Valuing Prevention of Death and Loss of Life Quality: Policy Implications of Using Value of Statistical Life and Quality Adjusted Life Year Estimates

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***Abstract*- Many areas of public policy deal with non-market benefits that are difficult to value, yet the accountability for public expenditure demands efficiency; this involves comparing the value of outcomes with costs. Different techniques have evolved to address the challenge.**

This paper discusses a specific example that is important in a range of policy areas: the values placed on saving life and improving life quality. This appears in analyses of public investments, or policy impacting on health and safety. We discuss alternative approaches to this valuation, i.e. the value of statistical life (VOSL), the value of life years lost (or saved) and the value of quality adjusted life years (QALYs).

Using a literature review, each measure is put in its appropriate policy context, by considering their fundamental logic. This suggests their potential fields of application and methods of determination of their values.

***Keywords*- Value of Statistical Life; Monetary Value Per QALY; Cost Effectiveness; Cost Benefit Analysis**

I. INTRODUCTION

Public policy interventions aimed at achieving future objectives inevitably involve estimated outcomes, which are, in practice, surrounded by uncertainties. Benefits expected from the implementation of a policy and the costs of doing so are generally compared in order to assess and evaluate the policy: this is a measure of efficiency [1]. Uncertainties are associated with both benefits and costs.

Treatment of these uncertainties in policy evaluation both ex-ante, and ex-post is our main concern. The problems relevant to safety and health questions are identified and our thoughts on dealing with them are discussed in this paper.

A. Policy Evaluation – Cost Effectiveness / Cost Benefit Analysis

As might be expected for issues that are the result of collective action, many public interventions (policy changes, or programme developments) involve costs or benefits (or mixes like longer life at less than perfect health), which are not straightforward to value. These intangible effects (pain and suffering, general loss of life quality, or the prevention of death) are not priced on normal markets and thus lack agreed values to compare with market-priced resources.

Assessments of such interventions cannot be complete without consistent values of these costs and benefits. Of course, there are situations where efficiency-indicating comparisons can be made without having to value the outcomes in monetary terms; we will ignore these here.

The key benefits of public interventions aimed at improving health and safety are reductions in risks of injury, loss of life quality, and death. The uncertainties related to such benefits have two components: uncertainties about the magnitude (scale) of benefits, and about their monetary valuations.

Ignoring these values, or using inappropriate values, may result in sub-optimal public investment decisions.

1) Implications of VOSL and QALY Applied in CBA and CE

The two measures commonly used for policy evaluation are cost effectiveness (CE) and cost benefit analysis (CBA). In CE, the costs per unit of benefit (e.g., per QALY) are compared. In CBA the total additional (marginal) cost of the change is compared with the total additional (marginal) benefit from it. The highest benefit cost ratio indicates the best option, ceteris paribus.

Life can be considered “priceless” – a view many people would emphasise. From a resource allocation viewpoint, however, this is a logical category error. Virtually any programme to reduce the risk of death and other undesirable effects requires

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resources that could have been used elsewhere to improve society's welfare. Thus, there is a limit to what society can rationally spend on prevention of death and loss of life quality.

Another approach to the same issue notes everybody dies at some point. So, successful risk reduction policies do not mean death, as such, is prevented; it is just postponed. This suggests that the benefit of a programme is the number of life years saved that would have otherwise been lost [2]. Since the status of health before death varies between people and can be an issue in selecting a policy, the loss of life years is often (especially in the health sector, where many of those being treated are not well either before or after the intervention) measured by quality adjusted life years (QALYs) or disability adjusted life years (DALYs). This concept dates from Zeckhauser and Shepard [3].

2) Common Practices in Health, Transport and Environment and Other Areas

In the health sector, it is common to use QALYs for CE analysis of treatments to find which costs the least per QALY gained. Some countries have fixed monetary values per QALY as benchmarks for medical treatment [4, 5]. Clearly, the use of a fixed monetary value per QALY involves the implicit assumption that each QALY should have the same value to society, in all circumstances, and irrespective of the number of QALYs gained.

