# Estimating a monetary value of a QALY from existing UK values of prevented fatalities

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## 1. Introduction

Debate about the monetary value of a quality adjusted life year (QALY) has existed in the health economics literature for some time. This has centred around debates as to the link between cost effectiveness and cost-benefit analysis[1-5] leading to calls for "information about the willingness to pay per unit of health effects to decide whether benefits exceed costs or not"[5]. More recently, concern about such a value has arisen in health technology assessment panels internationally. For example, in the UK, through evaluating single interventions in terms of their incremental cost per QALY gained, it is important for the National Institute for Clinical Excellence (NICE) to know what value to attach to such QALY gains. Similarly, as progress is made in measuring National Health Service (NHS) productivity in terms of reduced mortality, improvements in quality of life, and, possibly, QALYs, questions about the value to attach to such gains will, again, be raised.

One way to estimate such a value is to 'model' it from the existing value of preventing a statistical fatality (VPF) currently used in UK transport safety policy. The aim of the research presented in this paper is to report on such a modelling exercise. In the first section of the paper, the origins of the baseline VPF to be used in most of the calculations is presented, focussing in particular on the historical development of contingent valuation methods in this context. Two basic approaches used to convert from a VPF to a value of a QALY are then outlined. This is followed by a section focussing on sources of data for converting from the VPF to the value of a QALY according to these approaches. The results from the approaches are then outlined along with sensitivity analyses adjusting for quality of life and discounting. In the final section, caveats are discussed and some recommendations made as to future research and possible values to use pending the completion of such research.

## 2. Conceptual and theoretical issues

The notion of using contingent valuation methods to elicit a VPF (or "value of statistical life" or, VOSL) is closely related to the challenge of valuing a QALY (or "healthy year"). Before proceeding to outline the two approaches to be used for estimating a VPF-based value of a QALY and the data sources for our estimates, it is necessary to outline the source of the UK VPF. This monetary measure is based on the method of "willingness to pay" elicited in surveys by use of hypothetical WTP questions. This is essentially the contingent valuation approach in which respondents state values for the good in question rather than reveal them as a result of real market-based choices. Although revealed preference data are available internationally[6], they are not used routinely in UK government policy making and are not the focus here.

Under the "willingness-to-pay" approach to the valuation of safety, one first seeks to establish the maximum amounts that those affected would individually be willing to pay for (typically small) improvements in their own and others' safety. These amounts are then simply aggregated across all individuals to arrive at an overall value for the safety improvement concerned. The resultant figure is thus a clear reflection of what the safety improvement is "worth" to the affected group, relative to the alternative ways in which each individual might have spent his or her limited income.

Since 1988, the value of both fatal and non fatal casualties has been based on a consistent WTP approach. A report in *Road Accidents Great Britain: 1997*, showed a range of £750,000 to £1,250,000 to be an acceptable value of preventing a road accident fatality. The midpoint of this range was adopted as the VPF. The values are updated every year using an index which reflects inflation and real per capita economic growth.

To illustrate how the VPF is derived, assume that a group of 100,000 people benefit from a safety improvement that reduces the probability of premature death during the coming period by, on average, 1 in 100,000 for each member of the group. The expected number of fatalities within the group during the period will therefore be reduced by one and the safety improvement is described as involving the prevention of one statistical fatality. If the average WTP across the group for this safety improvement is £w the aggregate WTP is given by £w x 100,000. This figure is naturally referred to as the WTP-based VPF. Currently, the value used (at 2003 prices) is approximately £1.3 million.[7] This would correspond to a mean individual WTP of approximately £26 for a 2 in 100,000 reduction in the risk of death in a car accident during the coming year and is the basic value used in the work reported in this paper.

Before moving on, three points are worth noting. First, clearly, in the above example, average individual WTP, £w, for the average individual risk reduction of 1 in 100,000 is a reflection of the rate at which people in the group are willing to trade off wealth against risk "at the margin", in the sense that the trade-offs typically involve small variations in wealth and small variations in risk. Empirical work on the valuation of safety thus tends to focus upon these marginal wealth/risk trade-off rates.

Second, on a somewhat more cautionary and related note, it is important to appreciate that, defined in this way, the VPF is not a "value (or price) of life" in the sense of a sum that any given individual would accept in compensation for the certainty of his or her own death – for most of us, no finite sum would suffice for this purpose, so that in this sense life is literally priceless. Rather, the VPF is an aggregate WTP for typically very small reductions in individual risk of death (which, realistically, is what most safety improvements really offer at the individual level). Similarly, in basing a WTP-based monetary value of a QALY on the VPF, the value of a QALY can also be viewed as a group-aggregate WTP for *marginal* gains in quality of life or life expectancy given that, at least in the case of a randomly-selected sample of the public, such gains *will* typically be marginal, though of course the same cannot necessarily be said for those already suffering from health impairments. This is close to the argument made for taking an insurance-based approach to valuing publicly-provided health care whereby individual members of the community are informed about the probability of needing care as well as the probability of it being successful.[8,9]

Third, it is important to note that doubt has been cast upon the reliability and validity of WTP values for safety derived through the above direct contingent valuation method. As well as sequencing and framing effects, a prominent issue has been the lack of ability of the method to account for embedding and scope. That is, respondents tend to view safety improvements as a "good thing" and, therefore, will often state much the same WTP for different sizes of risk reduction, whether for fatal or non-fatal injuries.[10-12] It may be unreasonable to expect respondents to give accurate answers to hypothetical questions which involve direct trade-offs between wealth and small reductions in risk. Therefore, Carthy et al. suggested a less-direct contingent valuation/standard gamble (CV/SG) "chained" approach which breaks down the valuation process into a series of more manageable steps involving the chaining together responses to WTP and SG questions.[13] Using the CV/SG chained approach, respondents are initially presented with a question asking them about their WTP for the certainty of a complete cure for a given non-fatal road injury and their willingness to accept compensation for the certainty of remaining in the impaired health state (the combination of which, based on some reasonable assumptions about underlying preferences obeying minimal conditions of consistency and regularity, it is argued, gives a reasonable estimate of the marginal rate of substitution of wealth for the risk of the non-fatal injury). In a second stage, respondents are presented with a SG question aimed at determining the ratio of the health state value for death over that for the non-fatal injury. The monetary value from the first stage can then be combined with the ratio from the second stage to obtain a WTP for reduced risk of death. The current UK Department for Transport VPF was derived using this approach.

