Evaluating the Value of a Life Year (VOLY)

Air quality policies depend on realistic values for both societal costs and societal benefits.

Today's European air quality policy uses cost-benefit analysis (CBA) to assess the effectiveness of different measures to mitigate air pollution. This involves comparing the cost of achieving emission reductions with the benefits of reducing the concentrations and/or the deposition of different air pollutants. Because benefits can take many forms, converting them to a monetary basis (monetisation) is an important step. This article discusses monetisation of the health benefits associated with reducing concentrations of fine particulate matter (PM).

$PM_{2.5}$, that is particles that are smaller in diameter than 2.5 µm, is a key pollutant from a health perspective[1]. Data from epidemiological studies suggest that long-term exposure to $PM_{2.5}$ can increase human mortality risk. It follows that reducing $PM_{2.5}$ concentrations should reduce mortality risk and consequently result in a small increase in statistical life expectancy. The parameter that is chosen to describe this benefit is population life years, which is conventionally expressed as Years of Life Lost (YOLL) associated with the incremental risk. To monetise the health benefit associated with a given reduction in $PM_{2.5}$, it is therefore necessary to calculate the potential YOLL that would result and multiply it by the Value of a Life Year (VOLY). The determination of VOLY and its use in CBAs were discussed in CONCAWE Report 4/06. In this article, we discuss the appropriateness of VOLY values that are used today in air quality policy and present an alternative approach to deriving these values from the same base data.

[1] See CONCAWE *Review* Vol. 21, No. 1 for more information on $PM_{2.5}$ and Years of Life Lost (YOLL).

'Willingness to pay' surveys

Estimating the monetary value of a life year in a given population is not an easy thing to do. The accepted method is to survey people for their 'willingness to pay' (WTP) to achieve a small increase in statistical life expectancy (see the previous article in this *Review*). For example, if each person in a surveyed population is asked to pay for some treatment option that might result in a few months longer life expectancy on average in the population, how much would they be willing to pay? Such studies are very hard to conduct without bias, while ensuring that the participants understand there is no guarantee that they may actually benefit from the treatment.

The outcomes of these WTP surveys reveal the following:

- Different surveys return different results based on the questions that are asked and the population of people that are surveyed.
- Survey responses are quite varied and provide a distribution of monetary values, ranging from zero up to very high values.
- Most respondents to a WTP survey will say that they are willing to pay only a small amount for a particular treatment option while fewer respondents say that they are willing to pay much larger amounts. As a result of this skewed distribution of responses, the mean value of a WTP survey distribution is much larger than the median value. It is important, therefore, to know what results from the WTP survey best describe the preferences of the surveyed population.
- The monetary value for a full life year improvement is obtained by scaling the responses to a 12-month basis. However, for a short increase in life expectancy, WTP is relatively higher than for a longer increase, that is, the surveys indicate that a longer increase in life expectancy is considered to be less valuable than a short one.
- The WTP also depends on the future state of health. That is, the willingness to pay to increase life expectancy is typically lower if poor health is assumed rather than good health.

These outcomes indicate that considerable care is needed to properly interpret WTP survey results into monetary values for a life year.

In CONCAWE Report 4/06, several cost-benefit studies were compared including one (NewExt) that was used for the Thematic Strategy on Air Pollution (TSAP). This report concluded that the full distribution of VOLY should be used in CBAs and should not be simplified to a single value such as the distribution's mean or median result. In fact, the CBA methodology used in the Clean Air for Europe (CAFE) programme acknowledged that more robust results could be obtained by using the full distribution of WTP survey results, but the simplicity of using a single VOLY value continues to be the easy option for developing air quality policy.

