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A PROCEDURE FOR DETERMINING BENEFITS OF LIFESAVING FOR COAST GU--ETC(U)
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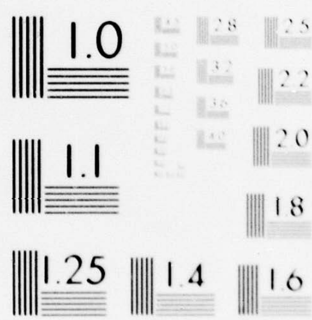

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by

(10) Timothy William Hylton

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(20. ABSTRACT Continued)

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A Procedure for Determining
Benefits of Lifesaving
for Coast Guard
Search and Rescue Programs

by

Timothy William Hylton
Lieutenant, United States Coast Guard
B.S., United States Coast Guard Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

A procedure is developed that places a value on Coast Guard efforts in lifesaving. The value is obtained for use in cost-benefit analysis of new programs. The procedure derives a dollar value for lifesaving by examining the potential changes in risk levels that are introduced by new Coast Guard programs. This value is the sum of three seperate components. The first two components are derived by the use of accounting methods and encompass the productivity and external losses brought on by the death of an individual. The third component is the value that an individual places upon his own life given a change in risk levels for a particular activity. This value is computed using willingness to pay procedures which utilize subjective measures of risk change values through interview techniques. These three components are combined and then applied to the Coast Guard problem of valuing changes in risk in the marine environment.

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I. INTRODUCTION

Cost-benefit analysis is a procedure commonly used to evaluate public programs. The procedure provides a method for organizing thoughts in a manner that allows for reasonable and consistent public decisions. The analysis differs from market decision-making since the objectives of most public programs are not financial, but rather social in nature. When applied, cost-benefit analysis will rank order various alternative programs in accordance with their respective benefits and costs.

A popular approach to cost-benefit analysis uses the potential Pareto improvement criterion which links projects to the transfer of dollars between gainers and losers of public projects. Any project has an income distribution effect. These transfers are based upon the goal that no person's welfare is diminished (after the compensating income transfers) by the project while the welfare of some is enhanced. The transfer of dollars to those who stand to lose in a project compensates them to a point of indifference on whether to complete the project or not. In practice these compensations are rarely used, but public projects are analyzed as if they were.

A hindrance to cost-benefit analysis is that since the project goals are social, rather than financial, dollar benefits are difficult to estimate. This is the difficulty that arises in the analysis of lifesaving programs. In order to quantify the benefits of lifesaving a judgement has to be made on the value of a human life. Some of the aspects to life valuation include the worth of individuals to society and family and the value that an individual would place upon his own life. The individual's worth would be evidenced by his participation in risky activities. Considerable research has addressed the subject of life valuation and this paper will explore some of the results. A procedure will be advanced that develops a logical response to economic considerations in life valuation in order to make it a useful tool in cost-benefit analysis. The end result will be designed for implementation by the Coast Guard in the analysis of its Search and Rescue programs.

The primary mission of the Coast Guard is the saving of life and property at sea. In pursuit of these efforts there is an overall objective of reducing the amount of risk faced by users of the marine environment. When new systems are introduced, or old systems retired, there will be subsequent incremental changes in the risk levels. These changes will be reflected as additional lives saved, or lost, each year. Without a procedure to transfer lives saved into dollar benefits, the evaluation of lifesaving programs cannot be effectively completed using standard cost-benefit procedures.

Chapter II will detail a few of the problems that are now being faced by the Coast Guard in their Search and Rescue

(SAR) programs. The principle problem is that of ever increasing caseloads for recreational boaters. These increases are forcing the Coast Guard to evaluate its program objectives. Since an austere budgetary climate exists at this time, the Coast Guard is not significantly increasing its SAR resources to match the rising demand. This could lead to a reduction of services to the public and a potentially higher level of risk for boaters. The issue of what risks are acceptable for the public has become important and will be used by the Coast Guard as they examine their program objectives. With this in mind the value of safety changes will be of paramount importance.

The subject of risk that is borne by the public has been gaining increased national attention. Technological advances, such as nuclear power, have brought to the forefront issues concerning the health and welfare of the public. The subject of risks, and what government should do about them, will be covered in Chapter III. Concepts such as voluntary and involuntary risks and their relationship to each other will be examined.

Considerable research has been completed on the proper approach to value a human life. The methods are almost as varied as the authors developing them. With this variety of choices the analyst has a perplexing problem of choosing the best one for his given situation. The procedures examined by this author can be classified into one or combinations of the following categories:

1. Accounting Procedures
2. Insurance Premiums Procedures
3. Willingness to Pay Procedures
4. Wage Compensation Procedures

Each of these categories will be reviewed in Chapter IV. The assumptions, computational aspects, data needs, and limitations for each category will be examined. Table 4.1 will show each category with some of the empirical values of life that have appeared in the literature.

Since Coast Guard activities are designed to reduce the risk levels faced by boaters, a procedure needs to be developed that places a value on the risk changes. Chapter V develops this procedure. The procedure first identifies those who benefit from risk change and then develops a method to quantify their value for saving a life. The beneficiaries identified are the family of the potential victim, the potential victim, and society. Both the society and family lose the productivity of the individual when he dies and they both have external costs imposed upon them as a result of death. The individual has an interest in prolonging his life since the utility of living is greater than that of dying. He therefore should exhibit a willingness to pay for more safety. The procedure in Chapter V calculates productivity losses and external costs through the use of accounting procedures. The individual's value on safety will be computed using the willingness to pay procedure. All of these values will then be added to derive the total benefit of a risk change.

Chapter VI completes the procedure by making it applicable to Coast Guard SAR programs. One study has already been completed for the Coast Guard on life valuation [13] and it recommended the use of only accounting methods. The value they obtained is valid for use in the computation of the total life value by accounting for productivity losses and external costs. The values obtained are in Appendix A. The value not computed in the study was that of self valuation. Data sources to aid in this computation and a method for the quantification of risk reduction versus cost will be given.

