FIREFORUM

The importance of Operational Safety economics for fire prevention and mitigation

Prof. Dr. Ir. Genserik Reniers, TUDelft/UAntwerpen

1

What are we talking about?

We are talking about decision-making regarding fire safety investments (prevention and protection),

to avoid or mitigate possible future consequences (losses),

due to fires related with company operations and activities,

and taking micro-economic parameters into the decision-making process.

2

Some basics. What is safety? What is risk?

Safety is a state (of the feeling/mind or real) of a person, a situation, a machine, and the alike. Safety **depends on the perspective** from which one looks at the state.

Without quantification it is not possible to take optimal safety measures based on 'a state'.

Many states are thinkable, and they don't tell anything about the consequences, probabilities, measures of states. Moreover, states change all the time and the **description of states doesn't allow to quantify them**.

For this, and to make the quantification of states possible, the **concept of 'risk'** is introduced.

3

Different types of risk

Type I : small risks – occupational risks with small consequences and high likelihood; example: in case of fire, **a small fire** with at most serious consequences (for instance, one fatality, financial costs < 1,000,000 euro)

Type II: major risks – disaster risks with major consequences and very low likelihood; example: in case of fire, **a large-scale fire** with disastrous consequences (for instance, more than one fatality, financial costs > 1,000,000 euro)

4

Why fire prevention and mitigation?

Delivering products and services : cfr. Attacker in football
Fire prevention and mitigation: cfr. Defender in football

Sustainable profits and happiness
are reached **by:**
- **Making profits / value creation**
- **Avoiding losses / avoid value destruction**

[*Remember:* excellent attackers lead to winning matches (ST) while excellent defenders lead to winning tournaments (LT)!]

5

Fires in Belgium and their toll

Every year about 25,000 house fires, and about 10,000 building fires in Belgium

Consequences: huge human harm and huge material damages;

For instance: numbers of fatalities only in house fires:

- 2014: 69
- 2015: 57
- 2016: 78
- 2017: 53
- 2018: 56
- 2019: 53
- 2020: 76
- 2021: 50
- 07/2022: *already* 46

6

Some derived facts

Too many fire accidents still happen, even in Belgium with all the regulations, mearures, rules, expertise and experience

Huge losses due to fires are a fact;

It pays off to invest in prevention and safety

→ So why is it then so difficult to have managers invest in fire prevention and mitigation in organisations?

7

Individual Psychological background: 'Loss aversion' bias

Suppose you are offered two options:

- (A) You receive 5,000€ from me (with certainty); and
- (B) We toss a coin. You receive 10,000€ from me if it is heads, otherwise (if it is tails), you receive nothing.

What will you chose?

Let's now consider two different options:

- (C) You have to pay me 5,000€ (with certainty); and
- (D) We toss a coin. You need to pay me 10,000€ if the coin turns up heads, otherwise (in case of tails), you don't need to pay me anything.

What will you chose?

8

Individual Psychological background: ‘Loss aversion’ bias

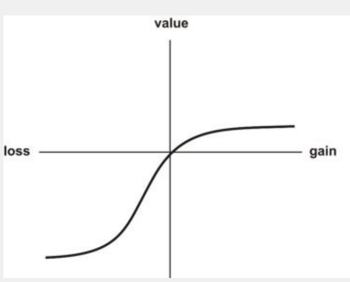
By far most people will prefer options (A) in the first case and (D) in the second case.

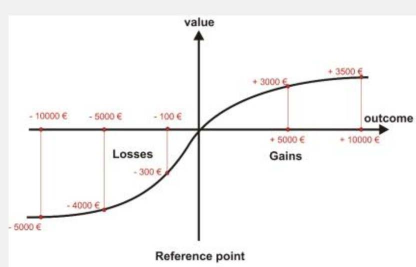
Hence, they go for the certainty regarding the positive risk (getting 5000€ with certainty), and at the same time they go for taking the gamble as regards the negative risk, and risking to pay 10,000€ with a level of uncertainty (there is a 50% probability that they will not have to pay anything) instead of paying 5,000€ for certain.

