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Abstract

There has been recent interest, for purposes of public decision-making, in the quantification of certain variables which have no directly observable market price. The quantification or "pricing" of one such variable, the increase or decrease in human mortality, is useful for decisions related to standard-setting and public programs.

This paper presents a survey of four basic methodologies which have been suggested for making this quantification. The historical development of each approach is traced, selected case studies are presented and the limitations of the methods are reviewed. Plans for continuing research in this area are summarized.

I. Introduction

With the recent popularity, primarily in the United States and in France, of cost/benefit analysis as a method for evaluating government programs, and with the current interest in "quality of life" as an alternative to purely growth criteria, the need to "quantify" intangible social costs and benefits has become apparent. One such intagible cost or benefit (defined as having no directly observable market value) is the loss or saving of human life (or the decrease or increase in human mortality). Although at present there is much debate and, in some cases, a certain vagueness or "mystique" concerning this concept of valuing human lives, it has a long history, and various methodologies for its practical application have been evolved. It is the purpose of this survey to trace the development and application of these techniques for evaluating life-saving or life-risking programs.

There is a wide range of public decisions which potentially affect human mortality. Public investment alternatives which have a possible safety or health impact (e.g. the choice between transportation options, energy options, etc.) or health and safety standards (e.g. seat belts, radioactivity releases, etc.) have a direct or indirect impact on population mortality rates. If the investment options are characterized by multiple impacts, and if the standards involve changes in one of many technically inter-

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dependent impacts, then any decision technique which balances negative and positive performance requires that these impacts be weighted in some manner. A "judgemental" weighting by the decision-maker (cost-effectiveness, or judgemental, approach) is one possibility. In the case of cost/benefit analysis,[1] the impacts must be reduced to a scalar, usually by expressing each in monetary units. Another possibility is to rank, in some manner, the preferences for each impact (possibly in "utiles") and select the projects according to some societal welfare function. In general, this literature survey includes applications developed for cost/benefit analysis, a"quantification" of "life values". Some recent theoretical literature, also included, pertains to the specification of societal preferences related to changes in mortality.

Four distinct approaches for quantifying human life values have been identified. The earliest, and currently most applied -- the "human-capital approach" which values a life in accordance with its potential for future productivity--has gained wide popularity because of the apparent ease in its quantification. A second approach, to quantify life values according to some implicit value observable in societal acceptance of both public and private risks of death, has had some recent attention but very little application. A third approach, which has received some mention in the literature, is to relate "life values" either to the life-insurance purchases or to judicial awards for mortality cases. The last and most recently developed approach, to value a life-saving or life-risking program according to the "risk" to which the population is exposed and the willingness of the population to pay to avoid this risk, has been extensively treated in the literature. However, contrary to the human-capital approach, the criteria necessary for the risk approach are not easily quantifiable, and thus its applicability is still questioned.

The survey will be divided into four sections corresponding to the four methodologies. Each will be discussed with reference to the historical development, the applications, and, finally, the appropriateness of the approach for public decision-making. All references, unless otherwise specified, will relate to experience in the United States.

II. The Human-Capital Approach

The most traditional and currently most expedient method for valuing a human life is the human-capital approach, based on the premise that a man's worth to society depends on his productivity. Man is regarded as a productive unit, as human capital. In some cases, such as witnessed in the United States slave markets of the 19th century, the "market price" of a man reflected the capitalized value of the productive capacity of the last or marginal slave.[2] The "slave value" was the value of a man as a

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[1] It is not the purpose here to critique cost/benefit procedures as a tool for public decision-making. There is a welfare basis (Mishan "Cost-Benefit Analysis") for such an approach, but only insofar as it relates to "efficiency" criteria; i.e. distributional impacts are ignored.

[2] For a discussion see Fogel and Engerman, "The Economics of Slavery," 1971.

machine--the price of capital equipment with expected future returns and costs over its (his) production; as such it was analogous to the human-capital measure which will be discussed in this section.

Historically, the human-capital approach has taken two forms. The first, the "net" approach, values man only insofar as he contributes to the rest of society, excluding himself. An individual's total contribution (value) is calculated by capitalizing to the present his earnings net of his consumption or "maintenance" costs. The second approach, the"gross" value of a man, includes the individual himself in society by not excluding his own consumption. The background, applications, and recent critiques of both approaches will be presented in this section.

The "Net" Value

The net value of an individual has been defined as that amount of his capitalized earnings which accrue not to himself but to others. Man is viewed as capital, his value being calculated by deducting from his capitalized earnings the sum of his future discounted consumption or his "maintenance" costs. Such a measure is ex post in that it excludes the person himself from society's welfare and includes only the economic losses suffered by others upon his demise.

This approach was first developed for the purpose of calculating the amount of life insurance a man must purchase to be considered "fully insured"[3] (Woods and Metzgar, 1927; Dublin and Lotka, 1946). This was thought to mean being insured to the full value of the portion of a man's expected earnings that accrues to his dependents. According to Dublin and Lotka, interest in a man's value only to his dependents justifies such a calculation: "We are concerned here with man as a wage-earner or salaried worker..... If such a man is removed by death, his family suffers, emotionally, a loss which escapes our powers of evaluation in figures, and with which we are, therefore, not concerned. But the family suffers, in addition, an economic loss, for which a fairly definite estimate in dollars and cents can be given." (p.3)

The concept of placing an economic value on a human life can be traced as far back as early Anglo-Saxon Law (see Dublin and Lotka, p.7), according to which, in the event of a murder, the slayer was liable to the victim's family for the amount of the "wer". The"wer" was an arbitrary appraisal but varied with the social class of the victim. Indirectly, it thus had some relation to his earnings or "economic worth". A more explicit

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[3]Actually, Adams (1974) reports on the first person to use such a calculation. Johnathan Swift, in 1729, in a brief essay titled "A Modest Proposal", demonstrated that the value of human life was simply a function of supply and demand. The optimal time to end it was that at which the selling price minus the cost of production was at a maximum which he computed to be one year.

calculation of the value of a man was made by William Farr[4] in 1853. Interested in determining a man's "capital value" as a base for a human property tax, he computed the value of a typical individual of given earning capacity by taking the present worth of average future earnings (future earning minus personal cost of living).[5]

The net value of man has since been used to calculate "societal" losses from both diseases and accidents. Selma Mushkin (1962), in her extensive review of the literature on health investment, refers to the developmental-cost concept, according to which man is viewed as a capital asset, and the rearing of children thus as an investment in capital.[6] All the costs of child rearing, including food and clothing, are comprised in the investment outlay.[7] At about the turn of the century, Irving Fisher (1909) became interested in the social benefits of increased health expenditure and the social costs of disease and illness. One of the costs of disease, the cost of premature death, he quantified by adapting the Farr procedure to U.S. data. Fisher did not, however, accept this monetary estimate without reservation. "Although the figures for national losses strike the popular imagination, they have little significance; in fact, money estimates in this field, even when made on

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[4]William Farr, Journal of the Statistical Society, as discussed by Dublin and Lotka, 1946, p.12.