The CV/SG chained approach is, perhaps, more realistic in that most people can relate to giving a monetary value for avoiding a non-fatal injury of the sort they are likely to have experienced, and people are not asked directly to place a monetary value on a small risk reduction. The method has shown promise in terms of being subject to less marked embedding effects and other biases than earlier approaches.[13]

## 3. Possible approaches to converting the VPF to a value of a QALY

Two main approaches have been developed to estimate a value of a QALY using the current VPF combined with a set of simplifying assumptions. These two approaches are distilled as the most realistic from the seven outlined in a recent report to NCCRM.[14] In this section the assumptions underlying each approach are outlined before describing each approach in more detail.

### *3.1 Simplifying assumptions*

In Highways Economics Note 1: 2004, the current VPF net of medical and ambulance costs as used by the Department for Transport is £1,311,490 (or $1.311 \times 10^6$) in 2003 prices.[7] This would correspond to a mean individual WTP of £26.23 for a 2 in 100,000 reduction in the risk of death in a car accident in the coming year. For approach 1 remaining life expectancy is taken to be 32 years. (See section 4.1 for an explanation of how this is derived). This remaining 32 years is initially assumed to be in full health. Thus, to illustrate the approaches, we first demonstrate how they convert the VPF into the value of a life year. Later in the paper we will further develop these approaches to estimate the value of a QALY, and incorporate discounting and adjustments for net output.

The first approach is based on the assumption that individual's value improvement in their own safety purely in terms of the number of years of life they will lose (taking account of risk and quality of those years) as a result of premature death. Although this represents just one approach, it can be interpreted in four different ways (see below), which is important for assessing the validity of the calculations. The second basic approach embodies the notion that valuations also arise in part from such QALY gains, but that they also include a basic value of living *per se*. Two models based on this second approach are described.

### *3.2 Approach 1*

Possibly the simplest and most natural way to think about this issue is to appreciate that the VPF is in fact an aggregate WTP across a large number of people for a risk reduction that will result in the prevention of one premature death during the coming year.[15] For our representative individual this would be the avoidance of the loss of 32 years of life expectancy. The WTP-based monetary value of each of these 32 years is, therefore, given by:

$$V_{1a} = \frac{£1.311 \text{ x } 10^6}{32}$$

$= £40,445$

Under this approach the WTP based value of a QALY would therefore be £40,445. (Note that the values of a life year presented in this section may not exactly match the preceding formulae or calculation given due to rounding errors. This is so that the values for $V_{1a\text{-}d}$ and $V_{2ab}$ match those presented in the results section, which are based on calculation using <u>exact</u> VPF and remaining life expectancy data, such calculations having been slightly simplified here for ease of exposition.

Another way of looking at this is to approximate the gain in life expectancy, $\Delta E_{y,}$ resulting from, say, a 2 x $10^{-5}$ reduction in the risk of death during the coming year for an individual with 32 years remaining life expectancy as:

$$\Delta E_y = 32 \times 2 \times 10^{-5}$$
$$= 6.4 \times 10^{-4}$$

which is equivalent to 0.2367 days.

Using the assumption that the mean individual WTP for a $2 \times 10^{-5}$ risk reduction is £26.23, we could then infer a WTP-based value of a QALY in two ways; either as an individual valuation or as a group aggregate.

If we assume linear proportionality in the relationship between individual WTP and increasing life expectancy then to obtain an individual WTP-based value of a QALY we simply multiply £26.23 by $\frac{365}{0.2367}$ to give
$V_{1b}$ = £40,445.

Alternatively we could aggregate WTP for 0.2367 days gain in life expectancy across $\frac{365}{0.2367}$ different individuals to give the same money value as above of

$V_{1c}$ = £40,445.

A fourth way of looking at approach 1 is, again, to use the assumption that mean individual WTP for a $2 \times 10^{-5}$ reduction in the risk of premature death is £26.23 for our individual with 32 years of remaining life expectancy. Thus, individual WTP for a reduction in the risk of losing each one of the remaining 32 years is given by:

$$W = \frac{£26.23}{32}$$

This means that aggregate WTP across 50,000 people for a 2 x $10^{-5}$ reduction in the risk of losing one year of life expectancy is given by

$$\frac{£26.23}{32} \times 50{,}000$$

$V_{1d}$ = £40,445

However, the 2 x $10^{-5}$ reduction in the risk of losing one year of life expectancy for each person in a group of 50,000 results in a saving of 50,000 x 2 x $10^{-5}$ = 1 year of life expectancy, so that this is also a group aggregate WTP figure for the value of a QALY.

Building on a point introduced at the end of section 3.1, it is worth reinforcing at this stage that although approaches 1a-1d all produce the same value of a QALY, there is a distinction between those produced as an individual valuation and those which give a group aggregate value. For an individual valuation we are assuming linear proportionality between individual WTP and the size of the risk reduction/gain in life expectancy. However, it is more likely that the relationship will be strictly concave because of income effects and binding mental accounting constraints. For this reason, taking a group aggregate approach (as in approaches 1c and 1d) appears to be a more credible option where the group aggregate WTP would lead to an expected gain of one year of life expectancy. This is important, because although one can reasonably criticise earlier estimates of the value of a QALY, which have all been based on approach 1a (see section 5.3), the more sound reasoning underlying approaches 1c and 1d combined with the knowledge that all approaches lead to the same result, would actually lend substantially greater credence to such earlier results.

