliance into full consideration; (ii) continuous improvement of an organization's achievements and performances.
4. The process approach is employed.
5. The models can be applied to every type of industrial organization.

Integrated risk management

Comparing a specific mgt system with an integrated mgt system, 3 ***differing aspects*** can be seen:

1. Integrated risk management systems recognize the positive as well as the negative possible outcomes of risks. Hence, both damage and loss on the one hand, and opportunities and innovation on the other hand, are simultaneously considered.
2. All kinds of risks are considered: operational, financial, strategic, juridical, etc. and hence, a balanced equilibrium is strived for.
3. The objectives of integrated management systems surpass compliance and continuous improvement.

Integrated Risk Management in practice



Concrete elaboration of integrated risk mgt system - approach

- Results (objectives, action plans, improvement measures)
- Approach (instruments to carry out daily operations)
- Implementation (realizing established aims)
- Evaluation (instruments to assess the efficiency and effectiveness of goal realization)
- Audit (use evaluation instruments and organize follow-up meetings)

Risk management **models**

- Before: domain of mainly civil engineers and medical doctors, determining the risk analysis method, risk acceptance criteria/levels and who estimated and evaluated the risks

Problem/conflict of method with modern society: trial and error method is no longer acceptable for public

- Now: **dilemma** (von Winterfeldt, 1992):
  “The experts should not control society’s technological choices, but the public and their political representatives are not sufficiently informed to assume complete control themselves”

WHO INFLUENCES RISK DECISION MAKING?

→ Multiple-stakeholder decision analysis process

timeline - 19th century till 1920s

19th century

1844 safety technique (UK)

1900

1906 safety first movement (US)
1910 external causes (US, Nl)

1919 accident proneness (UK)

1920

1926 hazard Ξ energy (US)
1927 accident costs 1:4 (US)
1928 causes 88:10:2 (US)
1929 mechanism 1:29:300 (US)

timeline – 1930s till 1950s

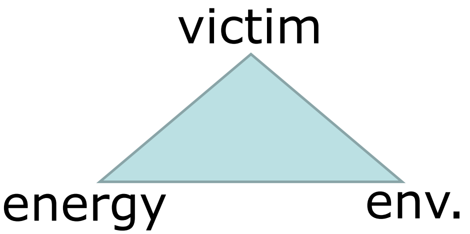
1930

1936 external factors (UK)

1940

1941 domino’s (US)
0perational research (UK)

1949 epi triangle (US)



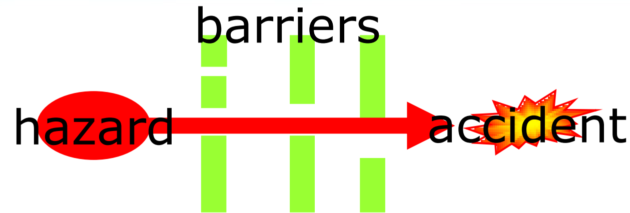
1950

1950 management (US)
1951 task dynamics (Nl)

timeline – 1960s till 1970s

1960

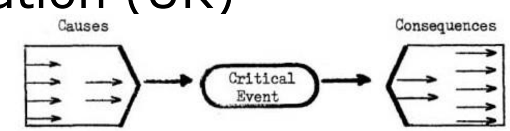
1961 barriers (US)



1960-3 hazop, fault tree, FMEA
1964 loss prevention
1966 iceberg, damage (US)
1967 man-machine system (UK)

1970

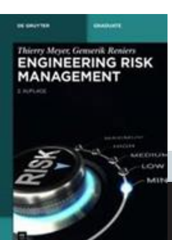
1971 organisational culture (UK)
1971 safety audits (US)
1971 disturbed information (UK)
1971 pre-bowtie (Den)
1973 MORT (US)



Flixborough
Beek
Seveso

1978 weak signals, incubation

3 Mile Island



timeline – 1980s till 1990s

1980

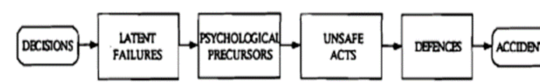
- 1980 safety climate (Israel)
- 1981 process disturbances (Sw)
- 1981 risk triplet $R=\{\langle s_i,p_i,x_i\rangle\}$ (US)
- 1982 skill-rule-knowledge (Den)

Bhopal, Mexico city, Chernobyl, Zeebrugge, Piper Alpha

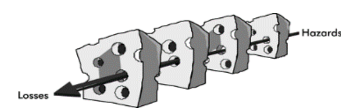
- 1984 normal accidents (US)
- 1985 inherent safe design (UK)
- 1986 safety culture (USSR)
- 1987 resistant pathogen (UK, Nl) 1987 high reliability (US)

1990

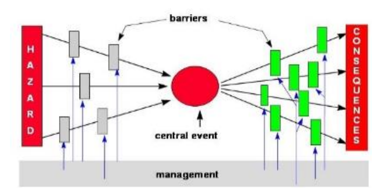
- 1992 latent failures (Nl)



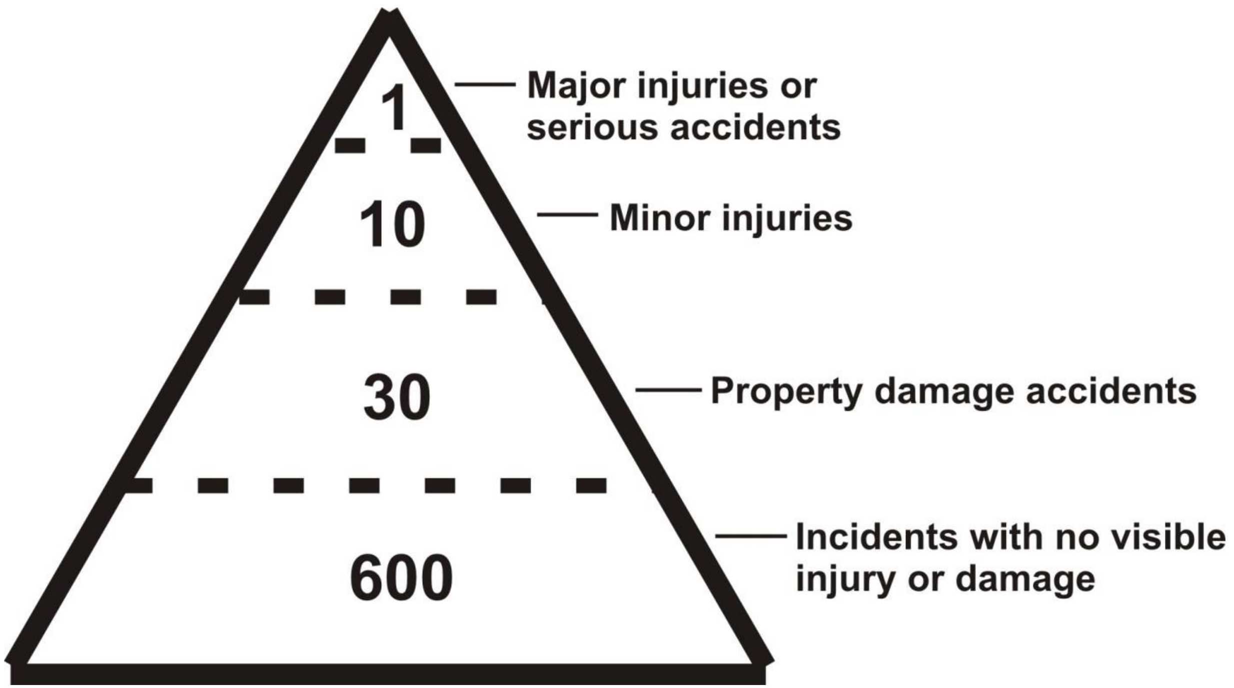
- 1994 impossible accidents (Nl)
- 1997 Swiss cheese (UK, Nl)