[5]This mehtod has since been duplicated by R. Ludtge (Deutsche Versicherungs-Zeitung) as quoted by Dublin and Lotka, 1946, p.13, who was again concerned with "insurance value" and expressly speaks of this pecuniary measure as relating only to the family and other interested persons.

[6]Health expenditure affects both the quality and length of life. Increased health expenditure enhances human capital by increasing both the number of persons and their productive capacity. In this way it is related to both safety and education.

[7]She attributes use of this approach to Contellon in his essay "The Nature of Commerce in General" (1775), to Quetelet (1835), and to Chadwick (1842) who, in his report on the Sanitary Conditions of the Labouring Population in Great Britain, established the idea of health programs as an integral part of economic policy. Mushkin quotes Chadwick as writing, "The economist for the advancement of his science may well treat the human being simply as an investment of capital...." (p.149).

the per capita basis, are of little value except as emphasizing the overwhelming importance of human vitality compared with those interests which are usually measured in money. It is impossible in any true sense to measure human life in terms of dollars and cents." (p.124)[8] Finally, Burton Weisbrod (1961), interested in the allocation of medical research amongst various deseases, quantified, as part of the social cost of each disease, the cost of premature death. He was interested in the monetary loss to society as a whole: "....the loss of life involves the loss of an actual or potential productive unit" (p.33). Unique to his calculation, Weisbrod includes the cost of premature burial.

Prior to Weisbrod, a net value calculation of losses from premature death appeared in 1956, when D.J. Reynolds, a British economist, estimated the social costs of deaths due to automobile accidents. He thought that loss of life should be addressed in two parts: the pain, fear and suffering imposed by the occurrence, or risk of occurrence, of road accidents; and the more concrete burdens of the net loss of output of goods and services. He cautions, however, "that for a variety of reasons it is beyond the competence of the economist to assign objective values to the losses suffered under the former" (p.393). He thus confines his analysis to the latter, calculating the net loss by first multiplying the average annual output per head by the expected working life of each age group and then deducting the average consumption per head. His method differs from Farr's and Fisher's, not in principle, but because he uses average rather than marginal output.

As recently as 1966, the net income approach has been used to calculate losses from accidents. In a special report prepared under contract for the Systems Research and Development Service (SRDS) by the Flight Safety Foundation (1966), it was estimated that the aggregate costs--aircraft damage, injury and fatality--of general aviation accidents (U.S.) in 1964 was $321.8 million. Of this amount, $268.1 million represented the cost of 977 general aviation fatalities. Each fatality was valued at an average of $274,000 as the "deceased's worth to his family", a figure which represented two-thirds of his estimated total income for the 25 years of his remaining productive life. In this report it is stated: "Other values of human life have been suggested by other sources but there are no positive measures. All figures seem to be subject to interpretation." (p.6)

The latest mention of using a "net expected earnings" approach can be found in Simon Rotenberg's 1968 discussion on the benefit of saftey: "....the cost of death is the sum of the values of the deceased person's expected contribution to the output of the

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[8] In his discussion of capitalizing earning power, Fisher cites an earlier study by Mayo Smith ("Statistics and Sociology"), who estimated that men and women between the ages of 15 and 45 averaged $1,000 in value, and that every imigrant must then represent a certain labour value--at least the value of a slave: $875. Further, the late Honorable Carol D. Wright, whom fisher quotes as a man "whose opinion was worth more, probably, than that of any other man in the United States", stated that he would not regard $1,000 as excessive (Fisher, p.118).

economy, if he had not lost his life, perhaps net of his expected consumption, the resources employed in medical therapy prior to his death, the administrative costs of relevant insurance schemes, the difference between the cost of early and late burial, and the grief of surviving kinfolk" (p.491).

Most of the analysts who have used the net value approach have been careful to specify that it is a measure of economic loss accruing to the family or to society only; yet many writers have been offended at the suggestion that this measure might reflect the entire loss to society associated with the death of one of its members. As an example, Ely Devons (1961) dubs this approach as "....quantification gone mad", and continues: "Estimating the 'net loss' to the community in this way leads, for example, to the fantastic result that if we could have more road accidents in which we succeeded in knocking down and killing old people we should reduce the 'net loss.' ....It is indeed a sad commentary on the state of public conscience if we have to be persuaded that measures to reduce road accidents will pay, in some economic sense, before we will listen seriously." (pp. 107, 108)

Devons was referring specifically to Reynolds' study on the cost of road accidents. Although Reynolds had stated that his estimates of human life were only a minimum, Devons was apprehensive over the possible implications of ignoring the individual's demand for his own life and the psychic costs involved. This apprehension was evidenced as early as 1909 when John Mill commented on Adam Smith's concept of human capital or "useful abilities": "The human being himself I do not class as wealth. He is the purpose for which wealth exists. But his acquired capacities, which exist only as a means, and have been called into existence by labour, fall rightly, as it seems to me, within that designation."[9]

The Gross Value

It was thought by some analysts that a gross value, one that includes total output of the individual that he and others consume, is a better measure to reflect social value. Rashi Fein (1958) was the first to discuss the pros and cons of the two approaches: "This (the net value) may appear a rather cold-hearted approach, for it implies that the family is 'better off' if a retired parent (not producing, but consuming) dies. The reader must remember that our discussion is limited to values as expressed in dollars and that, as long as we do not measure 'psychic values,' .... the family is 'better off' in dollars and cents." (p.15) Acknowledging that Dublin and Lotka's figures are

[9]John Stuart Mill, "Principles of Political Economy," as quoted by Dublin and Lotka, 1946, p.12.

correct for their purposes, he prefers, however, to use total income, because the individual himself is part of society's welfare. The consumption by the individual is an end in itself. "Assume a bachelor earns five thousand dollars a year in an economy without taxes. Assume, further, that his consumption expenditures per annum are five thousand dollars; savings, thus, are zero. Is this individual's net worth to society zero (five thousand produced minus five thousand consumed)? This would hardly seem to be the case. On the five thousand dollars income the individual enjoys life, and it is for this purpose that the social economy exists." (p.18-19)

Fein was not the first to use gross earnings as a measure of a man's social worth in terms of output. In 1699, Sir William Petty used such a measure to estimate the value of every head in England:

> Suppose the People of England be Six Millions in number, that their Expence at ℔7 per Head be Forty Two Millions; suppose also that the rent of the Lands be Eight Millions, and the yearly profit of all the Personal Estate be Eight Millions more; it must needs follow, that the Labour of the People must have supplied the remaining Twenty Six Millions, the which multipled by Twenty (the Mass of Mankind being worth Twenty Years purchase as well as Land) makes Five Hundred and Twenty Millions, as the value of the whole People; which number divided by Six Millions, makes above ℔80 to be the value of each Head of Man, Woman and Child, and of adult persons twice as much; from whence we may learn to compute the loss we have sustained by the plague, by the slaughter of men in war, and by sending them abroad into the service of foreign princes.[10]

Petty's estimate, although crude, is based on a man's average product capitalized over 20 years. He makes no allowance for the maintenance of the workers.