The major conclusion drawn by this paper is that the Coast Guard should be using life valuation in the computation of SAR program benefits. This is a consistent way to rationally account for the economic benefit of saving a life. Life valuation procedures will be useful in helping to define program objectives for SAR in that the total public benefit of maintaining certain risk levels can be weighed against the cost of meeting the objectives. Even if the Coast Guard does not use the explicit life valuations in program analysis the valuing will be accomplished in an implicit manner. Whatever budget level is used a certain number of people will be saved and some number will be lost - this places a value on the life of those people in an indirect manner.

II. BACKGROUND ON COAST GUARD SEARCH AND RESCUE

The Coast Guard's role in search and rescue is to administer laws and promulgate and enforce regulations for the safety of life and property on the high seas and other waters subject to the jurisdiction of the United States. In order to accomplish this objective the Congress has mandated that:

> In order to render aid to distressed persons, vessels, and aircraft on and under the high seas ... the Coast Guard may ... perform any and all acts necessary to rescue and aid persons and save property.[1]

In keeping with this Congressional mandate the Coast Guard has developed a complex and effective search and rescue organization. In order to assure continued efficient operation of this organization, the Coast Guard must continually evaluate the needs, both future and present, of the marine environment. As will be shown, the trend of increasing resource demands and an austere budgetary climate have combined to place strains on the SAR system. The ultimate result of this strain, if left unchecked, will be a reduction of services by the Coast Guard for the boating public.

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[1] United States Code, Title 14, section 88, (1976).

A. SUMMARY OF TRENDS IN SAR

In the performance of its SAR missions the Coast Guard responds to a considerable variety of cases. The cases range from swimmers in distress to difficulties on large merchant vessels and include recreational boats, aircraft, fishing vessels, and land structures. Even though this variety exists, the majority of cases, 94%, involve watercraft [14].

In their surveys of recreational boats [12] the Coast Guard has estimated the total number to be 9,604,000 boats in 1973 and 12,750,000 boats in 1976. This was an increase of over 30% for a three year period and they expect the upward trend to continue. This increase in recreational boats has precipitated an ever increasing workload for the Coast Guard. Figure 2.1 shows graphically the trend for yearly caseloads and extends it to 1983. As noted in the figure the growth rate of caseloads has been approximately 6% annually since 1968, with 1978 having over 86,000 responses. Coast Guard statistics [14] detail the breakdown of maritime SAR cases into various categories of vessels. These categories include, recreational boats, fishing boats, oceanographic, naval, merchant, and towing vessels. The recreational boats account for 78% of Coast Guard cases for 1978. Figure 2.2 shows the type of problems that are encountered by recreational boats when Coast Guard assistance is requested.

