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Is there a Statistical Value of a Life?

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In making decisions, rationality is often equated to economic rationality. This means that in every decision, the benefits should outweigh the costs, when both are expressed in monetary terms. Balancing of cost and benefits through monetary Cost Benefit Analysis (CBA), which is used more and more widely in health and safety decision-making, evokes the criticism that it leads to decisions in which only money counts; and all that cannot be expressed in money, or is perceived of no monetary value, is neglected. An important parameter in the CBA rationality, is the value of a statistical life (VOSL). Scientists serving decision makers in the attempts to monetize the VOSL have spent decades of research into what a reasonable value should be. These evaluations of the VOSL lead to widely varying results. This wide variation seems to move decisions on risks to life and health, from the political arena to the scientific laboratory. Scientists are required produce the right number after which politicians can then decide on the basis of CBA. In this paper it is argued that rather than attempting to harmonize on an average with large margins of uncertainty, the conclusion can be drawn that a consistent valuation of a human life cannot be expected. One should accept that standardization of the VOSL is limited by the – lack of – similarity in nature of the activity and the nature of the risk. In many cases one also 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.

1. Introduction

It would be of great help to decision makers to justify decisions which, as an unavoidable consequence, will at some time in the future lead to the death of a third party, if there were a universal principle on which decisions on hazardous activities and the risks associated with these could be based. Following an earlier paper on this subject (Ale et al., 2018), in the remainder of the paper, whether such a value exists and what the consequences for decision making are if it does and if it does not, is further explored.

2. Guiding principles

The quest for such moral principles (Kant, 1783) has been continuous through the ages. Thou shalt not kill is one of the Ten Commandments (NN, 2018). But even in the Bible this does not seem to prohibit going to war, with the unavoidable consequence that people will be killed. Nevertheless the principle that one should not kill or do harm (Hippocrates, 400BC) to the life and health of other people seems to be a moral principle, only to be broken in defence of one's own life, or in some countries as a punishment for somebody who broke the principle. Profit does not seem to be a valid reason to break this principle. It cannot be denied though that hazardous industrial processing and the transport of hazardous materials brings with it a continuous string of accidents in which people are harmed and killed. Generally there are two defences put forward. The first is that the damage is collateral, it was not the purpose of the activity. The second defence is that the harm is not certain a priori. There is a finite non-zero probability that people will be harmed, but it is uncertain whether this probability will indeed materialize in an actual event and it is uncertain who the victim will be. There used to be a third defence, which is that people who have accidents have to blame it on themselves (Burnham, 2008). Some people working in high-risk industries still hold this belief. However, research since the 1960s shows that this theory has little validity. The statistical argument is augmented by the lemma that all accidents can be