The more recent literature in which an estimate for the productive value of a man appears begins with a 1958 study prepared for the Federal Aviation Administration (FAA) by United Research Inc. To estimate the value of preventing the death of an air carrier passenger, the discounted value of the average passenger's expected income, $185,000, is considered appropriate. This is one of the earliest cost/benefit analyses of a project which involves the possible saving of lives. The authors are somewhat reluctant, however, to "quantify" the benefits. "Although there is no real justification for treating a lost life in terms of dollar values, nonetheless it is useful to place as many of the factors involved in as common terms as possible" (p.59).

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[10]Sir William Petty, "Political Arithmetic, or a Discourse Concerning the Extent and Value of Lands, People, Building, etc," as quoted by Dublin and Lotka, pp. 8-9. For a discussion, see Dublin and Lotka, 1946, p.14.

In the early sixties, as cost/benefit studies grew in popularity, it became increasingly important to quantify the benefits from saving lives. Carlson (1965) was one of the first to address the problem of saving lives from an economist's point of view, or in the more general framework of resource allocation. The allocation of funds to life-saving should, at least, be efficient in equating on the margin the dollar expenditure per life saved. To promote more rational decision-making, Carlson advocates use of the human capital approach. He admits many short-comings of the measure, but suggests that at least, as a first approximation, the human capital approach may be better than what is being used.

A refinement of the gross measure, and the most comprehensive to date, is contained in a 1962 study by Gary Fromm. Acknowledging that his concern is for the derivation of guidelines useful for investment decisions, Fromm reasons that a more comprehensive measure than simple pecuniary losses is necessary, one which allows the government to maximize the welfare of all its constituents. "Consideration of this problem flows from the view that in our society it is important for the government to attempt to maximize the welfare of all its constituents. Welfare here includes not only material factors, but also all the non-economic satisfactions which the individual may attain. Ideally, then, in constructing a measure of value for a human life, insofar as possible, one should take account of both economic and non-economic factors". (p.vi-43) Unfortunately, however, Fromm makes no attempt to include the non-economic factors in his measure; on the other hand he is the first to devise a more comprehensive base of economic losses resulting from a death. For the case of an air fatality, Fromm includes the loss to the individual himself (his discounted expected earnings), the loss to his family (2/3 of the discounted earnings), the loss to his community, his employer, the government (in taxes), and the airlines.[11]

Fromm emphasizes that these figures are by no means inclusive of all losses due to an air fatality, but can only serve as a minimum to the relevant figure; yet these calculations have since been considered as somewhat of an upper limit.[12] In a report prepared in 1962 by E. Bollay Associates under contract for the Systems Research Development Services (SRDS), a value of $251,000 for a general aviation fatality is calculated. They make note of the Fromm study but choose to use only the present value of the average stream of future earnings. In 1965, an in-house SRDS report again assigned a value of $250,000, using the same procedure as developed in the Bollay report. In 1965, the Institute for Defense Analysis, in a study of the North Atlantic

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[11]The average cost of an air carrier fatality in 1960 was determined to be $373,000 and of a general aviation fatality $422,000.

[12]Contrast this approach with the 1966 FSF report already discussed, in which a net income figure was used-- the economic loss accruing to the family only.

Air Traffic Control System, took the Fromm estimate as an upper limit to the value of an air fatality, the Bollay estimate as a medium-range estimate, and the liability limit prescribed by the 1929 Hague Protocol ($16,000) as a lower limit.[13] There was no analysis of the relative validity of these alternative estimates.[14]

The FAA has been the most prolific in the development and use of a measure for the value of life, but others have also been interested. One of the most careful and rigorous studies in valuing human lives for program analyses was a 1967 report prepared for the Social Security Administration by Dorothy Rice and Barbara Cooper. Using various rates of discount they calculate by age and sex the expected value of an individual's future earnings, again limiting the analysis to productive capacity. They comment that "these are by no means the only measures of the value of human life".(p.1954)

In 1970, two studies were published on the economic costs of air pollution, both necessarily dealing with a value of life. In the tradition of Weisbrod, the costs of various diseases, including the cost of mortality, were calculated. In the first study, "The Economic Costs of Air Pollution," Ronald Ridker calculated essentially the same measure as did Weisbrod, the gross loss in expected earnings plus the costs of premature burial. The second, a study by Lester Lave and E.P. Seskin, expanded the scope of diseases covered by Ridker, but used essentially the same measure, excluding the cost of premature burial. This estimate, however, was considered by the authors to be very conservative. "For conceptual meaning it should reflect not expected earnings but willingness-to-pay by the individual for improved longevity. The sum of income lost is a gross underestimate of willingness-to-pay." (p.37)

Cohen, in 1970, was the first to introduce the concept of life values to be used in evaluating safeguards for atomic energy applications. He suggests that $250 is the sum necessary to compensate an individual for accepting one rem of radiation exposure, a figure which is "....reasonably indicative of potential lifetime earning capacity." (p.13) Since Cohen assumes that 1,000 rems is the lethal dose and that the human effects of irradiation are linear with respect to dose, the

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[13] There is now an effort to increase this limit to $100,000 or possibly $150,000.

[14] For further comments on the Bollay, SPDS, and IDA reports, see Lanka and Gansle, "The Problem of Dollar Values for Air Traveller Safety", 1967. In their words, all these measures have "reflected a mixture of uneasiness and resignation in estimating the value of lives saved--implying a mistrust of the rationale for evaluating fatalities as presented in prior reports; acknowledging an inability to develop scientifically valid new estimates; and using some on-the-shelf data, with or without adjustment, as reasonable approximations." (p.7)

implied life value is $250,000. Lederberg (1971) calculated life values by estimating the fraction of the U.S. national health bill attributable to genetic mutations caused by background radiation. A death was treated as a loss in work time plus some additional medical expenses. Because of the uncertainties involved, he calculates values ranging from $50,000 to $1 million for a human life, depending on the age at which the death occurs. On this procedure he comments, "This kind of cost-accounting is morally insufferable, but we must find some de facto standard of value in making hard decisions." (p.4) Otway et al. (1971) were the first to apply such a life value estimate in the calculation of a cost/benefit ratio for a large-scale muclear project.

