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Prevention, precaution and resilience: Are they worth the cost?

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ABSTRACT

The assumption that risk, represented as an expected value of the loss could be implied to be a measure of safety, in a cost benefit analysis, is firmly entrenched in economic risk analysis. However, this does not mean that without a marker, the value of a loss, can be established with any necessary level of certainty to make such a cost balancing act ethically possible. The appropriateness of using the Value of a Statistical Life (VOSL) at all in a safety analysis, is a matter of perspective, which renders attempts to establish a uniform value of a statistical life questionable. This makes it questionable whether decisions from which values for a VOSL were evaluated, really were based on consideration of saving lives, or whether other arguments, such as available budget, were much more dominant. Ethical considerations do not seem to be in the frame of corporate risk management, where loss-of-life catastrophes appear to be simply the cost of doing business. Because there is no real basis for any estimate of the value of a statistical life, the values employed in cost-benefit analyses therefore only seem to serve the purpose of dissembling, concealing that the decision is taken on grounds other than saving human lives, or even that potential harm to humans was not even considered. The strict meaning given to resilience as at most to make a plan for recovery and see if we can live with the consequences, seems just another step towards putting the economy before people.

1. Introduction

There is a host of literature on the subject of the value of life, the value of a life saved or the value of a statistical life. We begin the main body of this paper by summarizing our findings in earlier papers on the value of human life. Then we discuss the various interpretations of safety, with emphasis on caution, robustness and resilience. We further discuss the costs of a selection of accidents and finally interpret these in the light of ethical considerations when choosing any one of the available safety options (see Fig. 1).

In (Ale et al, 2018) we discussed that the application of cost benefit analysis (CBA) often involved the setting of a value of a statistical human life (VOSL), which led to decades of research into what a reasonable value should be. These evaluations of the VOSL lead to widely varying results. We concluded that rather than attempting to harmonize on an average with large margins of uncertainty, the conclusion can be drawn that indeed there is no law of nature that determines what risk is acceptable and that, therefore, a consistent valuation of a human life cannot be expected. Nor can it be expected that there is a universally valid number for the acceptability of a risk. We argue that one should accept that standardization of acceptable risks has its practical limitations given the – lack of – similarity in nature of the activity and the nature of the risk. In fact, attempts to force standardization are counterproductive. In many cases, one has to accept the only available alternative not involving violence, which is a political debate, terminated by the more general rule of law or constitution on how to settle such a debate and then accept the decision.

In Ale et al, (2019). we concluded that statistical lives are not just an abstraction to make abstract cost benefit balancing possible. Once the statistical accident actually happens, real people are really killed. With that in mind, decision makers should justify why activities that will take lives are so important for society that taking these lives is justified. These lives are not put in a market and are not offered for sale. They are taken from involuntary citizens. A uniform value of a statistical life does not exist. That does not preclude that citizens should be treated equally under equal circumstances. It also does not preclude standard values for acceptable risk or even the VOSL in specific areas of policy. However, justification just on the basis that “another agency does it the same way”, is morally insufficient; especially if the relationship between safety and risk is a matter of perspective. Decision makers should realize that their

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decisions imply decisions on life and death and should justify these decisions commensurate with the weight that they carry

What these evaluations have in common, is that their starting point is the situation before an accident; and the question posed, is what amount of money companies, or societies, are prepared to spend on measures to prevent accidents and casualties. There is, however, little evidence on the incurred costs of accidents. Also, the costs of lives lost, or the costs of saving lives after an accident, is rarely if at all evaluated after the fact. If a life is saved, it is invariably judged as worth the effort.

In many cases the true costs of accidents cover not only loss of life. In most accidents there is significant material damage and damage to the environment, which makes it almost impossible to partition the costs over these various damage categories. The costs of accidents may only reveal themselves over decades, which also makes it difficult to compile the overall costs. Moreover, unlike most individuals, many companies, enterprises and society, can absorb staggering costs without making a significant dent in their net worth, their credit rating, or value on the stock exchange. As an example, the market value of Union Carbide, when it merged with Dow Chemical in 2001, was considerably higher than in 1984, when the Bhopal accident happened. (Gulijk, 2012). This may be another reason these evaluations after the fact, are seldom completed.