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prevented. The reality of death and injury statistics therefore is not applicable to the moral question of the acceptability of a future hazardous activity, because there is no intention to harm anybody.
Once it is recognized that harm also will be unavoidable in the future, a second line of defense is sought. This could be headed by “all men are created equal”. Although the undeniable right to life is a little violated by the probability of being killed, all people should be treated equally and therefore should be protected to an equal level. This reasoning leads to the question whether there is a de minimus level of risk that should be acceptable for all and for all activities. There are two approaches for this de minimus level.
One is to try and find a limit to the probability of death to which in an individual may be exposed. This approach keeps decisions on risk in the same domain: there is a probability of collateral damage and this probability is limited to an acceptable level.
The other approach that has gained popularity in the modern belief, is that all the world is a market; that everything has its price and that lives are as much a commodity as everything else. The assumption that there cannot be any reasonable objection against using the principles of the market, in which everything is for sale, and everything has a price which is set by market forces, is not universally held (Bacon, 1999). In this approach the value to be attached to a life has be set. Since lives are priceless, or at least stated to be, the concept of the value of a statistical life is used as a mechanism to balance costs, benefits and risks (Aven & Renn, 2018). A complication is that economists, although they recognize that the units associated with the VOSL reflect the aggregation of small risks across many individuals until that aggregate reflects a total of 1.0, or one statistical life, often assume that the non-specialist is wrong in understanding that a statistical life can become a real one (USEPA, 2010). This approach therefore may be attractive before the accident, but indeed, after the accident the statistical life becomes a real life of an identifiable person.
The ALARP principle is an example of an attempt to perform such a balancing act between benefits and costs, where the costs include the loss of life. The verdict in the UK case law in the case of Edwards v. National Coal Board (CoF, 1949) is generally understood to imply that the principle of ALARP is fulfilled when the point is reached that the cost of further reduction of a risk is disproportionally larger than the quantum with which the risk is reduced. However neither of the terms “disproportional”, “cost” and “quantum” is further defined. Therefore the ALARP principle may define what process should be followed, but it does not define an acceptable value for a statistical life.
Although political debates can be concluded by this method, after the accident, the debate usually reopens, questioning the validity of the decision to accept the risk, asking the question whether the moneys spent to reduce the risk were indeed appropriate and whether risking people’s lives for profit should be allowed at all. Sometimes authorities react by imposing new safety regulations, increasing the explicit or implicit value of the statistical lives involved. The Seveso directive is an EU example (EU, 1982). This then meets criticism from those who are of the opinion that authorities are too afraid of public opinion and therefore too risk averse (Helsloot, 2012).

3. The search for the Value of a Statistical Life

The search for the Value of a Statistical life can be performed from two perspectives. The perspective of the potential victim and the perspective of whoever has to pay for reducing the risk

3.1 The perspective of the victim

Moral principles are usually considered from the point of view of the potential victim. Members of the public prefer to be protected by clear limits set to levels of threats. Under the Napoleonic law system, which was introduced in all countries that were part of the French Empire under Napoleon, the law defines what are unlawful or unjust acts and defines for each of these the penalty, be it imprisonment, a fine or the payment of compensation. In this system, therefore, everything which is not explicitly forbidden is allowed (Ale, 2005). In this system also it is necessary to look at similarities between cases rather than differences, because one cannot have a separate regulation for each case. That in fact is one of the rationales behind Napoleonic law. So all LPG stations are treated equal and as part of the larger group of hazardous industries all covered by the SEVESO directive (EU, 1982). In the majority of EU countries the limits for industrial risks were set as minimum separation distances, with the aim of preventing all third party risk. In some countries such as the Netherlands these distances were deemed excessive given the space available and limits were set to the residual risk in terms of probability of death. The original value was set to 1:1,000,000 or 10^{-6}/y. This number was based on decisions made in the period following the great flood of 1953. In principle this limit was meant to be valid for all non-natural risks (OMR, 1988). In recent years this limit has become under increasing pressure mainly because of the costs associated with upholding it. For the protection against floods the decisions made in the 1950s were “re-interpreted” now to mean a maximum risk of 10^{-5}/y. The current flood defense program is based on this number (NN, 2013). The cost benefit analysis that led to this re-

interpretation can be found in Deltares (2011), but was stated not to be the basis for the decision. In the recent decision of the protection against earthquakes induced by the extraction of natural gas the cost element led to a further relaxation of the limits allowing a risk of 10^{-4}/y for existing houses for an undetermined period in the future. This makes the risk in these houses larger than the risk of traffic (currently $3*10^{-5}$/y). Although again the cost benefit analysis was officially not the basis for these decisions, it has become clear that the discussion about the value of a statistical life has become unavoidable.
In the common law practice each case in principle is judged on its own merits. As described above, the ALARP system does not specify what has to be achieved. Such a policy can be looked at from the perspective of the potential victim who would probably put emphasis on the As Low As part of ALARP.