WORKLOAD GROWTH

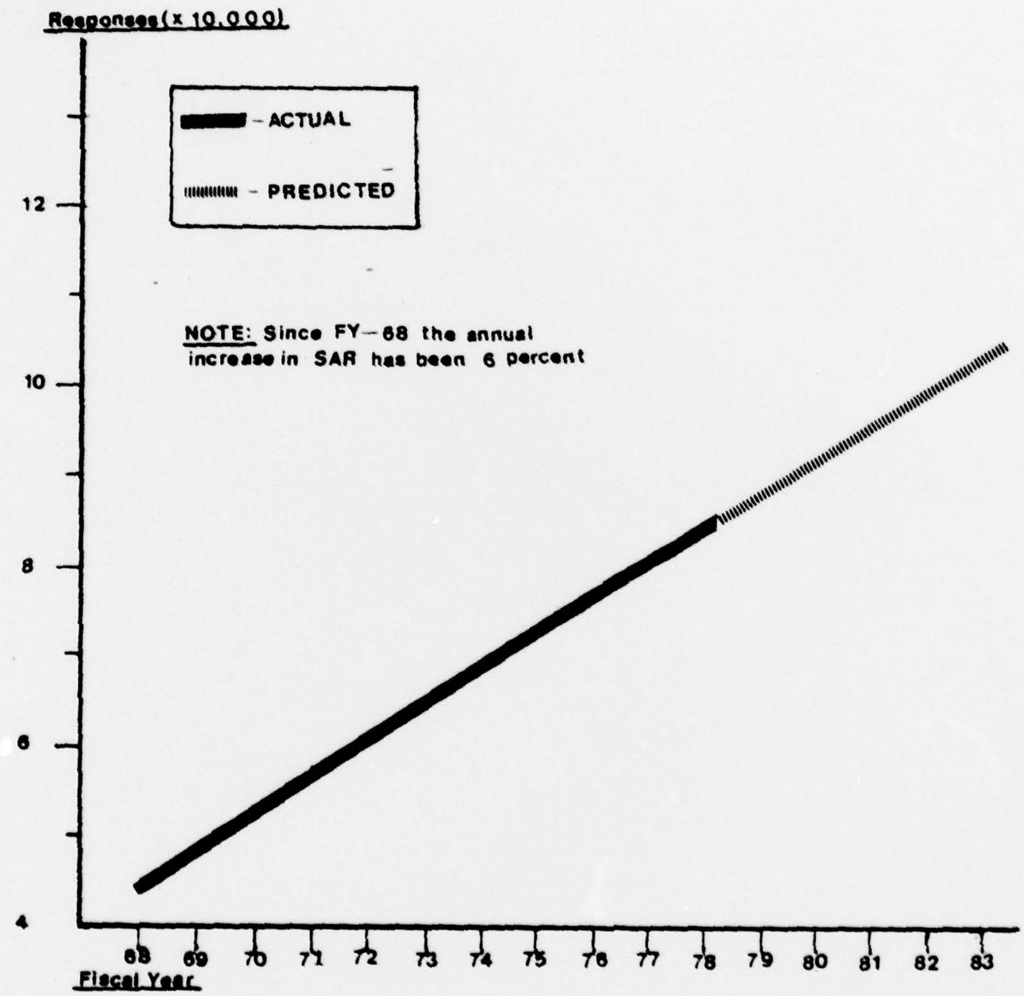

Figure 2.1
From Coast Guard SAR STATISTICS 1978

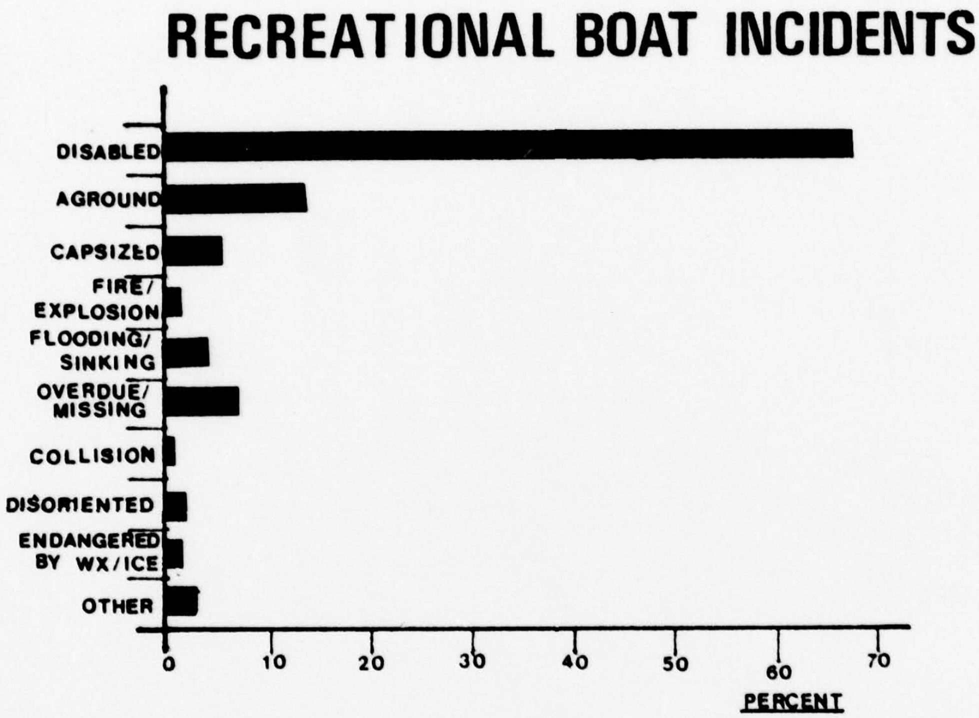

Figure 2.2
From Coast Guard SAR STATISTICS 1978

According to the Coast Guard,

> Recreational boaters represent the largest group of customers for Coast Guard services, currently accounting for over 78% of our response workload ... As a result of increased income and leisure time, it is anticipated that recreational boats will increase from 14 million in 1978 to 17 million in 1983, a growth of almost 5% a year.[2]

The only other vessel type that commands a significant share of the Coast Guard's SAR workload is the commercial fishing vessel. These vessels are involved in 11% of the Coast Guard's SAR effort but this figure is expected to remain stable in the years ahead. The Coast Guard's outlook for the future is:

> ... Over 124,000 calls for assistance are forecast for 1990. Our planning efforts will focus not only on the best resource types and facility locations, but will study such issues as SAR preventive measures, alternative means for rendering assistance, defining acceptable levels of risk, and utilization and coordination of our total national SAR resources.[3]

Thus all available evidence indicates that the Coast Gaurd can expect an ever increasing workload over the coming years.

B. IMPLICATIONS OF INCREASING SAR TRENDS

Increasing service demands coupled with budgetary restrictions will result in a cutback in services. The

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[2] U.S. Coast Guard, SAR Statistics 1978, March 1979, p. 13.

[3] Ibid, p. 7.

problem faced by the Coast Guard was recently summarized by the Commandant, Admiral J. B. Hayes,

> Now, what winds are blowing that are going to affect the future. First of all and clearly ... inflation and a tight budget. There is absolutely no question in my mind, like it or not, we are going to have to look in every nook and cranny of the Coast Guard for management improvement. ... I see no relief with the President attempting to balance the budget and reduce federal expenditures.[4]

As stated by the Commandant the Coast Guard will be required to manage its resources better in a period of budgetary pressures. The crucial issue is how to provide the public the same level of service in spite of these pressures.

As managers of maritime safety it is incumbent upon the Coast Guard to develop criteria by which they can properly perform their mission requirements. Since this area is constantly changing, the Coast Guard must be prepared to adjust properly to new situations. In recent Congressional hearings the Commandant stated,

> In search and rescue, we have a major study going on which really is looking at how we can better utilize our resources, how we can keep up with a growing problem and separate out the higher priority search and rescue problems from lower priority problems.[5]

So as indicated the Coast Guard is examining the SAR program in order to meet the needs of the future.

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[4]Admiral J.B. Hayes, "State of The Coast Guard," message filed for the record in Hearings before the House Subcommittee on the Dept. of Transportation Appropriations, 21 Feb 1979.

[5]From testimony before the same committee.

The results of the study will be used to assist in the planning for Coast Guard resources. Since the future is always uncertain, estimates need to be made of future activities. These estimates will be used to identify the techniques and resource allocations required to meet the needs of the marine environment. These techniques and resources may require additional expenditures or a reduction of expenditures. The decision that needs to be made by the Coast Guard is whether the changes that may be required in the future are justified when compared to program objectives. In defining program objectives the Coast Guard must consider the cost of attaining those objectives. Through techniques of cost-benefit analysis the merits of any change aimed at attaining program objectives can be judged.

One of the objectives of SAR is the saving of lives. By pursuing this objective the Coast Guard impacts the risks assumed by boaters through a reduction in the probability of them suffering a fatality. With the SAR system facing a period of transition, objectives concerning acceptable risk levels for the boater must be developed. Once this is completed cost comparisons of various methods of achieving the objectives can be made. Part of this process will require the definition of benefits for the reduction of risk. The definition of benefits will be covered by this paper.

III. RISK AND RISK REDUCTION

As noted in the previous chapter, the Coast Guard has responsibility for public safety in the marine environment. In order to assure this objective programs have to be evaluated for their cost-effectiveness. This involves placing a value on changes in risk. Before defining methods of risk change valuation, the nature of risk and the government's role in managing it should be explored. The subject of risk, specifically the risk of death, will be examined by this chapter in order to develop a framework by which various life valuation schemes can be explored.

