An analysis of the valuation of a human life

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ABSTRACT: This paper gives an analysis of the valuation of a human life. It will show various approaches as the outcome of decision processes in different fields. The differences found are analyzed and an alternative method of valuating human life is proposed.

1 INTRODUCTION

In risk management literature the valuation of a human life is depicted as a very difficult problem. Sometimes the question is called unethical, because a human life is considered to be invaluable.

However in the fields of technology, medicine and insurance decisions are taken that sometimes also involve the possibility of human suffering or death. These decisions are usually made by politicians, taking into account the aversion towards human suffering in an intuitive way. An analysis of these decisions shows, however, that the implicit value of a human life is always finite.

The economic aspect of the problem is, that the scarce national means have to be divided over many investments, among which are a number of possible investments in safety. Any rational decision mechanism must therefore be able to weigh the probability of profit against the probability of saving lives.

The growing application of risk based design methods makes it necessary to estimate the value of a human life, besides an assessment of the economic damage involved with failure of the system under design.

As mentioned, one of the approaches studies the outcomes of the political, or societal decision processes, the investments made in a society to enlarge the probability of saving an extra life. The cost, or investment made in practical cases to save an expected extra life (the investment divided by the decrease in expected number of casualties due to the investment) is denoted by CSX. This CSX value seems to be able to serve as a valuation of human life, as it indicates the willingness to pay for the saving of a life.

The problem with this approach is that the resulting CSX values differ widely. The values reported in literature [1,2,10] range from $ 1,000 for investments in sport and recreation to $ 100,000,000 for investments in the nuclear industry. Many authors mention this wide range as an indication that decisions concerning the protection of human life are irrational. The tacit assumption is that the CSX-value should be a constant number.

This paper will first show some CSX values, as the outcome of decision processes in different fields. Next the differences found will be analyzed. Finally another method of valuating human life is introduced and proposed.

2 SOME PRACTICAL CSX VALUES

An example that shows the establishment of the CSX value by merely looking at societal decisions is given by Brookshire [1]. The effect of adopting the Uniform Building Codes (UBC) and the Seismic Building Codes (SBC) in California in case of a Los

Angeles earthquake was estimated to save 3060 lives. With an estimated frequency of a serious earthquake of 1.2 %, an average of 37 lifes are saved annually. The costs to implement these codes was estimated to be $ 64 to 104 million per year. The resulting CSX = $ 1.7 to 2.8 million. But it might be clear that the material benefits (a substantial reduction of material damage) will have played an important role in the decision to improve the building codes. Therefore the resulting CSX value will be largely dependent on the material benefits.

Other literature [2,6,7,8] shows that the CSX values derived from political decisions differ to a large extent, from $ 1,000 to $ 100,000,000. This may show that a decision regarding safety cannot be taken without implicitly considering the material benefits.

3 RISK-BASED DECISION THEORY

A decision usually affects future events, about which uncertainty exists. It is very common to pursue the decision that will affect the future in the best possible way. Usually "best possible" is translated to money: the decision with the highest profit is the best. As we are dealing with future events, we have to compare expected profits. When we are not risk seeking nor risk avoiding, we can directly compare the expected profits (or losses) for every alternative. A clear description of this concept is given in [3].

When the number of alternatives increases, or when choices must be made in continuous variables, the suggested decision process becomes an optimization search.

One of the first optimization processes known to the authors that was explicitly carried out to support a societal decision concerning safety of material goods and human life, was the optimization of the dike height as part of the Delta-plan, in order to safeguard the central part of The Netherlands against flooding. This study and following advise was performed by Van Danzig [4,5] in the late 1950's. A slightly extended version of the analysis runs as follows.

The total damage, in case of flooding of the polder, amounts to

$$D + Nd$$

where D stands for the total material damage, N the expected number of casualties and d the value of a human life. This formula is rather crude (it does not incorporate the level of inundation for instance) but it serves the points made.

The probability of a flood depends on the height of the dike h and the probability of exceeding this dike height. The probability of exceedance P_f can be expressed (in the tail) by an exponential distribution:

$$P_f = e^{-\frac{h-A}{B}}$$

where A and B are parameters of the exponential distribution.