3.2 The perspective of who pays

One could however also take the position of the person or organization who has to foot the bill. They consider the citizens as an intractable and grumpy mob whose complaints after an accident should be addressed by an excuse and a service of remembrance but not with additional spending on safety (Helsloot, 2012). They emphasize the Reasonably Practicable side of the policy. The Office of Management and Budget in the US took the point of view of who pays for the measures, with the aim to reduce expenditure to the minimum required. Morall (1986, 1992) was as far as is known, the first to publish a table in which he presented the costs of saving lives. He found that at that time there seemed to be consistency as so far as measures that would have costed less than about 140M$ US, per live saved, were adopted and measures that costed more, were rejected. Tengs et al. (1995) produced a more extensive list with some 500 measures aimed at saving lives. They thought it would be beneficial if human lives should be valued equally, regardless of the decision. What they found was that the value varied by orders of magnitude. In traffic, the costs per life saved were much smaller than in medical interventions; smaller in preventing injury than in control of toxins in the environment. These estimates were criticized by Heinzerling (1998). She argued that that many of the estimates in these tables were wrong and using these tables as an argument for regulatory reform, i.e. base regulation on cost benefit reasoning, was invalid; because the tables show that measures entailing obvious excessive costs were rejected already. Moreover she argued that using the table as a starting point for a discussion and using 7M$US as a fixed criterion for the acceptance or rejection of measures, forgoes the – ethical – discussions that preceded each of the separate decisions. Morrall (2003) answers this criticism and adds another limit by stating that spending 21M$US on a health issue, takes away money elsewhere, which through “poverty” causes an additional statistical fatality. He concludes that it is better that employers save money on anti-toxin measures and treat the cancer patients among the workforce that result, because the total amount of money per life saved is less in the latter case than in the first. This completely ignores the question as to whether the money argument is sufficient to justify that an employer is entitled to impose a level of cancer incidence in his employees. Heinzerling (2000) takes this argumentation to the limit by stating – quite rightly- that the logical consequence of this argument is that it is beneficial to have somebody murdered, when the value of his death is worth more than his life. Heinzerling states therefore that a universal value of a statistical life does not exist.
The proverb that the absence of proof is not the same as the proof of absence is taken one step further by Doucouliagos et al. (2002). They assume that in the publications on the subject of VOSL there is a reduced probability the insignificant or negative VOSL values are reported. From this assumption they derive that the Value of 7M$US should really be around 2 M$US. The question can be raised though, whether there are grounds for this assumption as many of the studies were done to save money on risk reducing policies and therefore would report lower numbers if they were there.
In any case the conclusion drawn already in a report by the European Commission in 1995 (EUR, 1995) that the value of a statistical life remains elusive, is confirmed by the above. It is also confirmed by a meta-study performed by the OECD (2012). According to this study the VOSL is proportional to the GDP of the country were a study is done or a decision is evaluated and inversely proportional to the reduction in risk. Evaluating the costs of programs apparently shows that people are prepared to pay more for smaller risk reductions. A probable cause for this effect may be that the high VOSL to risk reduction ratios are found in countries that are already rich and where as a consequence the risks are already low. They conclude that finding a value of a statistical life tailored to a risk reduction program is far from simple. Firstly because there does not seem to exist a reference value and secondly the correlation coefficients needed to translate the value found in one situation to another are extremely uncertain. It is also confirmed by the USEPA (2010), which concludes that there are serious problems with the estimates available so far.
From comparing these two meta-studies a worrying aspect appears. In the USEPA study it is explained how values from different studies were converted to US dollar values in a single year: “when it was clear that an estimate reflected a household willingness to pay, we divided those estimates by the average household size for the country and year when the study was conducted. We then converted all estimates to U.S. dollars using

the Purchasing Power Parity Index for the dollar year of the estimates. Next, all estimates were converted to 2009 dollars using the Consumer Price Index (CPI) and adjusted for income growth over time assuming an income elasticity of 0.5". In the OECD study it is specified that all numbers are in US dollars 2005 but it is not specified how the conversion was done. The two studies were done for different sets of countries, but 10 countries occur in both studies. For these 10 countries 11 references are used in both studies. As a result, although some numbers in both studies are close, there is not a single number that is equal in both studies, even after correcting for the difference in reference year. This makes it intractable and impossible to discern what number should be used, should one want to derive a universal VOSL.
Therefore it could be safely stated that if there is a universal value of a statistical life, it has not been found yet. It is not a large step to infer that there is a high probability that this universal value does not exist, even though governments still attach values to statistical lives (HSE, 2001; Deltares, 2011; RVGZ, 2006).