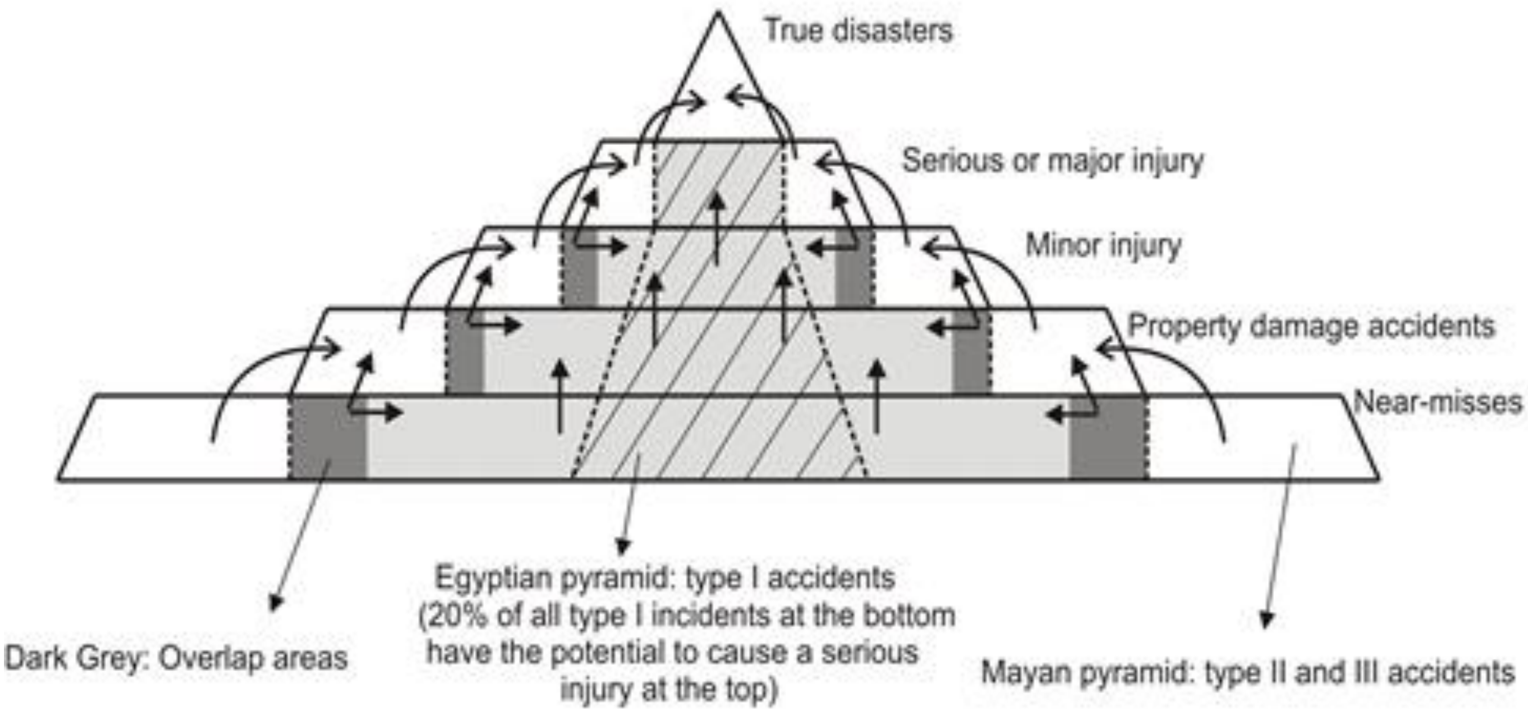
- 1997 drift to danger (Den)
- 1998 bowtie (Nl)



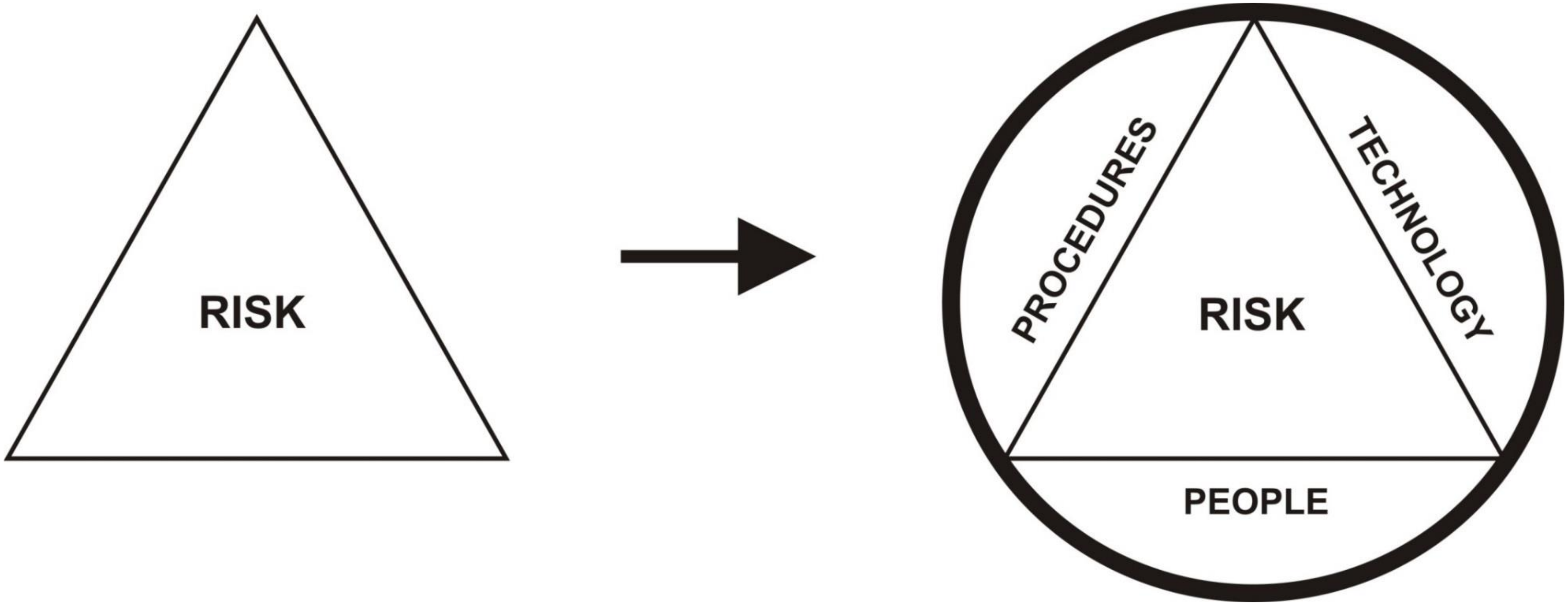
Risk management models: the accident pyramid (Bird)



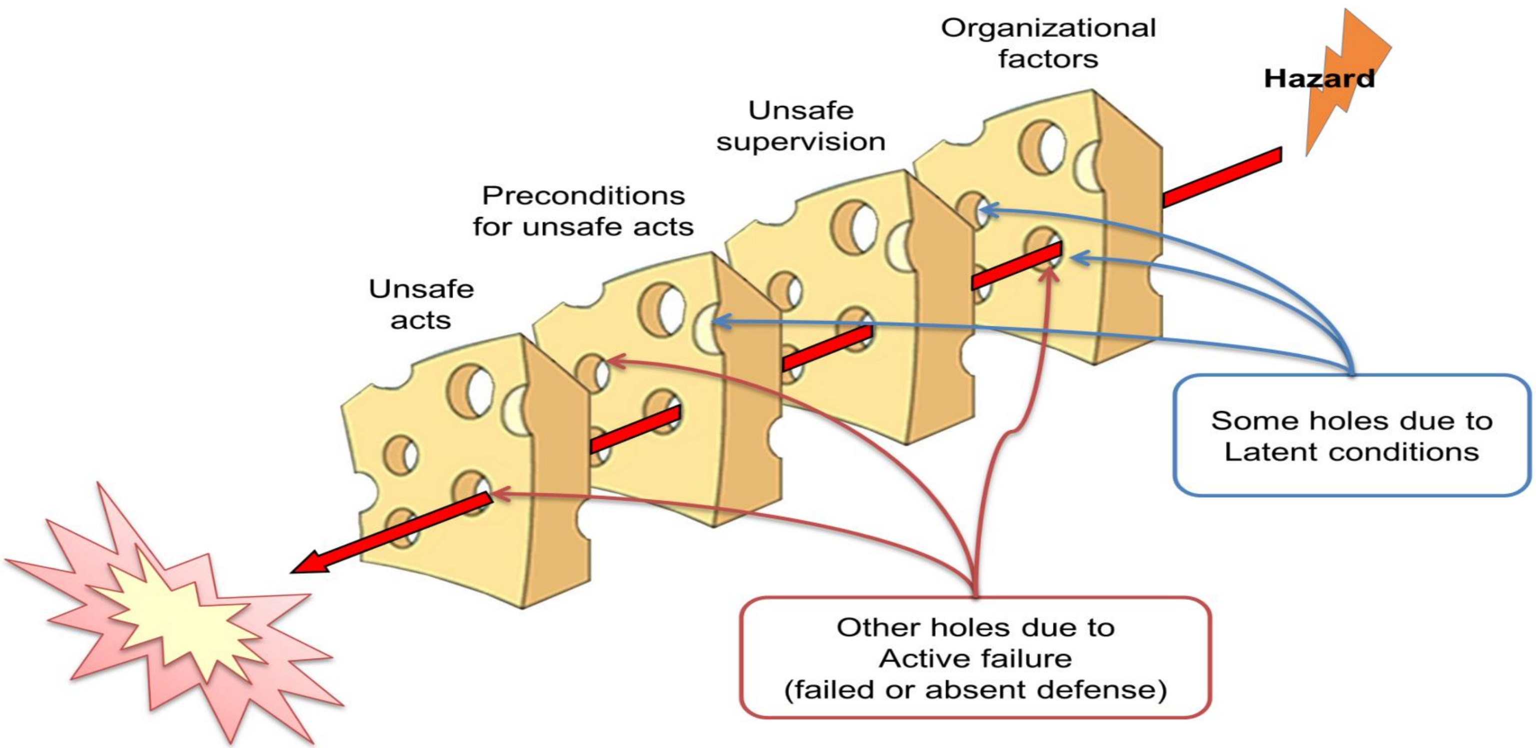
Risk management models: the accident pyramid improved (Reniers, Hopkins)



