REFERENCE VALUES FOR HUMAN LIFE:

An econometric analysis

of a contingent valuation in France [*]

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Published in Nathalie Schwab and Nils Soguel (1995)
Contingent Valuation, Transport Safety and Value of Life,
A. Kluwer, Boston.

Abstract

This paper offers an econometric analysis of a recent contingent valuation of road safety. The survey involved face-to-face interviews with a representative sample of 1000 persons. The interviewees were asked about their willingness-to-pay (WTP) to save 50 lives, 100 lives, 500 lives, 1000 lives, 2000 lives and 5000 lives, after being told that the number of traffic fatalities in France is 10000 per year. Supplementary questions were asked to test the consistency of the responses. Socio-economic questions complete the survey. The valuation question was phrased in terms of the number of lives saved, rather than a change in risk, because the psychological pre-tests showed that people have trouble understanding and accepting the concept of risk reduction.

WTP increases with the number of lives saved, but at a strongly decreasing rate: WTP per life saved varies by a factor of more than 20 between 50 and 5000 lives. This raises serious difficulties with the choice of a single reference value for public decisions. A detailed examination of the individual responses shows that different people have different mental models for their valuation, ranging from a lump sum payment regardless of number of lives saved, to a constant WTP per life saved. Based on extensive evidence of biases (embedding effect ad hypothetical bias) in CVM studies of non-use values, we adopt the recommendations of Schulze et al. for reducing these biases by means of a Box-Cox model. This renders the distribution of residues much more normal than for a linear model and yields a value of life which is equal to about a half of the mean of the raw data and close to the median.

[*] Supported in part by the ExternE Program (External Costs of Fuel Cycles) of the European Commission, DG XII, JOULE 2 Program. The contingent valuation was directed by M. Le Net and carried out by S. Belliat of ESOP.

INTRODUCTION

In 1993 the Commissariat Général du Plan, the Ministry of Equipment, EDF (the French Utility Company), and the Centre d'Energétique of the Ecole des Mines (within a contract from the ExternE Program of the European Commission), decided to finance a contingent valuation of the reference value of human life for road accidents. It is the first study using this methodology in France and it is part of a continuing research program under the direction of Mr. Le Net of the Ecole des Ponts et Chaussées on the implicit value of human life in the domain of road transportation. The present paper offers an econometric analysis of the results, and discusses the interpretation.

The contingent valuation method (CVM) has had much success during the last two decades, especially in the field of environmental economics. A recent survey of the studies using this methodology gathered more than 1400 titles (Carson et al., 1993). The interest of this method is to value items which, due to their characteristics, cannot be bought or sold on a market. This method allows to reveal preferences by asking people directly about the monetary value they put on the ex ante variation of their well-being due to a change in the offer of a public good. According to the response given to a specific question one can measure either the compensating or the equivalent variation of the surplus. The apparent simplicity of the method, together with a recent clarification of the rules to follow in order to obtain reliable results (Mitchell and Carson, 1989, Arrow et al., 1993), explain its success among economists : during the last ten years it has become the most widely method used to value natural assets. Moreover it can be used to obtain use and non-use value, and it solves correctly the problem of valuation when supply or demand are uncertain by giving the option price (Desaigues and Point, 1993).

First applied to the valuation of recreational assets (the first study was realized by R. Davis in 1963), this method is today used in new fields like air quality, visibility, existence value, and the reference value of human life. In this last domain studies are rare, certainly because the subject is difficult and the method at the limits of its capability. But a reference value for human life is necessary for the cost-benefit analysis of any policy aiming to improve safety and health, and to maintain a minimum of consistency between public investments.

There are other methods that have been used for determining a reference value, in particular the human capital method, used in the majority of the OECD countries (Le Net 1992). However, it, is generally considered imperfect by economists because it takes in account only direct costs (including loss of production), and thus underestimates certainly the real willingness to pay to avoid premature death. Alternative methods have been developed based on the observation of choices made by individuals: salary differences linked to different degrees of risk, and safety expenditures (for a review, see Viscusi, 1993). These methods give ex post values. They are not perfect in the sense that it is difficult to identify all the variables that explain the formation of a salary or a price. Soby and Ball (1991) give a complete review of the advantages and limits of these methods.

Table 1. Implicit values of life obtained by contingent valuation.
From Viscusi (1993).

Authors	Type of risk	Year of study	Implicit value of life (million$ $_{1990}$)
Jones-Lee et al. (1985)	Road accident	1982	3.8 (mean) 1.9 (median)
Gerking et al. (1988)	Work accident	1984	3.4 (mean)
Persson (1989)	Road accident	1986	2.7 (mean) 1.4(median)
Viscusi et al. (1991)	Road accident	1987	2.7 (median)
Miller and Guria (1991)	Road accident	1990	1.2

The values obtained by these methods diverge greatly. For example Ives et al. (1993) have analyzed 47 studies realized between 1973 and 1989, 60% of them using the hedonic wage methodology, 25% the observation of behavior, and 15% the contingent valuation. The values expressed in £$_{1990}$ range from 0.079 to 13.9 million £, with a mean of 2.7, a median of 1.6 and a standard deviation of 3 million £. Studies using the contingent valuation method are rare. The above authors have taken into account

7 CVM studies. One can add the study made by Persson (1989) for the Swedish government, and the one made by Miller and Guria (1991) for the government of New Zealand. The reader can find a summary of 7 of these studies in Jones-Lee (1989). The values given by these studies differ considerably. However, if one considers only the most recent ones, from Jones-Lee (1985) to Miller and Guria (1991), the scatter is reduced, to a range from 1.2 to 3.8 $M\$_{1990}$ (Viscusi 1993).

Several reasons can explain this scatter: the method of inquiry (interview or mail survey), the type of risk that is evaluated, the magnitude of risk reduction (several studies have shown that the value of life appears greater when the risk reduction is small), the perception of risk, and the econometric model used for the analysis (linear or semi-logarithmic). It is clear that in the absence of a common protocol the results can be highly sensitive to particular choices made by the authors of a study.