4. Natural and man-made risks

A further complication in the evaluation of a VOSL by meta-studies and literature reviews is that natural and man-made risks are lumped together. In health care the individual spends money to treat and when possible cure disease to prolong a healthy life. In the reduction of man-made risks the individual is asked to spend money on preventing being killed involuntarily as collateral damage from some activity of another.

4.1 Health care

The primary purpose of heath care is preventing illness, repairing damage already done and in cases that these two efforts fail, minimize suffering. A long healthy life is a universal wish and people will spend money on fulfilling that wish as long as they can afford it. There are people who can afford expensive doctors, or expensive health insurance and those who cannot. It may be a sobering thought but if you do not have the money to pay for a treatment, you will die. In the larger context of a national budget things obviously get more complicated, but the shared desire for a long healthy life makes societies spend what they can afford.
Ultimately there is a trade-off between policies on health care and defense, but these tradeoffs remain largely implicit. In this larger context- it is taken as a given that society needs all sort of services, without recurrent economic evaluation. The countervailing power is the taxpayer, who wants to pay as little as possible and wants value for money. The driving force behind decisions on spending money is complaints by the tax-payer. If the taxpaying citizen is dissatisfied with a service that service is allocated more money at the expense of another service until complaints arise on the latter. Extending the total budget, i.e. raising more tax is unpopular and therefore the last resort.
In terms of how the money is spent, the trade-offs could be relatively direct. If 1 expensive operation can be performed for the same money as 10 other less expensive ones and both operations yield life years then one could prioritize the most cost effective operations. However in practice it is nearly impossible to estimate the benefits of surgery or medication accurately enough to make such micro-adjustments.
Finally, although some cosmetic operations improve the mental health of a patient, many also do not improve health, but are carried out anyway. These could be justified by the fact that the latter operations are paid for privately, but this does not take into account that doctors and nurses are trained in universities and hospitals which are funded to a large extent by public money. So a strict trade-off would lead to a ban on these operations. In practice, this does not happen, and therefore even in a simple context such as this, completely economic optimization does not take place.

4.2 Man-made risks

In industrial risk, risks from traffic and many other activities, harm to health and life is collateral. In these cases loss of health and life is deemed unavoidable and the judgement call to make is twofold: whether, given this unavoidable loss, the activity should be allowed to be undertaken and whether there is enough done to reduce these losses to an acceptable level. Although all accidents can be avoided in principle they will not be in practice. The sobering reality is that people violate rules and technology is not perfect. The question to be answered is therefore, are we prepared to take the consequences of the imperfect reality to achieve some goal and if we are not, what are we prepared to spend to approach the theoretically attainable perfection in practice.
In evaluating measures taken in retrospect the resulting VOSL varies widely. Measures in the realm of road safety usually are cheap, while measures involving toxic materials, usually, are on the expensive side of the spectrum. One could be tempted to translate this into the different values apparently attached to a statistical life in different environments. But another interpretation is also possible this being that it is much easier and cheaper to make a road safer than it is to make a chemical plant handling toxic materials safer.

There is no trade-off of safety between different sorts of activities. There are activities; they are made as safe as is deemed possible; and after that it is take it or leave it. Activities for which it was judged that they could not be made safe against a reasonable price are discontinued. Given that the VOSL is found to be dependent on the GDP of a country one could reduce the money spent on safety in one country and spend it in a country were the VOSL is lower. That would reduce mortality on a global scale and Helsloot (2012) promotes this idea (PCM, 2012). In the realm of industrial risks life years are not offered. They are taken away against peoples will. The VOSL is the price that people are prepared to pay to avoid this.