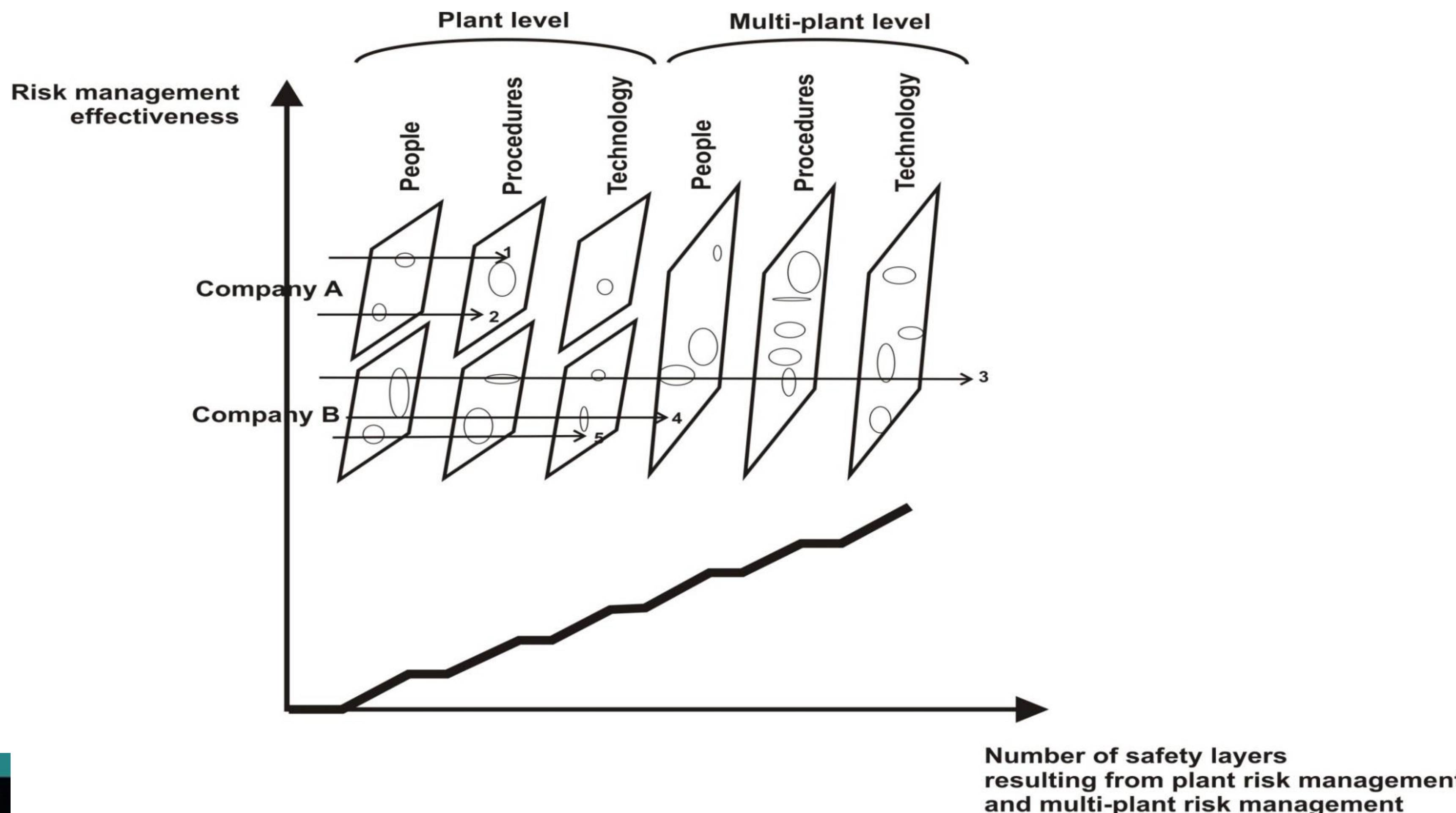
Risk management models: the P2T model (Reniers)



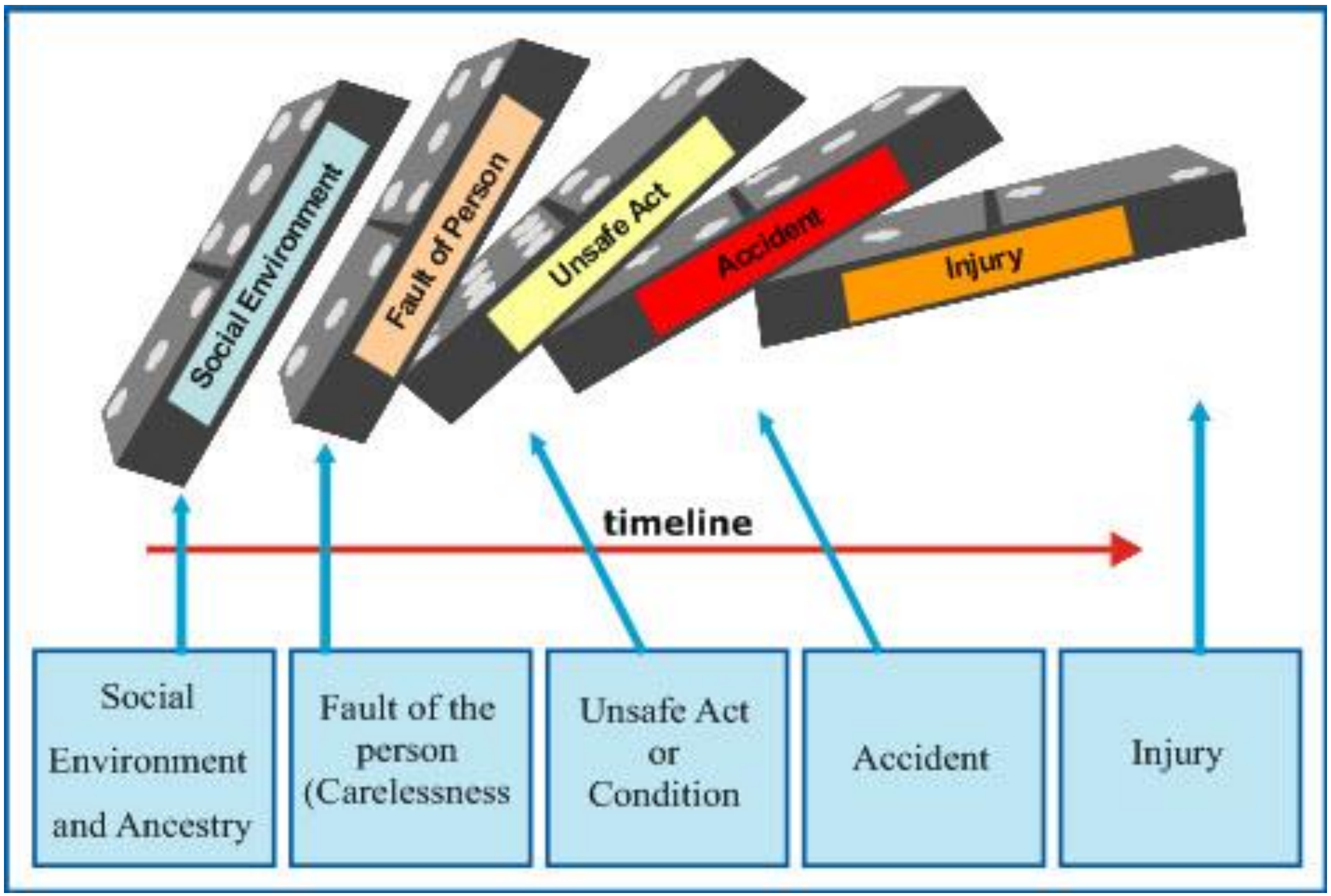
Risk management models: the Swiss cheese model (Reason)



Risk management models: the Swiss cheese model improved (Reniers)



Risk management models: the domino model for accidents (Heinrich)



Anatomy of an accident

- “Independent Protection Layers”: definition:

‘an IPL is a device, system or action that is capable of preventing a scenario from proceeding to its undesired consequence independent of the initiating event or the action of any other layer of protection associated with the scenario’

