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Risk is of all Time

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Summary

Risk is everywhere and always has been. Although these risks seem new, industrial risk, environmental risk and health risk have been around since the origin of mankind. Men always have been trying to minimise these risk and manage them where possible. The risks of modern technological society can be managed with the means this society has developed. But today just as always the decision to reduce risk is political. Risk reduction policies are difficult to maintain over prolonged periods of time. This holds especially for high consequence low probability events. The absence of occurrences over long periods of time reinforces the illusion that these events are impossible and will not happen. Until disaster strikes again!

Zusammenfassung

Risiko ist, und war immer, allgegenwärtig. Obwohl diese Risiken neu erscheinen, existieren industrielle, Umwelt- und Gesundheitsrisiken seit Anfang der Menschheit. Der Mensch hat immer versucht, diese Risiken zu minimieren und managen wo immer möglich. Mit den Risiken der modernen technologischen Gesellschaft kann mit den entwickelten Verfahren umgegangen werden. Heute wie in der Vergangenheit ist die Entscheidung zur Risikominimierung eine politische. Strategien zur Risikominimierung sind schwer über längere Zeiträume zu handhaben. Dies trifft insbesondere zu für sehr folgenschwere aber nur sehr seltene Ereignisse. Das Ausbleiben von solchen Ereignissen über längere Zeiträume stärkt die Illusion, dass sie nicht möglich sind und nicht eintreten werden. Bis zur nächsten Katastrophe!

Keywords

Risk, risk management, risk perception, bowtie models

Contents

1. Introduction

It is said that the present society is a risk society (BECK, 1986). And indeed some risks are new. And because of the global connectivity of our societies, many risks are shared by all. That does not take away though, that may ancient risks have had a similar standing in the society in which they where dominant. They formed a threat to the whole – known – world and all – known – societies were exposed.

Between 1347 and 1350 the plague or the Black Death wiped out one third of the population of Europe (CENTRAAL BUREAU VOOR DE STATISTIEK, 2004). In the 17th century the average life expectancy was 25 years and to become 45 was an exception.

Also what now is called industrial risk has roots in the early centuries. Already Plinius described illnesses among slaves (RAMAZZINI, 1700). In 1472 Dr U. Ellenbog from Augsburg wrote an eight page note on the hazards of silver, mercury and vapours of lead (ROSEN, 1976). Ailments of the lungs found in miners were described extensively by Georg Bauer (AGRICOLA, 1556). In the seventeenth century a significant part of the crew of ships sailing the East and West Indies never made it home. As recent as 1918 the Spanish flue killed 170,000 people in the Netherlands alone.

The Netherlands has a long history of having to deal with the threat of floods. In the middle ages several groups, such as Hugenotes and Jews, fled to the Netherlands because they were oppressed by their government. These people literally stepped down from the Central European Plane into the Low Lands, the swamp that is the Netherlands. The only authorities that were accepted for a long time were the „waterboards“. These were deemed necessary to manage the flood defences. The oldest waterboards were those of Schieland (1273), Rijnland (1286), and Delfland (1319). Now with 478 people per km2 one of the densest populated area‘s in the world and housing a harbour of Rotterdam, Schiphol Airport and a third of the refinery capacity of Europe managing the risks of resulting from the close proximity of people and industry has become just as important an activity as managing the risks of flooding.

Attempts to avoid unnecessary risk also has been part of human activities from as long as history is written. Those who had something to loose surrounded themselves and their possessions with walls, castles, guards and armies. If you had enough money you went outside of the city to escape the plague. And societies have put people into power in order to protect them from a long time ago.

This does not take away that worldwide and in absolute numbers the number of disasters and the associated costs increase. At the same time the population of the earth increases, suggesting that people more and more live in less and less suitable locations (OECD, 2003).

This raises the question why risk management looks so different today and why we have so much difficulty getting to an organised policy on risk, whether we are in public office, in government or in private enterprise. For this we first look at the evolution of risk especially in the 20th century. We look at the development of risk perception research and findings and then we look at methodologies to understand the genesis of accidents and strategies to eliminate them or reduce the probability.