The U.S. Atomic Energy Commission has only recently considered using monetary life values. Such a calculation can be found in a draft report scheduled for publication in 1975. It is reasoned that the cost to society of one man-day lost is approximately $50, a figure which is somewhat arbitrary but reportedly reflects average earnings ($15/day), medical and funeral expenses, and effects on family life. Since the loss of a life is on the average equivalent to 6,000 man-days lost, the life equivalent cost is $900,000. But it is cautioned that the figures are "arbitrary, assigned to permit rough comparisons, and carry with them no implied comment on the absolute value of a human life." (p.1-26) The latest AEC report (1974), known as the Rasmussen report, makes no calculations for the monetary value of avoiding possible risks of life.

A final area to be discussed in which a value of life has been developed is that of automobile safety. In 1972, the White House Office of Science and Technology estimated the average cost of a traffic death to be $140,000. This figure was based on the per capita income in the United States multiplied by the average number of years of life foregone as a result of a traffic fatality.[15] This average figure was reportedly used because it values all lives equally and avoids questions of the economic value of one life versus another.[16] In the words of Howard Gates, who served on the White House Study: "If you had an Ed Cole (president of General Motors) killed, that would cost the economy much more than, say, one Ralph Nader because Nader didn't earn so much. Neither one of them would accept that." (Washington Post, 1972) This $140,000 figure resulted in unfavorable cost/benefit ratios for both air pollution standards and the proposed requirement for airbags; it resulted in more favorable ratios for other safety devises such as seat belts.

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[15]The National Safety Council, in a memo dated July, 1971, set this value at $45,000 (based on discussions with Ed Wright, NSC, July, 1974).

[16]Compare this with the Fromm study which set the cost of a general aviation fatality higher than that of an air carrier fatality.

In 1972, shortly after the RECAT report, the National Highway Traffic Safety Administration (NHTSA) did a comprehensive study titled "Societal Costs of Motor Vehicle Accidents". Their objective was to include all quantifiable economic costs of a traffic fatality. Included were property damage ($1,500), medical costs ($1,125), funeral costs ($900), legal and court costs ($3,000), wage losses ($132,000), miscellaneous costs ($200), insurance administration ($4,700), losses to others ($1,300), employer losses ($1,000), community services ($7,000), pain suffering ($10,000)[17], home and family duties ($33,000), and assets ($5,000). The total cost per fatality was, then, $200,725. The largest item included, wage losses, was again calculated by discounting to the present average expected earnings. This approach differs from the Fromm calculation in that a portion of the wage bill is not double-counted as an additional loss to the family. The item "losses to others" included, for example, the time lost by relatives travelling to the hospital or to the funeral.

The NHTSA report epitomizes all past efforts to value a life economically. They recognized their efforts, however, as a quantification of only those costs which are directly or indirectly quantifiable--not as a "value of life".

> Our approach was to identify and present quantitative estimates of as many losses associated with motor vehicle accidents as possible. We have not quantified all losses associated with the tragedy of a highway accident. We have not placed a value on a human life, and we are not arguing that it is unwise to spend more than the amounts calculated.... We wish to emphasize that placing a value on a human life can be nothing more than a play with figures. We have provided an estimate of some of the quantifiable losses in societal welfare resulting from a fatality and can only hope that this estimate is not construed as some type of basis for determining the "optimal" or even worse, the "maximum" amount of expenditure to be allocated to saving lives. (NHTSA, 1972, A-1, A-3).

In spite of this warning, decisions have been and are being made on the basis of the $200,000 figure. For example, in a 1974 Department of Transportation report evaluating the proposed underride guards for trucks, it was estimated that 180 deaths per annum would be prevented at $200,000 per death for a total benefit of $36 million (for fatalities only). The costs were estimated at $310 million. Thus, the proposal was rejected. Similar analysis, again using $200,000 per life, is currently being prepared by the Department of Transportation on the feasibility of mandatory use of seat belts.

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[17] Calculated from insurance settlements.

Critique

In the last sections, we have traced the development of the human capital approach to life evaluation, from its original intent of evaluating life-insurance decisions and calculating ex post accident losses to its present status as a tool for evaluating investments which potentially risk or save lives. In the latter application, we have noted the dissatisfaction on the part of most policy-makers. For example, Dublin and Lotka, one of the first to develop such a methodology, reflected the setiment of most of their predecessors: "All estimates of losses to the community obtained by some elementary process of totaling losses to wage earners, immediate families, or the like, must be viewed with extreme reserve."[18] In general, it has been regarded as a measure for the minimum expense which society can justifiably undergo to save a life. It has never been suggested that it represents an optimal measure from the standpoint of societal welfare.

Thedia and Abraham (1961), both French engineers, were the first to state explicitly that the measure was not appropriate for evaluating projects ex ante which affect human lives ex post. In other words, they question making a decision which in the future might affect a man's life, based on criteria which presumes that the man is already deceased. On the question of how much a community should spend to save a life, they comment, "....neither the calculations taken from the insurance companies nor strictly economic calculations make it possible to give a strict reply to this question. ....it does not follow that because the death of an individual costs the community nothing, no attempt should be made to avoid it." (p.590)

Somewhat later, in a second French publication, by Rösch (1961), the human-capital approach was again criticized. "Even in a strictly economic context, a relationship can be established between the product of a human being and the price of life only if man is considered as a factor of production, but this relationship does not hold if life is considered a necessity". (p.137)

Schelling (1967) was the first to discuss comprehensively the problem of evaluating loss of life and limb for the purpose of government expenditure. He rejects the human-capital approach, suggesting that expected income, except insofar as it is part of the data which go into making individual tradeoffs on risk and income, has little to do with the value of one's life. In Schelling's words, "there is no reason to suppose that what a man would pay to eliminate some specific probability, P, of his own death is more than, less than, or equal to, P times his discounted expected earnings. In fact, there is no reason to suppose that a man's future earnings. discounted in any pertinent fashion, bear any particular relation to what he would pay to reduce some likelihood of his own death." (p.149) Schelling emphasizes

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[18] Dublin and Lotka (1946, p.327).

the individual's interest in decreasing his own risk of death, or, synonymously, increasing his life expectancy. He calls this the consumer interest. Once a program to save lives has been identified, it is relevant to determine what it is worth to the consumers or the people who stand to benefit from it. It should be their privilege, according to Schelling, to have the program if they are collectively willing to bear the costs.

It is interesting to note that a Federal Aviation Administration staff report (Lanka and Gansle, 1967), written shortly after the publication of the Schelling article, recommended consideration of a study effort along the lines suggested by Schelling, including discontinuation of the use of the human capital approach.

> Remaining lifetime earnings must be regarded as an invalid measure of even the minimum value of a life saved. What, then, is the significance of lifetime earnings for valuing lives saved? The conclusion here is that it can serve to measure in its net form the economic value of a life saved to other people only, i.e. to society. This value of itself is only a small and poor reason to undertake safety programs, i.e., to protect the economic well-being of the statistical people whose lives are not at stake (p.37).