A. RISK DEFINED

Risk can be defined simply as a chance of losing something. For the purposes of this paper it will be defined as the chance of losing one's life. Every activity that man participates in carries some level of risk to it. This risk will occur because of the activity precipitating death, or the fact that death can occur from other sources during participation in an activity. Most people are able to place a risky event into one of two categories. These categories are voluntary risks and involuntary risks. The placement of various activities into one of these categories is determined by the degree of control that an individual perceives he has over exposure to the risk of that activity. Since perceived control is a subjective judgement on the part of the individual there will be variations in perceptions from one individual to another. The amount of control perceived by the individual, will determine the degree to which he would desire the risk to be reduced by government action.

Another factor that plays a role in risk reduction benefits are the consequences of realized risks. Financial losses of various types occur at the death of a member of society. Therefore, in addition to physical risks, financial risks should also be considered. The next chapter gives a more complete overview of the financial losses which occur as a result of death.

B. GOVERNMENT ROLES IN RISK REDUCTION

When faced with a choice of reducing risk levels without consideration of a cost consequence, the general public would opt for a reduction in the risk. In general, most individuals prefer less risk to more risk when asked to make judgements on risky activities. This view is borne out by Fischoff [4] in a study on the perception of risks and benefits of various activities. This result is not surprising since the average individual would prefer not to die and would also desire the necessary steps be taken to reduce the risk of death. The important question that faces the individual and society is how much should the risk be reduced and how much should be spent to reduce the risk?

Government agencies, through various laws and regulations, are empowered to pursue risk reducing activities on behalf of the general public. These pursuits entail the definition of program objectives followed by analysis of procedures to achieve those objectives. The analysis of these programs requires the placing of a benefit measure on a saved life. The exact nature of a life value has been the subject of considerable coverage in economic literature, a sample of which is included in the bibliography. The literature shows disagreement, over the proper approach to life valuation. The disagreements generally involve the role of an individual's opinion in the analysis process. In the absence of clear direction various agencies of the Department of Transportation have developed their own methods of life valuation. These methods will be covered in the next chapter.

Starr [10] and Fischhoff [4] have both found evidence that people display a willingness to tolerate a higher level of risk in those situations for which they perceive themselves to have some control over the occurrence of the contingency. Since recreational boating is a voluntary activity, where people can control their participation, the Coast Guard is in a position that has more flexibility than is found for other government agencies involved in risk reduction programs. Of course the action of the Coast Guard in reducing the perceived risk of loss acts positively upon the publics demand for boating recreation.

C. HOW MUCH RISK REDUCTION?

As mentioned previously the government is responsible for reducing the risks involved in certain activities. A question arises of how much the public is willing to spend through taxes or reduction in use of resources to reduce the risk of undesired events? As public servants, various government agencies exercise jurisdiction over various risky activities and are responsible for making decisions concerning those risks. The procedure usually applied to this situation is a cost-benefit analysis of the program in question. If cost-benefit analysis, a derivative from economics, is to be a useful aid in defining and ranking alternatives, then it is necesary that costs and benefits be measured in commensurable units, i.e., dollars. Without a dollar measure for a life, comparisons of benefits and costs cannot be performed. Therefore, the job of the analyst is to derive a functional relationship between lives and dollars that can be applied to policy analysis. A few of these procedures will be outlined in the next chapter. Chapter V will then propose a procedure that could be applied to the Coast Guard's SAR program analysis.

IV. CURRENT PROCEDURES IN LIFE VALUATION

As noted in the previous chapter, the evaluation of public safety programs are normally completed using cost-benefit procedures. Since the outputs of these programs are saved lives, a procedure needs to be used that will place a dollar benefit on a saved life. A survey of the literature on life valuation yields several approaches to the problem. These approaches generally fall into one or combinations of several of the following categories:

1. Accounting Procedures
2. Insurance Premiums Procedures
3. Willingness to Pay Procedures
4. Wage Compensation Procedures

The analyst will draw on one or more of these procedures to satisfy the interest of those who benefit from lives saved. The remainder of this chapter will summarize each of the above procedures by looking at the underlying assumptions, detailing the methodology, and listing some of the data requirements for implementing the procedure.

A. ACCOUNTING PROCEDURES

Accounting procedures can be subdivided into four categories. These are:

1. Discounted Future Earnings
2. Family and Community Opportunity Losses
3. Resource Costs
4. Societal Valuations

These approaches attempt to identify the interests of society and the family in saving a life. The issues involved are lost incomes for society and family and externalities, such as hospital costs and repair costs, that are imposed when an individual dies.

1. Discounted Future Earnings

a. Assumptions

This procedure assumes that when a life is saved human capital is preserved in the form of inputs to the GNP. By implication, it appears that this approach would restrict the benefits of lifesaving to society alone. Conley [1] has indicated that this may not be the case, as will be discussed in the next chapter. If the assumption were true then the individual would be an indirect beneficiary of efforts to preserve society's human capital.

Several government agencies have used this procedure as part of their benefit computations. The discounted earnings comprise the major portion of the benefit values used by these agencies. The other inputs to their computations will be covered later in this section. Two agencies that have sponsored work in the area of life valuation are the Coast Guard and the National Highway Traffic Safety Administration (NHTSA). Both of the studies pointed to procedures that rely heavily upon accounting approaches with discounted future earnings being the largest portion [13]. One of the principle reasons for using this procedure is the ease in obtaining a reliable figure from available sources of data. The term reliable is used in the sense that the data are reliable and not in the sense that the method is accurate.

b. Procedure

There are two basic discounted future earnings figures that can be computed for an individual. These are the discounted gross earnings and the discounted net earnings. The gross earnings approach utilized the total output of an individual over his lifetime. The net earnings method will first subtract the amount that an individual will consume for himself each year and then discounts and sums the remainder. Both of these figures can be computed using equations detailed by Mishan [7]. For gross earnings,

$$V_g = \sum_{t=k}^{\infty} P_k^t \, Y_t (1+r)^{-(t-k)} \tag{4.1}$$

where,

V_g = discounted future gross earnings.

P_k^t = probability in the k'th year of an individual being alive in year t.

Y_t = expected gross earnings in year t.

r = prevailing discount rate in year t.

The computation for net earnings is,

$$V_n = \sum_{t=k}^{\infty} P_k^t (Y_t - C_t)(1 + r)^{-(t-k)} \qquad (4.2)$$

where,

V_n = discounted future net earnings

C_t = individual's personal consumption in period t.

c. Data Requirements

Before the computations of earnings can be made a statistical profile of those who participate in the activity being analyzed must be obtained. Once the population profile is obtained, the discounted earnings can be computed one of two ways. The first would be to compute the earnings of the groupings within the population and average according to the weights of their numbers within the population. Another approach would be to find the statistical or typical person of that population and use his discounted earnings as the value.