In other words, society's valuation of QALYs is fixed. Indeed, empirical work to measure the size of QALYs typically assumes this. This fixed monetary value per QALY (MVQ) is used also in CBA.

This study examines the value of statistical life (VOSL) and MVQ empirical estimation methodologies to better understand the monetary value per QALY, its estimation problems, and the related policy implications.

While it is common to use QALYs, traditionally for CE analysis and MVQ more recently for CBA in health, in other areas such as transport and environment, the typical approach is to use VOSL.

B. Key Question: Monetary Value Per QALY and VOSL – Should There Be a Compatibility?

The VOSL is seen as based on society's willingness to pay (WTP) to avoid a premature death. The monetary value per QALY following the same approach should be the amount of money society is willing to pay to avoid the loss of one premature QALY. The two approaches must be compatible to use them in different contexts depending on the appropriateness and convenience of using a particular approach.

C. Empirical Evidence – Where Does It Come From?

If all QALYs have the same value irrespective of the age and other social and demographic characteristics, and if the VOSL is the discounted present value of the sum of expected future QALYs, then the VOSL should be expected to be decreasing with age. The empirical evidence does not support this view (discussed later).

D. Potential Policy Implications

Constant MVQ suggests that the value to society of preventing the loss of a life is high for children, and gradually reducing with age. This implies that a project saving lives of elderly people would have relatively low social value, whereas saving the same number of children's lives would have considerably higher social value. This suggests a strong social preference for projects saving lives of younger people relative to older people, when considered as individual groups. However, recent empirical studies find that elderly are willing to pay more than younger people due to their saved endowments and fewer years of life expectancy [6].

This paper does not discuss the estimation process for VOSL on which there is a vast literature (see discussion in [7]). The objective here is to analyse the current state of art for estimating MVQ, its problems and impact on cost benefit analysis of health/safety policies.

II. VOSL

The VOSL is the value to society of a risk reduction that is expected to prevent one (unidentified) premature death. To avoid the concept of attaching a monetary value to a life, many researchers prefer to call it the value of preventing a "statistical" fatality (VPF) in order to emphasise the fact that it is actually the (possibly distributionally-weighted) sum of the amounts that individuals are willing to pay for small reductions in the risk of premature death, which, taken over the group of people affected, can be expected to prevent one fatality.

A. Basics and Implications

Empirical work shows that the VOSL varies between countries and also (in real terms) over time within a country. A major reason for international variations in official VOSL is the different methods of estimation [8]. Other factors include the difference in per capita income over time, initial risk levels, and other socio-economic factors [7].

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1) Altruistic Values

The societal value of risk reduction (as a concept) includes more than merely what an individual is willing to pay to reduce their own risk. Other members of society are also willing to contribute; this is the altruistic value. It could contribute as much as a 40% increase in societal VOSL [9, 10].

This quick review raises an issue for policy assessment: if an analytical method (e.g., CBA) is to be used, then it is important that appropriate social values (including those for intangibles) are applied. These values (of life, or health impairment) may vary with a range of parameters, such as age, nationality, or moral character. For instance, New Zealand's no-fault Accident Compensation Scheme was changed to prevent publicly-funded compensation[1] being paid to individuals injured in the course of an illegal activity. They are eligible for limited entitlements[2.]

B. More Complex VOSL Values – Subgroups?

Two sources of variation occur in studies. One is the context in which life risk is evaluated [11]. The willingness to pay (WTP) to reduce a risk is usually higher, where the effect is prolonged pain and suffering. For example, the United Kingdom Health and Safety Executive recommends using twice the VOSL value for cancer prevention than in other fields [12]. Other countries also use higher values for environmental effects (see discussion in [13]).

Some studies find variation by age (an "inverted U-shaped" relationship). This indicates relatively small VOSL for children, increasing to peak at the middle age and then declining. If these VOSL values are based on parents' willingness to pay, then the VOSL might be relatively small for them, since parents with small children are usually young with relatively low income. However, this effect means that VOSL for all members of such families would also be relatively small [14]. The VOSL for families without small children was found to be higher than those with children in this study, based on individual WTP for themselves and their children.