### *3.3 Approach 2*

In approaches 1a-1d we assume that WTP for a reduction in risk of premature death is the same as the WTP for the preservation of a given number of equally valued future life years. However, many peoples' WTP to reduce mortality may depend on other factors not directly related to time or future life span, such as a wish to see their family grow up or the pain caused to others if they die.[16] It may be more appropriate to model the relationship of individual WTP for safety as comprising a lump sum ($\alpha$), reflecting the pure value of living *per se*, and a component ($\beta E_i$) that depends on remaining life expectancy.

The simplest version of such a model would take the form:

$$M_i = \alpha + \beta E_i + u_i \qquad (1)$$

where $M_i$ is the $i^{th}$ individual's marginal rate of substitution of wealth for risk of death during the coming year in £ sterling (the population mean of which is taken to be the VPF under the WTP approach), $E_i$ is the $i^{th}$ individual's remaining years of life expectancy and $u_i$ is a random error term.

However, this would assume that the value of living *per se* ($\alpha$) is independent of remaining life expectancy, meaning that the value of living would be of the same order of magnitude for an 80 year old as it is for a 40 year old, which is highly improbable. Therefore a model was devised which allowed the value of living *per se* to decline with age past the age of 40, approaching zero as life expectancy approaches zero.

This can be represented by:

$$M_i = \alpha E_i^{1/2} + u_i \qquad \alpha>0$$

The problem with this model is that although it is reasonable to assume that above some level the pure value of living *per se* will be a declining function of age, it is still reasonable to assume that this value will remain strictly positive (though probably very small) however old a person is.

Thus, this model takes the form:

$$M_i = \alpha + \beta E_i^{1/2} + u_i \quad \alpha, \beta>0 \qquad (2)$$

In this equation the value of α is not, as in the linear form of equation (1), the value of living *per se* for everyone of any age over 40. It is the value of living for an individual close to death. To calculate the α for someone not close to death then we must take the tangent of the curve at the remaining life expectancy for that person and extend it back to the y axis where the intercept with that axis then gives the value of living *per se* for the person concerned.

The $M_i$-versus-age relationship estimated in three UK studies[10,13,17] is essentially an inverted-U shape, peaking in middle age. As a first approximation it would seem appropriate to take the average of $\frac{M_i}{\overline{M}}$ - where $\overline{M}$ is the population mean of $M_i$ – as being about 0.45 for an 80 year old and about 1.36 for a 40 year old. Given this, taking $\overline{M}$ = £1.311 million, assuming that remaining life expectancy for a 80 year old is effectively zero and a zero discount rate with no adjustment for declining quality of life in later years, would give, from equation (2):

$$E_i = 0 \Rightarrow \alpha = 0.45 \text{ x } 1.311 \text{ x } 10^6 \quad (3)$$

$$= £590{,}171$$

Strictly, if remaining life expectancy is zero then this is equivalent to being dead and there can logically be no value of living *per se*. In this instance, however, we are approximating remaining life expectancy to zero for the purpose of mathematical convenience. Such an assumption is intended to represent a situation where an individual has a very short remaining life expectancy which may even be only a few days.

Assuming that for a 40 year old remaining life expectancy is 39 years, then for a 40 year old:

$$E_i = 39 \Rightarrow (590{,}171) + (\beta \text{ x } 6.2433) = 1.36 \text{ x } 1.311 \text{ x } 10^6 \quad (4)$$

Subtracting (3) from (4) it therefore follows that:

$$\beta = \frac{0.91}{6.2433} \text{ x} 1.311 \text{x} 10^6 \quad (5)$$

$$= 1.9116 \text{ x } 10^5 \quad (6)$$

Hence from equations (2), (3) and (6)

$$M_i = (5.90 \text{ x } 10^5) + (1.9116 \text{ x } 10^5) \text{ x } E_i^{\frac{1}{2}} \quad (7)$$

From which it follows that:

$$\frac{dM_i}{dE_i} = ½ \text{ x } 1.9116 \text{ x } 10^5 \text{ x } E_i^{-\frac{1}{2}} \quad (8)$$

$$= 9.558 \times 10^4 \, E_i^{-\frac{1}{2}} \qquad (9)$$

Given that $E_i$ varies across the UK population, there exists a probability density function giving the proportion of the population having each particular value of $E_i$. The general form of this density function can be derived from statistical life tables. For the sake of simplicity it will be assumed that the probability density function for $E_i$ takes the form:

$$\rho\ (E_i) = \gamma\, E_i^{\frac{1}{2}} \qquad (10)$$

which entails that

$$\int_0^{39} \gamma\ E_i^{\frac{1}{2}}\ dE_i = 1 \qquad (11)$$

so that

$$\gamma \left[\frac{2}{3} x E_i^{\frac{3}{2}}\right]_0^{39} = 1 \qquad (12)$$

Hence

$$162.2362\ \gamma\ = 1 \qquad (13)$$

from which it follows that

$$\gamma\ = 0.006164 \qquad (14)$$

From equations (9), (11) and (14) we then have

$$V_{2a} = \int_0^{39} 9.558 \times 10^4 \times E_i^{-\frac{1}{2}} \times 0.006164 \times E_i^{\frac{1}{2}}\ dE_i \qquad (15)$$

$$= \quad [589.1551 E_i]_0^{39} \qquad (16)$$

$$= \quad 22{,}964 \qquad (17)$$

Hence

$$V_{2a} = £22{,}964 \qquad (18)$$

As already pointed out, in this approach we make the assumption that remaining life expectancy at 80 is zero. This assumption is, of course, questionable based on current UK life expectancy data. Likely remaining life expectancy at age 80 is around 8 years. This is incorporated into another version of approach 2 where life expectancy at age

80 has been increased to 8 years. This leads to an apparent inconsistency between the two versions. If we change the upper age to 88 in approaches 2a, however, this would lead to another inconsistency whereby the basis of the valuations at the upper end of the age range would be 88 for 2a, and 80 (with 8 years survival) for 2b below. Therefore, we have retained the perspective being that of an 80 year old (with different expected survival across the methods).