Mortality tables are necessary for use in computing expected lifetimes of the population members. These tables would be useful to assist in computing a value for P_k^t. Income profiles for the user population are also needed to compute the expected earning in future years. The Census Bureau publishes earning statistics in their statistical abstracts. The discount rate to be used is the subjective rate of an individual that expresses his preference of present value over future value. Most government agencies use 10% as this social discount rate.

2. Family and Community Opportunity Losses

Family opportunity losses are considered the value of services that are performed by the potential victim around the home. This figure would include those services performed by the wife of the household. Opportunity losses are difficult to determine exactly, therefore only estimates are used. The NHTSA uses this measure and estimates its value at approximately 25% of the expected wages for a given year [13].

Community opportunity losses are considered the value of volunteer work that a potential victim will contribute to the immediate community. Like the family opportunity losses these values are difficult to estimate accurately. The NHTSA estimates this value at 5-15% of the expected wages [13]. In computing the total discounted losses equation 4.1 can be used replacing Y_t with the opportunity loss being computed.

3. Resource Costs

Resource costs can be considered externalities that are a result of the probability of death of an individual. These are considered external in that they occur automatically in the event of a death. It is difficult to account for all of these costs but a representative sample would include police, fire and SAR resources who respond to the incident. Also included would be hospital and medical costs, administrative and legal fees, and repair of physical capital.

These are costs that are incurred by the community as a result of its forced participation in an individual's risk taking behavior.

4. Societal Valuations

Societal valuations involve the use of life values already computed for use in other programs. An example would be for the Coast Guard to use life values previously computed by the FAA in the analysis of SAR programs. Societal valuations could also be those amounts that society is willing to pay through decisions of its public agencies. This makes this type of a valuation more of a political decision rather than an economic one.

5. Limitations of Accounting Methods

A limitation to the use of accounting procedures is the implicit reliance upon maximization of the GNP as the principle objective to saving lives. This point was made by Mishan [7] when he stated that the ultimate objectives of public programs is not maximization of GNP. These procedures do have benefits in that they do account for society's interest in life saving and provide a means of including externalities into the benefit computations. The next chapter will utilize these methods as a part of overall benefit computation but reliance will not be placed upon the maximization of GNP as an objective.

There is another unacceptable policy implication to the discounted earnings approach of life valuation. There are certain segments of society that, by this method, will not be considered net contributors to the GNP. These segments would include the unemployed, the elderly, housewives, and the very young. The earning potential of these people is negligible when discounted. This lack of appreciable value on the lives of these people would tend to underestimate the true value of a life for benefit computations.

B. INSURANCE PREMIUMS PROCEDURES

1. Assumptions

Proponents of using premiums paid for life insurance policies as an indicator of the value of a life assume that an individual is willing to pay that amount to shield his family and those close to him from the risk of his death. The risk involved in this instance is strictly that of a financial loss caused by the death of the family breadwinner. This method is attractive because it is one area where the individual is playing a market role as a consumer of financial protection. The method assumes that the individual has perfect knowledge of risks involved when he purchases insurance.

2. Procedure

Essential to this procedure is the existence of a relationship between premiums paid and the risk of death. G. Fromm [6, 9] initially postulated that this relationship may be linear in nature. If this were true the value of a life, V, would be as follows:

$$V = \frac{w}{p} \qquad (4.3)$$

where,

w = premium paid on a policy

p = probability of death

While the linear relationship may look attractive in its simplicity there is little evidence that would support its use in life valuation procedures and has since been abandoned by Fromm. This lack of a linear relationship makes sense since individual utility functions are non-linear in nature.

3. Data Requirements

Life valuation procedures by the insurance premiums method are dependent upon population parameters in the same manner as the accounting methods. Potential victims would need to be identified and then classified according to age, sex, income levels, family size, education levels and etc. Insurance buying habits of this population would then have to be investigated. The information required should be obtainable through publications of the insurance industry. Mortality rates will also be required for this procedure.

4. Limitations

This procedure is aimed at market behaviof of individuals but there are limitations to its applicability to public policy analysis. Changes in the risk of certain activities has little to no impact on mortality rates, therefore life insurance premiums will not be sensitive to the risk changes. This would imply that linking premiums to safety changes is an invalid approach. Another factor is that this approach may exclude certain population elements. A case in point would be a single individual who has no insurance covereage. He pays no premiums, therefore his life value would not be quantifiable.

C. WILLINGNESS TO PAY PROCEDURES

1. Assumptions

This procedure assumes that the potential victims are consumers of safety and will display a willingness to pay for the reduction in the probability of death for risky activities. By utilizing techniques that allow a potential victim to place a value on increased safety a life valuation can be made. These techniques can involve anything from asking an individual how much he would forfeit to preserve his life to making estimations of his utility function for safety. Basic to this procedure is the assumption that an individual will value risk changes as if he were maximizing his welfare. By maximizing his welfare the potential victim will also be able to rank order his preferences as far as benefit tradeoffs for risk reduction. Estimates of self value can be made by observing an individual's behavior as a potential consumer of safety.

2. Procedure

While there is considerable literature developing the theoretical foundation for this procedure of life valuation there is a noticable lack of guidelines to put the theory into practice. Jones-Lee [5] does detail an example of how he approached the problem and derived some values of the estimated marginal value of a change in risk level for various individuals. Parts of his procedure will be utilized in the next chapter. The remainder of this section will be devoted to a brief summary of the procedure.

As a consumer of safety an individual can be expected to make decisions concerning how much should be spent for the reduction of risk for certain activities. When an individual makes a choice it can also be assumed that the present level of welfare enjoyed by the individual will either improve or at least remain the same. The utility function of initial wealth for any given period of time could be expressed as:

$$E(U) = (1-p)\,L(w) + p\,D(w) \qquad (4.4)$$

where,

$E(U)$ = individual's expected utility

p = probability of death in a period

$L(w)$ = utility of wealth to the individual if he survives the period

$D(w)$ = utility of wealth to the individual if he does not survive the period

w = individual's initial wealth

The restrictions on $L(w)$ are that it will be bounded above and will increase at a decreasing rate as w increases. $D(w)$ is assumed to be bounded above by $L(w)$ since the utility of wealth will be greater alive than dead. Also $D(w)$ will be a non-decreasing function of w.