THE CONTINGENT VALUATION METHOD APPLIED TO ROAD ACCIDENTS

The implicit model

Road safety is a public good that affects the well-being of individuals; the utility of this good varies from one individual to another. It is therefore logical to consider road safety as an argument of the utility function and to suppose that the individual is able to choose between the consumption of a private good and an improvement of road safety. An increase in the supply of this item increases the utility, which can be revealed by the willingness to pay to benefit of this improvement.

Let us consider the dual program of the consumer who is offered an improvement in the quality of a public good and who wants to minimize the sum of expenditures

$$\text{Min}_x \{p'_x, x\} \quad \text{under the constraint } U(x, Q, s) \geq U_0 \quad . \qquad (1)$$

The vectors x and p_x designate respectively the quantities and prices of the private goods. The scalar Q represents the quality of road safety. The vector s designates the socio-economic characteristics of the individual (age, gender, education, income, profession, ...). The initial situation corresponds to a safety level Q_0 and is taken as reference for the analysis of the consumer surplus.

The resolution of the dual program allows to define a function $e(p_x, Q_0, s, U_0)$ of minimal expenditures that yields the utility level U_0 corresponding to Q_0. Let e_0 be the corresponding level of total expenditures

$$e_0 = e(p_x, Q_0, s, U_0) + V(Q_0) \qquad (2)$$

where $V(Q_0)$ represents the amount that the individual has already been paying for road safety, e.g. via taxes.

When asked for their willingness to pay for an improvement in this good, an individual states a value which is equal to the compensating variation of his/her surplus. At constant utility and total expenditure (constant income) the willingness to pay WTP is given by

$$e(p_x, Q_0, s, U_0) + V(Q_0) = e(p_x, Q_1, s, U_0) + \{V(Q_0) + WTP\} \qquad (3)$$

hence

$$WTP = e(p_x, Q_0, s, U_0) - e(p_x, Q_1, s, U_0) \quad . \qquad (4)$$

This is the maximal expenditure by the individual that keeps his/her utility at the initial level

$$U_0 = U(Y, Q_0) = U(Y - WTP, Q_1) \qquad (5)$$

where Y is the income. The determination of WTP is made *ex ante*, based on short term optimization.

If one introduces the present probability p_0 of death from road accidents, the utility level U_0 is replaced by the expectation value

$$E(U_0) = (1 - p_0)\, U(Y, Q_0) \quad . \qquad (6)$$

The willingness to pay for a reduction of this probability from p_0 to p_1 is then given by

$$(1 - p_0)\, U_0(Y, Q_0) = (1 - p_1)\, U_1(Y - WTP, Q_1) \quad . \qquad (7)$$

Taking the derivative with respect to the probability (and dropping the subscript) one finds

$$\frac{\partial WTP}{\partial p} = \frac{\left\{\frac{\partial U(Y\text{-}WTP,Q)}{\partial Q}\frac{\partial Q}{\partial p} - \frac{U(Y - WTP, Q)}{(1-p)}\right\}}{\frac{\partial U(Y\text{-}WTP,Q)}{\partial Y}} \quad . \tag{8}$$

WTP increases as the probability of death is reduced; it also increases with increasing income.

One can use more complex models, such as the life cycle model of Cropper and Freeman (1991). But such models suppose that individuals are capable of carrying out a life cycle optimization, something that few seem to be able to do correctly. Furthermore, such a model does not include a component for altruism, a phenomenon which appears to make a significant contribution to WTP.

The construction of the WTP value

Applied to road accidents, the CVM attempts to set up a hypothetical market where different levels of road safety could be bought and sold. People are asked about their willingness to pay for an increase in safety, which can be immediately translated by a diminishing number of dead on the road, or by a diminution of the probability to be killed in a road accident. But is this implicit behavior model rich enough to explain the reaction of an individual who is offered an improvement of a public good, and who is supposed to value the corresponding compensating variation of his surplus ? Certainly not. To understand the exercise of valuation one must first ask what is the nature of the good to be valued. It is a public good because it is shared with all the group, and it has a double component : a personal component, and an altruistic component.

An increase in road safety diminishes the risk of personal accident, and thereby suffering, pain, extra expenses, loss of leisure.... It is possible that people do not take in account correctly the medical expenses, and the loss of production related to an accident. By seeking to reduce the risk of an accident a person can made tradeoffs between increasing his contribution to collective expenditures or investments in his own safety expenses (buying a better car, safety options, etc...). The application of the principle of weak complementarity (Mäler, 1974) can give interesting indications on the tradeoffs made.

The reduction of accident risk concerns not only the individual but also relatives, friends and unrelated people. The value attributed to this aspect of the public good is a non-use value, and belongs to the wider category of existence value. We must admit that it is very difficult for a person to distinguish, in his utility function, use values and non-use values. Under this condition how does an individual construct the value of this complex good, and then express it on a contingent market ?

If to express a use value one can consider that an individual minimizes his global expenditure function, and modifies the consumption of different goods so as to equalize their marginal utilities, it is much more difficult to maintain this hypothesis with a non-use good. We can consider that the budget of an individual is divided in sub-groups, and that, in the short term, the optimization is made within the part of the budget that is directly affected. If a person express the value of a good with a high component of non-use value, one can consider that he will optimize only on the part of the budget reserved for exceptional short term expenses like protection of the environment, gifts to charity,... The difficulty is that we do not know how important is the part of the budget reserved for this category of expenses. We can only suppose that it varies positively with income. To construct the value of the good "improving road safety" we have used the tool of contingent valuation. This tool is fragile, and its use for non-use values was questioned recently by the US. Administration NOAA (Arrow et al., 1993).

The reliability of the tool

The underlying hypothesis of CVM is that people have a consistent set of preferences, including those for public goods, such as clean air, beautiful landscape and road safety, and that these preferences can be revealed on a hypothetical market. However, the evolution of the research in this domain has shown that this hypothesis needs to be examined carefully, especially when one is dealing with goods unfamiliar to the individual. It now appears that for such unfamiliar goods different individuals can have very different mental models on which they base their valuation, and that they construct their valuation during the inquiry without preexisting references. Therefore the result can be extremely sensitive to the context and to specific information given during the inquiry. But certain authors believe that it is possible to improve the method to limit the biases that may thus arise (McClelland et al. 1992, Schulze et al. 1994).