2. Industrial risk

In the Netherlands some large scale accidents with explosives materials occurred as well. In 1654 the centre of Delft was demolished by the explosion of a powder tower. This explosion, which could be heard 80 km away, created the "horse market", which still exists as an open space (Fig. 1).

In 1807 a similar explosion took place. Now a barge laden with black powder exploded in the centre of Leiden. The van der Werf park today is still witness of this event. 150 people were killed among who 50 children, whose school was demolished by the blast. This explosion led to an imperial decree by Napoleon. The emperor stated that from then on a permit was needed for having an industrial facility. Three classes of industry were designated:

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Fig. 1: The big thunder of Delft in 1654

- Industries that were considered too dangerous to be inside a city. The authorities would indicate a location.
- Industries for which location inside a city could be considered if it could be demonstrated that there was no danger for the community.
- Industries that always could be located inside city limits.

In addition Napoleon stated that objections of future neighbours should be noted and addressed by the authority that made a decision. As the explosion in Leiden involved a ship, similar measures were taken with regards to the transportation of explosives and other dangerous materials. Interestingly the safety regulations in France can be traced back to the same imperial decree.

3. Risk management

The origin of modern risk management lies in the industrial accidents after World War II. In 1966 a fire in a storage facility for LPG in Feyzin, France killed 18 and wounded 81. This accident led to re-emphasis on design rules for bottom valves on pressure vessels. In the realm of physical planning no actions from the French or the European authorities seemed to have resulted from that accident.

Ten years later a number of similar accidents occurred: Flixborough (1974, 28 dead), Beek (1975, 14 dead) and Los Alfaques (1978, 216 dead). These accidents showed that the Feyzin accident was not a unique freak accident. Apparently LPG and other flammable substances could pose a serious threat to the workforce and to the surroundings.

In 1979 Prime-Minister van Agt, just as his predecessors, wrote a letter to parliament about the development of environmental policies as integral part of the nation's policies. In

Tab. 1: Zoning around LP G station

Distance to tank and/or fillingpoint (m)	Allowed building	
	Houses	Offices
0 – 25	none	none
25 – 50	max 2	max 10 people
50 – 100	max 8	max 30 people
100 – 150	max 15	max 60 people
> 150	no limit	no limit

this letter he introduced "External Safety" as separate from occupational safety. The Prime-Minister introduced and announced three elements of a new policy:

- appointment of the minister of environment as co-ordinator for hazardous materials,
- founding of a new separate policy body dealing with external safety, and
- announcement of new legislation covering external safety.

At the same time a major change in the energy market appeared imminent. This among other lead to a major market push for LPG as motor fuel. In 1978 a tank car exploded in a tank station. Although nobody was hurt in this accident, it became apparent that the population around the stations should be limited. The chief inspector for the environment decided not to wait for legislation. He issued an instruction for his inspectors to not approve a permit unless the conditions for distances and population densities as indicated in the Table 1 were satisfied (HIMH, 1981). This was the first explicit zoning measure around a hazardous activity.

A further potential increase in the transport of LPG through the Netherlands resulted from the desire to use LPG as feedstock for the production of ethylene. A committee was charged with developing a policy. A study was commissioned into the safety of the whole chain from import to final use. It became apparent that a policy aimed at insuring that no accident ever would harm the population would not be compatible with the limited space in the Netherlands. The committee decided that there should be a level of risk below which it is neither desirable nor economical to strive for further reduction. This statement implied that the level of risk should be established and that acceptability limits should be set.

At the same time authorities in the Rijnmond area started to be worried about the safety of the population around the large petro-chemical complexes in the area. Taking the Canvey Island study as an example (HSE CANVEY, 1978; HSE CANVEY, 1981), the Rijnmond authority embarked on a study to establish whether quantification of risk was feasible and would give results that would be useful in decision-making. The results (CREMER and WARNER, 1981) were promising with regards to the usefulness of the results. The quantification of risk as a routine exercise was judged not to be feasible unless information technology could be used to take away the burden of the many complicated calculations and reduce the time needed.