4.3 Commodity

Similar commodities are priced differently in different countries. Notorious is the Big-Mac index (Economist, 2018). The Big–Mac is a product that is standardized over the world. In Switzerland the consumer is prepared to pay 6.8 $US for it, in the Ukraine only 3.8 $US. The index has been proven to be a reliable indicator for the purchasing power of the citizens of a nation. The concept of the value of a statistical life implies that lives are commodities that are for sale and therefore can be priced. In that context it cannot be a surprise that evaluations of prices paid vary widely. It can also not be a surprise that one industry has to pay more for a quantum of risk than another. This can even be less a surprise in law systems were the judgement is preferably done on a case by case basis. One party creates the risk and another party will allow him to do so against a negotiated price. These costs may return to the potential victims in the form of taxes or the price of a product. But even then there is no law of nature that prescribes that the price of a life year should be uniform over the world and for all activities.
This raises the question why then pursue this quest, which in the light of more than 30 years of research seems futile. A possible answer is justification. Only a few countries published an explicit reasoning behind their choice of residual risk limit (OMR, 1988). Most countries justified their adopted risk level on previous decisions taken elsewhere, even if these were a myth (Kelly, 1991). Similarly it is much easier to specify a maximum of 80,000 euro/life-year saved as the maximum expenditure in health care “because another agency uses the same number” or “it follows from literature” than develop an ab initio justification based on a moral principle. It is even more difficult in industrial risk, were life years are taken away from involuntary citizens, to argue that spending more money on safety is reasonable, ethical and morally justified.

5. Relevance of Risk the antonym of Safe?

In efforts to establish a VOSL for use in economic analysis, it is implicitly assumed that safety and degrees of safe can be measured in terms of risk. However, it has been argued (Möller et al. 2006) that safety can be defined in terms of the three dimensions of risk; harm, probability and epistemic uncertainty. In a counter argument, it was argued (Aven, 2013) that the definition proposed by Möller et al., is a matter of the perspective that was chosen, 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. The assumption that risk represented as expected value of the loss could be implied to be a measure of safety in a cost benefit analysis was firmly entrenched in economic risk analysis. Nevertheless it can be observed that if risk as a measure of safety is a matter of perspective, then it follows that everything that is derived from the initial perspective is itself a function of perspective. Hence, the appropriateness of using VOSL at all in a safety analysis is a matter of perspective, without considering any second order perspectives, such as the perspective about the individual who is at risk about their own value, all of which renders the matter of a uniform value of a statistical life questionable.

6. Conclusion

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

References

Ale B.J.M., 2005, Tolerable or Acceptable, A comparison of risk regulation in the UK and in the Netherlands, Risk Analysis, 25, 231-241

Ale B.J.M., Hartford D.N.D., Slater, D.H., 2018, The practical value of life: priceless, or a CBA calculation?, Medical Research Archives ,6, 1-12

Aven T., 2013, Practical implications of the new risk perspectives, Reliability Engineering and System Safety, 115, 136–45

Aven T., Renn O., 2018, improving government policy on risk: Eight key principles, Reliability Engineering & System Safety, 76, 230-241

Bacon J.H., 1999, Categories and structures of manmade risks and related basic problems: a risk regulator's perspective, Risks and safety of technical systems, 10th Forum Engelberg; 1999 Mar 23-24

Burnham J.C., 2008. The syndrome of accident proneness (Unfallneigung): Why psychiatrists did not adopt and medicalize it, History of Psychiatry, 19, 251 – 274. DOI 10.1177/0957154X07077594

COF, 1949, Court of Appeal (UK) case nr 1949;1 A11 ER 743; Edwards v The National Coal Board

Deltares, 2011. Maatschappelijke kosten-baten analyse Waterveiligheid 21e eeuw (Societal Cost Benefit Analysis Water Safety 21 Century) Deltares, Delft, 1204144- 006-ZWS-0012

Doucouliagos C., Stanley T.D., Giles M., 2012, Are estimates of the value of a statistical life exaggerated? Journal of Health Economics 31,197– 206