For the present study we have, on purpose, chosen to place the individual in a situation of certainty, because psychologists have shown that individuals have much trouble understanding what a reduction of risk means. That should help us avoid extreme values for small reductions of risk. And yet, that is the result we found. We will see below, what explanation can be given for this result. We have also tried to make the questions as clear and comprehensible as possible, in a way that establishes a direct link between a road accident and everyday life. But we must admit that people are not familiar with this kind of public good. And they are supposed to anticipate correctly the variation of their well-being. Lack of experience and difficulties in the valuing exercise are likely to lead them to give either a lump sum, regardless the level of improvement, or to overestimate their true WTP.

The principal types of bias

In the context of CVM a bias means a discrepancy between the values obtained with the questionnaire and the values that would have been found in a real market. The literature on this issue is extensive, see e.g. Carson and Mitchell (1989). Here we will discuss the major biases: the embedding bias and the hypothetical bias.

a) The embedding bias

The existence of this bias, first noted by Kahneman and Knetsch (1992) and then extensively studied in Hausman (1993), poses a major challenge to economists on the significance of CVM results. The bias arises when the respondents give a value that expresses something entirely different from what was intended by the researcher who has formulated the questions: a kind of moral satisfaction rather than the valuation of a specific good. Thus a change in the quantity of the good to be valued (e.g. saving 50 lives or 5000 lives) may have only a small impact on the values given if they reflect a general moral satisfaction rather than a change in utility due to the good in question.

By now numerous studies have confirmed the existence of this bias, e.g. Rowe et al. (1991) for oil spills, and Schulze et al. (1991) for visibility. No doubt this bias is often present in non-use values, for which individuals are not familiar. Two reasons have been offered to explain the existence of this bias. The first, proposed by Kahneman and Knetsch (1992), involves the moral satisfaction of contributing to a good cause. People tend to give a lump sum for good causes, regardless the quantity of the good offered. The second explanation involves the mental model the individual uses for constructing his valuation; this model can be totally different from the one assumed by the investigator. For example among the people who have been asked for their WTP for improving visibility in the Denver area, many include health benefits in their valuation or even additional public goods. They develop a mental model of joint products.

From experience economists have learned that this bias can be reduced by

- giving a clear and complete description of the good to be valued,
- using a realistic payment vehicle, to make the respondent feel that he/she is asked to participate in a transaction rather than donating to a charity (Cummings et al. 1986).

But is not enough, and the use of a verbal protocol (Schkade and Payne 1994) for testing the understanding of the questionnaire is highly recommended.

b) The hypothetical bias

This bias has been revealed by laboratory experiments, where hypothetical WTP could be compared with real payments. People unfamiliar with the good to value have a tendency to overestimate their WTP. A survey by Schulze et al (1994) of five recent studies shows that the ratio of values given in response to hypothetical and to real situations averages 2.5.

Furthermore, the distribution of values given by the respondents to a CVM survey tends to be highly skewed, with a large tail at high values: a few individuals state extremely (and apparently unrealistically) high values. Part of this phenomenon may be related to the hypothetical bias as suggested by the observation that supplying additional information tends to reduce the variance of WTP and render the distribution of the residuals of the regression model more normal.

To correct this bias one can use a semi-logarithmic model, Schulze et al (1994) recommend making the implicit hypothesis that the error is proportional to WTP, or a Box-Cox model, which improves the distribution of residuals by rendering it more normal.

The valuation question: open question or referendum

The NOAA report (Arrow et al., 1993) recommends using the referendum question (answer yes or no to a given value), following economists who think that it is preferable for respondents to be price takers. However, laboratory studies have shown that people tend to anchor their WTP on the value proposed. Furthermore, a referendum question necessitates significantly larger samples (66% larger than for the open question). Therefore the open question has been used for the current study. Moreover, this latter solution allows us to correct the hypothetical bias by using a Box-Cox model (which is not possible with the referendum format).

ANALYSIS OF THE RESULTS OF THE FRENCH ROAD SAFETY STUDY

The Questionnaire

The inquiry was carried out during the first months of 1994. The questionnaire was built after an in-depth psychological investigation of a representative sample of 50 persons. This pretest revealed the difficulties most people encounter with the concept of risk reduction. Even after explanations were given, people reject the idea of residual risk, because they refuse to be a potential victim. Most people tend to view risk in binary terms: either there is a risk or not. Thus any reduction of a risk, e.g. from 2 per 1000 to 1 per 1000, is not perceived as significant because the danger still exists. The education received by the large majority of people does not enable them to comprehend the concept of degrees of risk.

Based on these insights from the pretests, the questionnaire was formulated in terms of clear scenarios. After a first question concerning his/her estimation of the number of fatal and non fatal accidents, the information of 10 000 deaths and 200 000 injuries per year in France is given. Then the interviewee is asked for his WTP, per household and per year, to save 50 lives, 100 lives, 500 lives, 1000 lives, 2000 lives, 5000 lives. The payment vehicle is an increase in taxes, which will be used by the government to improve road safety. The valuation question is open; no payment card is proposed. Supplementary questions are asked to check the consistency of the responses, in addition to the usual socio-economic questions. There were also questions about preferences with regard to the age and gender of a person to be saved The questionnaire was administered by face-to-face interview of about 20 minutes to a sample of 1000 persons, chosen to be representative of France according to the quota method (stratification by age, gender, profession, region, ...).

Results

Of the 1000 respondents, all but 18 give an answer to the WTP questions (0 or positive), but 89 refuse to answer the one about income. We also note that 16% do not own a car. We will now analyze the key WTP results.

WTP and estimation of risk

The answer to the first question gives the opportunity to test whether there is a correlation between an individual's WTP and his/her preexisting estimation of the risk. The answers cover a large spread: 25% of population underestimates greatly (at less than 1/3 of the true value) the risk of death, and 63% of the population underestimates the risk of injuries while 14% overestimates (at more than 1.5 times the true value) the risk of fatal accidents, and 4% the risk of injuries.