The Rijnmond Authority together with the ministry of environment embarked on the venture towards an automated method for quantification of risk. Now, twenty plus years later the process still is not fully automated. Such a level of automation no longer is desired either. But the techniques developed since together with the rapid development of computational capability has lead to workable systems with reasonable return times.

3.1 Risk matrices

The division of risk in three bands introduced by Napoleon can be found back in the risk matrices that are used frequently to support and structure decision making (Fig. 2). In these matrices the two dimensions of risk: probability and consequences are separated out and plotted against each other. Any combination of consequence and probability is a point in this two dimensional space. Alternatively the risk profile of any activity can be plotted as a so-called complementary cumulative distribution curve (CCDC). In such a curve the probability of exceeding certain consequences are given as a function of these consequences.

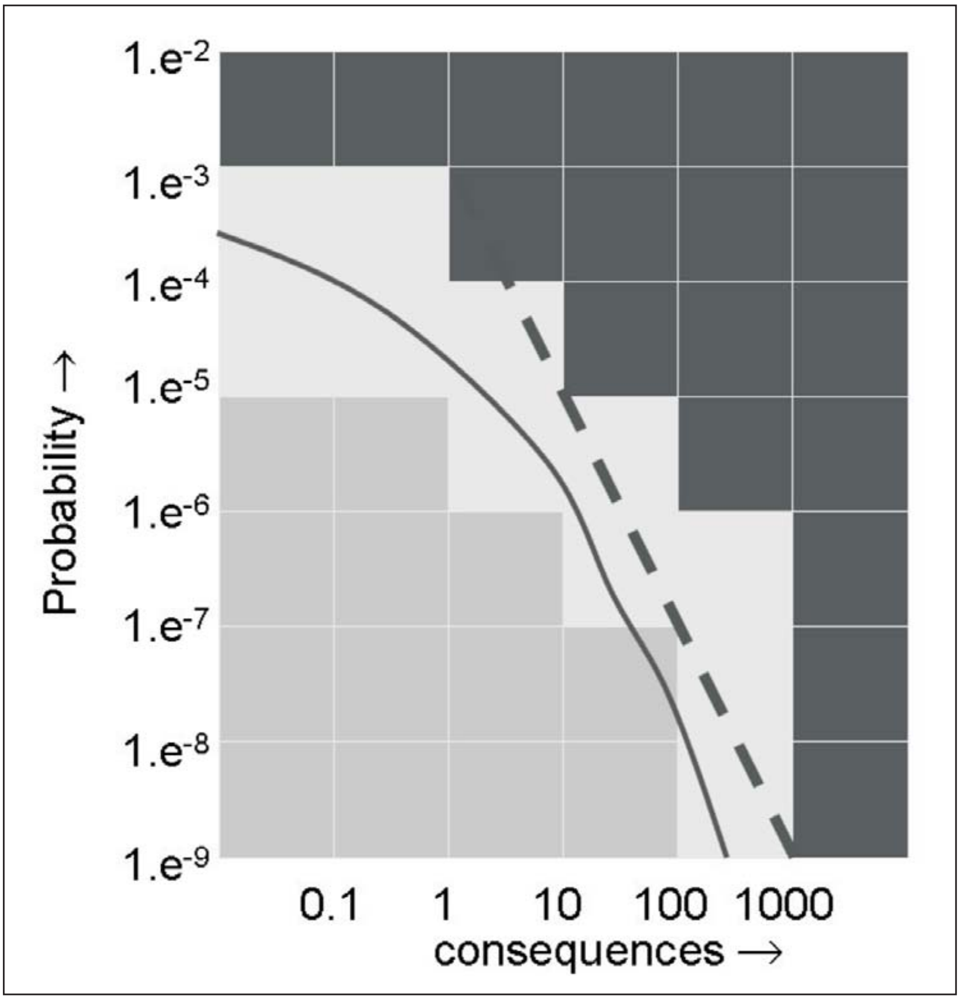

Fig. 2: Risk matrix

The plot area can be divided into three areas: acceptable, conditionally acceptable and unacceptable. Whenever the risk is not in the acceptable area measures have to be taken or at last contemplated. Of particular interest is the region in the lower right hand corner of the matrix where those risks are located of which the consequences cannot be borne. These risks have to be transferred e.g. by insurance, or have to be eliminated – regardless how low the probability - as the consequences would lead to ruin.