Finally, Mishan (1971) has criticized both the gross and net capital approaches evaluating human life. The gross income approach which values lives according to the loss of potential future earnings, Mishan writes, "can be rationalized only if the criterion adopted in any economic reorganization turns on the value of its contribution to GNP, or more accurately, to net national product." (p.689) Such a measure is based not on the principle of in some sense maximizing societal welfare or total "utility", but rather on maximizing output or production. It values livelihood and not lives. The net product approach, which values lives according to the loss of potential earnings net of consumption, is not satisfactory, according to Mishan, because it has no regard for the feelings of the potential decedents. It ignores society ex ante and concentrates wholly on society ex post." (p.680)

These criticisms of the human-capital or life-time earnings approach are concisely summed up by Rappaport in Hirshleifer et al. (1974). He gives the following three grounds for rejecting the approach.

> 1. The lifetime-earnings measure is deterministic. Actually, there is no theoretical basis for using such a measure, in the first place. But if there were, it would <u>seem</u> to refer to a conceptual experiment of trading "a life" for money. In practice, we are usually evaluating small increases in the <u>probability</u> of death. Clearly, our answer must come to grips with risk attitudes; and it is well known that uncertain losses are (usually) subjectively valued at larger than the statistical expectation.
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> 2. Lifetime-earnings takes no account of leisure. If there were no saving or borrowing, consumption activity would be proportional to earnings and this problem would

disappear. But the phenomenon of retirement places a severe burden on such a simplification. The human capital measure seems to undervalue old peoples' lives vis-à-vis working-age people.

3. The lifetime-earnings measure does not include externalities. Many people feel loss from the death of another even though they derive no financial benefit from that person. (p.2,3)

III. Implicit Societal Evaluation

In the last section, the human-capital approach for valuing a human life was reviewed. Although it is currently the most popular method (U.S.) for evaluating public programs which affect human mortality, it is considered by economists to be inappropriate as a quantification for purposes of a cost/benefit analysis. In this section, an alternative measure, an "implicit" societal evaluation, will be discussed.

Since society, through its political processes, in fact makes decisions on investment expenditures which occasionally increase or decrease the number of deaths, an implicit value of human life can be calculated. Such a method requires no direct calculation of the loss of potential earnings or spending. Instead, it approaches the problem from a social point of view by estimating the expenditure society actually makes to save a life. If, for example, an arrangement is made that will increase safety, and save an estimated five lives, at a cost of $100,000, then the implicit value of a life is $20,000.

Carlson (1963) was the first to calculate implicit life values. He reviews selected government programs, including the B-58 ejection system, in which the implicit value of life is somewhere between $1.7 and $9.0 million, and the emergency procedures for pilots flying jet fighters, in which the implicit value (for recommending ejection) is something greater than $270,000. Carlson's purpose, however, was not to suggest that these measures be used for making future investment decisions, but only to show that since the implicit values cover such a range, more efficient decisions could be made with a standardized "value of life".[19]

Georges Morlat, a Professor at the Institute of Statistics of the University of Paris, dealt with the problem of life values in 1970, in connection with his research on medical decision-making. He suggests several methods, including the human-capital approach, for valuing a life, but for purposes of his analysis he chooses to use the "cost of protection accepted by a community to save anonymous persons." Hence, he uses an implicit valuation of life.

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[19] Fromm, in 1965, again mentions the calculation of an implicit value, but only as a basis for comparing projects. This information he states, could prove useful in ranking the relative desirability of projects.

Morlat recognizes that there is a wide range of costs which society undertakes to save lives. He calculates that, in France, $30,000 is spent per life saved in road accident prevention, and $800,000 to $1 million in aviation accident prevention. Such differences, he speculates, might not appear so scandalous if one recognizes that many people enjoy risk-taking, i.e. willingly accept higher risks in driving an auto for certain psychological benefits. Also, he suggests that persons are not indifferent to the manner in which they die, whether it be in a road accident or a plane accident. He cautions, however, that these divergencies may not be so acceptable once the costs are made explicit to the decision-makers. Yet, Morlat considers the acceptance of these implicit values as representative of community preferences for different types of risks. He leaves aside the question whether such implicit values in fact reflect the psychological phenomena of different "means of death," or rather the inefficiency of decision makers in making allocations.

Sinclair (1972) suggests use of an implicit value for evaluating industrial safety projects. It is possible to determine the cost effectiveness of any life-saving project by examining the marginal expense of the "last life saved". Such an approach, however, is limited to ranking those projects with a single product, life-saving. It is not applicable to, say, highway improvements where safety is only one of the objectives.

Starr (1969), in his article "Societal Benefit versus Technological Risk", attempts to uncover historical risk versus benefit relations for the societal and individual acceptance of voluntary and involuntary risks. He poses the question of what benefits were necessary to compensate affected individuals for accepting risks of death. In other words, he attempts to estimate both the implicit value individuals put on their own lives by accepting voluntary risks, and the implicit value society puts on social risks by preventing them. His selected risks include, for example, the Vietnam war, hunting, general aviation, motor vehicles, electric power, natural disasters, and so forth. The benefit is calculated by estimating money spent to participate in or to avoid the activity.

Starr's general methodology has been critically reviewed (Otway and Cohen, 1975). What is perhaps more important than the results is the question of the feasibility of such a methodology for use in making future risk/benefit decisions. According to Starr, "....because this methodology is based on historical data, it does not serve to distinguish what is 'best' for society from what is traditionally acceptable" (p.1232). But in an apparent contradiction he later suggests: "Application of this approach to other areas of responsibility is self-evident. It provides a useful methodology for answering the question 'How safe is safe enough?'" (p.1237) That traditionally accepted risk/benefit tradeoffs can provide a rationale for making current decisions on safety has been accepted in much of the analysis done in the area of nuclear power.

Critique

Although calculation of implicit life values is useful to determine discrepancies in life-saving expenditures;[20] the use of these values for making decisions is considered less than optimal. Mishan (Evaluation of Life and Limb: A Theoretical Approach, 1971) criticizes this procedure for decisions which have been implicitly made in democratic societies. On an implicit value placed on life by the political process, he comments that the 'justification appears somewhat circular....the idea of deriving quantitative values from the political process is clearly contrary to the idea of deriving them from an independent economic criterion.... By recourse to a method that refers a question, or part of a question, received from the political process back again to the political process, the economist appears to be concealing some deficiency in the relevant data or 'some weakness in the logic of the criteria'" (p.690). In other words, unless it is assumed that societal decisions on life-death tradeoffs have been made in the past according to some notion of optimization, such decisions should not be an input into current decision-making. In the words of Starr, "....it (this methodology) does not serve to distinguish what is 'best' for society...." (p.1232).

IV. Insurance Premiums and Court-Decided Compensation

In the last section, an alternative to the human-capital approach, an implicit valuation of life, was reviewed. Other alternatives, including the amount of insurance a man purchases and the compensation awarded by the courts for mortality cases, have also been suggested and will be discussed in this section.