Moving onto approach 2b, we assume here that the pure value of living *per se* is inversely proportional to age (in contrast to approach 2a where the relationship is decreasing and concave). To this pure value of living *per se* is then added a term that is proportional to remaining life expectancy, $E_i$.

The model takes the form:

$$Mi = \frac{\alpha}{80 - E_i} + \beta E_i \qquad (19)$$

The value of $E_i$ used to calculate the value of living *per se* (in the first part of this formula) will be the same for all of the assumptions we make concerning discounting and quality of life adjustments and will be based on undiscounted life years. The value of $E_i$ used to calculate $\beta E_i$ (in the second part of the formula) will differ depending on whether we are including discounting and quality of life.

To estimate initial values of α and β, as in approach 2a, the $\frac{M_i}{\overline{\overline{M}}}$ values derived from the 1997 Department for Environment, Transport and the Regions sample survey are again used whereby the ratio is equal to 1.36 for a 40 year old and 0.45 for an 80 year old. We also make the assumption that at age 80 remaining life expectancy is 8 years based on government actuary department data on remaining life expectancy (see section 4.1 for further explanation).

Thus, for an older person:

$$\frac{\alpha}{80 - 8} + 8\,\beta = 0.45 \text{ x } 1.311 \text{ x } 10^6 \qquad (20)$$

and for a 40 year old:

$$\frac{\alpha}{80 - 39} + 39\,\beta = 1.36 \text{ x } 1.311 \text{ x } 10^6 \qquad (21)$$

Multiplying both sides of (20) by $\frac{72}{41}$ gives

$$\frac{\alpha}{41} + 13.31\,\beta = 0.79 \text{ x } 1.311 \text{ x} 10^6 \qquad (22)$$

and subtracting (22) from (21) gives

$$25.6\,\beta = 0.57 \text{ x } 1.311 \text{ x } 10^6$$

$= 0.68695 \times 10^6$

$$\beta = £28{,}877 \qquad (23)$$

To calculate α substitute β in (21):

$\alpha = 6.95 \times 10^7 - 4.39 \times 10^7$
(24)

$= 26{,}993{,}945$

Although the β in equations (19)-(24) could be interpreted as the monetary value of a QALY, this would be open to the criticism that this coefficient should instead represent the mean over the relevant population of the *full* derivative of $M_i$ with respect to $E_i$.

Thus, using the values of α and β derived above in equations (23) and (24) and, for the sake of analytical tractability, assuming the probability density function takes the form $\rho(E_i) = \frac{1}{39}$ for those between the ages of 40 and 80, it then follows that the monetary value of a QALY will be given by:

$$V_{2b} = \int_8^{39} \frac{dM_i}{dE_i} \frac{1}{39} dE_i \qquad (25)$$

From (19) we have

$$\frac{dM_i}{dE_i} = \alpha(80 - E_i)^{-2} + \beta \qquad (26)$$

$$= 26.994 \times 10^6 (80 - Ei)^{-2} + 28{,}877 \qquad (27)$$

Hence

$$V_{2b} = \int_8^{39} \left[26.994 x 10^6 (80 - E_i)^{-2} + 28{,}877\right] \frac{1}{39} dE_i \qquad (28)$$

$$= \frac{31}{39} x 28{,}877 + \int_8^{39} 26.994\ x 10^6 (80 - E_i)^{-2} \frac{1}{39} dE_i \qquad (29)$$

$$= 22{,}953 + \int_8^{39} 692{,}152 (80 - E_i)^{-2} dE_i \qquad (30)$$

$$= 22{,}953 + \left[692{,}152 (80 - E_i)^{-1}\right]_8^{39} \qquad (31)$$

$$= 22{,}953 + \left[16{,}881 - 9{,}613\right] \qquad (32)$$

$V_{2b} = £30{,}222$

## 4. Data sources

### *4.1 Estimating remaining life expectancy*

All the approaches described above require an estimate of remaining life expectancy. This is used to reflect the life years lost from a fatality and facilitate the conversion of the VPF into a value per life year.

Approach 1 compares the VPF with a representative life expectancy for the sample population used to elicit the VPF. Details of the ages and gender of the sample's members are not available. However, it is known that the sample was randomly drawn from the adult population. The mix of the sample population is assumed to reflect the adult population for Great Britain as given by data from the Office for National Statistics. This suggests an average age for males of 46, an average age for females of 48, and a gender mix of 52%:48%, the majority being female. Weighted by population shares, the mean of male life expectancy at 46 and the female life expectancy at 48 gives the life expectancy used in approach 1.

Approach 2 assesses the value per life year in relation to two specific ages – 40 and 80. The life expectancy at 40 is the average of the male and female life expectancies at 40 weighted by the gender shares of the population at 40. Likewise, the life expectancy at 80 is the average of the male and female life expectancies at 80 weighted by the gender shares of the population at 80.

Life expectancy by age and gender is calculated using the Interim Life Tables produced by the Government Actuary's Department (GAD) (www.gad.gov.uk). These tables give, by gender and age, the mortality rate (represented by GAD using the notation $q_x$) between age x and age x+1 (the probability that a person aged x will die before reaching age x+1).