In practice any consequence proves to be acceptable when the probability is sufficiently remote and the advantages to be gained by embarking the risky activity are sufficiently large.

Therefore the red or unacceptable area is seldom demarcated by a vertical line. Rather the limit is some sort of sloping line as depicted by the dotted line in the figure.

The use of risk matrices is not restricted any more to the chemical industry. Many applications are found in finance and insurance industries (MACARTHY et al., 2004).

3.2 Criteria

Having decided that risk quantification is the way to go the inseparable counterpart had to be developed as well. Questions to be answered included were what to do with the results, and how to make sure the analyses would actually be made and used in decision making. Regional and local authorities as well as industry asked for guidance regarding the acceptability of risk. The bases for this guidance was found in documents and decisions taken earlier.

An important base line was found in decisions made regarding the sea defences of the Netherlands. In 1953 a large part of the south west of the Netherlands was flooded as a result of a combination of heavy storms, high tides and insufficient strength and maintenance of the diking system. Almost two thousand people lost their lives and the material damage was enormous especially because the Netherlands was still recovering from World War II. The Netherlands embarked on a project to strengthen the sea defences, including a drastic shortening of the coastline by damming off all but one of the major estuaries of the Rhine/Maas delta. The design criteria were determined on the basis of a proposal of the so-called "Delta Committee" who proposed that the dikes should be so high that the sea would only reach the top once every 10,000 years (DELTA COMMISSIE, 1960). The probability of the dike collapsing is a factor of 10 lower. The probability of drowning is another factor of 10 lower, so that the recommendation of the Delta Committee implies an individual risk of drowning in the areas at risk of 1 in a million per year. This recommendation was subsequently converted into law.

This value of risk was reaffirmed when a decision had to be taken about the construction of the closure of the Oosterschelde estuary. For reasons of preserving the ecosystems the design was changed from a closed solid dam, to a movable barrier. This barrier should give the same protection as the dams. In this manner Dutch parliament had a history of debating safety in terms of probabilistic expectations, which came in handy when industrial risk had to be discussed.

The value of 1 in a million per year corresponds to about 1 % of the probability of being killed on the road in the mid 80-ties. This became the maximum acceptable addition to the risk of death for any individual resulting from industrial accidents.

For societal risk the anchor point was found in the "interim viewpoint" regarding LPG points of sale mentioned above. When combined with value already chosen for individual risk this led to the point 10 people killed at a frequency of 1 in 100,000 per year. As societal risk usually is depicted as an FN curve having the frequency of exceeding N victims as a function of N, the limit had to be given the same form. Thus the slope of the limit line had to be determined. It was decided to incorporate the apparent aversion against large disasters in de the national limit by having the slope steeper than –1. Several values circulated in literature at the time, ranging from –1.2 to –2 (FARMER, 1967; MELEIS and ERDMAN, 1972; TURKENBURG, 1974; WILSON, 1975, OKRENT, 1981; RABASH, 1985; SMETS, 1985; HUBERT et al., 1990). In the end it was decided to adopt a slope of –2 for the limit line. In order to bind the decision space at the lower end of the risk spectrum limits of negligibility were set for individual risk and societal risk alike at 1% of value of the acceptability limit. The

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resulting complex of limit values was laid down in a policy document called "premises for risk management".

The accident in Bhopal, where some 3000 people were killed as a result of a release of methyl isocyanate, helped to promote the adoption of European legislation. The SEVESO directive, named after a small village in Italy where dioxine was relaesed in an accident, became the vehicle to implement these policies into law in the Netherlands just as in many other members of the EU. The "Hazards of Major Accidents Decree" demanded that top tier establishments would submit a safety report, in which a quantified risk analysis performed according to the set standards, would be presented. This information then subsequently could be used by local planners for zoning decision and by the emergency services for disaster abatement planning.