Table 2 Estimates and true values for traffic fatalities in France.

	Mean estimate	Median estimate	True values 1993
Number of deaths/yr	28 345	8 000	9 568
Number of injuries/yr	101 000	25 000	188 504

But there is no significant correlation, over the entire population, between WTP and estimation of risk. The group who largely underestimates the risk of death gives the same median WTP as the population as a whole. Only the group who largely overestimates the risk, appears to relate WTP and estimation of risk: their WTP exceeds the general median by 15%.

WTP and number of lives saved

Table 3 shows mean and median WTP as function of the number of lives saved. The resulting reference value of life is also shown, calculated according to the formula :

Reference value of life (9)

= Number of households in France × WTP/number of lives saved

with 21 535 000 households. As can be seen in Figure 1, the reference value of life thus obtained is approximately ($R^2 = 0.985$) a straight line on a log-log plot, given by (with t statistics in parentheses)

$$\ln(\text{Value of life}) = \underset{(38.8)}{4.62} + \underset{(16.4)}{0.3} \ln(\text{Number of lives saved}) \qquad (10)$$

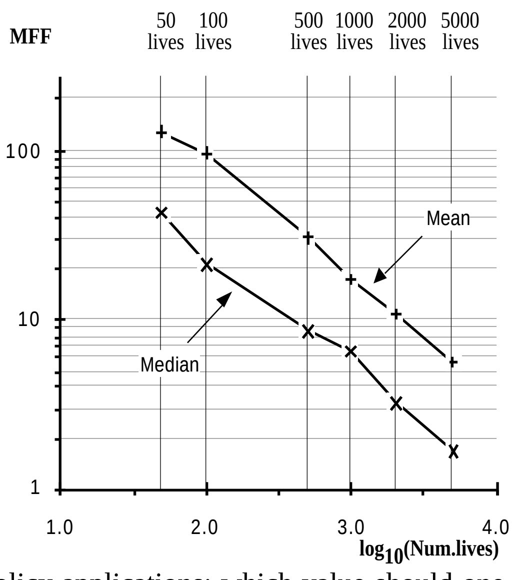
These data can also be seen on a linear scale in Figure 8 at the end of the paper. There is a wide range of possible numbers for the value of life, differing by a factor of 23 between the one obtained with 50 lives saved and the one with 5000 lives saved. While indications of a variation with risk have been found before, no previous study has asked questions that highlight this phenomenon so clearly.

Table 3 WTP as function of number of lives saved.
(1 FF ≈ 1/7 ecu ≈ 1/5.3 US$)

Lives to be saved	WTP Mean [FF]	WTP Trimmed Mean * [FF]	WTP Median [FF]	Reference value of life **mean** [10^6 FF]	Reference value of life **median** [10^6 FF]
50	303	258	100	130.2	43
100	454	376	100	97.8	21.5
500	637	516	200	30.5	8.6
1000	819	612	300	17.6	6.5
2000	995	720	300	10.7	3.2
5000	1305	824	400	5.6	1.7

* *by trimming all values ≥ 10 000 FF (1.8% of the responses)*

Figure 1 Mean and median reference value of life as function of number of lives saved.



This result is troubling for policy applications: which value should one choose, mean or median, and for which number of lives saved? To help provide an answer, we take a closer look at the individual responses.

Mental models and the expression of WTP

A look at individual responses shows that people use a variety of different mental models for their WTP values. While it is not practical to show almost a thousand individual responses, we can demonstrate the key features in Figures 2 and 3.

Figure 2 Variation of individual WTP values as function of number of lives saved: the four typical patterns

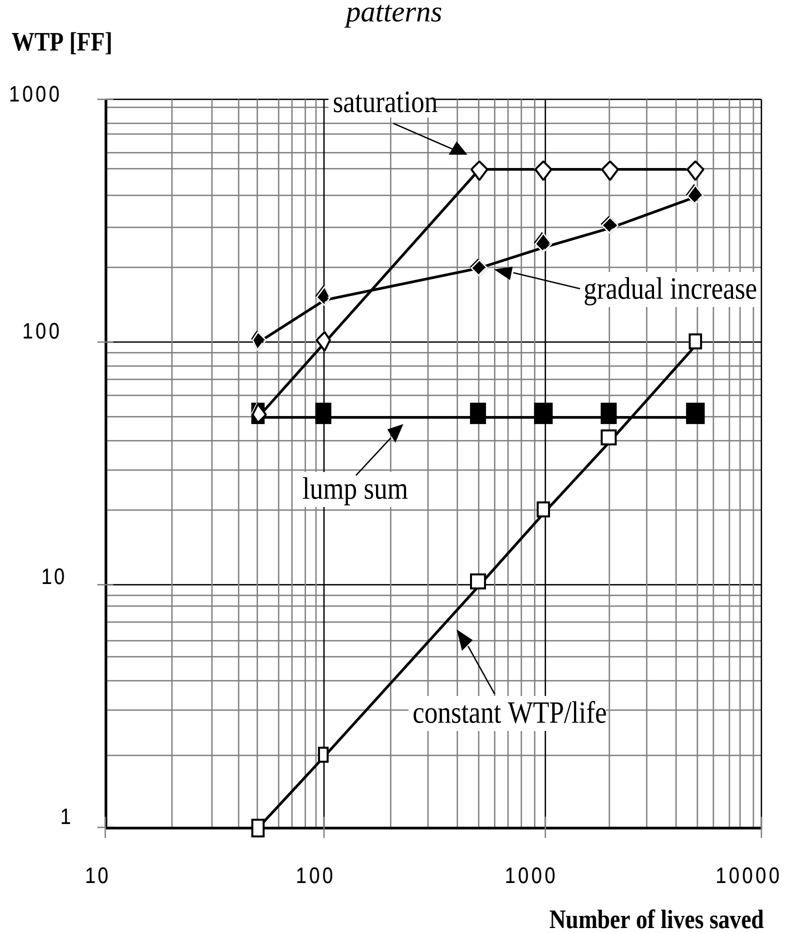


Figure 2 displays four typical patterns of responses as a log-log plot of WTP versus number of lives saved. There are two extremes. One is the straight line labeled "constant WTP/life"; these respondents calculate their WTP response by multiplying a constant value per life by the number of lives saved. The other extreme is the horizontal line labeled "lump sum"; these respondents give a fixed value, regardless of the number of lives saved.