In support of higher values of children's safety, Viscusi [15] notes that "the young have more to lose than the old and the special societal concern with averting risks to children reflects this difference". Even so, since the WTP amount depends on parents' income, VOSL based on parents' WTP may not be as high as the average for all adults [14].

1) Beyond the Faceless Individual

This raises the question of whether the policy is being designed (and thus evaluated) for a "typical" group of citizens – as if there were a "veil" between the policy-makers and those affected, thereby preventing their identities (and other attributes) being known. In other words, should the details of the affected be included in policy decisions, and if so, what (differentiated) social values should be placed on those who benefit?

If we consider societal WTP for various defined subgroups, then of course the values can be different due to the various altruistic considerations from other members of society. People are more likely to be willing to pay for improving safety of others' children than for non-related adults. Such variations in altruism are part of a known wider pattern. For instance, a study in the USA showed that people were more altruistic to residents of the same state, than to those living in other states [16].

Believing that no society would like to value children's safety lower than that for adults, an international workshop involving experts from Austria, Switzerland, France, Sweden, the Netherlands and Malta in 2004 recommended adopting the same VOSL for children as for adults, until child-specific values were available [17].

Some recent study results [6] challenge the view that VOSL is relatively low for people at advanced age. Increases in life expectancy, together with people's ability to be productively active for longer periods, and the level of endowments people of an advanced age acquire over time, mean that the amount of money they would be willing to pay to reduce their risk of death is not necessarily lower than that of the younger. This study finds no evidence that VOSL varies with age. Moreover, the authors report that a study found those older than 60 years would be willing to pay more than the younger group.

III. QALY

QALY is a measure of health status using a perfectly healthy life as a reference point. DALYs measure the burden of a disease or disability in a population by the gap between the population's health and a hypothetical ideal health condition [4]. DALY refers to a disabled status of health and the number of years gained at that, or an improved status. Since the QALY concept appears to be more commonly used, our discussion is focused on the monetary value per QALY. A similar discussion on DALY would also lead to similar conclusions.

[1] Reflecting public views it can be seen as a societal value.

[2] See http://www.acc.co.nz/about-acc/media-centre/frequently-asked-questions/ABA00105#P48_4455

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A. Basics and Implications

A change in health or safety risk generally not only affects the likelihood of death, but also that of impairments, which would reduce the quality of life. Two analytical frameworks are used for studies of such effects. One approach assumes that any impaired status of health can be measured as an appropriate proportion of a healthy life and the monetary value would be that proportion of the VOSL. Another approach is to estimate the MVQ which, in many studies, is not done directly, but calculated from the VOSL, which causes problems discussed below.

Under the first approach, the loss of life quality due to an injury is estimated through WTP-based surveys, where health status is measured relative to a normal healthy life, or through the development of a utility index. Many studies have used the former. The first major study appears to be that of Jones-Lee and colleagues [18, 19].

Under the second approach, the loss of utility due to impairments is estimated through the development of a Health Utility Index [20]. The Health Utility Index is a generic health status index based on both qualitative and quantitative aspects of health. The index is formed after estimating the values of different attributes at different levels of impairment. For example, attributes may include mobility, self-care, pain, sensation, cognition, emotion, etc. and each can be at different proportions of full health. A status of health can then be evaluated by participants in surveys considering how they rate these attributes. In this approach, some combinations of attribute impairment can even be considered worse than death.

An important factor that underlies the second approach is the extent to which the relationship between the assessed proportion of healthy life quality and its value as a proportion of VOSL is linear. The possibility of a non-linear relationship, e.g., a concave or convex relationship, cannot be ignored. The interpretation of the former is that the marginal loss of life quality decreases with the increase in loss of life quality; with the opposite linkage in a convex relationship. While either is theoretically possible, a logical starting point without appropriate empirical data is to assume the value to society of a percentage loss of life quality as the same percentage of the VOSL - linear.