→ Result is NOT LOGICAL: “Loss Aversion”

9

Individual Psychological background: ‘Loss aversion’ bias





We do not gamble with gains,
while we tend to gamble with losses (because we really hate to lose)!

10

Individual Psychological background: 'Loss aversion' bias

Translating this psychological principle into safety terminology, it is clear that company management would be **more inclined to invest in production ('certain gains') than to invest in (fire) prevention ('uncertain gains')**.

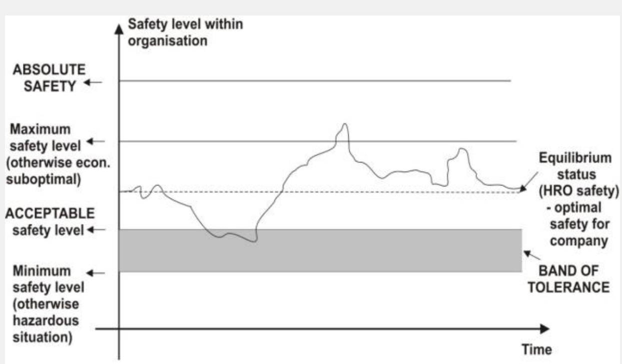
Also, management is **more inclined to risk highly improbable accidents ('uncertain losses') than to make large (fire) investments ('certain losses') in dealing with such accidents**.

→ Management should be aware of this basic psychological principle, and when taking prevention investment decisions, the fact that we have some predetermined preferences in our mind, should be taken into account !

→ **Importance of economics** for making decisions **more objective** regarding fire safety and prevention investments

11

Hence, what operational safety economics can do for fire prevention and mitigation, is to **help to find the balance**



12

Bold prediction

Operational safety and prevention economics = emerging field of interest to academia and industry

→ Will be much more important in future academic research AND industrial decision-making

Let us now provide **some simple examples** of how it can be useful in industrial practice, **and some background thoughts**

13

Some important thoughts w.r.t. economics in relation to safety decisions

- Psychological biases/effects
- Different types of risk (small fire scenarios, large fire scenarios)
- Ethical aspects (human harm versus material damage)
- Relative decisions

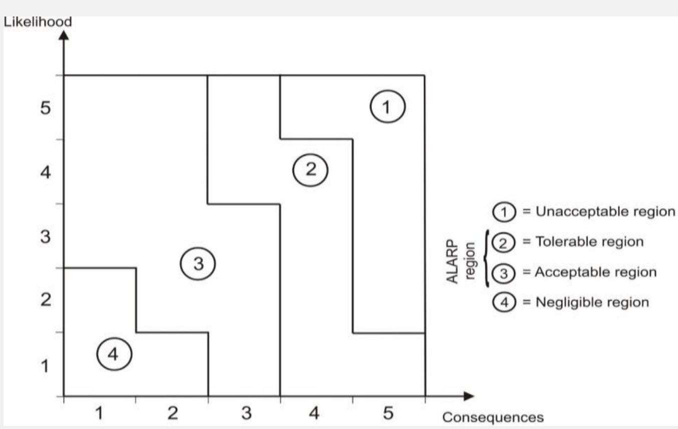
14

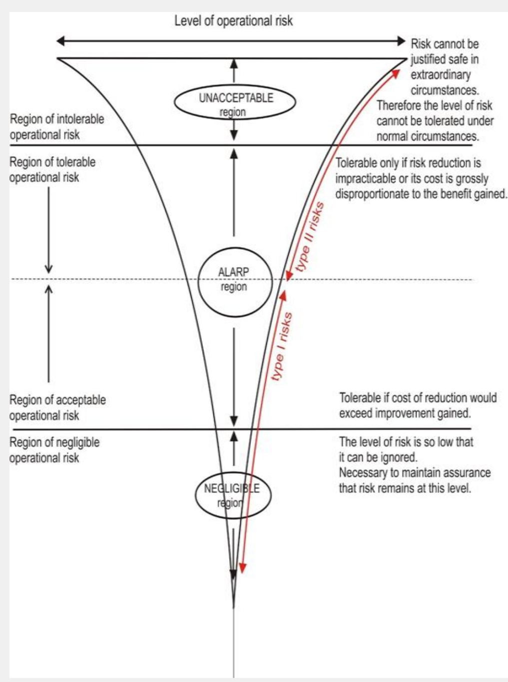
Ethical aspects, f.i. the value of a human life