In addition to these two extreme patterns, the curve labeled "saturation" represents a very common pattern. These individuals begin with a fairly high WTP relative to their budget when faced with the first question about 50 lives saved, but as the number of lives saved increases from question to question, a point is reached where these respondents seem to say "I can't pay any more".

Finally the curve labeled "gradual increase" shows a pattern intermediate between the "lump sum" and "constant WTP/life"; these respondents appear to increase their WTP in some intuitive manner without performing a calculation, and less than the "constant WTP/life" pattern. The values in Figure 2 also demonstrate the phenomenon of anchoring at round values in the local currency.

To give an idea of the frequency of the different patterns, let us plot in Figure 3 the number of responses for different values of the ratio

$$\frac{\mathrm{WTP/life}_{max}}{\mathrm{WTP/life}_{min}}$$

$\mathrm{WTP/life}_{min}$ and $\mathrm{WTP/life}_{max}$ being the minimum and the maximum of an individual's response over the range 50 lives to 5000 lives. The number of responses for each of the patterns is shown in Table 4.

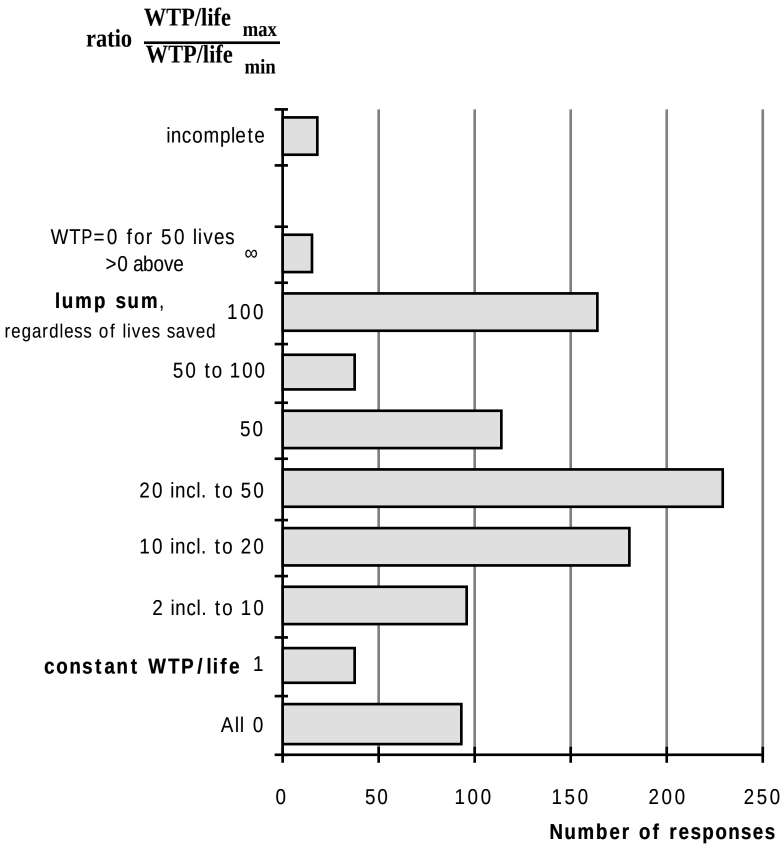
Note that the "lump sum" type represents 19% of the individuals with nonzero WTP. It is obviously problematic to extract a single reference value of life from a data set with such a mixture of different mental models.

Table 4 The number of responses for each of the patterns

Pattern	Number of responses	% of nonzero responses
"constant WTP/life"	39	4%
"gradual increase"	368	41%
"saturation"	315	36%
"lump sum"	165	19%

It is interesting to remark that :
- of the 39 "constant WTP/life" responses, 19 persons give a value WTP/life = 1 FF, which is certainly an example of anchoring at the number of lives;
- 94 persons have a WTP of zero;
- 55% of the nonzero responses ("lump sum" and "saturation") are not consistent with the economic model: an improvement in safety (from 2000 to 5000 lives saved) is valued at zero.

Figure 3 Number of responses with indicated values of the ratio of WTP/life$_{min}$ over WTP/life$_{max}$.



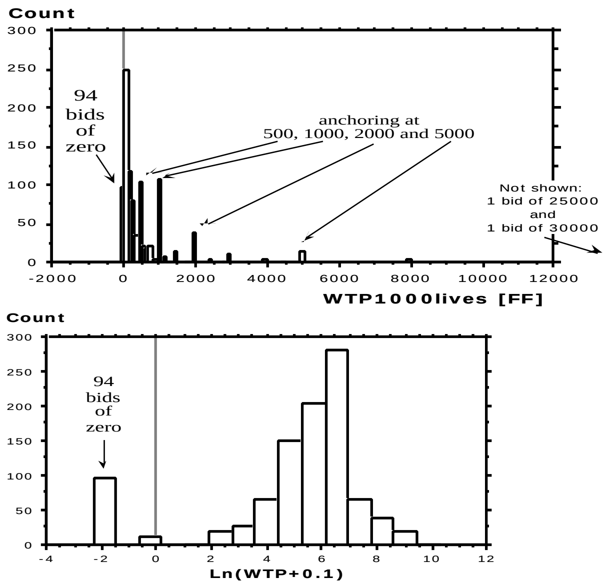
3.2.4. The distribution of WTP bids

It is interesting to show further detail on the distribution of WTP values. In Figure 4 we plot the frequency distribution for 1000 lives, using a linear scale for WTP in Figure 5a, and a logarithmic scale in Figure 5b. The linear scale highlights the anchoring at round values, in particular 500 FF, 1000 FF, 2000 FF and 5000 FF, but it is awkward for showing the tails of the distribution which become visible on a logarithmic scale. The logarithmic plot in Figure 5b shows that the distribution is approximately lognormal, with the exception of the zero bids (which in this figure have been plotted at ln(0.1)) and the lowest nonzero bids (of 1 FF). The fairly high number of 1 FF bids relative to the next higher nonzero bids suggests that the boundary between zero and nonzero may not be sharp. 1 FF (≈ US$ 0.2) is such a small amount as to be practically zero.