Using a 40-year-old male as an example; the mortality rates are first used to calculate the probability of living through each potential year of life from 40 to an assumed maximum of 100 (the GAD Life Tables do not cover ages above 100). The probability of a 40-year-old living through to 41 is simply 1 minus the male mortality rate at 40; the probability of a 40-year-old eventually surviving through his 41$^{st}$ to 42$^{nd}$ birthday is 1 minus the male mortality rate at 41 weighted by the probability he lives to 41 (i.e. 1 minus the male mortality rate at 40), and so on. The sum of the probabilities of living through each potential year of life between 40 and 100 is the estimated life expectancy of a 40-year-old male. The same broad methodology is used to calculate life expectancy for other ages and gender.

It would be simpler to use GAD's directly published life expectancies rather than calculating them indirectly from GAD mortality rates. However, this method would cause problems when the approaches are modified to take into account quality of life and discounting. For instance, the section below explains how the approaches can produce a value per QALY. In this context, using the direct life expectancy figure would effectively assume a 100% chance of people experiencing the relatively high-quality younger life years up to that age and then a 0% chance of experiencing the relatively low-quality older life years beyond that age. In fact, not everyone will live to the age implied by the direct life expectancy and some will live beyond it. This method would therefore overestimate expected QALYs and, thus, underestimate the QALY value.

*4.2 Estimating a value per quality adjusted life year*

The worked examples in section 3 show how the two main approaches can convert the VPF into a value per life year. These approaches can be modified to convert the VPF into a QALY value by replacing life expectancy in the formulas with quality adjusted life expectancy.

The method for calculating expected QALYs is very similar to the life expectancy calculations explained above. The only modification to the methodology is to apply a quality of life weight to the probability of each potential year of life. The sum of the quality adjusted probabilities of living through each potential year of life gives the expected QALYs.

The quality of life weights, along a scale from zero for death to “1” for full health, are taken from *UK population norms for EQ-5D.*[18] (Although the current UK EQ-5D tariff includes states worse than death, which would receive a value below zero, such states are not relevant to the population considered here). This gives utility values, elicited using the EQ-5D, by age and gender. The EQ-5D is a generic measure of health status which defines health in terms of five different domains; mobility, self-care, usual activities, pain or discomfort, and anxiety and depression. Each domain has three levels; no problems, some problems or severe problems. The combination of attributes and levels produces 245 health states including “dead” and “unconscious”. A scoring system, based on the time trade off, is available which gives a utility value for each of the 245 health states.

*4.3 Discounting and adjusting for net output*

Both the value per life year approaches and the value per QALY approaches have also been modified to take into account discounting at a rate of 1.5% (as per the recommended rate of pure time preference given in Her Majesty’s Treasury Green Book). This 1.5% discount rate is one part of the overall discount rate of 3.5% recommended in the Green Book. The full discount rate is made up of two parts; a rate of pure time preference and a part which reflects the fact that per capita consumption is expected to grow over time implying future consumption will be plentiful relative to current consumption and, thus, will have a lower marginal utility of consumption. However, theory shows that a WTP-based VPF can be expected to grow at much the same rate as the marginal utility of consumption declines and so we have only used a discount rate which reflects the rate of pure time preference in our calculations.

The 1.5% discount rate has been applied to the series of (quality adjusted) probabilities of living through each potential year of life. The discounted life expectancies and discounted QALY expectancies then replace life expectancies and QALY expectancies in the calculations.

Net output is usually assumed to be 10% of gross output.[19] Therefore, as part of the sensitivity analysis, the value of a QALY is estimated using both the VPF as referenced in the current Highways Economics Note 1 and as this value minus 10% of gross output, reducing the VPF to £1,266,379.

## 5. Results

The results from each of the approaches are shown in Table 1.

**Table 1 Estimates of the value of a life year and a QALY**

| | | Value per…… | | | |
|---|---|---|---|---|---|
| | | Life Year | | QALY | |
| | | Undiscounted | Discounted | Undiscounted | Discounted |
| Full VPF | Approach 1 | 40,445 | 51,759 | 51,323 | 65,142 |
| | Approach 2a | 22,964 | 30,663 | 28,465 | 37,530 |
| | Approach 2b | 30,222 | 40,521 | 34,908 | 46,144 |
| VPF excluding net output | Approach 1 | 39,054 | 49,978 | 49,558 | 62,901 |
| | Approach 2a | 22,174 | 29,608 | 27,486 | 36,239 |
| | Approach 2b | 29,182 | 39,127 | 33,708 | 44,556 |

Values were estimated for each approach using a number of different assumptions as to whether quality of life and discounting were incorporated, along with the basic methods presented in sections 3.2 and 3.3.

Looking at the results for the case where no quality of life adjustments or discounting have been made we can see that the results from approach 2 show lower values of a life year and QALY than those estimated using approach 1 which is what would be expected. This would be because, in approach 2, the VPF incorporates a value of life *per se* element; therefore QALYs explain a lower total part of the VPF and have a lower apparent value.

Discounting and quality of life adjustments lead to higher values than those which are based only on undiscounted life years. This is because the initial value is based on the ratio of VPF to the number of life years. As we introduce quality adjustments or discounting the denominator falls (i.e. the number of discounted QALYs is less than the number of life years) and the ratio increases. In QALY terms, this follows because, by definition, a life year can never generate more than one QALY and typically it would generate less than one QALY. As such, it would make sense that that one QALY would be valued higher than one life year.

The results calculated using the VPF excluding net output are lower than those using the full VPF but follow the same pattern when discounting and quality of life adjustments are made.

For the full VPF the lowest value is given by approach $2_a$ when there is no discounting or quality of life adjustments and is £22,964. The highest value comes from approach 1 with discounting and quality of life adjustments and is £65,142.