Nevertheless, these costs should have a bearing on the discussion as to whether measures aimed at preventing accidents – classified as belonging to the SAFETY-I domain - are less attractive than measures aimed at continued and improved resilience functionality, usually classified as measures belonging to the SAFETY-II domain.

In this paper, we look back on our previous evaluations of the literature on the value of human lives, whether statistical, or real; and we investigate whether choices in the past, between hardening a system to prevent accidents, or accepting the accident and strengthening its ability to recover from them, have a relationship with estimates of the value of a life: or alternatively, that other considerations are more dominant. Amongst these we put the famous statement by Trevor Kletz (http-12) -:'If you think safety is expensive, try an accident' - and also a statement by Tacitus (110AD) that is often quoted as "The desire for safety stands against every great and noble enterprise" but reads in Latin "nisi impunitatis cupido retinuisset, magnis semper conatibus adversa" which literally means "the desire to remain without punishment, always stands against great works"; the context being that Flavius contemplated a murder (of Nero), which Tacitus (110AD) apparently thought would have been a good idea, but the thought of being caught held him back.

2. The concepts of precaution or resilience

There seems to be an obvious difference in the way these terms are misused in the artificial SAFETY-I vs SAFETY-II debates. Since its introduction, the resilience label acquired a multitude of concepts; from the use of more effective barriers, to designing in some functionality to monitor, respond, adapt and learn from actual operational experiences. Resilience engineering expects that an intelligent human being (or subsystem?) can intervene before all is lost. It tends to support the idea that systems should have sufficient "designed-in" capacity to resist and recover from unanticipated upsets. The unfortunate side effect of this line of thought is that it entices engineers to refrain from further analysis of possible deviations and their consequences and the incorporation of further protective measures. Another complication may be that a malfunction is caused by a different mechanism. The antithetic result may be that resilience can degenerate into unfounded faith, when an organization assesses itself as being resilient (Ale et al, 2020).

"Resilience" in its meaning as the ability to recover after the fact (NN, 2021) accepts a priori and without further consideration the damage caused by an adverse event. In its purest definition it even accepts that the means to recovery will have to be found after the fact in order to avoid the opportunity costs of preparing for events and disasters that may never materialize.

Resilience in its meaning as being able to absorb the remaining occurrence of deviations before they result in harm, provides additional safeguards and capacities over and beyond the minimum necessary to make a system work. This form of resilience is not really different from precaution.

"Precaution" tries to prevent adverse events by analyzing the effect of potential deviations from intent and design and if these deviations can lead to harm to operators, community, environment and stakeholders, find ways of avoiding them or at least reduce the probability. By avoiding adverse events "Precaution" promotes the working of systems as intended and let the output approach as much as possible its theoretical potential through increased, lasting reliability. The ingenuity of