Figure 4 The frequency distribution for 1000 lives,
using a) linear scale, b) logarithmic scale

a)

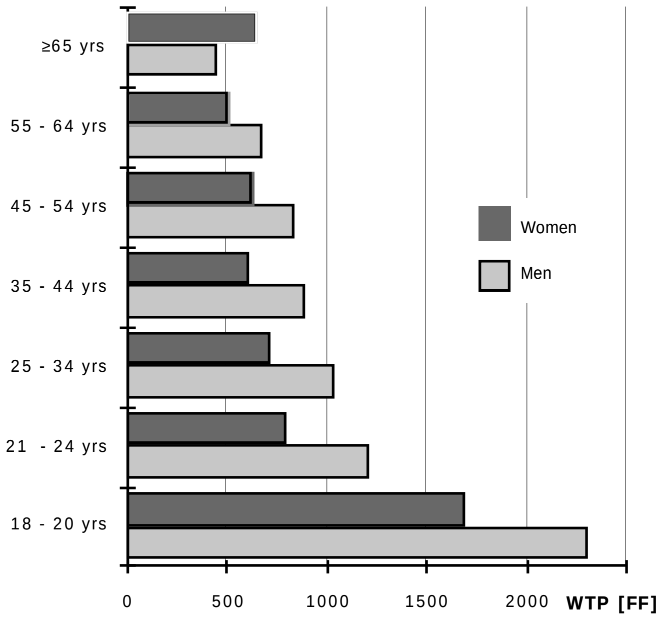
b)



3.2.5 WTP by age and by gender

The distribution of WTP by age and by gender of interviewee is shown in Figure 5.

Figure 5 Distribution of WTP as function of gender and age
[WTP in FF/household, to save 1000 lives]



Some important conclusions can be drawn from this graph:

- WTP decreases with age: older people seem to be more conscious of their budget constraint, whereas young people seem to express a "fair value" rather than a true WTP. This raises an important question : should one ask people about their WTP if they have no budget constraint, and therefore cannot carry out the mental exercise of substitution in their utility function. Apparently this happened with people under 20 years of age.
- Women are likely to pay less than men, except above 65 years.

Stability and consistency of answers

It was not a prime objective of the questionnaire to test the stability of the answers. Nonetheless, a supplementary question was asked in the middle of the questionnaire about the maximum WTP to save 1000 lives. The result shows that the answers were not very stable : 23% revise their WTP downward, 35% revise their WTP upward, 42% have a stable answer. Half of those who revise their WTP situate their answer in a range of +/- 500 FF of their old value.

As a consistency check, people were asked "How much are you willing to pay for a safety option for your car, if it protects only the driver, and how much if it protects all passengers?". We assume that this investment is amortized over 5 years. As shown in table 5, we obtain numbers of the same order magnitude as those obtained to save between 500 and 5000 lives.

Table 5 WTP (in FF) for a safety option for your car.

	WTP to protect driver only	**WTP to protect all passengers**
Mean	2301	4431
Median	1000	2000
Median/year	**200**	**400**

Choice of a behavioral model of WTP

In this section we try to develop correlations that could explain the individual WTP bids as a function of the available socio-economic variables. The goal is twofold. The first is a correction of the hypothetical bias. The second goal is to permit transferability of the results to other countries.

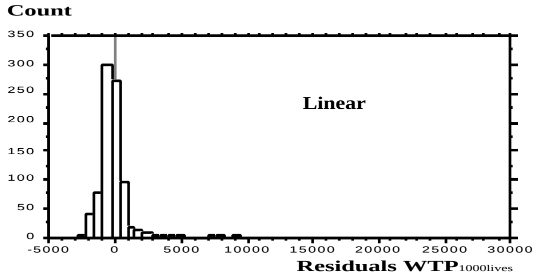
There are two natural criteria for the choice of the best model:

- the distribution of the residuals ε (it should be normal with $E(\varepsilon) = 0$ et $V(\varepsilon) = \sigma^2$),
- the significance of the explanatory variables (their standard errors should be small).

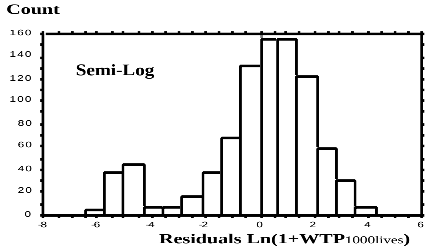
We use the following three models: linear, semi-logarithmic and Box-Cox. The key results are summarized in Table 6. The distribution of the residuals is plotted in Figure 6.

Figure 6 Frequency distribution of residuals for the three models
a) linear model, b) semi-logarithmic model, c) Box-Cox model

a)



b)



c)

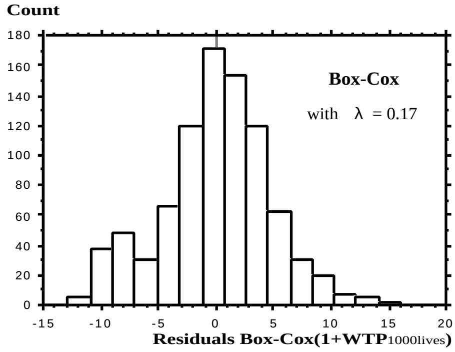


Table 6 The coefficients β_i of the three models (t statistics in parenthesis). The most significant variables (t > 2.0) are indicated in bold face