Economist, 2018, <www.economist.com/news/2018/07/11/the-big-mac-index> accessed 18-07-2018

EU, 1982, European Union Directives 82/501/EEG (Pb EG 1982, L 230) and 87/216/EEG (Pb EG 1987, L85) ("Seveso directive")

EUR, 1995, Externe, Externalities of Energy, vol2, Methodology, European Commission EUR 16521 EN

HeLsloot I., 2012, Veiligheid als (bij)product, Oratie Radboud Universiteit Nijmegen, the Netherlands <crisislab.nl/wordpress/wp-content/uploads/Oratie_Ira_Helsloot_21-09-2012.pdf> accessed 18-07-2018

Helsloot I., Schmidt A., 2012, The Intractable Citizen and the Single-Minded Risk Expert – Mechanisms Causing the Risk Regulation Reflex Pointed Out in the Dutch Risk and Responsibility Programme, European Journal of Risk Regulation, 3, 305 – 312.

HSE, 2001, Reducing Risk, Protecting People, Her Majesty's Stationery Office, Norwich NR3 1BQ, ISBN 0 7176 2151 0 p36

Heinzerling L., 1998, Regulatory costs of mythic proportions. The Yale Law Journal. 107, 1981-2070

Heinzerling L., 2000, The rights of statistical people, Harvard. Environmental Review, 24, 189-207

Hippocrates., 400BC, <<archive.is/20180304084630/https://www.ordomedic.be/nl/orde/artseneed/eed-hippocrates/>> accessed 16.07.2018

Kant, I., 1783, Kritik der reinen Vernunft, Der Philosophischen bibliothek band 37, Leipzig 1919, Verlag von Felix Meiner.

Kelly K.E., 1991, The Myth of As a Definition of Acceptable Risk, Environmental Toxicology International, Seatle, USA.

Möller, N., Hanson, S.O., Peterson, M., 2006, safety is more than the antonym of risk, Journal of applied philosophy, 23 nr 4 419 - 432

Morall III J.F., 1986, A Review of the record, Regulation. 10, (2)

Morall III J.F., 1992, Controling regulatory costs: the use of regulatory budgeting. Paris: OECD/GD

Morall III J.F., 2003. Saving lives: A review of the record. AEI-Brookings Joint Center for Regulatory studies, Working Paper No. 03-6<ssrn.com/abstract=424523> or <dx.doi.org/10.2139/ssrn.424523> accessed 17-07-2018

NN, 2013, Letter of 26 April 2013 to the Second Chamber of Parliament, Ministerie van Infrastructuur en Milieu nr IENM/BSK 2013/19920, The Hague, The Netherlands

NN, 2018, <<en.wikipedia.org/wiki/Ten_Commandments>> accessed 16.07.2018

OECD, 2012, The Value oF Statistical Life: A Meta-Analysis, ENV/EPOC/WPNEP(2010)9/FINAL, Paris, France

OMR, 1988, Omgaan met Risico's, Tweede Kamer, vergaderjaar 1988-1989, 21137, nr 5. Under the same number the translation in English is titled: Premises for Risk Management, The Hague, The Netherlands

PCM, 2012, <<crisislab.nl/wordpress/wp-content/uploads/Maar_het_is_zonde__van_het_geld _NRC.NEXT_ 13.pdf>> accessed 18-07-2018

RVGZ (2006), Zinnige en duurzame zorg. (Sane and Sustainable Care) Den Haag: Raad voor de Volksgezondheid en Zorg, The Netherlands.

Tengs T.O., Adams M.E., Pliskin J.S., Safran D.G., Siegel J.E., Weinstein M.C., 1995, Five hundred lifesaving interventions and their cost effectiveness. Risk Analysis. 15, 369-390

USEPA, 2010, Valuing Mortality Risk Reductions for Environmental Policy: A White Paper, draft for consultation with the Science Advisory Board–Environmental Economics Advisory Committee, EPA, Washington.