The values of living *per se* estimated for approaches $2_a$ and $2_b$ are shown in Appendix 1. The value of living *per se* is a constant for approach $2_a$ but varies with remaining life expectancy for $2_b$.

## 6. Discussion

### *6.1 Further interpretation of results*

Two main approaches have been used to estimate the value of a QALY. Different perspectives can be taken on the value produced by approach 1. The difference between them is that approaches 1a and 1b are based on an individual valuation whereas approaches 1c and 1d are based on a group aggregate. The latter two, whereby the risk reduction across a large group of people would result in an expected gain of one year of life expectancy, are more credible.

Approach 1 is based on the assumption that WTP for the reduction in the risk of immediate premature death is equal to the WTP for the preservation of a given number of equally valued future life years. However, it may be that WTP for a reduction in the risk of death will be based on other factors. Approach 2 incorporates this by including a value of living *per se* component along with a component which depends upon remaining life expectancy. The values arising from approach 2 are, thus, lower than those from approach 1 because part of the VPF reflects a value of living element and QALYs or life years explain only a fraction of the total.

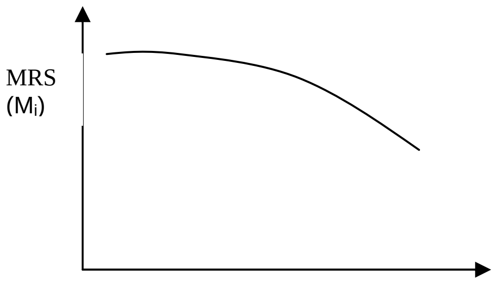
Another way of looking at this is in terms of QALY-types. By spreading the value of avoiding a risk of immediate premature death across all future QALYs gained, it could be argued that the higher values elicited under approach 1 are for "rule-of-rescue"-type, or life saving QALYs. On the other hand, what is revealed by approach 2 is that beyond the basic value of living *per se* QALYs are valued less because they arise merely from life extension and not the immediacy of life-saving. The sense of this is illustrated by transferring the "rule-of-rescue" logic to approach 2; if this were done, then the QALY gains associated with the value of lives saved would have to be supplemented with the basic value of living *per se*. To illustrate, taking a 60 year old (simply because such a person would fall half way between the approximate ages of 40 and 80 which have been used in many of our calculations), if the recommended value to emanate from approach 1 were £64,000 per QALY (see 6.4 below) and this person had 20 more years to live, his/her value of life would be estimated at £1.28M. Using approach 2b, Table 3 in Appendix 2 reveals a basic value of living for a 60 year old as £429,000 to which we would add 20 more years valued at £42,500 each (see 6.4 below) to arrive at value of £1.279M. Thus, the approaches arrive at valuations which are almost identical.

In practical terms, these arguments would imply that QALYs arising from emergency services would receive a higher value than QALYs arising from, say, elective surgery such as a coronary artery bypass graft which extends life but is not immediately life saving. This raises the possibility of a third type, which is QALYs arising from quality-of-life-enhancement only. Our calculations of this value of a QALY have not been included in the main text of the paper because we are less sure of them. However, the calculations are contained in Appendix 2. Based on these, we get, as one might expect, an even lower value of a QALY of £6000-21,000.

### *6.2 Caveats*

The VPF used in this paper is based on a value estimated through an empirical study on a population sample. The results from this study show the relationship between the marginal rate of substitution of wealth for the risk of death ($M_i$) and age as an inverted U shaped peaking in middle age. If perfect capital markets existed theory would predict that the relationship between $M_i$ and age would take the form outlined in Figure 1.[20]

**Figure 1 MRS–life expectancy relationship with perfect capital markets**




There would be a strictly downward sloping relationship between $M_i$ and age on the basis that younger people would have access to borrowing against future life time earnings. In reality, younger people do not have access to borrowing which leads to the inverted U shaped relationship and our results, based on real data, reflect the current regulatory situation.

A further point to note relating to the inverted U shaped relationship is that it implies for a 70-80 year old that the VPF is approximately 0.45 times the population average VPF whilst for a 40 year old it would be around 1.36 times the population VPF. This would give a ratio of around 3:1 (i.e. 1.36/0.45). However, the 40 year old/80 year old QALY ratio would be around 8:1 (i.e. a 40 year old facing imminent death would expect eight times the QALY gains of an 80 year old in the same situation). This difference in the ratios may indicate that there is some sort of "pure value of living" being incorporated into individuals' estimates of the VPF in that there is a basic value of living incorporated into each of the monetary values; thus, the ratio of such values is not quite as exaggerated as that for QALYs alone. This is further indicated by the empirical evidence which shows that the VPF at age 40 is around 1.36 times the population mean VPF while the VPF at age 60 is about 1.04 times the population mean giving a $VPF_{60}/VPF_{40}$ ratio of 0.8. The ratio of life expectancy at age 60 to life expectancy at age 40 is 0.5 so that the VPF is not proportional to remaining life expectancy which is also consistent with a "pure value of living". Another way of explaining this is that, as death approaches, an individual's VPF becomes less sensitive to the number of expected remaining QALYs and some form of innate and underlying attachment for living becomes relatively more prominent in the individual's deliberations. .

### *6.3 Value of a QALY literature*

The suggestion for using the VPF to calculate a WTP per QALY for use in CEAs is not new[21], and there have been a small number of studies which have attempted to do this. The calculation suggested has been, as in approach 1, to divide the VOSL by the discounted QALYs gained for a saved life. For example, Swedish data produce an estimate of a WTP per QALY gained of around US $90,000[21] (approx. £57,000 in 2003 prices).