The difference between the median and mean VOLY values (in Euros) from the NewExt and NEEDS studies

Table 1 Comparison of the median and mean values from NewExt and one version of the NEEDS study

Study	Median VOLY	Mean VOLY
NewExt Study (2005)	€52,000	€118,000
NEEDS Study with an assumed increase in life expectancy of three months (2009)	€19,000	€42,000

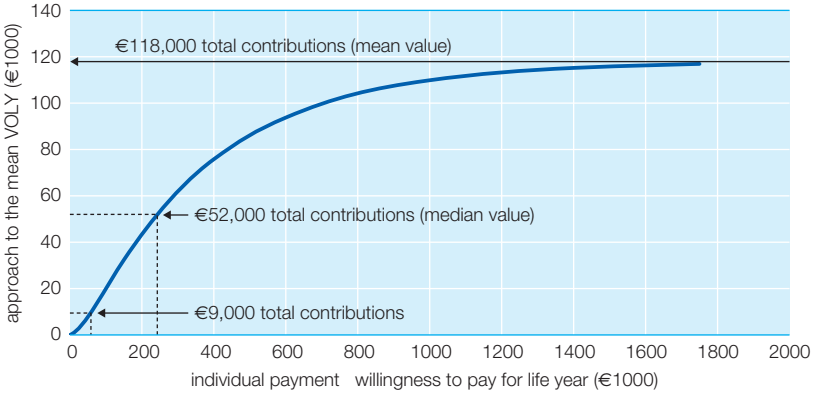
are shown in Table 1. The NEEDS study included more countries and improved the survey technique compared to the NewExt study, so the NEEDS study is widely considered to be the better of these two studies.

The VOLY used in CAFE was €52,000[2] which was the median value from the NewExt study. It would be consistent therefore to use the median value of €19,000 from the better NEEDS study. However, the current policy round assumes a VOLY value of €57,000, which is the CAFE value adjusted for inflation.

So which property of the WTP distribution is best for this purpose: the mean, median or mode? It can be argued that the mean value of the WTP distribution is the statistically correct single value with which to represent the survey results. It can also be argued that the median value is the most appropriate parameter because it represents the WTP that divides the sample population equally by choice of paying a higher or lower value. Further, it can be argued that the modal value is most appropriate because it represents the most popular choice.

[2] AEA, 2007. *Analysis of the Costs and Benefits of Proposed Revisions to the National Emission Ceilings Directive. NEC CBA Report 2. CBA of TSAP and EP target optimisation model runs*. AEA Technology, London, UK.

Figure 1 Integration of the 'willingness to pay' responses of survey respondents using the NewExt study data



If the WTP distribution were symmetrical, as is a normal distribution, all three values describing the distribution would be equivalent. This is not the case for WTP surveys, however, because the distribution of responses is skewed to lower values and approximate a Weibull distribution. In the following calculations, the survey results from previous studies are described using a Weibull distribution defined by the reported mean and median WTP values.

We can illustrate a key weakness in using either the mean or median values when using WTP study results to evaluate benefits. The NewExt results are used to illustrate the case.

Consider how the mean of such a distribution is calculated. All the responses to the WTP survey are added together and the sum is divided by the total number of respondents. Figure 1 shows this process using the Weibull fit to the NewExt study results. Increasing WTP responses are ranked along the x-axis while the running total of contributions, always divided by the total number of survey respondents, is plotted on the y-axis. When the responses from all of the respondents have been counted, the total approaches a mean value of €118,000.

Figure 1 clearly shows just how asymmetric the WTP distribution is. Consider the argument for using a median VOLY, representing the view of exactly half of the survey population. While the median VOLY in the NewExt study was found to be €52,000, the running total of contributions up to this WTP amounts to just €9,000, as shown in Figure 1. When the running total has reached €52,000, individuals who have pledged €240,000 are contributing. Applying the same analysis to the NEEDS survey data, the running total for contributions up to the median WTP of €19,000 would be just €3,000.

These results suggest that even the 'democratic' choice of the median value from a WTP survey is questionable as an estimate of VOLY.

Are there other approaches that would represent a fairer way to determine VOLY?

'Maximised Societal Revenue' approach

CONCAWE proposes that a simple flat fee analysis would be a better way to determine VOLY from a WTP survey. In this approach, a fee would only be paid by those who express a WTP that is higher than or equal to the fee. The flat fee value is chosen to maximise the revenue from the survey population, normalised by the total population. This revenue becomes the 'VOLY' in place of the fee. The attractiveness of this flat fee approach is that it reflects the full distribution of expressed WTP values, is less sensitive to the very highest choices and is fairer to the highest bidders.