- Different approaches exist to assess the value of a human life - “human capital”, “contingent valuation” (WTA, WTP)
- Approaches lead to the same conclusion: more success in life results in greater personal value
- Average value of a statistical life varies almost perfectly lineary with the income (on the level of countries)
- Variation from €50,000 to €25,000,000 (factor 500 !)
- There is actually no reason to use the same value for a human life all over the world: safety is all about making **relative** decisions
- Moreover, it is rationally possible/justifiable to assume that people are prepared to pay more to reduce higher-likelihood type II risks than to reduce lower-likelihood type II risks

15

Risk matrix and risk ‘regions’





16

Some simple examples how to use economics for fire prevention - Quantifying risk

Risks consist of hazards/likelihood, exposure, profits/losses

$R_i = K_i \times G_i$ (i : safety state or 'scenario')

$R_i = K_i \times G_i^a$ (a=1: risk-neutral attitude; a<1: risk-seeking; a>1: risk-avers)

Reality as it happens, could be seen as a continuous expected value of summated scenarios all having a certain likelihood to happen and thereby leading to certain consequences.

17

Expected value - example

Assume: Very roughly speaking, three possible scenarios (possible states) are possible
[remark that in daily reality evidently the number of scenarios is infinite, in which a huge number of scenarios are characterized by extremely low probabilities.]

The 3 scenarios are:

Scenario 1: we go home with new knowledge: probability = 0.90; consequence = +50,000€
Scenario 2: small fire: probability = 0.099; consequence = -10,000€
Scenario 3: major fire: probability = 0.001; consequence = -40,000,000€

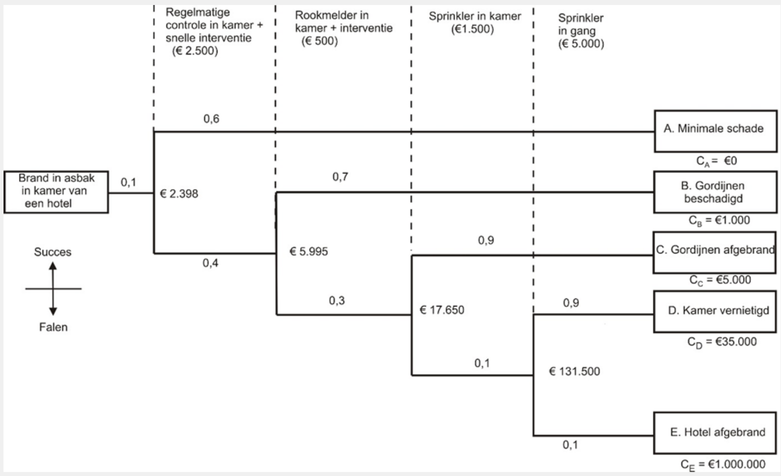
The expected value of the risk of this situation (a very simplified reality) can then be calculated for a risk-neutral attitude (a=1) in the following way:

$$0.9 \times 50{,}000€ + 0.099 \times (-10{,}000€) + 0.001 \times (-40{,}000{,}000€) = 4{,}010€$$

Remark that we also considered the positive risk-scenario in this example. If we focus on negative operational risks (SAFETY!) we can also only take negative scenarios/consequences.