Insurance Premiums

It is sometimes suggested that some relationship exists between the value an individual places on his own life and the amount of life insurance he chooses to purchase. This relationship is based on the premium a man is willing to pay, and the probability of his being killed as a result of engaging in some specific activity. For example, Fromm (1965) calculates that, in 1962, the probability of a passenger being killed in a plane trip was approximately .00017 per cent. If the passenger values his life at $400,000 he should be willing to pay $.68 per trip to reduce that probability to zero.

However, when a passenger purchases life insurance, he does not actually reduce the probability of an accident. Fromm, in the above example, concludes that this amount ($.68) is spent not to insure that a certain sum be paid to his dependents in the case of death, but to reduce the probability of death. The passenger would not necessarily pay $.68 to insure that his livelihood continue to accrue to his family. In fact, Mishan (1971) points

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[20] Cohen has estimated many more points on this "revealed societal preference curve".

out that a bachelor with no dependents would have no reason to take out flight insurance "notwithstanding the fact that he could be as reluctant as the next man to depart this fugacious life at short notice" (p.691). Hence, the amount of insurance a man takes out reflects only his concern for his dependents, but it is not a measure of the value he sets on his own life.

Court-Decided Compensation

Court-decided compensation or jury awards have been used extensively as estimates of the disbenefit of pain and suffering (see, for example, studies by Heaton (1971) and Peszek (1973)). Seldom, however, have court awards served as an estimate for the disbenefit of loss of life. The first mention of such a method for calculating life values can be found in a report by Thedie and Abraham (1961), in which the "price of life" is calculated as some arbitrary proportion of jury awards for pain and suffering.

Cohen (1970) points out that a life value of $250,000 is "not inconsistent with recent legal awards in loss-of-life claim judgements" (p.13). He notes, further, that this figure is also "reasonably indicative of potential lifetime-earning capacity" (p.13). But such a relationship is not unexpected since, as pointed out by Carlson (1963), the human-capital or expected-earnings figure is often used by the court in deciding compensation for fatalities.[21] Unfortunately, then, juries do not acknowledge their function of establishing incentives (see Calabresi (1970)). The person killed cannot be compensated post hoc. Hence, as Rappaport (in Hirshleifer, 1974) concludes, "we cannot swallow whole the results of court decisions" (p.79).

In spite of the difficulties, the Federal Aviation Administration has recently suggested this approach. In a draft order to develop a cost/benefit method for selecting and ranking airport traffic control towers, the F.A.A. recommends a figure of $300,000 and $390,000 for an air carrier fatality and a general aviation fatality, respectively. These figures are calculated from the CAB non-Warsaw-Pact accident payments for the period 1966 to 1970 and extrapolated to 1974.

V. The Risk Approach

Most decisions to undertake projects which potentially save or risk lives do not deal with ex ante "identifiable" persons. The decision, for example, to install highway guards is based on a calculation of "expected lives saved", but the identity of the individuals is not known. In contrast, a decision to "save a drowning girl" or "provide a kidney

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[21] Holmes points out, however, that the distribution of compensation discriminates against the survivors of fatality cases because there is a lower probability of recovery for "income loss" than for medical expenses.

machine" deals with identifiable persons. In the former case, where the recipients of a life-saving expenditure are anonymous, an alternative to calculating "expected lives saved" is to calculate the reduction in the probability of death for each affected individual. This is referred to as the "risk approach".

This approach is applicable, again, to cost/benefit analysis. Probabilistic measures are substituted for expected outcomes, and certainty equivalents, defined as certain outcomes which are preferentially equivalent to probabilistic ones, are included in the costs. If all the outcomes or impacts of the project are to be reduced to a scalar measure, then the certainty equivalents are normally expressed in monetary terms.

Thedie and Abraham (1961) were the first to distinguish an "identifiable" death from a "statistical" death and thus introduce the concept of risk. "It is impossible to weigh in the balance certain deaths and probable deaths, even if the latter are in greater number. The assessment we are going to make calls for anonymity and therefore, we can only deal with small risks, minor probabilities. When we talk of saving a human life, the question is really only one of avoiding a probable death, resulting from the multiplication of a slight probability by a large population" (p.591).

The more recent literature on the subject has also recognized this distinction. "Interest will not be centered in knowing the integral worth of every 'sparrow' but in knowing the value and cost of putting nets under 'falling sparrows'" (Carlson, 1963, p.3). "It is not the worth of human life that I shall discuss, but of 'life-saving,' of preventing death. And it is not a particular death, but a statistical death" (Schelling, 1967, p.127). "It is never the case that a specific person, or a number of specific persons, can be designated in advance as being those who are certain to be killed if a particular project is undertaken" (Mishan, 1971, p.639).

The methodologies for assessing these risks of death have differed considerably. Thedie and Abraham caution that the assessment cannot be purely the outcome of objective data, but should be determined by a collective decision. All the economist can do is guide the government in making such a decision. However, because of the political difficulties involved in taking a stand on the issue, Thedie and Abraham attempt to reach a figure themselves. They include in the measure what they refer to as the "affective factors,[22] one of which is the denial to the individual of his "desire to live." This "pretium viveda," or price of life, is unique to their analysis. It is an outcome of their attempt to value lives ex ante, to include in the community's welfare the possible victim. The 1957 value of the "pretium viveda"

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[22]The "affective factors" include the following: (1) the sorrow caused to the victim's family; (2) the injury to the nation in its "imperative rule to preserve the lives of its members, irrespective of the advantages to be derived, and whether or not the persons concerned have families;" and (3) the injury to the individual himself by the denial of his desire to live.

was determined to be 14,000 French Francs. As discussed in the last section, the derivation appears somewhat arbitrary. It is set in proportion to "court judgements" for pain and suffering, but how the proportions are determined is not discussed. This price, however, seems to be in no way reflective of the risk or probability of death.

Schelling, on the other hand, maintains that the direct benefit of safety and health programs is not the value of the lives saved, but rather the value of a reduction in the statistical probability of death within a given population. The appropriate question to answer is: what is it worth to reduce the statistical probability of death by the amount the health or safety program promises? The problem then is not one of saving an identifiable individual but of evaluating programs which affect life expectancy i.e. disease prevention, safety regulation, flood control, personal protection, and so forth. What is it worth to decrease the risk of death to some identifiable group? Schelling proposes that the relevant value of life is, in actuality, the value of risk reduction. The total willingness to pay for this reduction will probably include, besides the individual's self interest, the interest of family, friends, and society.[23]

Mishan (1971a) adopts the approach suggested by Schelling--that in evaluating life saving programs, the relevant benefit is not the expected number of lives saved but the value of reducing the risk of death to the relevant population. He is interested in deriving a value which is consistent with the principles of evaluation in cost/benefit analysis. As such, programs which involve some increased or decreased risk of death should be evaluated by reference to the Pareto principle--"what each member of the community is willing to pay or would expect to receive for the estimated chage of risk." Evaluations consistent with this principle are such that at least one person in the economy can be made better off, with none being made worse off[24]. This principle provides the rationale of all cost/benefit calculations.