Figure 2 shows how this approach would change as the flat fee increases. Results are compared for three studies: NewExt and two versions of the NEEDS study where risk reductions leading to an increase in life expectancy of either three or six months are assumed.

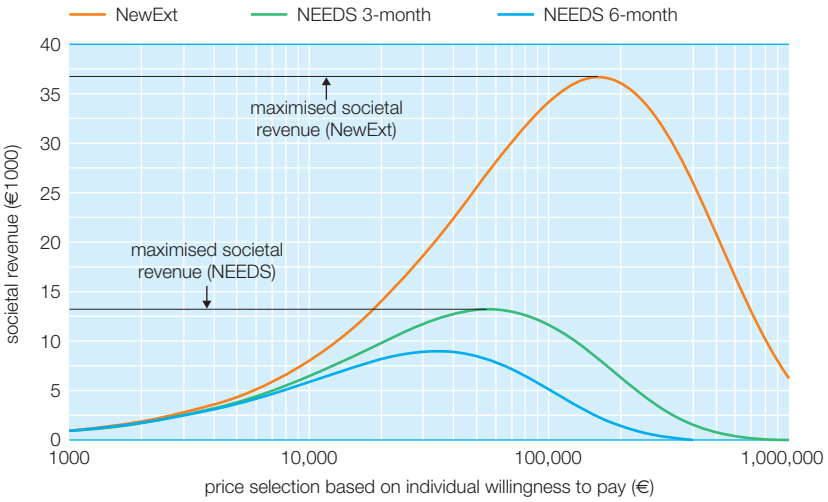
When the flat fee is low, more people would be expected to pay but the total amount of money raised would also be small. As the flat fee increases, fewer people would be expected to pay but the payments are larger so that the revenue increases more rapidly. Eventually, a maximum revenue is reached after which the number of people paying decreases faster than the fee increases. We call the point at which the revenue is maximised the 'Maximised Societal Revenue', expressed on a per capita basis.

The corresponding values of the 'Maximised Societal Revenue' are shown in Table 2 for the NewExt and NEEDS data as well as for the earlier UK DEFRA studies. The values range between €9,000 and €13,000 for the NEEDS study and between €3,400 and €13,000 for the UK DEFRA study.

Conclusions

Using a single value from a WTP survey, such as the mean or median, to characterise the VOLY in policy-oriented CBAs is not a robust approach. As shown here and in CONCAWE Report 4/06, the full distribution of survey results should be used because the skewed shape of the WTP distribution is not properly captured by a single value.

Figure 2 Societal revenue versus the 'willingness to pay' for three different studies



It has been shown that VOLY, and hence monetary benefits, depends disproportionately on the choices of a small fraction of the surveyed population. If a single value must be used to describe such WTP surveys, then a simple flat fee analysis is a better approach which takes the contributions from those willing to pay most but caps their exposure. We believe that this 'Maximised Societal Revenue' approach reflects the full distribution of WTP survey results and reduces the dominance of more extreme values. This approach gives VOLY values in the range €9,000 to €13,000, based on the NEEDS WTP study, which is considerably less than the €57,000 used in current policy development.

Table 2 Maximised Societal Revenue, median and mean values of the 'willingness to pay' for VOLY (in Euros per life year increase in life expectancy) from several studies

Study	Maximised Societal Revenue	Median VOLY	Mean VOLY
NewExt	€37,000	€52,000	€118,000
NEEDS 3-month	€13,000	€19,000	€42,000
NEEDS 6-month	€9,100	€14,000	€27,000
DEFRA 1-month	€13,000	€15,000	€45,000
DEFRA 3-month	€5,500	€2,200	€23,000
DEFRA 6-month	€3,400	€2,700	€13,000

Note: '1-month', '3-month' and '6-month' refer to the different risk-reduction choices in these WTP studies.