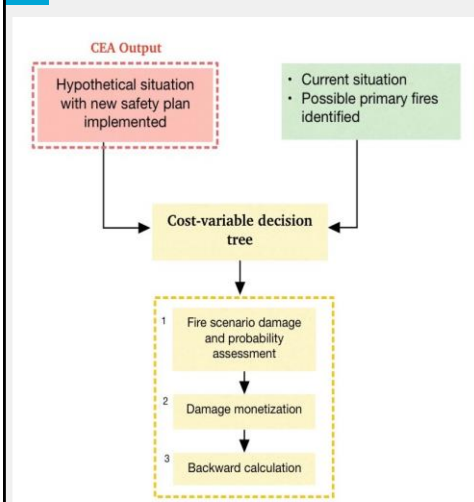
18

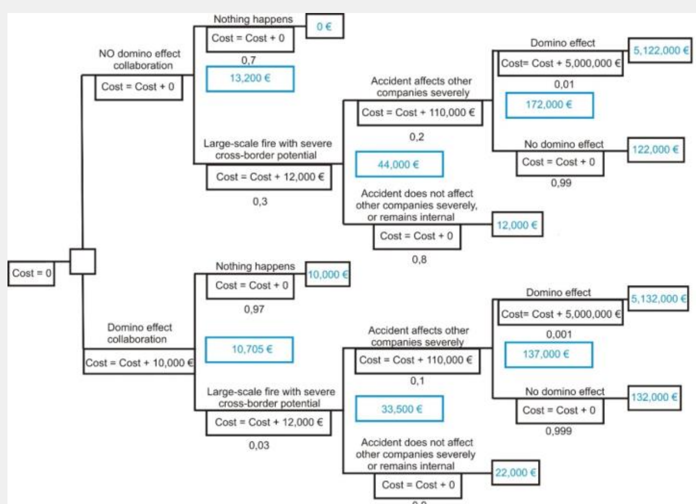
Expected value in Decision Tree
Decision tree based on scenario thinking – illustrative example



19

Decision tree based on the variable cost approach – illustrative example





20

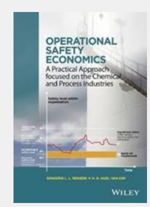
Micro-economic concepts to quantify risks and/or to carry out an economic safety analysis or a safety investment analysis

- Hypothetical benefits
- Discount factor
- Time horizon
- Payback period
- Internal rate of return
- Annuities
- Net Present Value
- Disproportion factor
- Opportunity costs

21

Cost categories and subcategories: fire prevention and mitigation investments or SAFETY COSTS

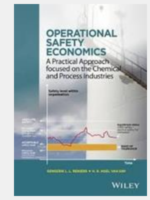
Type of safety cost	Subcategory of safety cost
Initiation	Investigation Selection and design Material Training Changing guidelines and informing
Installation	Production loss Start-up Equipment Installation team
Operation	Utilities
Maintenance	Material Maintenance team Production loss Start-up
Inspection	inspection team
Logistics and transport safety	Transport and loading/unloading of hazardous materials Storage of hazardous materials Drafting control lists Safety documents
Contractor safety	Contractor selection Training
Other safety	Other prevention measures



22

Benefit categories and subcategories: Hypothetical benefits or AVOIDED LOSSES

Type of avoided accident cost	Subcategory of avoided accident cost
Supply chain	Production-related (type I + type II) Start-up (type I + type II) Schedule-related (type I + type II)
Damage	Damage to own material/property (type I + type II) Damage to other companies' material/property (type II) Damage to surrounding living areas (type II) Damage to public material property (type II)
Legal	Fines (type I + type II) Interim lawyers (type II) Specialized lawyers (type II) Internal research team (type II) Experts at hearings (type II) Legislation (type II) Permit- and license (type II)
Insurance	Insurance premium (type I + type II)
Human and Environmental	Compensation victims (type I + type II) Injured employees (type I + type II) Recruitment (type I + type II) Environmental damage (type I + type II)
Personnel	Productivity of personnel (type I + type II) Training of new or temporary employees (type I + type II) Wages (type I + type II)
Medical	Medical treatment at location (type I + type II) Medical treatment in hospitals and revalidation (type I + type II) Using medical equipment and devices (type I + type II) Medical transport (type I + type II)
Intervention	Intervention (type I + type II)
Reputation	Share price (type II)
Other	Accident investigation (type I + type II) Manager working time (type I + type II) Clean-up (type I + type II)



23

Investment analysis – illustrative example

Assume : safety budget = €500,000. Time horizon = 10 years.