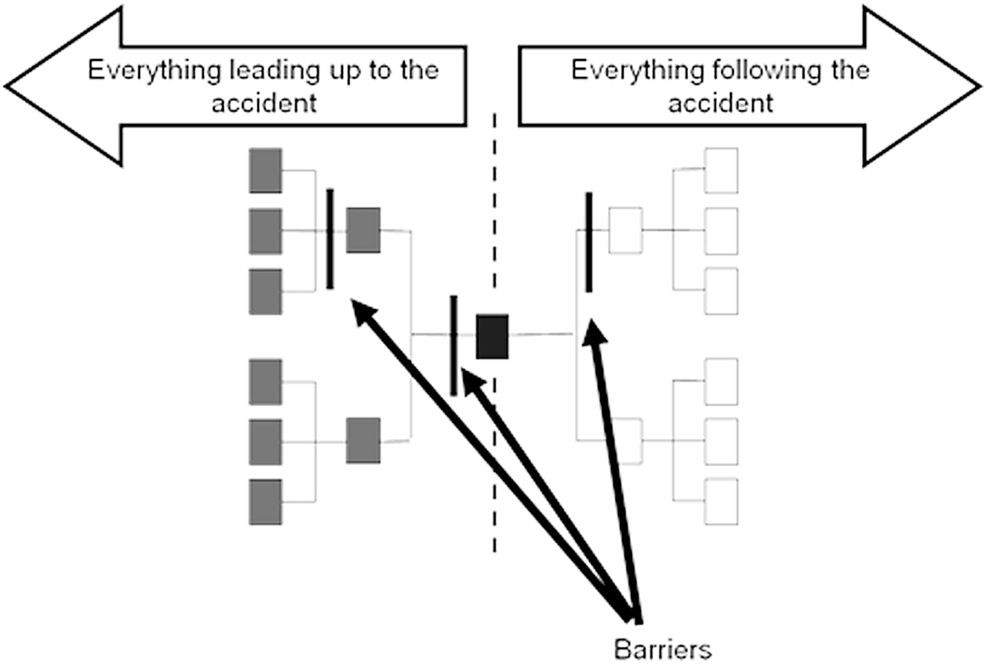

Fig. 1. Basic bow-tie diagram.

experienced humans is used to analyze and remedy problems before they arrive.

Where in the past precautionary analyses have not been performed, or the lessons from such analyses have been disregarded, the fact that each system is part of the larger system of systems that constitutes society was implicitly ignored. Remedial actions after an explosion involve the fire-department and other rescue services. Keeping the wounded alive requires hospitals, nurses and educational facilities such as universities to educate them. An accident that results from an ill-considered off-piste skiing trip, requires emergency service personnel to risk their own lives and thus the livelihood of their families, to affect a rescue. Mountain villages have to prepare and maintain these rescue capabilities as a precaution and don't rely on the resilience of the skiers.

Whether the functioning of a system is protected by precautionary or resilience type actions, somebody has to pay for it. Resilience in the meaning of recovery operations after an accident also involves services that cost money. The difference between the two is often that precaution has to be paid for by the institution that poses the risk to itself or to society and resilience usually has to be paid by the society of systems outside the institution. The short-term costs of precaution are also usually higher than the short-term costs of resilience, especially when the latter is restricted to making a recovery plan. When, for recovery, one relies on others, the costs of being prepared to be resilient have to be borne by the outside world.

The choice between precaution and resilience then raises profound ethical questions: is it ethical to leave it to the pilots of an airplane to find a solution for persistent nose down commands given by a computer program rather than make sure the computer does only give these commands when appropriate.

But precaution requires analysis; and analysis requires tractability. Most technological systems are put together by humans and therefore are tractable, even if that would require the designer's detailed notes. The potential interactions of systems with other systems may be more difficult to analyze and understand, but ignoring these interactions and deciding to wait and see, is a choice that potentially puts the burden on another system – such as leaving combustible cladding on a tower block and wait and see what the fire-department can do with the fire. Such a choice is not only a question of money but also one of ethics.

A completely new ethical question arises with the inclusion of artificially intelligent self-learning systems (http-11). What these systems may encounter cannot be predicted and thus what they may learn from it cannot be guaranteed. In the Netherlands a system to detect possible fraud automatically, was found to have "learned", that people with low income and a non-Dutch sounding surname, must be criminals. As a result parental support benefit money for children was revoked creating catastrophic financial problems for thousands of families, before it was corrected. Since this was brought to light, two cabinet ministers have lost their jobs, criminal charges have been made against the designers of the system and it will take years to sort out the mess and millions in compensation for the families involved. When all sorts of hardware – cars, refrigerators, power stations – can communicate with each other, how do we know what they are communicating about. As AI systems are intractable because of their very nature, the question of precaution or resilience attains an even larger ethical dimension: how much are we prepared to protect human lives and are we prepared to forego the use of a technology that endangers human lives in an intractable way; or do we go down the road of ultimate resilience: confidence that we always can deal with "it" when "it" happens.

3. Choosing between precaution and resilience

In safety thinking, precaution has acquired multiple interpretations, each of which narrow the original wide meaning of the word: taking an action to prevent something unpleasant or dangerous happening (http-1). The precautionary principle is not precisely defined (http-2). In the realm of safety, precaution is often interpreted as not embarking on an activity that can have uncertain negative consequences, even if there is no scientific evidence that harm may actually result.