An examination of studies which have calculated the value of a life was undertaken by Hirth et al. in an attempt to work out an implicit value of a QALY.[22] Results were categorised by the type of estimation process used to estimate the value of life e.g. contingent valuation, human capital and revealed preference. The value of a life estimates were converted into the value of a QALY using a method similar to approach 1. For contingent valuation studies the median value of a QALY was $161,305 in 1997 U.S dollars (approx. £102,000 in 2003 prices). This estimate was based on eight contingent valuation studies which asked either WTP for risk reduction or willingness to accept risk questions. The eight studies came from the UK, Denmark, France, Canada and the US. The overall median value of a QALY from the revealed preference and contingent valuation studies was $265,345 (approx. £168,000 in 2003 prices). Sensitivity analysis showed that the values were sensitive to the discount rate but not to the remaining life expectancy or the assumption of fixed duration of life.

In an Australian study, the value of a QALY was estimated from the value of a statistical life using a method similar to approach 1.[23] Working on the basis of trying to estimate the value of a QALY for Australia which has no general VPF, a VPF of A$2.5 million was estimated using overseas studies and values. Using this VPF of A$2.5 million and the assumptions of 40 years of remaining life expectancy and a discount rate of 3%, would give a value of a QALY of A$108,000 (approx. £51,000 in 2003 prices).

Each published study that has attempted to estimate the value of a QALY has used the method we have described as approach 1. However, none of the studies distinguish between linear proportionality and group aggregate approaches, or attempt to estimate values of a pure value of living. Although each of these studies have estimated a value of a QALY using a method like approach 1, the type of information on remaining life expectancy and quality of life is not the same. The study by Hirth et al.[22] is the most comparable to the one outlined in this paper. They incorporate information from standard US life tables on remaining life expectancy and quality of life data from the Beaver Dam health outcomes study[24] and apply them in the same way we have described in previous sections to estimate a WTP for a QALY value. From the information provided in the Swedish study, it is not possible to establish how remaining life expectancy was estimated and if it is comparable to the way it has been estimated in our study. However, their quality of life data also comes from the EQ-5D using the Swedish tariff.[21] The Australian study is based on hypothetical data on the VPF and remaining life expectancy. The value of a life year estimate is not adjusted for quality of life as it is assumed that one QALY is equal to one year in full health.[23]

The VPF used in each of these three studies will have an impact as to how much larger or smaller the estimate of the value of a QALY will be in comparison to those presented in section 5. The Swedish study uses a VPF of US$1.4m and the Australian study uses a VPF of A$2.5m, both of which are lower than the current VPF used by the UK Department for Transport, and therefore will result in a lower value of a QALY. The value of a QALY, based on contingent valuation studies, presented by Hirth et al. is a median value based on eight individual estimates where the VPF ranges from US$1.2m through to US$25m. The VPF values at the upper end of this range will increase the median value of a QALY above those that we have estimated.

Two recent papers by Williams[25] and Rawlins and Culyer[26] have proposed values of a QALY which are not based on the VPF. Based on their experience and observations of the NICE process, Rawlins and Culyer state that interventions with a cost per QALY of over £25,000-£35,000 would need special reasons for being accepted, which could be interpreted as the revealed preference of NICE. Williams proposes a much lower figure of £18,000 based on the premise that in the UK this is the amount that we have in real resources to provide all the needs of the average citizen. He implies that, with this amount available to spend on meeting all needs, it is excessive to spend almost twice that (assuming a £30,000 benchmark) on health care alone and reinforces this by stating that a £30,000 benchmark represents more than 20 times the UK average health care expenditure per person per annum. However, given that payments to health care are based on many contributing so that few can benefit, and that relatively few people use the NHS (at least as an inpatient and, thus, for more serious conditions) each year, such a benchmark of £30,000 (or one based on the calculations printed in this paper) might be appropriate.

*6.4 Recommendations*

The results from this study provide a first step in trying to estimate the value of a QALY in the UK. Following on from this we would recommend further study in terms of both developing the sophistication of these approaches and through empirical estimation. For example, given that the transfer of the VPF from the transport setting may not fully reflect the values individuals' would prefer in a health setting it is important to conduct an empirical study to obtain, from a representative sample of the population, a direct monetary value of a QALY.

As approaches 1 and 2 are based on different methodological frameworks, we present two sets of recommended values. Focusing on discounted and quality adjusted values, from approach 1, and a point about halfway between the full VPF-based value and that excluding net output, we propose a value of around £64,000. From approach 2 (but giving less weight to 2a than 2b), we would propose a value of a QALY of about £42,500. The result from approach 2a has been weighted down because it assumes maximum life expectancy at age 80 is zero, which has subsequently proved to be unfounded. Going further, based on these results, we would recommend that QALYs arising from life–saving interventions be valued at the higher rate, with those arising from life extending interventions valued at the lower rate. Interventions which enhance quality of life only would receive an even lower value in the £6000-21000 range (see Appendix 2). Other considerations might simply be the preference of the decision-maker for a particular method based on other purposes to which the value will be applied. The value from approach 1 will be more sensitive to life years gained. However, it is simpler and may be more preferred to approach 2 if the reader does not agree with the concept of a value of living *per se* component. Whichever value(s) is (are) chosen, each would be higher than those recently proposed by Williams[25] and Rawlins and Culyer[26] and that currently used by NICE.