B. VOSL, MVQ Compatibility

The monetary value per QALY (MVQ) is now commonly used in many CBAs. Usually MVQ is estimated either from (empirically) established VOSL or through specific surveys. The first approach is more common, but it demands that the two values are compatible. The latter provides direct estimates of value per QALY. It is an implicit assumption in QALY analysis that MVQ is the same for all, and in all circumstances.

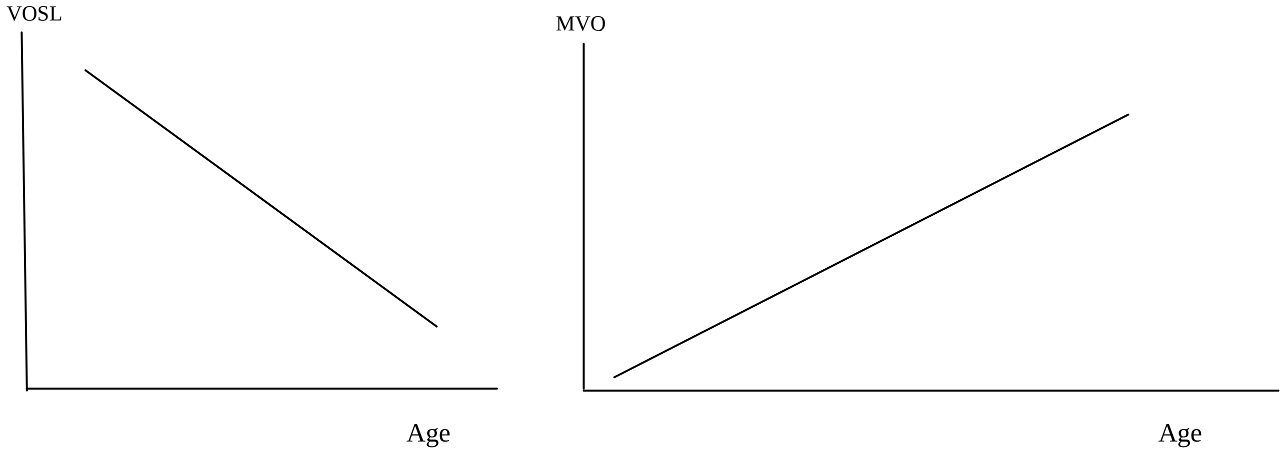
The key step to estimate MVQ from the VOSL is to regard the value of a life year as “the annuity which when discounted over the remaining life span of the individual at risk would equal the estimate of VOSL” [21, p47].

Here the VOSL is assumed to be the discounted present value of monetary values of all future QALYs.

1) What Does This Link Mean? Is It Logical?

The value of a loss of statistical life based on MVQ should be equal to VOSL at any particular age if VOSL is the discounted present value of MVQ for the remaining life expectancy at that age.

Studies have used the empirical VOSL estimates based on transportation risk changes and the average number of years lost in traffic crashes to determine the value per life year using a discount rate, and thus the value of a QALY (for an example see [22]). The validity of this approach depends on the distribution of VOSL by age. This is logically sound only if VOSL varies by age, so that VOSL relates to MVQ and QALYs. Empirical evidence is not straightforward.



a: VOSL by age with constant MVQ b: MVQ by age with constant VOSL

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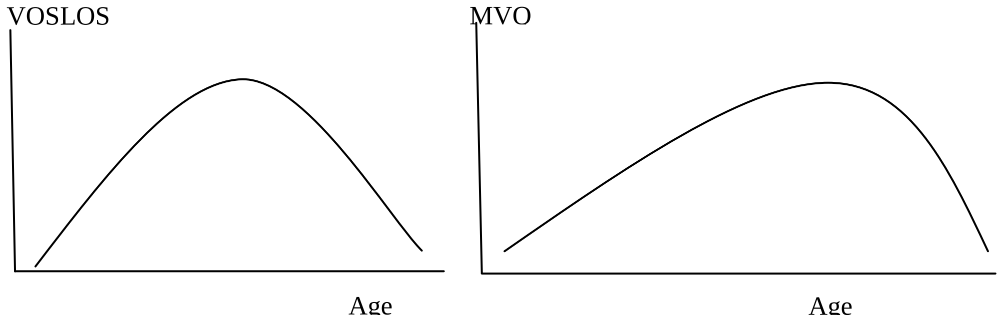

c: VOSL varying by age

d: MVQ by age with varying VOSL

Note: The relationships shown are for illustration only. These may take other shapes.