Now it is assumed that an individual would be willing to pay a premium, v, in order to reduce his risk when participating in an activity. This willingness to pay is based upon the premise that the individual's expected welfare will improve or remain the same as the welfare before the payment. Therefore,

$$(1-\bar{p})\ L(\bar{w}-v) + \bar{p}\ D(\bar{w}-v) = (1-p)\ L(\bar{w}) + p\ D(\bar{w}) \quad (4.5)$$

where,

$\bar{p}$ = the new level of risk purchased

v = premium paid to reduce risk

By manipulating the variable $\bar{p}$, estimates of the premium amount that an individual will pay for varying levels of risk reduction can be determined. This will allow for the construction of a schedule of compensations that would be required to induce an individual to assume a greater level of risk. These schedules of compensations and payments can be used to develop a functional relationship between v and $\bar{p}$, expressed as $v(\bar{p})$. Jones-Lee [5] has shown that based upon the assumptions concerning L(w) and D(w) the behavior of $v(\bar{p})$ is,

$$\frac{\partial v}{\partial \bar{p}} < 0 \quad \text{where} \quad (0 \leq \bar{p} < 1)$$

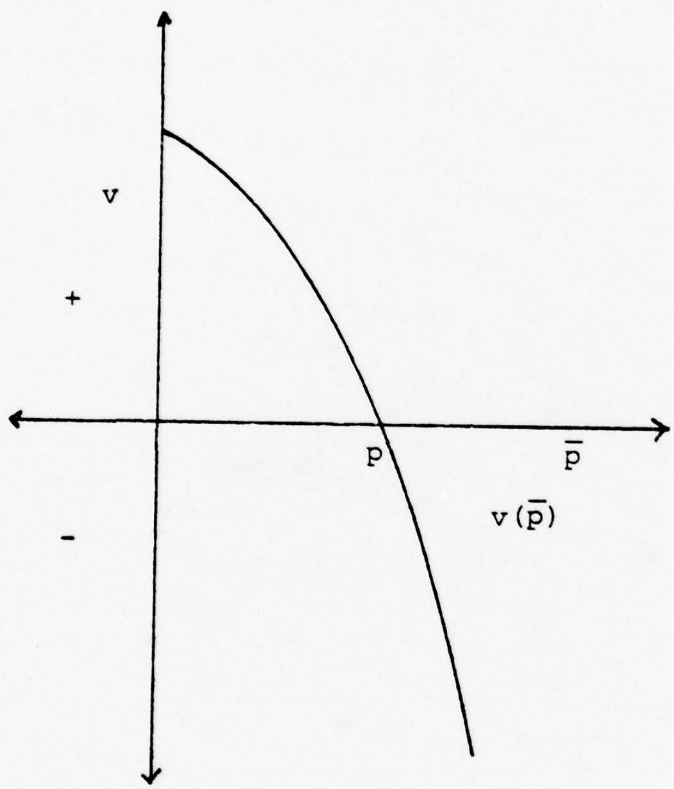
and,

$$\frac{\partial^2 v}{\partial \bar{p}^2} < 0 \quad \text{where} \quad (0 \leq \bar{p} < 1).$$

The first order condition indicates that the size of the premium is inversely proportional to $\bar{p}$. The second order condition indicates that the function $v(\bar{p})$ is concave in the downward direction. The graphical representation of this is shown in Figure 4.1. The point at which the function crosses the $\bar{p}$ axis is the initial level of risk experienced by the individual and no premium will be paid or received. As can be noted in the figure, an increase in the risk for an activity will require a compensation for the individual to assume it.

From the functional relationship, $v(\bar{p})$, a marginal value for the changed risk level can be computed. This would be the value that the potential victim has placed on his life for that particular risk change. When a program is introduced to reduce the risk of a certain activity the

FIGURE 4.1



benefit achieved in human life would be computed as $\frac{\partial v}{\partial \bar{p}}$ evaluated at the new level of risk.

3. Data Requirements

Data collection for this procedure is not the same as the previous two methods. All that was required previously was the collection of various statistics from either industry sources or government sources. While this method does require knowledge of risk levels for various activities, an interview approach is recommended to collect information concerning individual's attitudes toward paying for risk changes. The people being interviewed should be from a broadly defined population to yield a cross section of society. An interview approach that could be used for this method is covered in Chapter VI.

4. Limitations

The principle limitation to this particular method is the difficulty that people have in conceptualizing the impact of low probability events. Risk reduction normally involves dealing with activities that have a low probability of occurrence. The ability of a person to distinguish and evaluate changes in these low levels of risk is a difficult task. The method proposed by Jones-Lee is one of the few that have attempted to come to grips with this problem. This lack of reliability in judging low probability events has inhibited the use of willingness to pay procedures on life valuation analyses.

D. WAGE COMPENSATION PROCEDURES

1. Assumptions

This procedure is similar to self valuation procedures but it restricts attention to the labor market in order to see if a relationship exists between job hazards and wages. This approach assumes that job risks are offset by compensation in the form of increased wages. Thus a worker will receive extra wages to work in a higher risk environment. Whereas willingness to pay procedures generally dealt with the reduction of risk, this procedure examines the opposite. Fundamental to this concept is the assumption that jobs that involve a higher risk to the worker are indeed compensated, and further that the worker will attempt to maximize his own welfare. It must also be assumed that the individual has perfect knowledge of the risks involved in his occupation.