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**Internet sources of data used in calculations**

Population Data 13/08/2004: http://www.statistics.gov.uk/statbase/ssdataset.asp?vlnk=7491&More=Y
GAD data 13/08/2004: http://www.gad.gov.uk/Life_Tables/Interim_life_tables.htm
HM treasury Green Book 13/8/2004:http://greenbook.treasury.gov.uk/

## Appendix 1 Values of living *per se* (£)

**Table 2: Value of living *per se* for approach 2a**

| Based on VPF | Based on VPF excluding net output |
|---|---|
| 590,171 | 569,871 |

**Table 3: Value of living *per se* for approach 2b (£)***

| Age | Value of living *per se* (rounded to the nearest '000) | Age | Value of living *per se* (rounded to the nearest '000) |
|---|---|---|---|
| 18 and under | 1,274,000 | 60 | 429,000 |
| 19 | 1,216,000 | 61 | 424,000 |
| 20 | 1,164,000 | 62 | 418,000 |
| 21 | 1,115,000 | 63 | 413,000 |
| 22 | 1,070,000 | 64 | 407,000 |
| 23 | 1,028,000 | 65 | 402,000 |
| 24 | 990,000 | 66 | 398,000 |
| 25 | 954,000 | 67 | 393,000 |
| 26 | 919,000 | 68 | 389,000 |
| 27 | 888,000 | 69 | 384,000 |
| 28 | 859,000 | 70 | 380,000 |
| 29 | 831,000 | 71 | 377,000 |
| 30 | 806,000 | 72 | 373,000 |
| 31 | 782,000 | 73 | 370,000 |
| 32 | 759,000 | 74 | 366,000 |
| 33 | 738,000 | 75 | 363,000 |
| 34 | 718,000 | 76 | 360,000 |
| 35 | 699,000 | 77 | 357,000 |
| 36 | 681,000 | 78 | 355,000 |
| 37 | 664,000 | 79 | 352,000 |
| 38 | 648,000 | 80 | 350,000 |
| 39 | 633,000 | 81 | 347,000 |
| 40 | 618,000 | 82 | 345,000 |
| 41 | 604,000 | 83 | 343,000 |
| 42 | 590,000 | 84 | 341,000 |
| 43 | 578,000 | 85 | 339,000 |
| 44 | 566,000 | 86 | 338,000 |
| 45 | 554,000 | 87 | 336,000 |
| 46 | 543,000 | 88 | 334,000 |
| 47 | 533,000 | 89 | 333,000 |
| 48 | 523,000 | 90 | 332,000 |
| 49 | 513,000 | 91 | 330,000 |
| 50 | 504,000 | 92 | 329,000 |
| 51 | 495,000 | 93 | 328,000 |
| 52 | 486,000 | 94 | 327,000 |
| 53 | 478,000 | 95 | 326,000 |
| 54 | 470,000 | 96 | 325,000 |
| 55 | 463,000 | 97 | 324,000 |
| 56 | 455,000 | 98 | 323,000 |
| 57 | 449,000 | 99 | 321,000 |
| 58 | 442,000 | 100 | 319,000 |
| 59 | 436,000 | | |

*Individual estimates of the value of living *per se* for the under 18s are not included here as they are based on data extrapolated from the over 18 population which may not be a reflection of their true valuation.

## Appendix 2 Estimating the value of a QALY from the elicited values of preventing serious injuries

Using the UK Department for Transport's values of serious injuries (VSIs), a value of a QALY can be estimated that incorporates only changes in quality of life. The VSI is based on the valuation of eight different severities of serious injuries which range from injuries that will last only a few days and require no hospital treatment, through to permanent paralysis and brain damage.[10]

The EQ-5D was used to calculate the quality of life (QoL) loss for each of the eight injuries. Most of the injuries are described over three time periods; in-hospital effects, after effects within the first year and after effects over remaining life expectancy. Thus, for each injury, we first calculated a utility value using the EQ-5D tariff for each of these three time periods. For each time period the QALY loss was calculated as follows:

QoL loss = QoL weight for UK population – EQ-5D tariff value for injury, and

QALY loss = QoL Loss x Duration (years).

The duration of "effects over remaining life expectancy" was taken to be weighted UK remaining life expectancy minus the duration of time periods one and two. The total QALY loss for each injury is then the sum of the QALY losses across each time period.

The original estimation of the VSI was based on a population sample survey in which respondents valued each injury against death. The standard gamble technique was used to obtain this value, which was then used to calculate the marginal rate of substitution (MRS) of the injury against death. The value of preventing this injury is then the fraction of the VPF that is given by the MRS, i.e. if the MRS is 0.09, the value of preventing this injury will be 9% of the VPF. Thus, the value of a QALY for each injury, i =1-8

$$= \frac{\text{VPF x MRS}_i}{\text{QALY loss}_i}$$

and,

$$V_6 = \sum_{i=1}^{8} (\text{Value of a QALY})_i \, P_i$$

Where $P_i$ = probability of occurrence of injury $_i$.

The value of a QALY was estimated using both the mean and median best standard gamble results presented by Jones-Lee et al.[10]. As it turned out, only four injuries (X, W, S, and R) were used in the calculation of the value of a QALY as these were the only injuries for which standard gamble values were directly derived. As illustrated above, each injury is weighted by its probability of occurrence so that a weighted mean value of a QALY is estimated. Mean and median values of a QALY were calculated from the individual value of a QALY estimates for each of the four injuries, leading to the results in Table 4.

**Table 4 Estimates of the value of a QALY from the prevention of non-fatal injuries**

| | Weighted Mean (£) Of injuries X,W,S and R | Median (£) of injuries X,W,S and R |
|---|---|---|
| Mean SG | 383,545 | 302,403 |
| Median SG | 21,030 | 5,908 |

The results estimated using the mean standard gamble values are significantly higher than those of any of the other approaches. The mean standard gamble values for each of the health states are positive values greater than zero while the median standard gamble values for the less severe injuries W and X are equal to zero. The use of the median standard gamble results would appear to be more appropriate as 75% of the sample returned a zero standard gamble valuation for injury X and 81% of the sample gave a zero valuation for injury W. Using the median standard gamble values the results (in the range £6000-21,000) are more in line with what would be expected with the value of a QALY estimated on the basis of changes in quality of life only being lower than those estimated using approaches 1 and 2 in the main text.