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[23]In a critique of Schelling's article, Gary Fromm (1971) challenges the willingness-to-pay criterion as a good indicator in determining the proper scope and magnitude of programs to reduce the risk of death. Willingness to pay, according to Fromm does not establish a unique value of life if the welfare function is unknown. He further questions willingness-to-pay as a valid measure because, first, individuals typically ignore the external social costs in making their personal decisions, and second, many individuals derive a positive utility from taking small risks. Such gambling with their life is based often on subjective, incomplete and inaccurate information.

[24]The assumption is that the gainers can compensate the losers and there remains a net gain. Thus, there is a potential Pareto improvement even if this compensation is not, in fact, made.

The relevant benefit of life-saving programs, consistent with the Pareto principle, is what each member of the community is willing to pay to avoid the risk.[25] Mishan identifies four distinct types of risk to be anticipated. He first, voluntary risks, are relevant to projects in which the users voluntarily "purchase" the product and in so doing accept the risk. Insofar as the benefits of such projects are calculated by reference to estimates of consumers' surplus, no allowance need be made for additional risk of loss of life, since the sum each person is willing to pay is net of all the risks.[26] However, account must be taken in the cost/benefit analysis of involuntarily assumed risks (Mishan identifies three).[27] These can be regarded as diseconomies external to the particular project or industry. The first, a direct involuntary risk, is the risk inflicted directly on an individual who has made no choice to "consume the project" or avail himself of its services. The second, or indirect risk, is that of infection of others, e.g., infection of polio. The third involuntary risk arises from the general concern, both financial and psychic, of other members of the population when one member is exposed to a certain risk of death.

All involuntary risks, both direct and indirect, must be evaluated in terms of the sum of money necessary to compensate the affected persons for bearing the risk. Mishan emphasizes that the concept of evaluating programs according to the Pareto principle is not simply an alternative to existing methods, but is the only economically justifiable method.

Empirical Work

Both Schelling and Mishan have proposed that for the evaluation of a program which saves human lives, it is relevant to determine what it is worth to the affected population or "consumers." It should be their privilege to have the program if they are collectively willing to bear the costs. The question is how to estimate this willingness to pay on the part of the consumers.

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[25]This willingness to pay is derived in Mishan's analysis from "utility theory." In a recent article by Papp et al. (1974), it is suggested that utility analysis be used for evaluating risks of nuclear facilities.

[26]For example, in a cost/benefit analysis of the tobacco industry, there is no need to subtract from the benefits the risk of lung cancer, since this risk is reflected in the demand for smoking.

[27]An example of involuntary risks is the risks assumed by the population adjacent to a nuclear power station.

Schelling suggests two approaches. The first is to rely on market data, and the second to survey the relevant population via questionnaires. Both methods, according to Schelling, are imperfect, but he prefers the survey approach. The problem with the use of market data, Schelling points out, is that "market decisions people make (in the case of accepting risk of death) relate to contingencies for which the probabilities themselves are unknown to the consumer, sometimes barely available to the person who seeks the statistics, invariably applicable in only rough degree, and mixed with joint products that make the evidence ambiguous." (p.148). Schelling concedes that in the questionnaire approach, it is difficult for the consumer to state what it is worth to him to reduce the risk of death; people are not good at answering hypothetical questions or assessing small probabilities of big events. To avoid this problem he suggests a technique of scaling the risks, or making roundabout decisions on more easily conceivable probalistic situations, which will indirectly imply a preference for avoiding smaller risks. An additional complication is that individuals are concerned not just with reducing probabilities of death but also with avoiding the anxiety associated with anticipating such probabilities.

Fromm (1968), in a critique of Schelling's article, questions the practicability of using questionnaires. First, he notes that surveys which ask hypothetical questions rarely receive accurate responses. Fromm's opinion is "that society is better advised to treat individual decisions in this area as imperfect and not rely on willingness to pay as the primary criterion for fixing the scope or magnitude of life-saving programs" (p.174). Willingness to pay should not be ignored completely, however, but should be used as a guide to the minimum and not the maximum expenditure.

On the prospect of giving applicable and quantifiable measures for risk avoidance which are consistent with the Pareto principle, Mishan is also not so optimistic. He suggests a questionnaire method acknowledging that the method is imperfect but that "the data yielded by surveys based on the questionnaire method are better than none, or better than data obtained by persisting with some current measures...." (p.705).

With the exception of two informal surveys by Cohen (1970) and Otway (1972), there have been no substantial efforts to devise and implement a questionnaire approach for obtaining willingness to accept risk of death.[28] Cohen surveyed a group of health physicists to determine the monetary compensation necessary for each to accept one rad of radiation exposure. The responses varied from $10 to $5,000 assuming a linear relation between exposure and probability of death (at some future date) with 1,000 rads equaling the fatal dose, the implied life values ranged,

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[28] Rappaport (1974) reports on one such survey which I have not had a chance to review. The report by Acton ("Evaluating Public Programmes to Save Lives: The Case of Heart Attacks," Rand Corp. Report R-950-RC, January 1973) surveys persons' willingness to pay for safety measures with respect to emergency coronary care.

according to Cohen, from $10,000 to $50,000. Otway took a more indirect approach in a survey of individuals' recollections of catastrophic accidents. He observed from the responses that when the ratio of property damage to number of lives lost in a particular event exceeded $250,000, all respondents remembered primarily the property damage to the exclusion of life loss. According to Otway, "this seems to represent a subconscious assessment of life values at about $200,000 per life" (p.7).

There has been only one attempt to estimate the demand for risk avoidance using observed market behavior. Thaler and Rosen (1973), in a recent article, attempt to impute a set of implicit marginal prices for various levels of risk by observing the relationship between risky jobs and wage rates. "Different work situations exhibit vastly different work-related probabilities of death and injury. Moreover, lots of data are available on wages in these jobs, on the personal characteristics of firms who offer them. Further, parties who voluntarily face such risks daily and as a major part of their lives or production processes have special interests in obtaining reliable and objective information about the nature of the risk involved. Finally, we have uncovered a new source of genuine actuarial data on death rates in risky occupations that until now has not been used for estimation" (pp.2, 3). This method of analysis is based on Adam Smith's ancient suggestion that individuals must be induced to take risky jobs through a set of compensating differences in wage rates.

By use of regression analysis, and after tackling several econometric problems inherent in practically all studies which attempt to specify demand relationships, Thaler and Rosen estimate the value of life to be in the neighbourhood of $200,000 (1967). There are several important qualifications of this estimate. The most critical assumption is that individuals are aware of the risks when they accept certain jobs. A major theoretical problem is that Thaler and Rosen assume linearity of risk and compensation (indifference function), and thus merely extrapolate from compensation for small risks to obtain a figure of $200,000 when the probability of death is equal to one. The approach is still somewhat preliminary and the figures cannot yet be considered operational. However, it is an important first step in the estimation of risk compensation relationships.