The wider meaning of precaution encompasses also taking measures, which prevent a deviation from normal, or desired, or defined circumstances resulting in an unwanted event, or to prevent an event resulting in harmful consequences. In terms of the often used "bow-tie" model), Ale (2009) these would be the barriers in between causes and the center event and the barriers between the center event and the consequences.

As previously explained Ale (2009) what is defined as the center event can be chosen at will. Although it is customary to take loss of control, or loss of containment (LOC), as the center event, a particular deviation can be taken as the center event as well. In that case the barriers at the right-hand side of the bow-tie would for instance represent barriers or measures taken after a Hazard and Operability study (HAZOP) (CIA, 1977) had identified that certain deviations would result in an unwanted LOC. There is criticism of the bow-tie approach, because it does not capture the complicated multicausal and interlinked complexity of how events evolve in reality. But as can be seen in (Gulijk et al., 2013) and (Ale et al., 2009), complicated modelling structures such as Bayesian Belief Nets can be built to describe these interactions, while the basic idea of causality is retained. Precaution therefore according to Hollnagel and Wears (2015) is rooted in SAFETI-I and therefore only half the story.

Finding the cause of an accident at the beginning of a linear sequence of events, would not do justice to the real complexities of engineered systems in a dynamic society. Instruments such as fault tree analysis and quantitative risk analyses can help prevent accidents, not only after they have happened but also before, are sometimes underplayed as old fashioned and dogmatic, e.g. by depicting a monk or a priest next to a logic tree diagram. But non-linearity of the interactions between parts of systems and between systems and their surroundings is sometimes understood as being that events can have multiple causes: and sometimes it is difficult, or even not possible to find the definitive cause when the underlying processes, such as turbulence, are governed by complex interactions that can be represented by non-linear differential equations. Sometimes there is no conceptual description other than that it is "non-linear" and "chaotic" and therefore cannot be analyzed by linear logic. It should be recognized however that the first application of fault-tree analysis on the launch of the minuteman missile was performed before the rocket was launched and before any launch failed (Ericson, 1999; Watson, 1961). Potential causes therefore can be found before an accident happened and not necessarily afterwards. It should also be recognized that for most accidents, the post-mortem analysis shows a surprisingly simple and linear sequence of events. It also should be recognized that "SAFETY-I" and the precautionary approach is the firm basis of good safety engineering and still needs to contribute to safe and cost-effective production and transport (Leveson, 2020).

Nevertheless, resilience is sometimes juxta-positioned against precaution, as a "new" way of thinking, sometimes called SAFETY-II (Hollnagel et al., 2006). The key application of SAFETY-II concepts seems to be more and more in "resilience" applications. As stated by Leveson in 2020 (ibid.), resilience is only vaguely defined as making sure that things go right. But just as in SAFETY-I the definition of what constitutes a failure is only operationalized, when in a real-life situation, the focus of analysis is determined. Also, the nature of compensating system behavior and the characteristics of a resilience structure, is only manifest, when an in-depth analysis is performed.

After the crash of the Turkish Airline flight 1951 in 2009 (Ale et al., 2010), the number of people (i.e. passengers and crew, dead and alive) were counted and one American was missing. He showed up in New York some 10 h later and was stopped by the immigration officers (an APB was set on his passport). The American marine had left the scene of the accident with only mild scratches, walked to the near highway, hailed a taxi, got to Schiphol Airport and made his connection to New York. He came home safely. Now was this a successful demonstration of human resilience or did the system cope?

According to Hollnagel et al. (2006) a system acquires resilience if the organization and the hardware and people in it are able to react to deviations from "normal" caused by natural variations or by extreme and even unexpected events, to prevent an accident from happening. However according to Linkov and Trump (2019) this is called "robustness" and therefore could be assumed to be built in to well-designed systems and hence covered by SAFETI-I. Whereas perhaps "resilience" should be defined as the ability to recover after an out of design limits excursion, or an accident has occurred. The addition of a recovery step after an incident was also used by Papazouglou and Ale (2007), where rapid and adequate medical help was positioned after the accident, such as falling from a scaffold had taken place and the consequences the traditional right-hand side of the bow-tie – such as hitting the ground at speed - had materialized (Fig. 2 from Ale, 2006) (see Fig. 3).