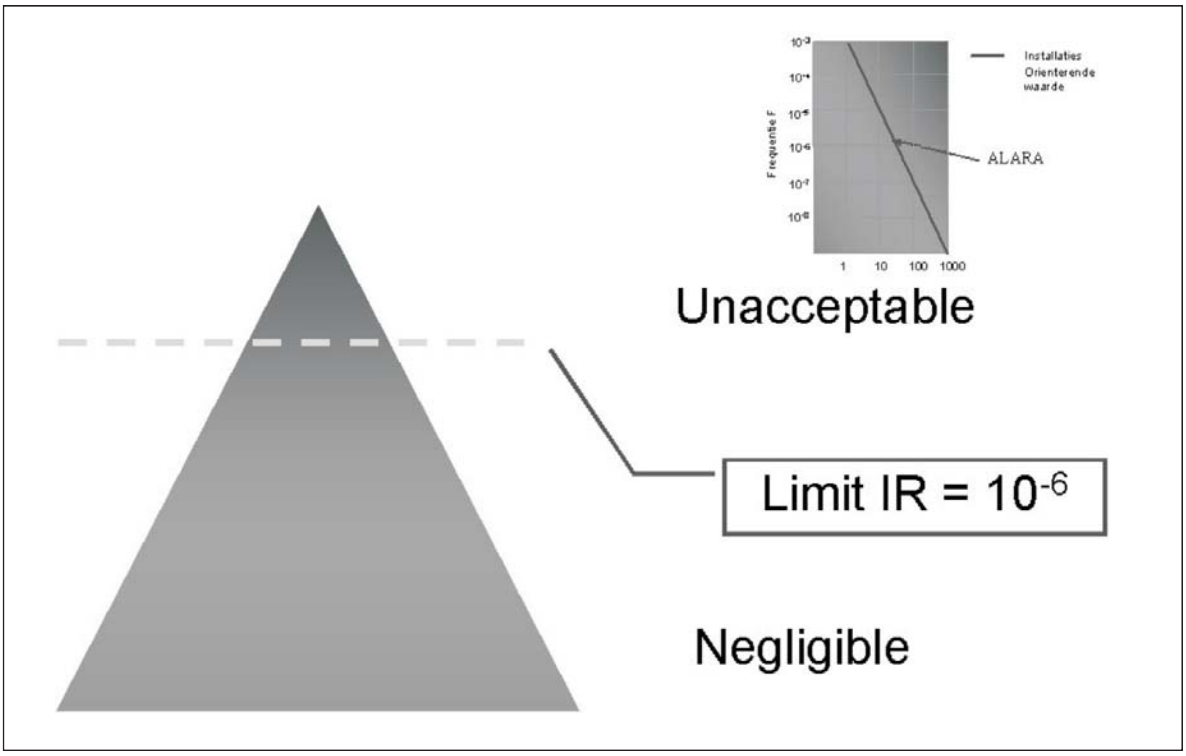

Fig. 3: Risk triangle and criteria

On 13 may 2000 an explosion occurred in a fireworks storage and trading facility in Enschede, the Netherlands. Twenty-two people were killed and some 900 injured. The material damage was approximately 400 MEuro. This lead to a further re-enforcement of the policy in the Decree on External Safety of Establishments (BEVI), in which the risk limits were again specified (Fig. 3).

4. Perception

A major factor influencing the people's reaction to potentially hazardous activities is what generally is described as risk perception.

In part these perceptions are driven by the way, by which information is processed by our brain. One of the features is that information that strengthens existing ideas is more readily absorbed than information to the contrary. In Table 2 the mortality of various activities is given. The numbers are applicable for the Netherlands. From the table it can be seen that the probability of any Dutchman to be killed by an accident in a chemical plant not being an employee is 6 orders of magnitude smaller than the probability of dying of a smoking induced illness (if he or she is a smoker).