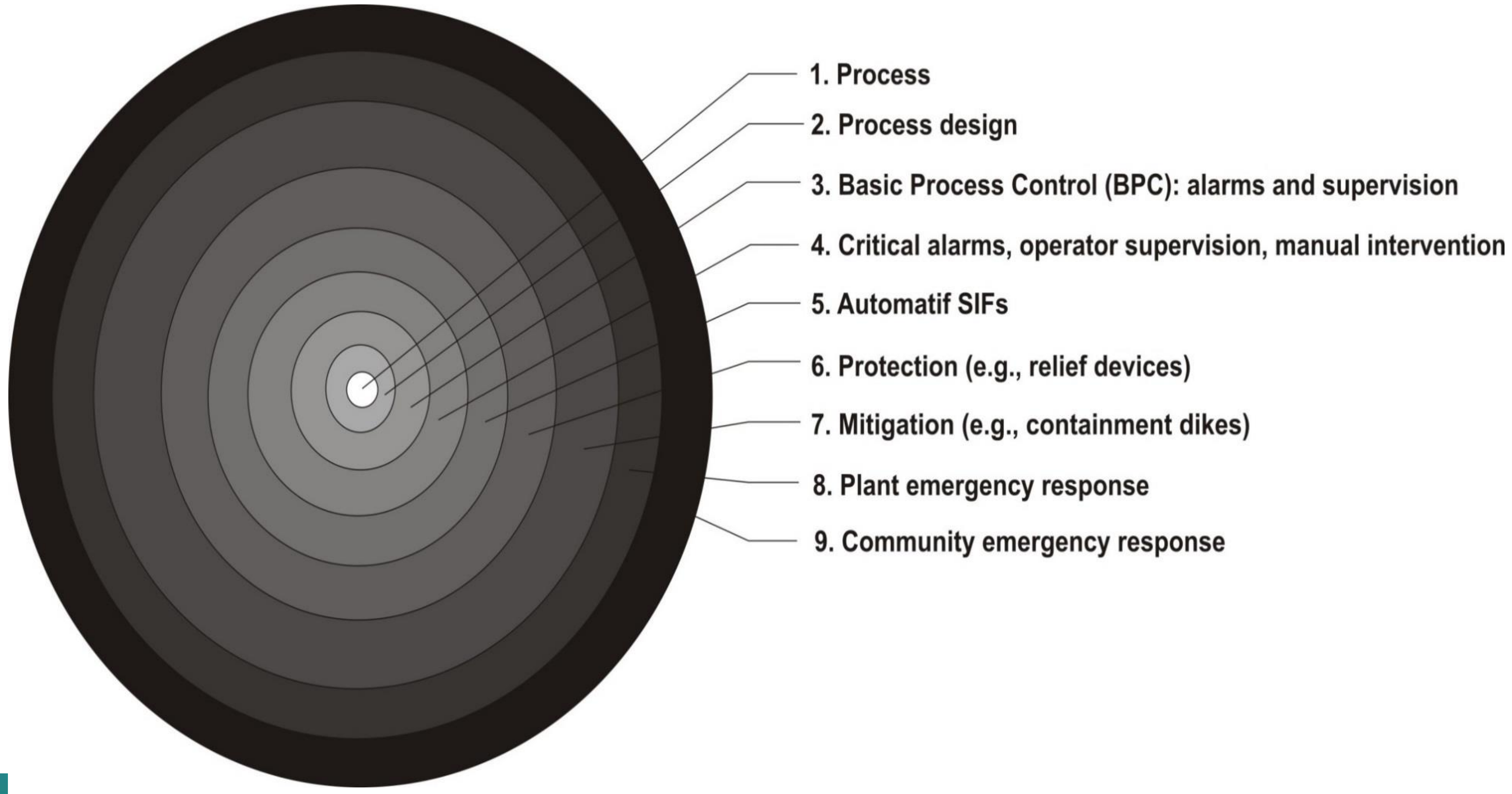
Anatomy of an accident

- "Independent Protection Layers"

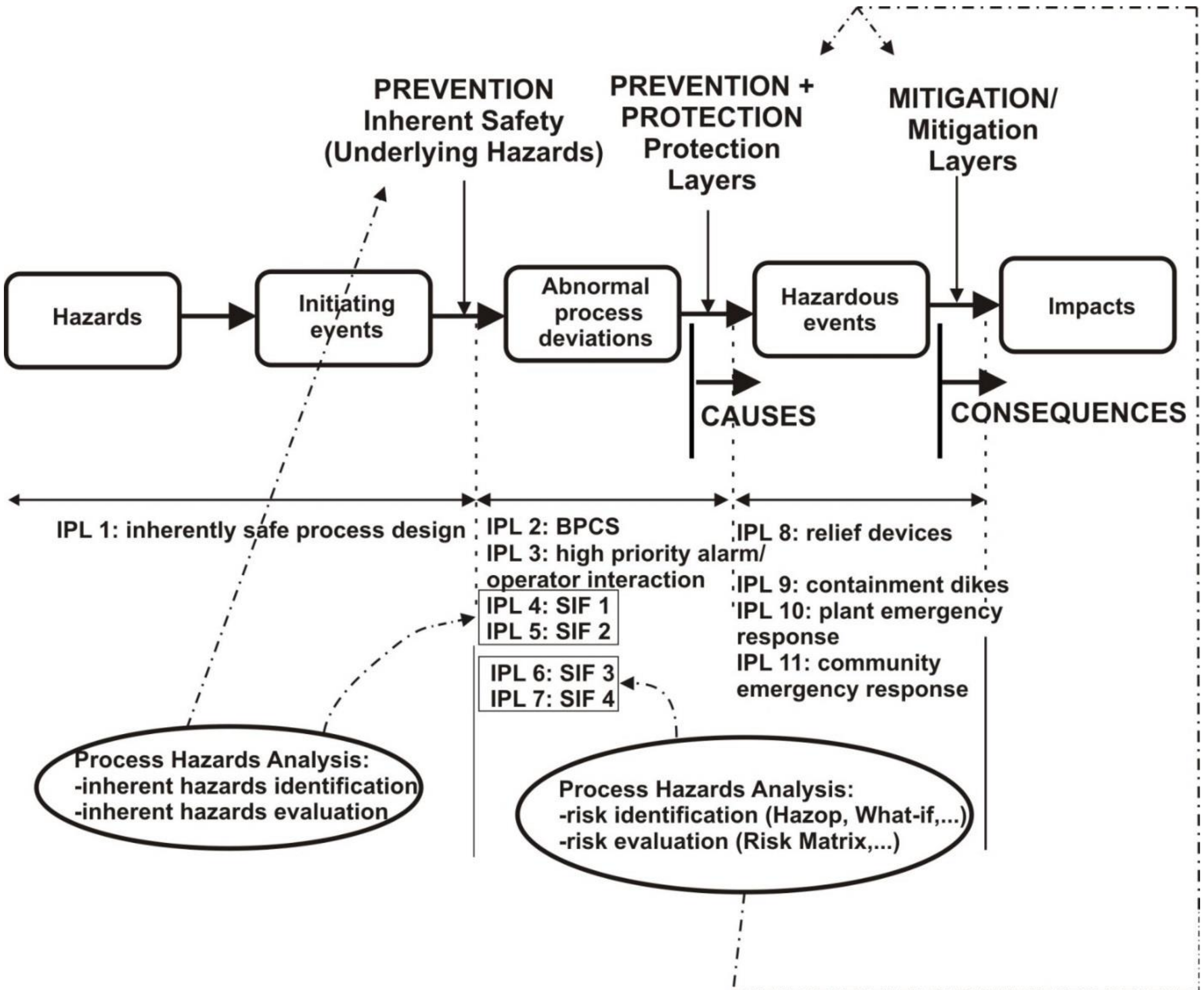
Having following characteristics:

  - (i) Specific – designed to prevent or to mitigate specific, potentially hazardous events;
  - (ii) Independent – independent of the other protective layers associated with the identified hazard;
  - (iii) Dependable – can be counted on to operate in a prescribed manner with an acceptable reliability. Both random and systematic failure modes are addressed in the assessment of dependability;
  - (iv) Auditable – designed to facilitate regular validation (including testing) and maintenance of the protective functions;
  - (v) Reducing – the likelihood of the identified hazardous event must be reduced by a factor of at least 100.