Variables	**mean of sample** (% if 0, 1)	**Linear model**	**Semi-log model**	**Box-Cox model** $\lambda = 0.17$
Gender (f=0, m=1)		-3.59 (-0.02)	-0.07 (-0.39)	-0.03 (-0.08)
Age (years)		**-16.3** **(-2.59)**	-0.005 (-0.74)	-0.02 (-1.4)
Profession (head of household): Farmer (yes =1, else 0)	2%	193.4 (0.33)	0.12 (0.19)	0.66 (0.4)
Craftsman (yes =1, else 0)	6%	-97.8 (-0.24)	0.05 (0.11)	0.36 (0.28)
Managerial staff (yes =1, else 0)	10%	700.3 (1.95)	0.03 (0.08)	0.68 (0.57)
Employee (yes =1, else 0)	49%	-187.5 (-0.70)	-0.34 (-1.16)	-0.47 (-0.45)
Retired (yes =1, else 0)	25%	233.9 (0.72)	-0.22 (-0.61)	0.1 (0.09)
Socio-Economic Class of interviewee (=1 if not head of household, else 0)	28%	-289.6 (-1.42)	-0.38 (-1.7)	-0.82 (-1.65)
Children present (yes =1, else 0)	34%	-379.3 (-1.92)	**-0.57** **(-2.63)**	**-1.6** **(-2.19)**
Persons in household (number of persons)	2.7	124.2 (1.68)	**0.18** **(2.23)**	0.35 (1.84)
Size of urban area (5 levels, increasing)		75.05 (1.51)	0.08 (1.57)	**0.24** **(2.0)**
Owner of car (yes =1, else 0)	84%	-419.3 (-1.66)	-0.74 (-0.26)	-0.38 (-0.6)
Principal driver (yes =1, else 0)	64%	-43.3 (-0.22)	-0.27 (-1.27)	-0.64 (-1.25)
Two-wheel vehicle (yes =1, else 0)	**6%**	**1159.2** **(4.07)**	**0.84** **(2.66)**	**2.44** **(3.5)**
Km/year (number)	17 700	5.2E-3 (1.6)	1.8E-6 (0.51)	0.8E-5 (1.08)
Accident with hospitalization, interviewee (yes =1, else 0)	15%	-360.5 (-1.87)	0.04 (0.21)	-0.29 (-0.62)
Accident with hospitalization, someone close (yes =1, else 0)	31%	61.8 (0.42)	-0.05 (-0.036)	-0.03 (-0.01)
Education (4 levels, increasing)	2.6	-7.43 -0.09)	0.07 (0.86)	0.15 (0.78)
Income of household (8 levels, increasing)	4.0	**154.3** **(3.01)**	**0.13** **(2.38)**	**0.38** **(3.01)**
Constant		1.67	4.68	5.49
R^2		0.10	0.06	0.08
WTP mean		819	187	269
WTP median		300		

1) Linear Model

Let us suppose that the willingness to pay WTP is a linear function of the explanatory variables x_i, with coefficients β_i. Since our choice of explanatory variables is certainly not complete, the true value WTP stated by the interviewee differs from the linear combination of explanatory variables by a residual ε

$$WTP = \sum_i \beta_i x_i + \varepsilon \qquad (11)$$

The distribution of residuals, shown in Figure 6a, is highly skewed, implying that this model is inappropriate.

2) Semi-logarithmic model

If we suppose that the hypothetical error is proportional to the given value (McClelland et al., 1991), a logarithmic transformation of the WTP, renders the distribution of errors normal.

Let WTP be the real WTP, and WTP* the answer given

$$WTP^* = WTP\ \rho \qquad (12)$$

and

$$\ln(WTP^*) = \ln(WTP) + \varepsilon \qquad \text{where } \varepsilon = \ln(\rho). \qquad (13)$$

This model also uses a linear combination of explanatory variables, but as dependent variable one chooses ln(WTP)

$$\ln(WTP) = \sum_i \beta_i x_i + \varepsilon \qquad (14)$$

This is a plausible assumption and it is confirmed by the fact that the distribution of residuals ε in Figure 6b is approximately lognormal. To circumvent the problem of taking the logarithm of zero values, we have added a small amount (1 F) to WTP before carrying out the regression; this amount will be subtracted again when the model is applied.

3) Box-Cox model

The Box-Cox model is based on the transformation of a variable z according to

$$z \rightarrow \frac{z^\lambda - 1}{\lambda}$$

with a parameter λ (between 0 and 1) adjusted such as to render the distribution of errors as normal as possible.

In general such a transformation could be applied both to the independent and the dependent variables, with different values of λ for each. In the present case we transform only the dependent variable WTP. Thus the model becomes

$$\frac{WTP^\lambda - 1}{\lambda} = \sum_i \beta_i x_i + \varepsilon \qquad (15)$$

Note that the linear and the semi-logarithmic model are special cases of this model because the transformation becomes

For λ=0, $z \rightarrow \ln(z)$ (logarithmic model)

For λ=1, $z \rightarrow z - 1$ (linear model)

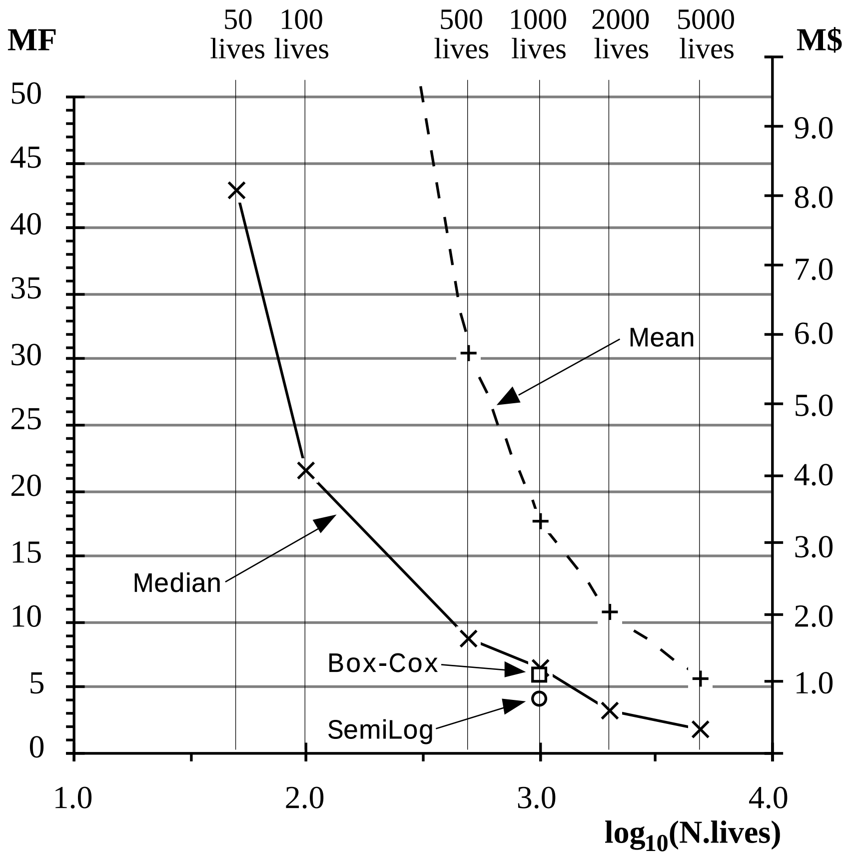
We have used the computer program Shazam. The best fit is obtained with λ = 0.17, fairly close to the semi-logarithmic model. As shown in Figure 6c, of the three models the Box-Cox yields the distribution of residuals which is closest to normal - not surprising since this model can be considered a generalization of the other two.