Tab. 2: Probabilities of death and probabilities of winning lotteries

Activity	Winning a lottery	Probabilty (/yr)
Smoking		$5*10^{-3}$
Traffic		$8*10^{-5}$
Lightning		$5*10^{-7}$
Bee-Sting		$2*10^{-7}$
Flood		$1*10^{-7}$
	Staatsloterij	$1*10^{-7}$
	Bankgiroloterij	$4*10^{-8}$
	Lotto	$2*10^{-8}$
Falling Aircraft		$2*10^{-8}$
	Postcodeloterij	$1*10^{-8}$
Chemical Industry		$6*10^{-9}$
	Sponsorloterij	$3*10^{-12}$

On the basis of these numbers a decision maker has a fair point when assuming that the probability of him being confronted with a disaster in the chemical industry is remote and hardly probable. Especially when one notes that the present Netherlands are only some 200 years old

In the table also the probabilities are given of winning the main prize for five of the nation's lotteries. One can see that winning the „sponsorlottery" is three orders of magnitude smaller than being the victim of a chemical accident. Nevertheless these lottery tickets are readily sold and there regularly is a winner. Apparently the probability of winning this lottery is considered by many remote but possible, or even probable. This difference in appreciation of the numerical information is closely related to the psycho-social theories of risk perception. According go these theories there are many factors shaping the perception of risky activities (VLEK, 1996; SLOVIC, 1999; SJOBERG, 2000). The top 10 of the most listed are:

- Extent and probability of damage
- Catastrophic potential
- Involuntariness
- Non-equity
- Uncontrollability
- Lack of confidence
- New technology
- Non-clarity about advantages
- Familiarity with the victims
- Harmful intent

Combining these factors with the mortality discussed above reinforces that people are more willing to accept a certain small loss than an uncertain large loss. And because the probability of a large disaster is small, long periods of time may elapse after one disaster before another strike. In this period the notion that improbable equals impossible is steadily reinforced and thus the impetus that exists shortly after a disaster to do something about it disappears.

As the factors that influence the judgement of a risky activity are different for differing activities it cannot be expected that a single set of risk criteria is applicable to all activities. Nevertheless a policy may look more organized as the set of applicable criteria is small.

On the other hand it is argued that these factors make it impossible to set general standards, as every situation and every activity is different. In a more extreme stance it is argued that risk is a social construct rather than something that in principle can be determined scientifically. In this view there are so many subjective choices made in risk analyses that they cannot be called objective science at all (VAN ASSELT, 2000). Scientists are just other lay-people. There judgement is influenced by the same factors, but in addition they let their science influence by their political judgements. It is no surprises that the more objectivist risk analysts argue that scientific judgements and political judgements are not the same thing and that objective quantification of risk is a scientific exercise. Indeed such objectivity is necessary to make cost benefit based decisions. In such argumentation the value of the risk should be as objective as the – monetary – value of potential risk reducing measures (TENGS et al., 1995).

Any policy should conform to general principles of justice and democracy, be it setting a speed limit or a limit on risk. The results should be predictable for the stakeholders and for the public and execution should be measurable against objective standards. This holds even when arguments are formulated in more qualitative terms such as "As Low As Reasonably Achievable" or "gross disproportionality". It should always be borne in mind that any stakeholder in any regulatory system can resort to getting a dispute settled in court.

How valid the arguments may be, they nevertheless are of great help to stakeholders that have no interest in having risks limited by a government policy in the short run. And as the last accident disappears in past history the pressure to be firm on risk dissolves.

4.1 Bow-ties

Whenever a strategy or policy is defined that asks for reduction of risk, an analysis has to be made of what would be the optimal place to interfere with the causal chain from cause to accident and consequences in order to obtain the desired reduction. Bowtie models are tools for integrating broad classes of cause-consequence models. The familiar fault and tree-event tree models are 'bowtied' in this way; indeed, attaching the fault tree's 'top event' with the event tree's 'initiating event' originally suggested the bowtie metaphor. The bowtie may be conceived as a 'lens' for focusing on causal chains and 'projecting' these onto the space of consequences. These consequences will ultimately be factored into decision problems for risk management. Hence the bowtie's consequence side forms an interface with the decision models. Decisions taken will reflect backwards to causes. This structure not only has proven a worthwhile concept in accident prediction, it also has proven its worth in analysing past accidents and suggesting improvements to prevent further re-occurrence (GROENEWEG, 1998) (Fig. 4).