As was discussed in (Ale et al, 2020), a building fitted with an automatic sprinkler system is made resilient against a fire: this resilience could be called robustness. However, if the fire gets out of hand anyway, the fire department is the next line of defense, thereby expanding the fire resilience system to include the fire department. In high rise apartment buildings, the so-called "stay put" approach makes sense in many circumstances. If the fire is below you an attempt to leave the building may lead you to the fire and into danger. In the Grenfell disaster the fire spread to, around and up the outside cladding of the building. From then on, the safety of the occupants depended solely on the fire department, which given the circumstances (Moore-Bick, 2019), the resilience of the system for the fire thus included the fire department (Slater, 2019). In the aftermath the community resilience system apparently needed the council, the neighbors and a large range of charitable organizations to feed, re-house and re-equip the survivors. Therefore, whether any approach or measure is called precaution, robustness (and SAFETY-I) or resilient (and SAFETY-II) depends on a purely arbitrary definition of what constitutes the system of concern. As such, the differences between SAFETY-II and SAFETY-I are purely artificial. Responsible and conservative safety management requires both; belt and braces, rigor and resilience, not either/or.

As was described in Ale et al. (2020), resilience has obtained a more and more ominous meaning, which supports the idea that when relying on the resilience of the people involved, precautionary measures such as spare capacities in stocks are both unnecessary and unjustified, in view of the opportunity costs of committing money for events that may not happen. There is the view (Jongejan et al, 2011) that preparing for low probability events is not worth the money. In that view resilience measures are reduced to disaster response plans and other almost cost-free exercises with parsimony slowly replacing precaution. However, resilience in the meaning of a system regaining its former functionality after a setback, gets an ethical dimension when it is considered that a human life when ended, cannot be restored, or rebooted. This re-focuses the question on whether to spend money on precautionary measures aimed at preventing accidents or harm, or on "extra" resilience measures such as spare parts, rescue services and the associated equipment to be prepared for a recovery operation after an accident. Whether this is worth the money then has obtained a profound ethical dimension (Aven and Zio, 2020). The question then, is whether ethical considerations are in the frame of corporate risk management, where sometimes loss-of-life catastrophes seem to be simply the cost of doing business, or a case of: 'some would call the market cynical, while others would call it realistic' Herbst et al. (1996). It also raises the question as to whether any decision is only ethically justified when a strictly financial cost/benefit ratio is positive (Helsloot and Schmidt, 2012). If the latter is indeed the case,