The results show that the variables with a positive influence on WTP are: income, the presence of a two-wheel vehicle (higher awareness of risk), the size of the urban area, and the number of persons in the household. The variables with a negative influence on WTP are age, the presence of children, and the interviewee not being the head of the household (women tend to have lower WTP than men). A more surprising result is that people who have had an accident do not increase their WTP. The R^2 are very low, but we note that they are of the same order of those found in similar studies.

Conclusions

Among CVM studies of the reference value of life, the present study has the unique advantage of having asked a range of valuation questions covering a wide range of risk reduction. The resulting value, calculated according to Eq.9, varies by a factor of more than 20 depending on whether the number of lives to be saved is 50 or 5000, as shown in Figures 1 and 7 (this variation is about the same, whether one takes the mean or the median of the WTP bids). Clearly, the results of such studies are fragile and the interpretation is a delicate matter.

Figure 7 Comparison of results for reference value of life



This finding of the present study further underlines the risk of biases in CVM of goods that are unfamiliar to the interviewee. Schulze et al. (1994), in a review of studies that compare CVM with bids made under more realistic conditions, have found overestimation by factors around 2.5; moreover they have also demonstrated that the hypothetical bias can be partly corrected by a Box-Cox model. The results of this correction procedure are numerically close to the replacement of the mean by the median of the distribution of CVM bids. In the case of the present study we find that this procedure reduces the reference value of life by a factor of about 3 relative to the value obtained from the simple arithmetic mean.

The large difference between median and mean arises from a small number of individuals with extremely high bids. This raises policy questions about the utilization of the results. Using the mean for the determination of public expenditures would appear equitable only if everybody could be made to pay according to his stated valuation. But if the elicitation of valuation is made in an anonymous manner (as is the case here), the median appears more equitable. To illustrate this point with numbers from the present study: 76 % of the population bid less than the mean and they would be overcharged if a policy were based on the mean. Of course, no single policy based on an anonymous elicitation of values can satisfy everyone's preferences, but at least the median satisfies the greatest possible fraction of the population.

To understand the apparent variation of the value of life with the number of lives saved, we have taken a look at the individual responses. We have found that they can be classified in terms of four types of pattern, reflecting different mental models, ranging from the "lump sum" pattern (same WTP regardless of number of lives saved) to the "constant WTP/life" pattern. Furthermore, the responses show strong clustering at round currency values (50 FF, 100 FF, ...). It is obviously problematic to extract a single reference value of life from a data set with such a mixture of different mental models. The large "lump sum" component of the responses and the anchoring effect make us wonder to what extent the resulting value of life, calculated according to Eq.9 by multiplication by the number of households in the country, depends on size and currency of the country in which the survey is carried out.

The questions about WTP for lives saved elicit an unspecified mixture of use and non-use value (selfishness + altruism). The questionnaire also tried to identify the selfish component of the WTP value by asking for the amount an individual is willing to pay for an option that would increase the safety of his/her next car. Although these results cannot be directly compared because the level of risk reduction was not specified, they suggest the same order of magnitude for the value of life.

The problems brought to light in this study lead us to recommend that for future CVM studies on the value of life it would be better to give the respondents the opportunity to think about the issue and revise their valuation, perhaps after several days. A single interview of 20 min is too short for reflection and for revision of WTP. We also believe that the budget constraint needs to be made more explicit, by adding questions such as *"What was the amount of your income taxes last year ?"* and *"Do you agree to pay the amount to save 5000 lives + your income taxes every year? (If not ,please revise your bids)"*.

Since this survey was commissioned by the government of France with the goal of providing guidance for the level of expenditures for road safety, the choice of a specific value takes on special urgency. A possible interpretation of the results is to say that, among the scenarios for the WTP elicitation, reducing traffic deaths by 10% is perhaps the most reasonable goal for the intermediate future, a goal that may appear both plausible and significant to the respondents. Together with the recommendations of Schulze et al. (1994) for correcting the hypothetical bias, this leads to the recommendation of the value obtained from the Box-Cox model for 1000 lives saved: **5.5 Million FF (1 Million $)**, close to the values proposed by Persson and by Miller and Guria.

For another justification of this value consider the median WTP per household values in Table 3. In terms of median WTP there are only four levels, corresponding to four levels of road safety improvement:

"low quality" (median WTP = 100 FF, for 50 and 100 lives saved)
"medium quality" (median WTP = 200 FF, for 500 lives saved)
"good quality" (median WTP = 300 FF, for 1000 and 2000 lives saved)
"very good quality" (median WTP = 400 FF, for 5000 lives saved)

(the latter is approximately equal to the WTP for a safety option that protects all occupants of a car). The "good quality" level of 300 FF corresponds to a reference value of life of 6.5 Million FF at 1000 lives saved and 3.2 Million FF at 2000 lives saved.

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