The selection of the centre of the bow-tie is crucial for the analysis. Any event can be

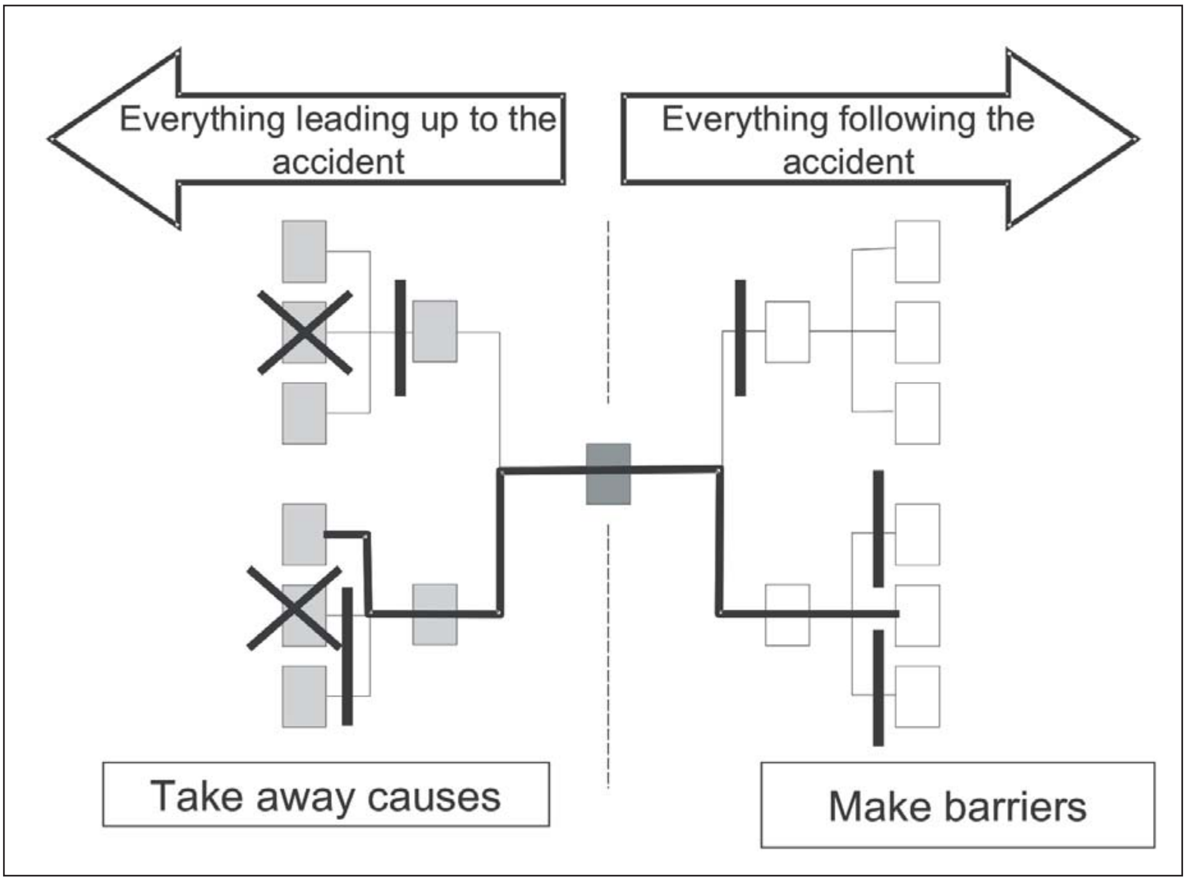

Fig. 4: Bow-tie and Murphy's law

taken as this centre. The causes and consequences of this event form the bow-tie and form a slice out of all the things that happen in this world.. Any event can be considered a cause and any event can be considered a consequence. Events can therefore serve as causes and as consequences in many bow-ties, each with its own centre. However: once the centre is chosen, no other events will be visible in the bow-tie than those which are in the causal chains running through the centre.