If the investment in a higher dike has a fixed part I_0 (initial costs, for instance to mobilize equipment) and a part I_1 that varies with the required dike height (for instance the cost of the soil to build the dike), the total expected costs can be expressed as:

$$E(C_{tot}) = I_0 + I_1(h - h_0) + P_f(D + Nd)PV$$

where h_0 is the existing dike height and PV the present value factor.

The minimal costs are found by differentiating this equation with respect to the dike height and equating the resulting expression to zero:

Solving the optimisation yields the optimal dike height and the related probability of flooding. If the resulting dike height exceeds the existing dike height and the total costs in the present situation exceed the total costs in the situation of a higher dike, than the dike should be heightened to the optimal level.

The optimal condition can be expressed by:

$$P_{f,opt} = \frac{I_1 B}{(D + Nd)PV}$$

$P_{f,0}$ and $P_{f,opt}$ are the probabilities of flooding before and after heightening of the dike. The expected damage reduction must outweigh the investments of building a higher dike. The cost of the additional dike height is:

$$\begin{aligned} I &= I_0 + I_1(h_{opt} - h_0) = \\ &= I_0 + I_1\left(A - B\ln\left(\frac{I_1 B}{(D + Nd)PV}\right) - h_0\right) \end{aligned}$$

The expected number of saved lives can be calculated as:

$$E(N_{saved\_lifes}) = (P_{f,0} - P_{f,opt})N$$

The cost per year of (statistically) saving a human life becomes:

$$CSX = \frac{I}{(P_{f,0} - P_{f,opt})N.PV}$$

which formula immediately shows that the valuation of a human life d is not equal to CSX: the material damage D plays an important role in safety related decisions.

To mimic decisions were an investment has to be made for every exposed person to reduce his probability of dying a slightly different model is derived. Now the investment depends on the number of persons besides the size of the protective or preventive measure. The total of investment and present value of the risk becomes:

$$E(C_{tot}) = I_0 + I_{11}(h - h_0)N + P_f(D + Nd)PV$$

By differentiation the optimal level of protection expressed by $p^*_{f,opt}$ can be determined:

$$P^*_{f,opt} = \frac{I_{11}BN}{(D + Nd)PV}$$

If the material damage D equals zero, the optimal probability of failure becomes independent of the number of persons:

$$P^*_{f,opt} = \frac{I_{11}B}{d.PV}$$

The total investment in safety is dependent on the number of persons and given by:

$$\begin{aligned} II &= I_0 + I_{11}(h_{opt} - h_0)N = \\ &= I_0 + I_{11}\left(A - B\ln\left(\frac{I_{11}BN}{(D + Nd)PV}\right) - h_0\right)N \end{aligned}$$

The number of lives saved does not differ from the case above. Thus the value of the cost per live saved becomes:

$$CSX = \frac{II}{(P_{f,0} - P^*_{f,opt})N.PV}$$

Also in this case the CSX-value is a function of but certainly not equal to the value of human life d.

If one studies the value of CSX for numerical values of the coefficients it appears to be remarkable stable for perturbations of these values.

In fact only the existing situation as defined by $P_{f,0}$ and the number of exposed persons influence the value of CSX. This influence is mainly exerted via the denominator of CSX, the number of lives saved.

Here one should observe that the likely value of the optimal safety is bracketed by 0.1 $P_{f,0} > P_{f,opt} > 0$. Thus the number of lives saved is relatively stable and bounded by $P_{f,0}$.N at the upper bound and by 0.9 $P_{f,0}$.N at the lower bound.

So the value of CSX is mainly determined by the total cost of the measure I or II and the the potential number of lives saved $P_{f,0}$.N as defined by the existing situation at t_0.

4 AN ALTERNATIVE TO VALUE HUMAN LIFE

If, despite ethical objections, a price has to be put on a human life, an objective number is the present value of the Nett National Product (NNP) per head of the country under study (Nett National Product = Gross National Product (GNP) minus Depreciation). For the Netherlands the NNP per head equals approximately $ 19,400 per year. Thus, the value of a human life, being the present value of this amount over an average lifetime of, say, 70 years, is estimated in the range from $ 450,000 to $ 800,000, depending on the real rate of interest.

The consequence of this approach is that the value of human life in a developing country is be considerable lower. This may seem strange and unethical, but it actually accentuates one advantage of the economic optimalization of safety, that is, the proposed investments in safety are affordable in the context of the national economy.

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