Categories of costs	Subcategories of costs	Value
Initial costs	Investigation and preliminary study (€)	15,400
	Machine purchase costs (€)	280,000
	Initial Training (€)	25,000
	Changing layouts and production operations (€)	110,500
Installation costs	Machine configuration and testing (€)	5,500
	Equipment costs (€)	15,400
	Installation team costs (€)	25,000
Operating costs	Energy costs (€/y)	38,500
Maintenance costs	Material costs (€/y)	15,000
	Maintenance team costs (€/y)	7,750
Inspection costs	Inspection team costs (€/y)	2,500
Other safety costs	Other safety costs (€/y)	2,500

Type of benefits	Subcategory	Value
Supply chain benefits	Production savings (€/y)	135,000
	Expected additional profits due to increased sales (€/y)	25,000
Damage benefits	Damage to own material/property (€/y)	2,500
Legal benefits	Fines (€/y)	10,000
Insurance benefits	Insurance premium (€/y)	20,000
Human and Environmental benefits	Yearly reduction of days of illness (€/y)	2,500
Other benefits	Cleaning (€/y)	4,500

24

Investment analysis – illustrative example (2)

Then:

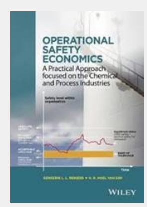
The costs and benefits are either a one-off event or yearly. The one-off costs and benefits are carried out in year zero. The yearly costs and benefits return every year during the whole time horizon (of 10 years) of the investment, and are considered at the end of every year (normal annuity). In total, it concerns **€66,250 of yearly costs, and €199,500 of yearly benefits**.

Based on the Table of costs, the total **one-off investment cost in year zero** is estimated to be **€476,800**. The Net Present Value can be calculated (based on the given cash-flows from the illustrative tables) if we assume a **discount factor of 3%**. In this case, the **NPV = €659,850**. Since this investment represents a positive NPV, it is profitable and can be recommended.

The **PBP of the investment is 3.84 years**, thus after 3 years and about 10 months the investment costs will be earned back via the hypothetical benefits, and in the subsequent period until the time horizon (10 years in this case) there will be hypothetical benefits.

The parameter Internal Rate of Return is also sometimes used to achieve a clear picture of the quality of an investment. In casu is **IRR = 24.93%.**

Other techniques that can be used



- Borda algorithm
- Mathematical calculation of the DF based on the FN-curve
- Cost-benefit analysis
- Cost-effectiveness analysis
- Multi-Criteria Analysis
- Multi-atribute theory
- Safety value function
- Use of Bayesian Netwerk theory
- Use of LIMited Influence Diagrams

Conclusions and recommendations – observations

- The **combination of economic aspects** (budgets, costs and benefits, wages, discount factor, etc.) **and safety aspects** (fire safety, evacuation training, technological measures for avoiding disasters, etc.), although two fields regarded to be very important for companies, **is currently discussed too little**
- **Fire safety measures** are **often based on** simple risk analyses and **'belly feeling'**
- **Costs and hypothetical benefits** of fire safety measures are insufficiently used for feeding economic analyes, and also the **different types of risk, opportunity costs**, etc. are micro-economic parameters that are not employed enough in industrial practice

27

Conclusions and recommendations

- Bring **micro-economic models** and approaches **into account for fire safety investment decision-making and in a thorough and solid** (adequate) **way**
- Ideally, **also ethical aspects** need to be involved in the decision-making process – this new way of determining risks would provide a more balanced picture for the decision-maker
- Balanced decision-making leads to **the creation of more support for fire safety decisions with higher management** (investments lead to – hypothetical – profits) **AND with citizens and authorities** (when, despite all fire safety measures taken, things would go wrong after all)
- **Fire safety fundamentally contributes to the long-term profitability of an organization and in this regard should be seen at the same level as production and innovation**

28

FIREFORUM

Thank you for your attention!

Genserik.reniers@uantwerpen.be

29