This could raise some interesting questions. What has to be considered as the centre event of a – lethal – accident of a parachute jumper. The moment that his parachute did not open, the moment that his parachute was packed in the wrong way or the moment that the reserve parachute failed to open. Any of these three approaches leads to a valid bow-tie, and to a valid quantification of his risk of falling, but the analysis will be much more detailed on some aspects and much less detailed on others depending on the choice of the centre event. As a result the options for remedial action will be different.

4.2 Events as barriers

When the a certain consequence is deemed unacceptable or when the probability of a certain outcome is deemed too high, measures have to be taken to either take away the causes or block the progression from cause to accident. The classical way of presenting this and handling this in a mathematical way is to combine the path originating from a cause with a path from a safeguard into an „AND"-gate, which means that the cause and the failure of the safeguard have to occur simultaneously to result in the consequence. This concept however proved to be difficult to grasp for decision makers. Therefore these safeguards are often depicted as barriers in the path from cause to consequence (Figure 5), an idea originally developed by Haddon, who introduced the barrier concept in 1973 (HADDON, 1973). The number of barriers in the path then could form the basis for a layer of protection analysis (LOPA). In any case this way of presenting layers of protection proves to be helpful for decisionmakers. When in an analysis a path is detected that does not have any barriers in it, it constitutes a – latent – deficiency in the system that according to Murphy's law will sooner or later lead to ruin.

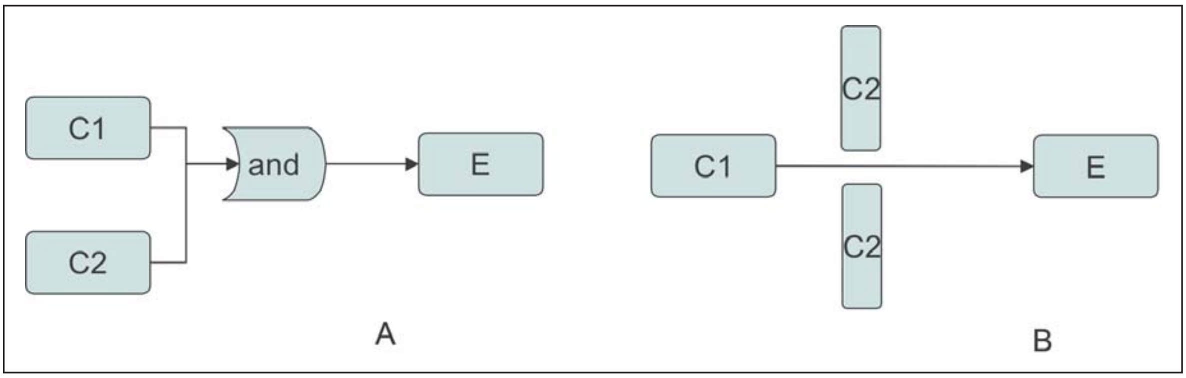

Fig. 5: And-gate representation (A) and barrier representation (B) of the same causal configuration

5. Concluding remarks

Modern times are not necessarily more risky than earlier times. There have been many threats to humanity that indeed wiped out significant portions of the known population. Life expectancy has not been as high as it is today, at least in the „first" world. There are some new risks and may be contrary to historic times it is now known for sure that the known world is all the world there is. But the historic people thought the same.

All over history it has been difficult to maintain risk containment or risk management strategies for prolonged periods of time. For low probability large consequence type risks this is to a significant extent inherent to the way the human brain processes information. Every day a disaster does not happen the idea gets reinforced that it cannot happen at all.

Nevertheless there are many good methods to systematically deal with risks and many are part of the policy of governments. Due to the dense population and the intensive use of space in the Netherlands, the Dutch authorities have an advanced position in governmental risk management, which combines the sue of quantitative analytical methods with set criteria and rules for justifying risk taking by authorities.

Risk analysts have a role to play in the discussion about risks. They are in a position to point out that the absence so far of an accident does not mean its impossibility. And they should do so in the interest of the innocent bystanders, who are the people of who the lives, health and property are at stake.

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