IPLs for Process Safety in the chemical industry

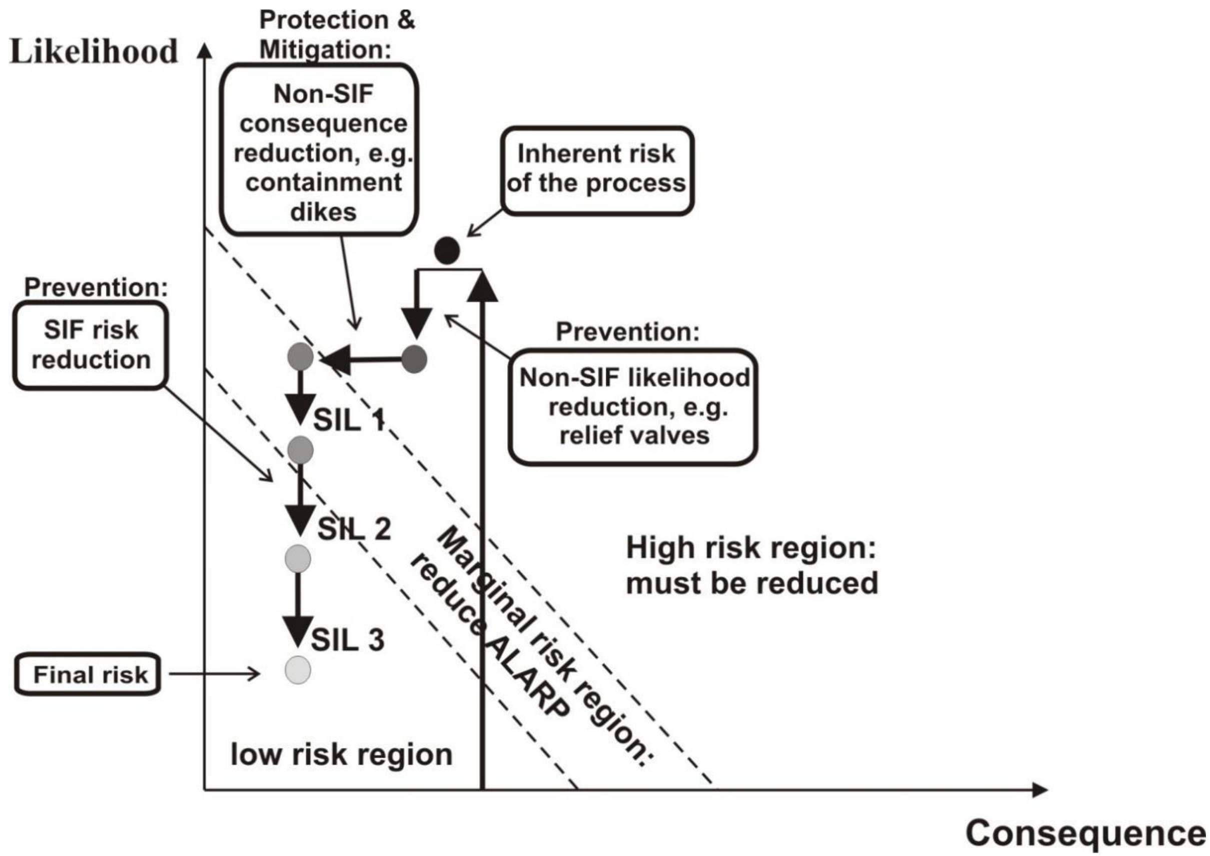


IPLs for safety in the chemical industry

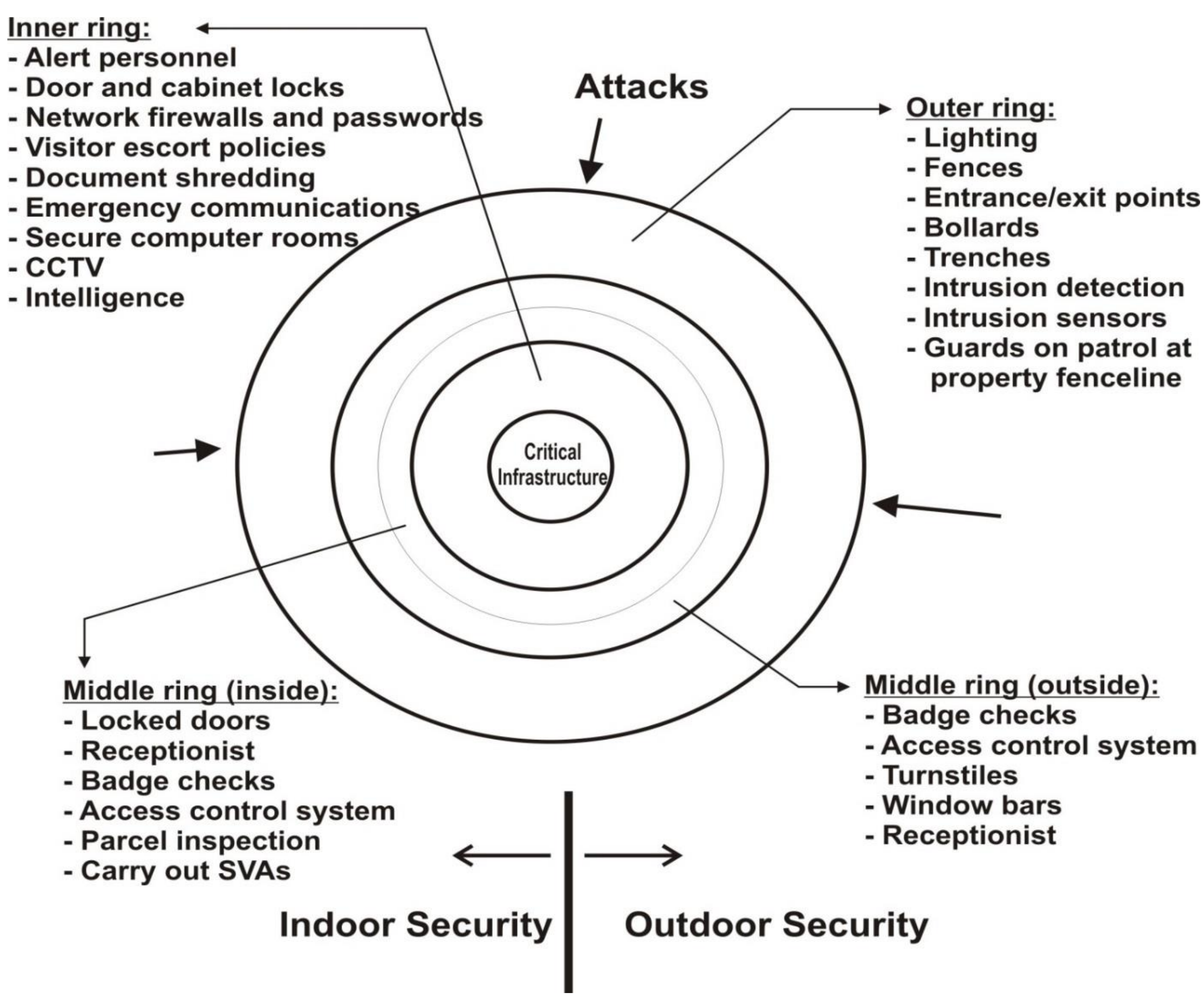


The effect of risk reduction measures wrt safety in the chemical industry

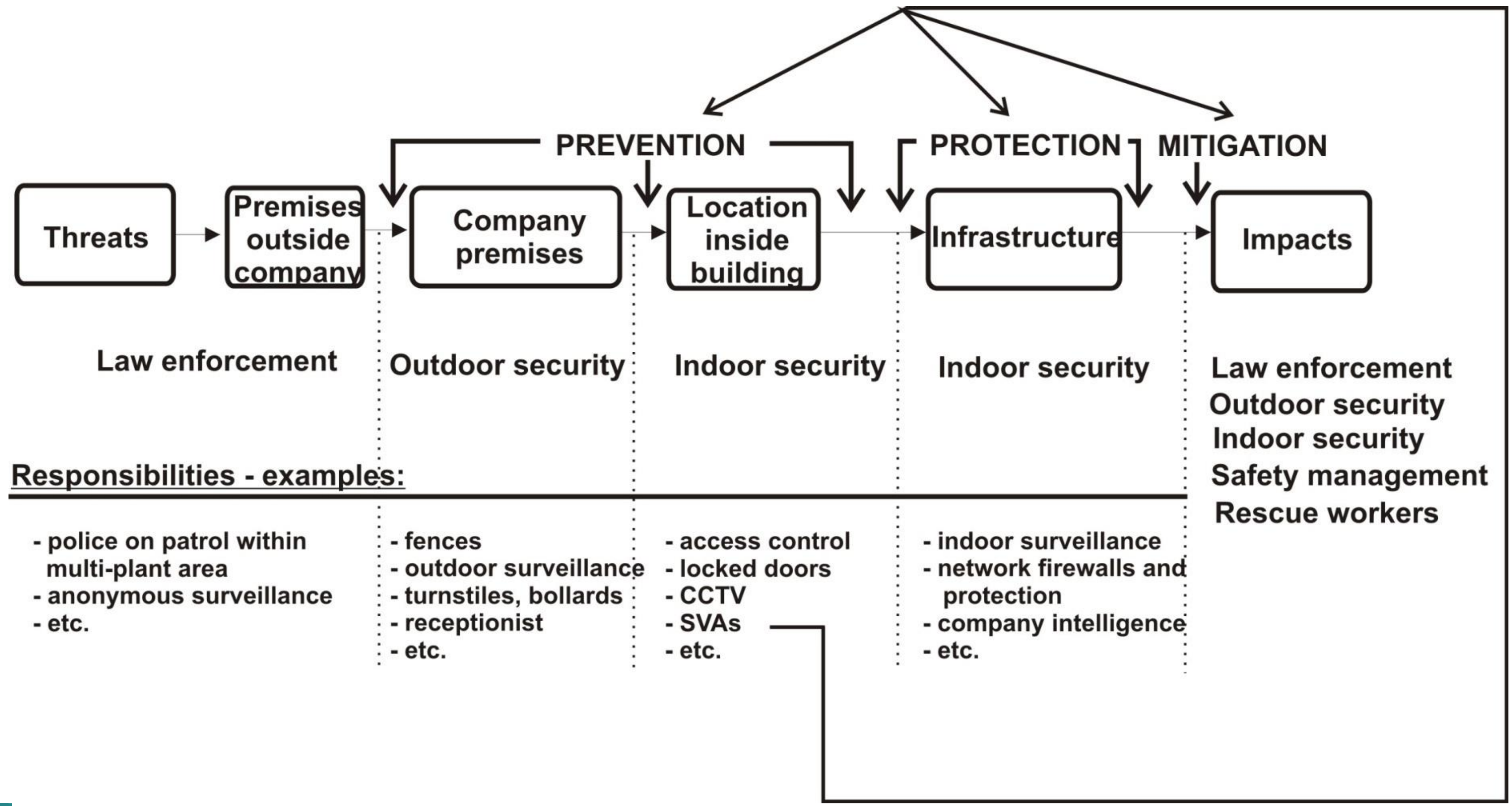
- **Remember:** primary purpose of risk evaluation methods is to determine whether there are sufficient layers of protection against an accident scenario



IPLs for Security in the chemical industry: see also Lecture 4



Protection Layers for security in the chemical industry: see also Lecture 4



Individuals and groups at risk

When carrying out a risk assessment distinction has to be made between:

- Statistical person: no special property, personality, living location, etc.