2. Procedure

Research in wage compensation procedures has focused on the development of mathematical models that describe the relationship between various job factors. Considerable research has been completed by Viscusi [16] and the team of Thaler and Rosen [16]. Each of the studies developed risk indices for various jobs and regressed wages on them. Viscusi used two models to complete his analysis. The first used earnings in the equation with risk indices and yielded a linear form that equated a constant price per unit of job risk. His second form utilized a semilogarithmic form, utilizing log earnings, and that yielded a rising price per unit of job risk. Therefore for every change in job risk a change in the wage compensation can be computed. Using this relationship a value of a life can be computed as:

$$V = \frac{\Delta w}{\Delta p} \tag{4.6}$$

where,

Δw = change in wage compensation

Δp = change in job risk

Thaler and Rosen's values were around $200,000, in 1969 dollars, while Viscusi obtained values of well over a million dollars. Viscusi attempts to explain this variation in values by comparing the types of jobs studied to see if different risk levels were evident. He found this to be the case and he theorized that the marginal value that the worker places on his life will vary in relation to the percentage of the population exposed to the risk. This makes sense when compared to standard supply curves that provide more product (lives) for a higher price. By exploiting these variations Viscusi advances the concept of a life value schedule for a population. Using his hypothesis it can be assumed that as the percentage of the population exposed to a level of risk increases the value that they place on their lives will also increase. This relationship is shown in Figure 4.2. The figure is a plot of life value vs. percentage of the population exposed. Using this hypothesis the lower figure computed by Thaler and Rosen can be explained by the fact that they examined those jobs which carried a higher risk and had a smaller portion of the population exposed to it. This resulted in a lower value being placed on the lives in their study.

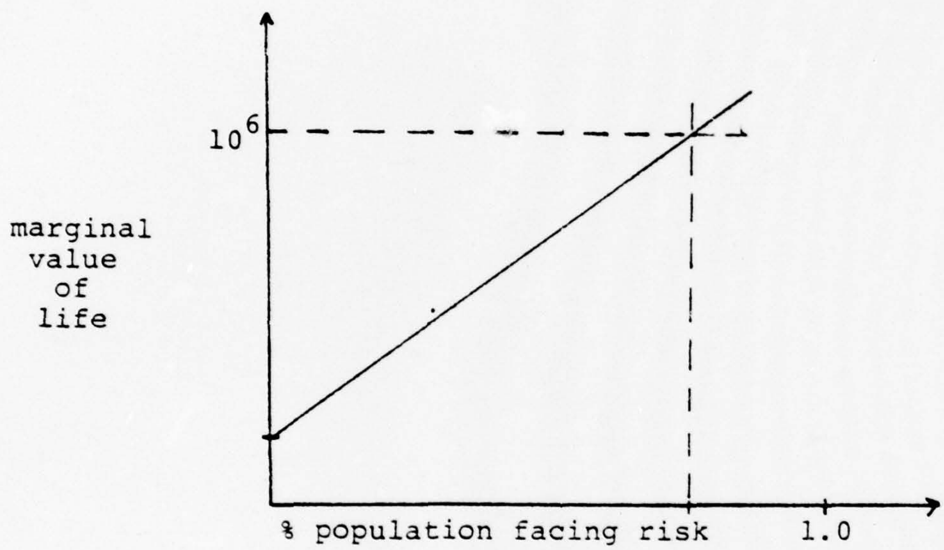


Figure 4.2

3. <u>Data Requirements</u>

Use of this method requires a knowledge of various industrial risk levels, wage levels, and worker population characteristics. There is a good amount of data that can be obtained from various government sources.

4. Limitations

The use of labor market compensations to value a life assume perfectly competitive labor markets. If this were the case then the wage compensations would accurately reflect the value a worker places upon his life. The problem is that perfectly competitive labor markets do not ordinarily exist and the worker may not be fully informed of the job risks. This lack of information could cause an underestimate of the true value he places on his life. There is also a tendency for many attractive low risk jobs to be higher paying jobs. This higher pay is due to desirability rather than risk factors.

E. SUMMARY

Table 4.1 lists the various methods of life valuation and gives empirical estimates of some of the values obtained using them. As can be noted from the table there is considerable variation in the values derived by using the procedures. This presents a quandry for the analyst that needs to select a method of life valuation. Of the four procedures covered, only accounting methods do not take a market behavior approach to life valuation. From an economic standpoint market behavior would be the easiest to defend.

The accounting approach is used in many cases because it is the most easily substantiated in terms of data validity. The principle failing of this procedure, though, is the lack of consideration of the desires of the potential victim.

TABLE 4.1

METHOD	VALUE	REF
ACCOUNTING		
Lost Wages	140K - 270K	12
Family Opportunity	35K	12
Comm. Opportunity	5K - 10K	12
Resource Costs	12K	12
Societal Valuation	200K	12
Insurance Premium	no values found in literature	
Willingness to Pay	28K - 5 Mil	5, 12 15
Wage Compensation	200K - 1 Mil	15

The insurance premiums approach has no proponents that recommend its use, therefore it is not presently being utilized. This lack of use stems from the inability to link premium payments to safety changes. Since the safety changes invoked by a program affect only small portions of overall risk, the changes in mortality will be insignificant. If this is the case then premiums will be inflexible when compared to these safety changes. The willingness to pay procedures are sound in a theoretical sense but difficulties arise in translating individual perceptions of risk changes into dollar values. Without a procedure by which an individual can scale risks, he will have difficulty in conceptualizing changes. The wage compensation procedures also provide a sound approach to life valuation. The drawback is the wage negotiation process where political concerns and bargaining by representatives may mask the true value a worker will place on his life.

In summary, all four procedures have flaws that could be a cause for concern when making an application to policy analysis. The next chapter will define an approach that will attempt to minimize the limitations of these methods. The procedure draws on steps outlined in two of the categories covered. It is an approach that considers first those who benefit from a risk reduction and then develops a method to address the benefits that accrue to each of them.

V. PROCEDURE FOR DETERMINING LIFESAVING BENEFITS

The previous chapter covered several methods of life valuation that have appeared in the literature. With such a wide range of procedures a question arises of which one is sufficient for use in program analysis? This chapter attempts to define an approach that could prove useful to the analyst. The procedure draws on accounting and willingness to pay methods to value a risk change.

Before presenting the details of the procedure it is first necessary to identify the nature of the end result of the program. Rather than examining the savings of specific people, analyses of public safety programs look at the statistical life. This statistical life is in the form of a reduced risk of death. If asked to place a value on the life of an identifiable person, such as a family member or someone close, an individual would likely place an extremely high, or unlimited value on it. The worth of someone close is indeed unlimited or incalculable and therefore any expense incurred to save that person would be emotionally justified. When dealing with statistical lives that are saved, or lost, emotional involvement is virtually eliminated. This is due to the fact that unidentified portions of a larger population are being examined.