Fig. 1VOSL - MVQ link

If the value per QALY is independent of age, then VOSL must consistently and significantly decline with age as shown in Fig. 1 (parts a and b), a relationship not found in any study. The VOSL for children would be high and that for elderly people low.

Some studies find an “inverted U-shaped” distribution, e.g., Fig.1 part c, of VOSL by age [19, 23, 24]. Logically, MVQ would show a similar “inverted U-shaped” relationship, e.g., Fig.1 part d, [24]. Other studies do not find any significant variation in VOSL by age [25, 26].

An “inverted U-shaped” relationship between VOSL and age indicates relatively small VOSL for children. But as the previous discussion (Section 2.2) shows, this is not easy to interpret. The VOSL for families without small children is found to be higher than those with children, based on individual’s WTP for themselves and their children [14].

As noted, there is a fundamental problem in this approach since it demands that VOSL differs by age; but empirical work suggests that it may not vary substantially with age. Moreover, using the average age at death, the value per year of life lost (or per QALY) can be considered as specific to that age only and not necessarily valid for all ages. This challenges the idea that VOSL is the discounted present value of future QALYs, unless QALYs vary by age.

Therefore, estimating the value per QALY at the average age, and then applying it to different age groups to estimate the value to society of loss of life quality in those groups is inconsistent with the way the data has been collected. And when this estimate is used to produce the social value of loss of life of elderly people (where loss of life years is small), it gives much lower values than the estimate from VOSL. As discussed, some empirical work finds VOSL for elderly at a high level, perhaps reflecting that they see scarce life years having considerably higher value than do younger people.

Moreover, it is doubtful if this approach is at all valid. When a person is asked about their willingness to pay for safety, do they really think of how many years of life may be gained by reducing a typical risk of death, at his/her age? If this is not what is going on, then the VOSL cannot be considered the discounted present value of remaining years of life expectancy.

The relationship between VOSL and MVQ is not straightforward. Studies have considered VOSL as the aggregate value of years of life expectancy lost [27, 12]. In the simplest form, the value of each year of life expectancy is the VOSL divided by the average life expectancy lost. A model developed by Mason et al. [12] provides a better framework. Mathematically, it is described as $M_i = \alpha E_i^{\beta}$ where M_i is the marginal rate of substitution of wealth for risk of death during the coming year and E_i is the life expectancy of individual i.

Mason et al. [12] estimated the average value of a life year using both conventional models developed earlier [27] and new models developed by them. The new models are more comprehensive and provide a framework for determining the value of a life year at an individual age or age group. As noted by Hammitt [2], the value of a statistical life year is “usually taken as constant over the population within an analysis, in some cases different values have been applied or recommended depending on the age of the affected population or the type of risk”. However, a problem arises when this value is used to estimate the social loss or gain for a specific group, e.g., children or elderly people as has been applied in some cases [22].

Using an “inverted U-shaped” relationship between age and VOSL, Mason et al. [12] estimated the values of α and β for the downward sloping part of the VOSL curve, i.e. above 40 years of age, and assumed that as the average for the whole population. Following their logic, the value per QALY (as the marginal rate of change in VOSL) would be negative for the other part (upward sloping) because VOSL increases when life expectancy decreases.

Mason et al. [12] justify their approach: “since the VPF-age relationship over early years of adulthood is largely a result of a fundamental change in preferences and attitudes rather than a change in an individual’s future hazard rates then estimation of

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the value of a gain in life expectancy should be based only on the time interval over which the VPF is a decreasing function of age" (p. 938-939).