- Identified group of people (e.g. next to chemical plant)

- Hypothetical person → specific scenarios: have been defined solely to carry out a specific risk assessment (e.g. protected/not protected: has to be specified)

  (critical group = group of hypothetical people who are significantly more exposed to particular risks than a statistical person)

Individual risk

- An individual risk can be defined in general as

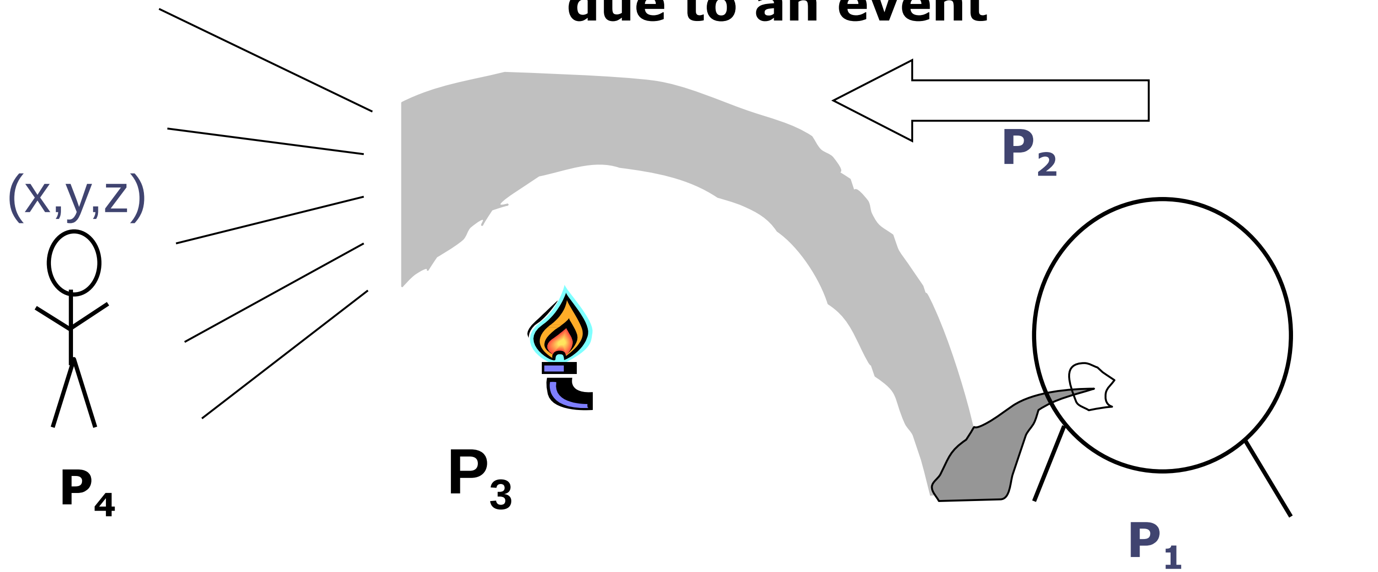
‘the frequency with which a person may expect to sustain a specified level of harm as a result of an adverse event involving a specific hazard’ [10^{-4} – 10^{-7}]

- **Legislators often use levels of individual risk with ‘specified level of harm’ equal to ‘fatality’ (such risks are called ‘individual fatality risks’), as a regulatory approach to setting risk criteria.**

In the process industries for example, the individual (fatality) risk is defined as the risk that an unprotected individual would face from a facility if he/she remained fixed at one spot 24 hours a day 365 days per year.

Calculation of Individual Risk

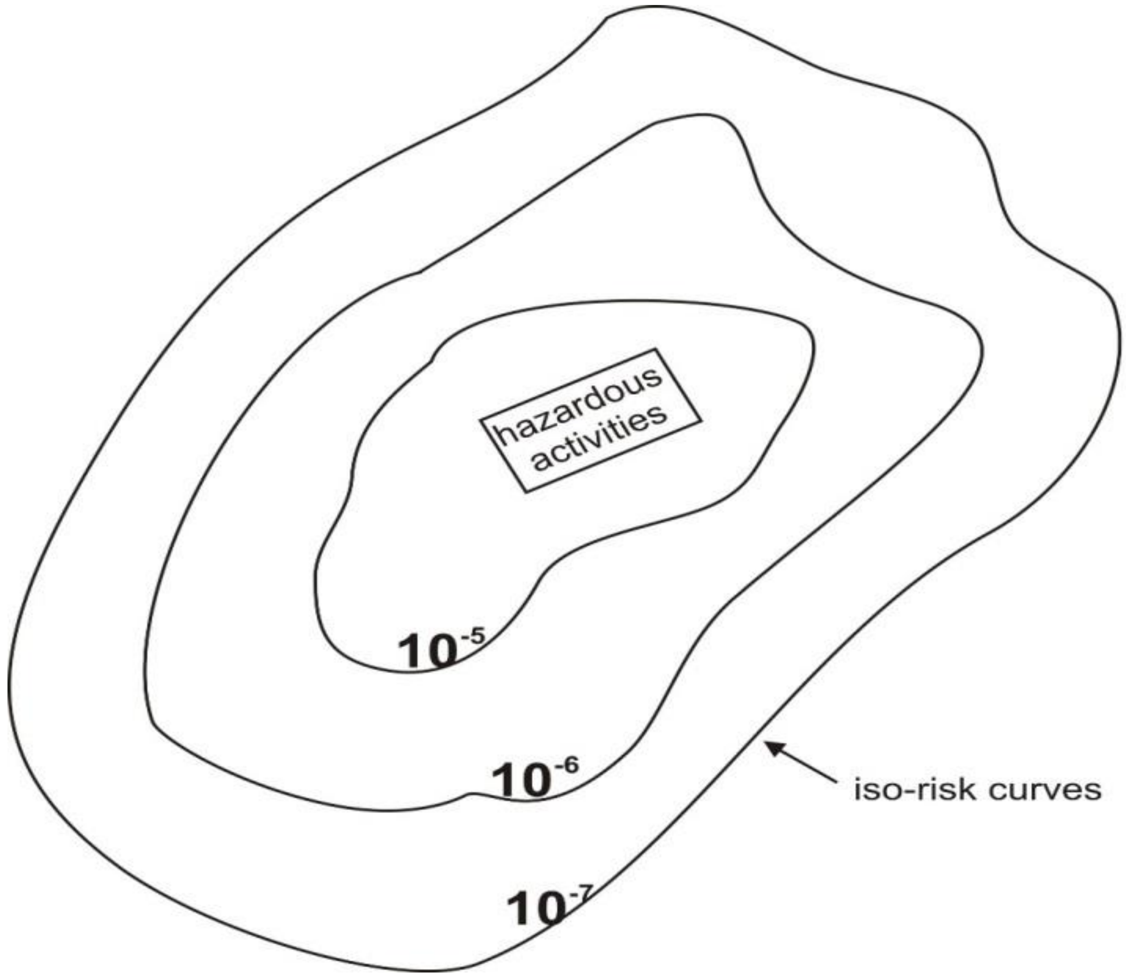
IR(x,y,z): Probability on a lethal accident at location (x,y,z) due to an event