Theoretical Work

There appear to be many opportunities for investigating empirically, through the use of either questionnaire or market data, the risk-compensation tradeoff or individual preference function for risk avoidance. But, as Rappaport (in Hirshleifer, 1974) has pointed out, before such studies are undertaken, "it would be well to consider what results we would expect" (p.4). Given certain behavioral assumptions, it is possible in theory to determine the individual's expected tradeoff between risk acceptance and monetary compensation. There have been several recent attempts to model these preferences, but it is beyond the scope

of this survey to discuss these in any detail. A more comprehensive review of these models can be found in a forthcoming paper by this author.

A theoretical derivation of individual risk preference functions was first postulated by Raiffa (1969). Assuming that the individual is an "expected utility maximizer",[29] the problem is to determine his willingness to reduce some probability of his death[30] at the cost of some portion of his assets. As such, it fits into the more general problem of assessing utility functions which consist of multiple attributes--in this case, the dual attributes of survival probability and monetary assets. Raiffa develops a technique for estimating these utility functions based on individual responses to questions, revealing preferences between a certain "payoff", on the one hand, and a probabilistic payoff on the other hand.[31]

A slightly different approach has been developed in recent models by Usher (1971), Conley (1973), and Jones-Lee (1974). The common feature of these models is that each specifies the individual life-time objective function as a function of a lifetime consumption and survival probability.[32] Both Usher and Conley develop models of life cycle planning including the role of uncertain mortality, and Jones-Lee includes in addition a "bequest motive".[33] Assuming again that the individual is an "expected utility maximizer", the individual's willingness to pay (from personal consumption) for an increase in survival probability can be calculated by maximizing the objective function. Contrary to the Raiffa approach, this tradeoff or willingness to pay can then be calculated from data on life time consumption (without information on the individual's response to a hypothetical experiment). Hirshleifer (1974) points out that this "value of life" is formally similar to the human capital approach (discussed in the first section) since, in all cases, this tradeoff of assets

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[29] For a definition, see John von Neumann and Oskar Morgenstern, "Theory of Games and Economic Behavior", Princeton University Press, Princeton, N.J., 1953.

[30] Assuming that the individual both is a "lone bachelor" and suffers no "anxiety" over any future impending probability of death.

[31] If the utility of some given survival probability P and personal assets A is an additive function of the utility of each, i.e. $U(P,A) = U(P) + U(A)$, then the individual's utility function can be assessed given information on the utility of the assets, plus knowledge of two (P,A) pairs for which the individual is indifferent.

[32] Conley includes all activities in the objective function, but later expresses the "value of life" as a function of only the utility of consumption.

[33] Both Usher and Conley assume the "lone bachelor" case. All three models ignore the problem of anxiety.

for survival probability is a function of the utility of consumption.[34] In fact, if it can be assumed that the utility of consumption exhibits diminishing marginal utility, then the traditional human capital approach understates willingness to pay.

VI. Conclusions

The four possible approaches for evaluating the "worth of a human life" for purposes of public decision-making include the "human-capital" approach, an "implicit evaluation," insurance measures or court compensation, and the "risk" approach. According to the human capital approach, a lost life is viewed as a loss in human capital with a certain productive capacity, a proxy for which can be the discounted loss in future expected earnings. An "implicit evaluation" is based on the premise that the value of human life implied from past expenditures on public health or safety form a precedent for current evaluations. Similar precedents are set with court decisions awarding compensation for loss of life, providing for the loss to the dependents. Court decisions are thus related to "optimal" insurance decisions which provide for the dependents, and consequently have also been suggested as a method for evaluating loss in human life. A final approach is to evaluate programs which affect human mortality, not by statistical expectations, but in accordance with the monetary sum necessary to compensate the population for accepting a certain probability of a possible death, the "certainty equivalent".

The most interesting points revealed by this survey can be summarized as follows:

1) The human capital approach, originally developed for purposes of calculating "optimal" insurance, reflects only that amount of an individual's potential future income accruing to others, the "net" value, or accruing both to others and to himself, the "gross" value. Originally, it served as an approximation to the ex post "societal loss" from accidents or diseases; later, because of the ease in its quantification, it was adopted as an ex ante value of avoiding accidents or diseases. It is currently, in the United States and in the context of cost/benefit analysis, the most popular method for quantifying the benefits of life-saving programs. For this purpose it has been criticized by economists as inappropriate, violating the conditions for efficient decisions which serve as the basic rationale of the cost/benefit methodology.

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[34] This conclusion follows directly from the specification of the objective function as dependent only on consumption and survival probability. Its appropriateness is discussed in Linnerooth (1975).

2) An "implicit" value of human life, calculated from past public decisions which potentially affected human mortality, originally served only to demonstrate the inefficiency of such decisions. But another perspective, suggested in the French literature, is to consider such decisions as reflecting not inefficiency, but divergent preferences for the "manner in which one dies." It has thus been recently advocated by some as a possible approach for making current public decisions, but its appropriateness is still subject to debate.

3) Both court-decided compensation for loss of life and optimal life insurance decisions reflect the individual's will to provide appropriate compensation to the dependents for their loss in income as a result of the death, they are equivalent to the human-capital approach.

4) The evaluation of a public program which increases (decreases) human mortality, ignoring the statistical expectation of lives saved (lost) and concentrating only on the reduction (increase) in the risk of death, is termed the "risk approach." Appropriate within the context of a cost/benefit analysis (sometimes referred to as benefit/risk analysis) it eliminates, on the part of the decision-maker, the necessity to define an absolute "value of life". The appropriate benefit (or cost) is not the value of a life saved but becomes the value of reducing the probability (usually small) of loss of life. The assumption is that preferences for risk reduction are not linear. Several attempts, by both opinion sampling and econometric techniques with market data, have been made to estimate these preferences, but the results are not conclusive. There have been some recent efforts to model, given certain behavioral axioms, an individual's preferences for risk avoidance.

It is hoped that this survey has clarified the various methodologies for evaluating programs which change human mortality, and that it will serve as an introduction to current efforts by the Joint IAEA/IIASA Project to quantify life values. The question of evaluating risk to human life is part of a broader question of the public acceptance of large-scale technologies and the importance of socio-psychological mechanisms in the acceptance of technological risks (see Otway, 1975). A primary objective of the Joint Project is to gain an improved understanding of how societies judge the acceptability of new technologies and how societal attitudes, and anticipated responses, may be integrated into the decision-making process. In this context, societal response to risks related to mortality will be evaluated, both theoretically and empirically. The results will be an important input into current IIASA efforts comparing energy options and setting "optimal" standards.

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