Another explanation of the "inverted U shaped" relationship could be that MVQ varies with age and it increases with age at the early stage of life, as shown by Aldy and Viscusi [24]. Even for the downward sloping part of the VOSL-age relationship, it is not obvious that the MVQ should be the same.

This further demonstrates that MVQ is unlikely to be invariant with age.

2) Direct Estimates

Few studies estimate the value of a QALY directly, based on WTP surveys. Some papers question the validity of using VOSL to estimate MVQ [28, 29] and fixed monetary value per MVQ [30-32].

Another important consideration for WTP per QALY is the variation in health states over time. The value for chronic health states may be different from the value where health varies over time [33].

3) Value by Size of QALY

There is an implicit assumption for a constant MVQ that the value of two QALYs is 2MVQ, and that of three QALYs is 3MVQ, and so on. There are no obvious reasons for this to be the case. Even for the same person, the value of a QALY may change over time, since future health status depends, to a large extent, on the current health status.

It is also possible that MVQ varies with the magnitude of QALYs gained. Mason et al. [12] discussed whether because of attitude and preference of young people, their WTP is lower than what would be expected from the MVQ of future life years.

This would be the case if their future MVQ is discounted at a higher rate. Then the value for marginal QALYs would be lower as the number gained increases. And this would be so if the discount rate depends on how the WTP for future QALYs varies with the quality of health now and that expected.

Mason et al. [12] also note that the probability of death at a certain age is "conditional on having survived to that point". This also applies to the survival curve developed by Hammitt [2] to estimate the value of a life year. This further suggests that the value per QALY is likely to change over time, i.e. the value of the first QALY could be higher than the value of the second QALY.

C. Constant vs. Variable

Both QALY and VOSL are used to evaluate programmes (or treatments) and policies that reduce the risk of death or worsen health conditions. QALYs are routinely used in evaluating risk changes in medical fields, particularly public health, whereas WTP based VOSL is widely used in evaluating risk reductions in transportation and environment [34]. The QALY concept is commonly used in CEs where the cost per QALY gained is compared between options that generally treat the same condition and yield reasonably similar health outcomes. CE is a comparison form of CBA, focusing on the way of achieving a goal with the least cost; it pursues productive efficiency. It cannot be used for allocative or dynamic efficiency gains as it is confined to a single goal.

There can be situations where QALY value is expected to remain constant, even if there is a view that it may vary. In that case, assuming a constant QALY does not cause problems. This can happen, for example, within a narrow age range. Such a situation, where value per QALY is not going to change outside of a narrow range, means a constant MVQ causes little distortion in policy evaluations.

However, it is not without complexity. Care is required to ensure that, e.g., the age range is reasonably homogeneous. Consider the variation in VOSL in a group of elderly people, normally there would be variation in life expectancy between males and females. That would cause a significant variation in male/ female MVQs. On the other hand, if the VOSL is higher for older age females, then a constant MVQ within that range is likely to be appropriate.

This underlines the need to estimate the MVQ for each group separately. As discussed, it is not appropriate to estimate MVQ from VOSL at the average age of death. With no or low variation in VOSL by age, the MVQ is expected to vary with age.

D. Suitability of Using QALY vs. VOSL

An advantage of VOSL is that it can be used in full-blown CBA, and thus supports the quest for wider efficiency analysis. To use QALYs in a CBA, monetary values are needed so that the discounted present value of QALYs could be the same value as the VOSL at any given age.

A link between monetary values per QALY and VOSL is desirable to carry out systematic CBAs of interventions. It is necessary because the loss to society of premature deaths is better measured by VOSL. But for non-fatal injuries and also for lower-quality health status, the QALYs loss varies with the type of non-fatal injury or the health effects of diseases. In such

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cases, estimation of QALYs and their monetary values to society make sense. However, to express the values to society of the loss of health quality and the loss of life in one scale for estimating the total loss, the two measures must be compatible.

In the absence of such values, the estimates of the value per QALY based on VOSL should vary with age. Otherwise, there is scope for inefficient allocation of resources. Besides, the monetary value per QALY may vary for different types and sizes of QALYs gained.