P_4 ← P_3 ← P_2 ← P_1

event dispersion release

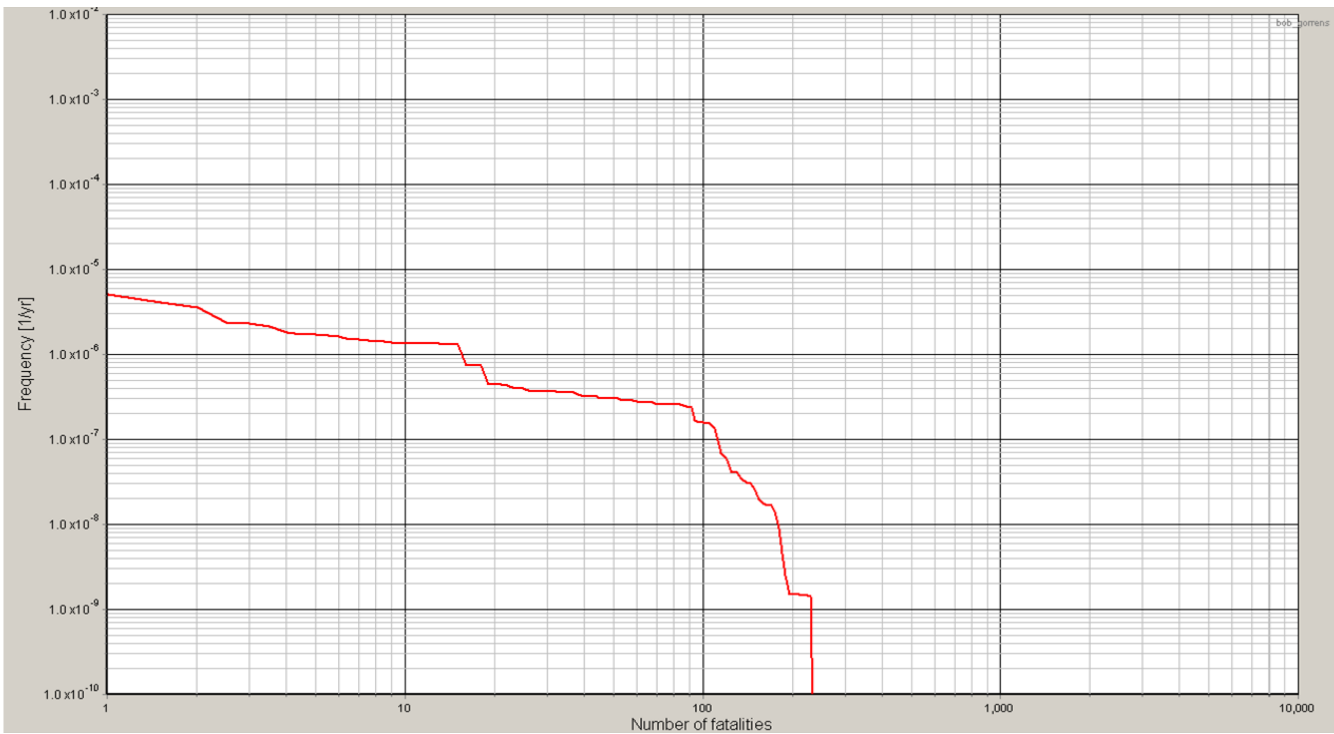
Individual risk curves



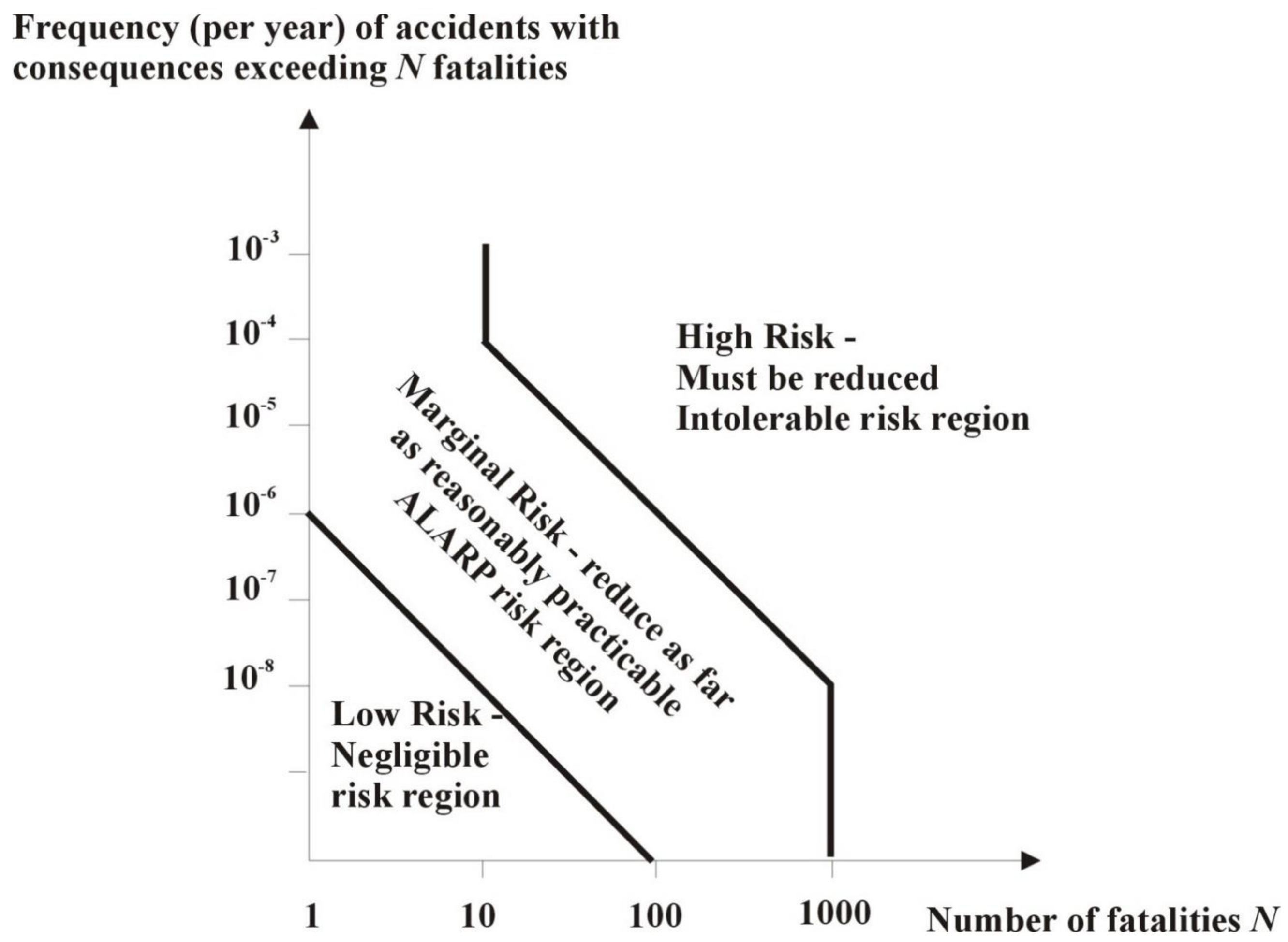
Societal risk

- The societal risk is **the probability that a group of a certain size will be harmed – usually killed – simultaneously by the same event or accident**.

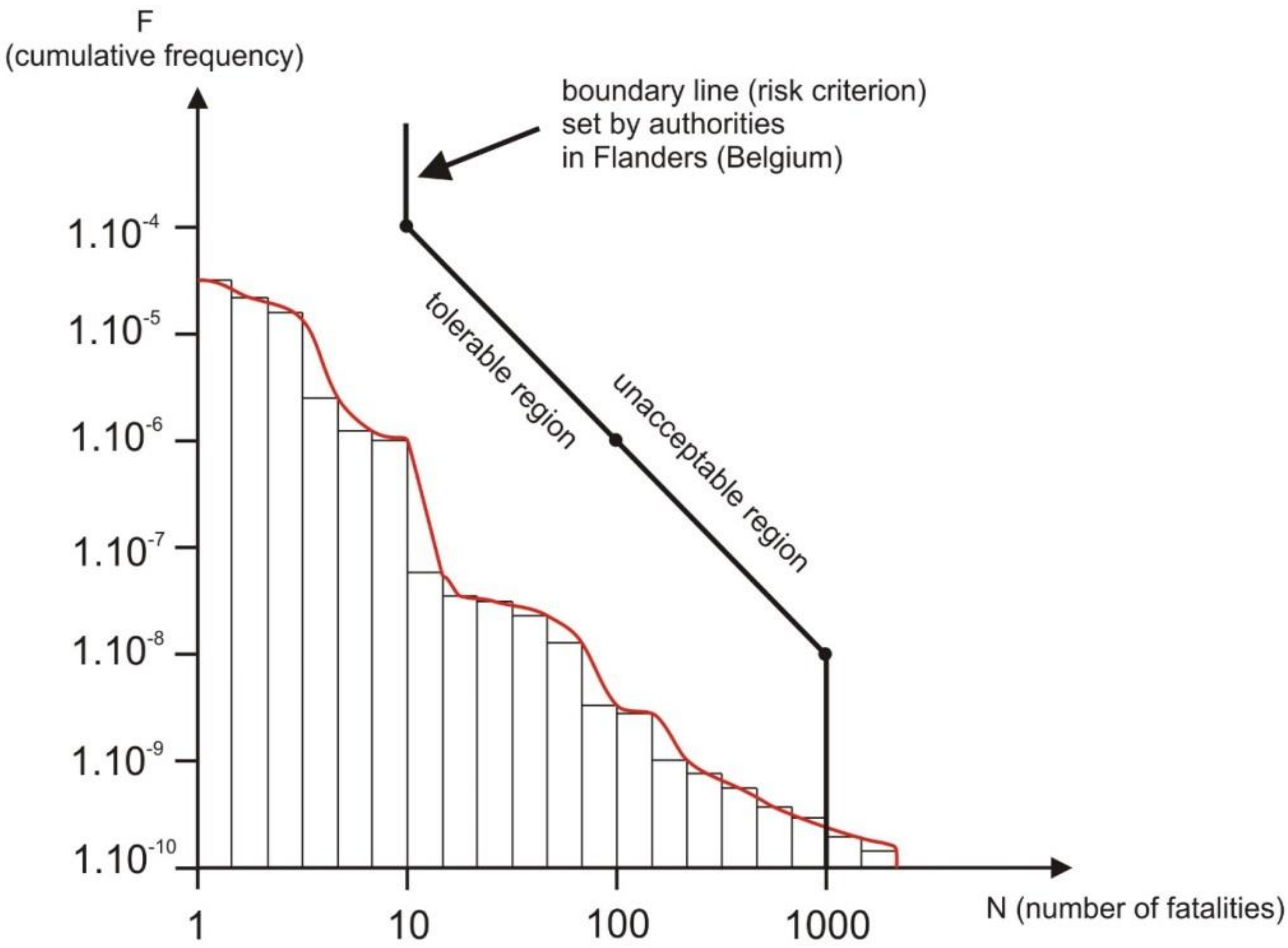
Representation: FN-curve:



Approach to defining societal risk criteria



Example


F
(cumulative frequency)
boundary line (risk criterion)
set by authorities
in Flanders (Belgium)
1.10-4
1.10-5
1.10-6
1.10-7
1.10-8
1.10-9
1.10-10
tolerable region
unacceptable region
1
10
100
1000
N (number of fatalities)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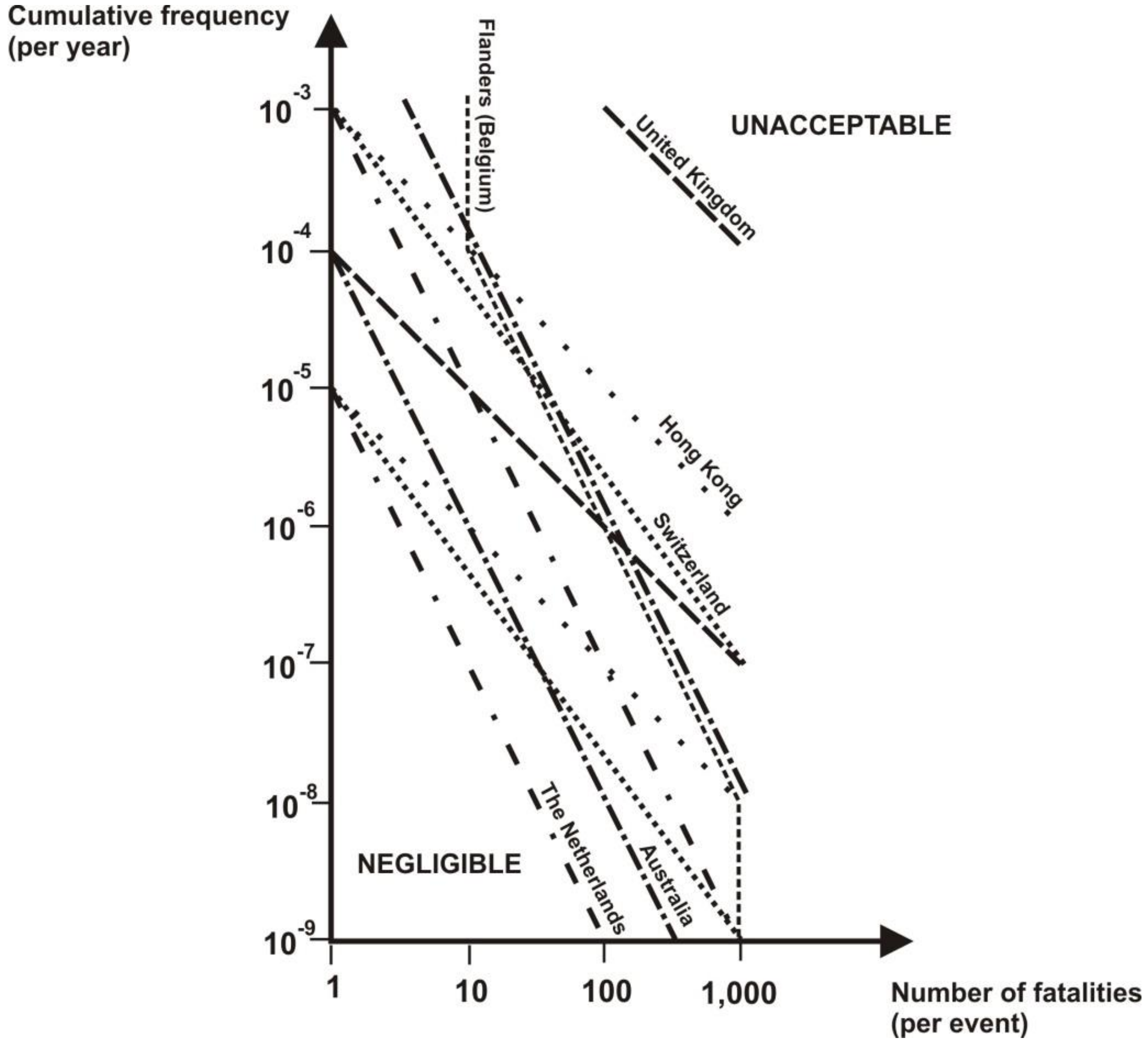
Approach to defining societal risk criteria



Structure of analysis

- System description
- Identification of scenarios s
- Estimation of likelihood(/probability) p
- Estimation of consequences x
- Interpretation of results R
  - Analysis, characterisation

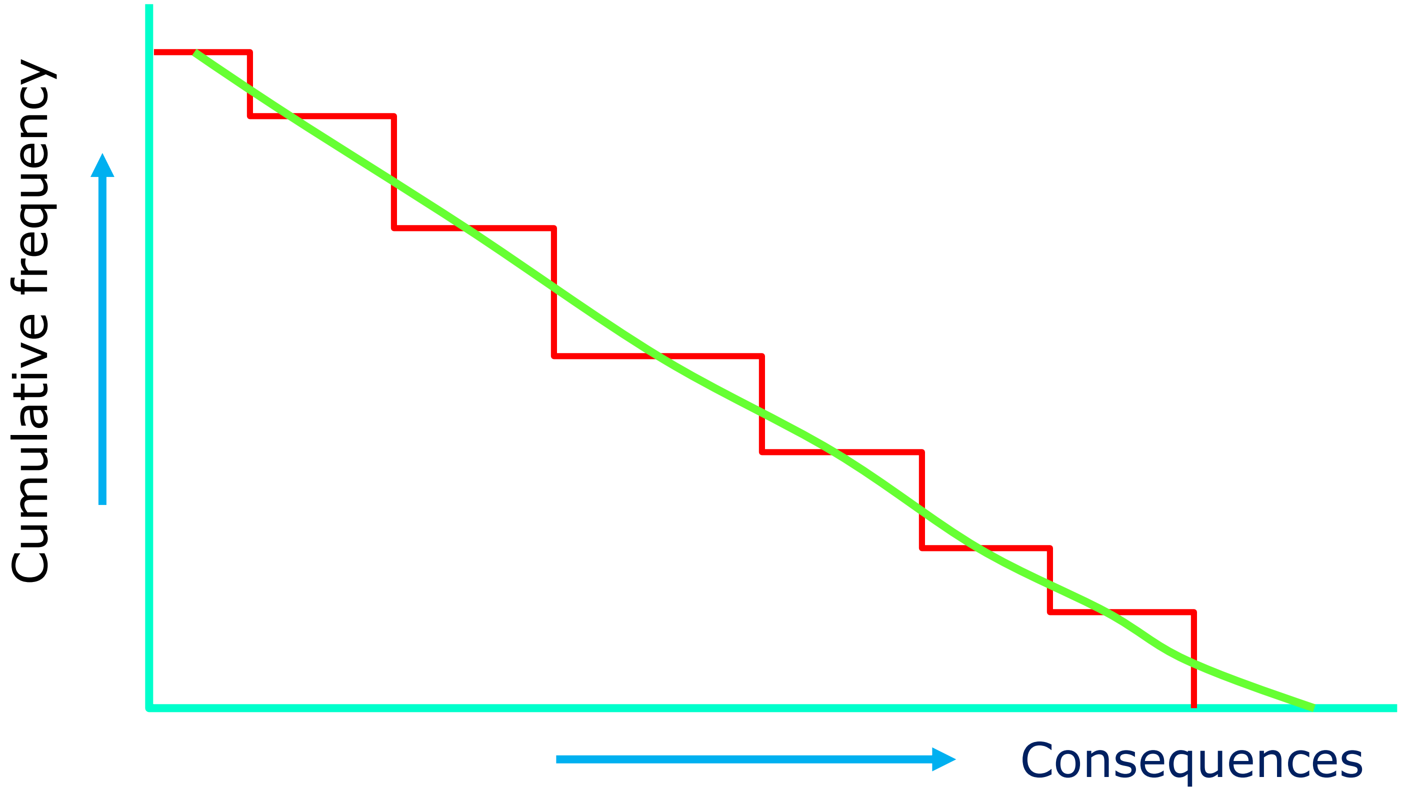
List of scenarios

scenario	probability	consequences
S_1	p_1	x_1
S_2	p_2	x_2
.	.	.
.	.	.
.	.	.
S_N	p_N	x_N

Ranking of scenarios

scenario	probability	consequences (large to small)	cumulative probability
s_1	p_1	x_1	$P_1 = P_2 + p_1$
s_2	p_2	x_2	$P_2 = P_3 + p_2$
.	.	.	.
.	.	.	.
.	.	.	.
s_i	p_i	x_i	$P_i = P_{i+l} + p_i$
.	.	.	.
.	.	.	.
.	.	.	.
s_{N-1}	p_{N-1}	x_{N-1}	$P_{N-1} = P_N + p_{N-1}$
s_N	p_N	x_N	$P_N = p_N$

Group risk curve (F-N curve)



Exercise

Draft an FN-curve (Groupcurve), based on the following sample QRA results:

Event	Number of fatalities	Frequency, f, per year
1	12	$4.8\ 10^{-3}$
2	123	$6.2\ 10^{-6}$
3	33	$7.8\ 10^{-3}$
4	33	$9.1\ 10^{-4}$
5	29	$6.3\ 10^{-3}$
6	16	$7.0\ 10^{-4}$
7	67	$8.0\ 10^{-5}$
8	10	$4.0\ 10^{-3}$
9	52	$1.2\ 10^{-6}$
10	3	$3.4\ 10^{-4}$