Fig. 3. extended culture ladder ().
adapted from Hudson, 2007

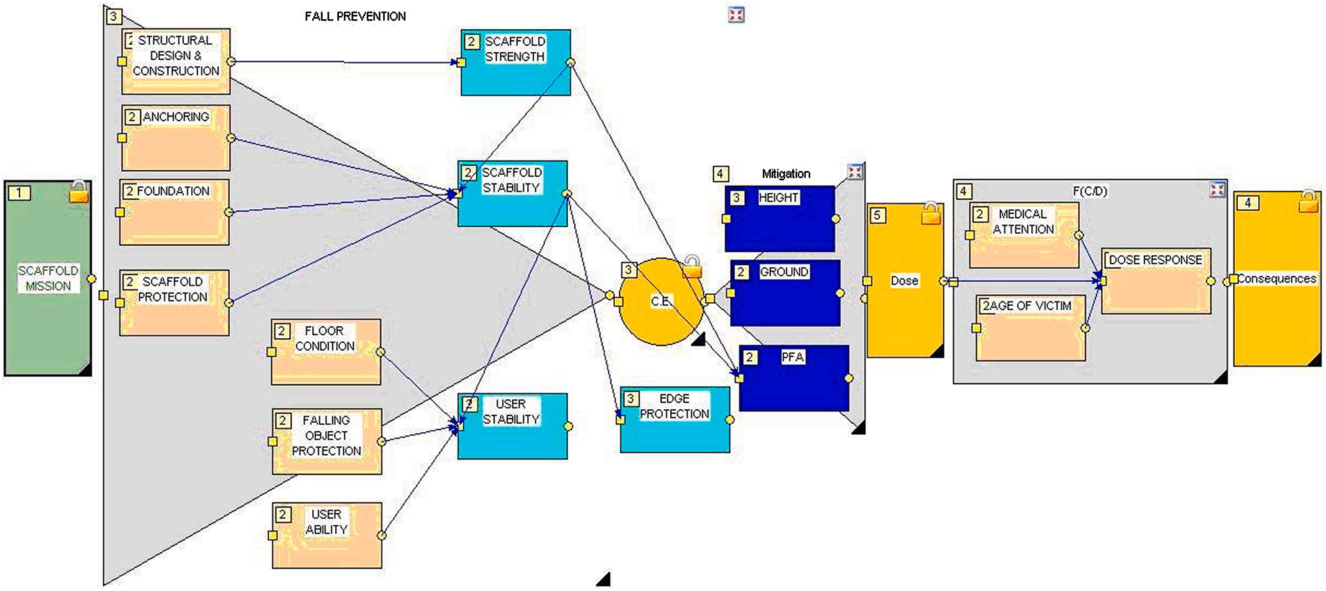

Fig. 2. Bow-tie showing resilience components (from Ale, 2006).

evaluation of the value of a human life is unavoidable if lives are a matter of concern. However, as Cameron (1963) put it: “not everything that can be counted counts, and not everything that counts can be counted”, emphasizing that the choice of treating human lives as a commodity, is in itself an ethical choice.

4. The value of human life

Although it is often stated that the value of human life is priceless, there have been numerous attempts to put a price on the value of a life (VOL) or the value of a statistical life (VOSL), where the distinction between these concepts involves important ethical differences.

In Ale et al. (2018) we concluded that these attempts were inspired by the desire to justify the acceptance of a risk of an activity, or an industry. If the acceptance of a risk, which was deemed acceptable for another activity or industry, and the costs for this level of risk could be evaluated as well as the number of lives not lost, the division of the two could be used as the implicit, or explicit valuation of a life, a life-year, or a statistical life. However, these evaluations of a VOSL, lead to widely varying results. In practice, the budget available for a hazardous activity or development often, if not always, determines the level of residual risk to be justified for the purpose of project evaluation. This is one of the main underlying reasons why these evaluations of the VOSL lead to widely varying results. Therefore, a consistent valuation of a human life cannot be realistically expected.

In Ale et al. (2019) we concluded that in efforts to establish a VOSL for use in cost benefit analyses, there are a number of implicit assumptions. One is that there is a market on which human lives can be bought for a price; and decision makers can decide whether the price is worth paying given the enterprise they wish to undertake, or endorse. This assumption implies another assumption, which is that on this market, humans voluntarily offer their lives for sale. In political decisions on the acceptability of a risk, however, the more controversial problems are with those risks that are caused by one individual, or institution, but borne by another individual or institution, and that that the exposure to that risk is not voluntary.

We also concluded that using VOSL as a unit of costs, implies that safety and degrees of safe can be measured in terms of risk. However, it is argued by Aven (2018) that the definition of risk is a matter of the perspective that was chosen; e.g. that risk is the antonym of safe, and that other perspectives of risk are admissible. This leads to the conclusion that the use of the terms risk, safety and the relationship between these two is a matter of the perspective of the individual or group, and how they decide within the constraints of logic, to define this relationship or whether or not logic enters the formulation of the perspective at all. The assumption that risk, represented as an expected value of the loss could be implied to be a measure of safety, in a cost benefit analysis, is firmly entrenched in economic risk analysis. However, this does not mean that without a marker, the value of a loss, or a potential loss, can be established with any necessary level of certainty to make such a cost balancing act ethically possible. Hence, the appropriateness of using VOSL at all in a safety analysis, is a matter of perspective, which renders attempts to establish a uniform value of a statistical life questionable. This in turn makes it questionable whether the decisions from which values for a VOSL were evaluated, as was done for instance by Tengs et al. (1995), really were based on consideration of saving lives, or that other arguments, such as available budget, were much more dominant.