IV. POLICY IMPLICATIONS

The WTP-based VOSL is the value of a risk reduction that is expected to prevent a statistical fatality. The risk reduction can be associated with a transport-related or a health-related death or a fatality from another tragedy. CBA of an intervention would estimate the number of fatalities and loss of life quality that would be prevented as a result of the risk reduction and then compute the monetary value of that risk reduction, as the benefit.

As discussed, conceptually, for an adult, the amount the individual would be willing to pay if they were the life involved is only part of the value. And empirically, patterns show up in altruistic values; these need to be considered in sensible policy decisions.

Realistically, all people do not face the same level of risk, nor they are willing to pay the same amount of money to reduce risk levels to a fixed extent; it depends, for instance, on the amount of resources available. So the marginal rate of substitution of wealth for risk lowering varies between people, along with their wealth. However, for policy evaluations, it is desirable to consider only one VOSL, which should represent the social value of the risk reduction. This suggests that the appropriate value is the VOSL for a representative citizen[3].

While in a CBA the objective is to achieve the potential Pareto optimality, it is not always possible. A policy analysis may need to consider detailed distributions of benefits and costs and those who are involved.

A. Where Can We Use Each of These Measures?

We need appropriate MVQ to value the loss of life quality in CBAs. Even in such circumstances, the assumption of constant MVQ is not necessarily valid. However, as discussed, it is possible that for particular policies, MVQ is unlikely to vary much and thus constant values are no problem.

Values can be derived from specific surveys following [12] or another approach for specific age groups. Once estimated for each age group, they can be used in CBAs.

Similarly, if the group affected by intervention is not representative, specialised VOSL may be apt. Such values could be gathered by WTP survey methods [7].

B. What Issues Remain?

Despite years of investigation of these concepts, practical areas remain to be resolved. A selection follows.

1) Children

Parents' WTP based on VOSL for children is likely to be smaller than average social values. High VOSL for children based on the same MVQ for all is theoretically consistent only if altruistic values explain the difference. Some studies suggest higher altruistic values for children than for adults. However, that would not explain high values estimated from MVQ based on average loss of life years in traffic crashes and a given VOSL for society.

The lack of direct information on VOSL for infants and still-born babies is serious for evaluations of interventions aimed at these groups. Use of inappropriate VOSL could mean inefficient choices.

2) Older People

Similar problems arise when interventions are related to older people; VOSL estimated from a constant MVQ would be very low. However, studies show that accumulation of endowments and longer life expectancy means the WTP for health and safety improvement of elderly people is not lower than the average, and may be higher. Public interventions in health and safety improvements of elderly people would be under-valued, if based on constant MVQ. This would imply too little support for interventions predominantly benefiting older people.

This suggests that using MVQ from VOSL and average loss of life years in traffic fatalities in CBA is systemically inefficient.

[3] This concept might be linked to Rawls' ideas [35].

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It is thus important that more appropriate estimates of MVQ are carried out and the possibility of variation by age and any other social category should be explored. Until such estimates are available, it would be more appropriate to express the loss of life quality in terms of a proportion of VOSL as is commonly done for transport safety.

3) Disasters

Events involving multiple loss of life and the social response to them have consistently suggested that their social value is complicated; in particular, it seems possible that normal linearity in VOSL (three deaths have social cost of 3VOSL) breaks down when many deaths are simultaneous. This topic is associated with CBA work on disasters and needs further investigation as it changes the social value function.

V. CONCLUSIONS

This paper has looked at the logical requirements for using two different concepts in practical policy assessment. A literature review and an analytical approach were used to conclude that the two concepts (VOSL and QALY) have different roles, but are both needed in many instances. This though means they need to be coherent to be used together.

In particular, it was found that a key need is that the empirical data source of their values must be appropriate to prevent incompatible material being used together. This suggests more direct survey work to produce WTP values for QALYs.

Also, the use of CBAs for policies affecting community subsets demands a more granular set of values so the different population subgroups can be reflected in the findings.

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