5. The cost of accidents

The actual costs of accidents are difficult to obtain. Shortly after an accident the direct costs may be reported, but they often do not include the costs of the public services involved in firefighting, evacuation, sheltering and treatment of victims, search and rescue, rebuilding and reconstruction, costs of inquiries and costs in the longer term, when the record of a particular accident are no longer kept. In the following, a few examples are given for which it is believed that the cost estimates are reasonably accurate. These examples serve to show that it is difficult to evaluate the costs of accidents in terms of costs per life lost.

5.1. *Enschede disaster*

On 13 May 2000, an explosion occurred in a fireworks storage and trading facility located, since 1978, in the midst of a densely populated area in Enschede, the Netherlands. Twenty-two people were killed and some 900 injured. The material damage was approximately €500 M (Euro) (Uitdehaag et al, 2001). The total cost could be given as €23 M per life. On the other hand, if one were to value human lives as sometimes is done in cost benefit analyses, at 6 Million Euro and assign half of this value for a life lost accidentally, the costs of lives lost in this accident is €66 M, only 13% of the total cost of the accident. One could also attempt to evaluate the costs of preventing the accident. In 1998 the company changed hands for €1.2 M (Oosting,2001). The desirability of maintaining the industrial activity at that location was already doubtful. Hence the company only obtained a temporary license, valid for a year, which unfortunately was subsequently continuously extended during the 22 years until it exploded. Rather than giving a permit to operate, to a new owner, the city could have bought the company and terminated the activity, which would have prevented the disaster. Given the location of the factory, the city probably could have regained some of the costs, but even if the costs of preventing the disaster are set equal to the value of the company, the costs would have been only €55,000 per life saved or €1300 per life-year. However, as €1.2 Mo was considered to be a lot of money for the facility, the cost per life saved issue never arose.

5.2. *B737-max*

The Boeing 737 MAX passenger airliner was involved in two crashes, Lion Air Flight 610 on October 29, 2018 and Ethiopian Airlines Flight 302 on March 10, 2019. In these two crashes 346 people lost their lives. The costs to January 2020 are estimated at 18 Billion $US (http-3) which equates to $US 52 Million per life lost. These costs include compensation to airlines and victims’ families, lost business, and legal fees. These costs are much larger than the US$ 145,000 per life that Boeing paid to the families of the deceased (http-4), the total of which amount to US$ 50 Million. If again a figure of €3 M is used for an accidental death and parity between Euro and US dollar is assumed, the value of lives lost would be €1 Billion, 5.5% of the total damage. The B737Max costs could have been avoided if the company had followed the simple SAFETY-I rule and not made a single point of failure potentially catastrophic. Rather there was reliance on the SAFETY-II principle that an aircraft that flies and lands without outward manifestations of problems relies on the pilots to solve any of the envisaged problems internally should they arise. This maybe would have required a more thorough analysis, the costs of which would have been and are negligible, when compared with the current costs of the problem that resulted from being less thorough.

5.3. *Deepwater horizon*

The costs of the Deepwater Horizon accident in 2010 are estimated at US$65Billion in 2018 (http-5). These are predominantly attributable to the costs of the cleanup of the Gulf of Mexico. However according to (http-6), at least US$4 Billion can be attributed directly to the loss of life, as they are the settlement costs in the manslaughter case. This is about 6% of the total cost. In the accident 11 people lost their life, leading to a cost per life of US$364 Million. If again lives lost accidentally are valued at €3 M or US$3M, the costs of lives would have a value of US$33 M, which is 0.05% of the costs of the disaster. As the operation was already tens of millions over budget (http-7), the costs of further delays to fix the problem with the concrete would have been insignificant, when compared with the total costs of the disaster.

5.4. Piper alpha

In the accident with the Piper Alpha oil platform in 1988, 167 people lost their lives. The costs of the accident are estimated to be US$3.4 Billion (http-8), half of which was the cost of the loss of the oil rig. Corrected for inflation this would be US$6.8 Billion ($-2020). The remaining costs can be attributed to the cost of human lives, which amounts to US$20 million per life ($ 2020). If again the lives would have costed at US$3 Million the costs of loss of lives would have amounted to US$501 Million or 7.5% of the total costs. Although the evaluation led to major changes in the way safety is managed at oil rigs, the accident would have been prevented had the crew used tag-in tag-out labels at no additional cost. An investment in subsea isolation valves for the risers, as required in the Norwegian sector, would also have been cost effective.

5.5. Phillips petroleum

On October 23, 1989, a series of explosions and fire occurred at the Phillips Petroleum Company's Houston Chemical Complex (HCC) facility near the Houston Ship Channel in Pasadena, Texas, United States. The initial blast registered 3.5 on the Richter scale, and the conflagration took 10 h to bring under control. The explosions killed 23 employees and injured 314. The costs are estimated at US$1.4 Billion ($ 2020); (http-9), or 61 Million per life. If again the lives would have costed at US$3 Million, the costs of loss of lives would have amounted to US$69 Million, or 5% of the total costs. The technical cause was identified as being the fact that the air connections for opening and closing a valve were identical, and had been improperly reversed when last reconnected. As a result, the valve would have been open while the switch in the control room was in the "valve closed" position. Making this error impossible would have cost a few hundred dollars (including design and administrative costs), and obviously involving somebody that could have recognized this potential problem in a pre-construction analysis (http-10).

5.6. The costs per life of accidents

From the examples above it can be seen that Trevor Kletz (http-12) was right: "if you think safety is expensive try an accident". But it is difficult to extract the costs of lives lost from the cost estimates. One could use the same method that is used to calculate the costs of measures to save lives; that is, divide the total cost of the measure by the – statistical - number of lives not lost., Alternatively, as is done by Tengs et al. (1995) and by Helsloot and Scholtens (2010) take the costs of the accident and divide it by the number of lives lost. The results of such a calculation are staggering when compared with what is generally adopted for the value of a statistical life. Conversely that the costs of lives lost accidentally when valued at €3 M, a practice that we do not recommend (Ale et al, 2018, 2019), are a very small percentage of the accident costs. The costs of compensation to be paid is marginal when compared to the total costs utilizing this standard VOSL.

6. Conclusion

Post-accident Values of Life are significantly higher than pre-accident estimates. The companies involved in the above accidents all still exist, albeit sometimes under a different name. Therefore, the observation of Gulijk (2012) still stands. Major multi-nationals are capable of absorbing incredible amounts of financial damage following catastrophes, before stock markets react. This is partly due to the complexity of modern financial market where risks can be sold, or transferred easily from the operative entity, to another entity. The findings suggest that Hudson's (2007) HSE culture ladder, requires a step below the pathological, to reflect the reaction of the stock exchange market on major catastrophes: the negligent level. If the financial risks of catastrophes are covered, market traders rarely assign further consequences for the loss of life to the company through the lowering stock prices.

When the value of a statistical life is taken, as is customary in Cost-Benefit analyses, human lives turn out to be a relatively inexpensive commodity. Therefore, human lives are not adequately protected by cost benefit arguments. On the contrary, cost benefit calculations are likely to make risking human lives acceptable. It is therefore not surprising that they are used in this way (NN, 2015). Only ethical considerations such as "thou shall not kill" (Zandvoort, 2004), or restricted liberty, or the right to be safeguarded, can provide additional protection. The ethical principle of restricted liberty holds that everyone is free to do what he/she pleases as long as he/she does not harm others. This principle has a long history in Western culture. An equivalent formulation of the restricted liberty principle is the right to be safeguarded: Everyone has the right to be safeguarded from the consequences of another person's actions. An implication of this is, that actions are right, if and only if: either there are no (possible) consequences for others; or those who will experience the (possible) consequences have consented after having been fully informed.

However ethical considerations do not seem to be in the frame of corporate risk management, where loss-of-life catastrophes are simply the cost of doing business or as Herbst et al. (1996) puts it: 'some would call the market cynical, while others would call it realistic'.

Living without risk is impossible. Therefor discussions about the acceptability of hazardous technology will continue; as will the discussion about the amount of money society is prepared to spend on reducing the associated risk. Because there is no real basis for any estimate of the value of a statistical life, the values employed in cost-benefit analyses therefore only seem to serve the purpose of dissembling, concealing that the decision is taken on grounds other than considerations of avoiding loss of human lives, or even that potential harm to humans was not even considered. The strict meaning often given to resilience as at most to make a plan for recovery and see if we can live with the consequences after the fact, seems just another step towards putting the economy before people.

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