Once the estimate of the number of additional lives saved due to a program is accomplished a procedure is needed to transfer that estimate into a dollar benefit. The lives saved result from a change in the fatality rate for the activity being examined. This change in risk will form the basis for a benefit measure in that a marginal value for the change will be computed. The problem facing the analyst is one of developing a transfer function that can be economically justified.

When making benefit computations for lifesaving programs, it is necessary to identify the beneficiaries of saved lives. Those who benefit from reduced fatalities can be placed in two broad categories and one specific category. The first broad category is society, who loses both through the productivity loss of one of its members and external costs imposed by the death. The external costs are those covered in the previous chapter under resource losses. The second category is the family and those close to the deceased. The losses are externally imposed and include income losses and opportunity losses. The specific beneficiary is the individual whose life is preserved. The procedure advanced in this chapter will attempt to address the interest of all of these parties. The procedure presented is drawn principally from Jones-Lee's [5] work on human life valuation.

A. IDENTIFICATION OF BENEFITS OF LIFESAVING

When an individual dies, the society, the family, and the community lose the productive services of that person. Thus when an individual's life is preserved the value of his preservation is worth at least as much as his productive output. This worth, V_1, would be the discounted future earnings and opportunity inputs to family and community.

External costs are imposed upon various factions as a result of the death of an individual. These factions are society, employers, family and various private organizations such as hospitals and insurance companies. The costs imposed on society include the maintenance of emergency services such as police, firemen, ambulances, and search and rescue facilities. Also imposed on society is the cost of repairing any public property damaged in an accidental death. Employers would have to pay for training replacements and other costs associated with replacement of the deceased. The family will bear the costs of funeral, administrative fees such as legal advice and they will pay for the repair of personal property. Hospitals need to maintain facilities for emergency care of injured. All of these externally imposed costs, V_2, would be saved if an individual's life was prolonged.

The values V_1 and V_2 therefore represent the economic loss that is imposed upon society and the family by the death of an individual. Neither of these values will account for the value that individual's place upon their own lives. In order to account for this value a third component, V_3, needs to be added. This value would be the average value of life obtained by using individual marginal valuations of risk changes. Jones-Lee notes that this is essentially using marginal values to obtain an average value. The next section details a method for obtaining this value which is based upon the potential Pareto improvement criterion. This criterion implies that there is a total aggregate cost, C, of a program that if paid, or received, by individuals of a population will produce at a minimum an indifference to implementing the safety changes. As mentioned before the next section will detail the technique for doing this.

The three components of life value can now be summarized as follows:

1. V_1 = the average value of avoided net output loss per life saved.
2. V_2 = the average value of avoided external and resource costs per life saved.
3. V_3 = the average value of a life per se.

B. COMPUTATION OF V_3 FOR A POPULATION

When computing the marginal value of safety changes for individuals, it is assumed that they have full and complete information concerning the risks, costs, and consequences of the activity being analyzed. The individual will also behave in a manner consistent with utility maximization. To arrive at the average value of the marginal valuations the incremental change in risk is required. This value, δp_i, is held constant for all individuals. The risks involved in individual valuations are considered subjective but holding them constant allows computational ease. Therefore:

$$\delta p_i = -X/N \quad (i = 1,\ldots,N) \qquad (5.1)$$

where,

X = additional lives saved

N = population total

A reduction of risk is assumed for this procedure which accounts for the negative value for δp_i. As noted in the previous chapter each individual will have a function $v(\bar{p})$ that reflects a willingness to pay for risk changes. The marginal value of this function yields a life value for a given risk level. Aggregating across a population yields a total cost for a risk change. Thus,

$$C = \sum_{i=1}^{N} \left(\frac{\partial v_i}{\partial p_i}\right)_{\bar{p}_i} \cdot \delta p_i \qquad (5.2)$$

where,

C = Cost for changed risk level

$\frac{\partial v_i}{\partial p_i}$ = marginal value of change in safety

δp_i = incremental change in risk

$\bar{p}_i$ = initial level of risk experienced by population

Substituting $-X/N$ for δp_i:

$$C = \frac{X\left[\sum_{i=1}^{N} - \left(\frac{\partial v_i}{\partial p_i}\right)_{\bar{p}_i}\right]}{N} \qquad (5.3)$$

Since it is assumed that an individual's welfare at least remains the same by the change in risk the cost will at least equal the benefit of a life saved, V_3. For the population aggregate to obtain the identity:

$$C \equiv X \cdot V_3 \tag{5.4}$$

and by substitution:

$$X \cdot V_3 = \frac{X\left[\sum_{i=1}^{N} - \left(\frac{\partial v_i}{\partial p_i}\right)\overline{p}_i\right]}{N} \tag{5.5}$$

Therefore:

$$V_3 = \frac{\sum_{i=1}^{N} - \left(\frac{\partial v_i}{\partial p_i}\right)\overline{p}_i}{N} \tag{5.6}$$

This is the average marginal value of a safety improvement for the population being examined.

Before moving on to computing the total benefit of saving a life the nature of the individual's marginal value of life will be examined. Specifically the upper and lower bounds on the value will be explored. Conley [1] has advanced the theory that the value an individual places on his own life will be greater than his lifetime earning potential. Thus when a person assesses the value of risk changes he mentally accounts for his future earning potential. If this is true then the discounted future earnings would be a lower bound on an individual's self value.

To find an upper bound on the self value the function $v(\bar{p})$ needs to be examined. An individual participating in an activity would presumably be willing to pay to increase his safety, but at a decreasing rate. This decreasing rate would provide a decreasing marginal value of life that will approach zero as risk approaches zero. On the other hand a compensation would be required to induce an individual to continue an activity whose risk has increased. According to Jones-Lee [5] there is some value of risk, below unity, that an individual, if given a choice, cannot be induced to assume for any compensation. Beyond this point the value of the activity to the individual is no longer worth the risk involved. The marginal value of $v(\bar{p})$ at this point yields the upper bound.

C. BENEFIT COMPUTATION

The benefits of a lifesaving program that saves X additional lives can be computed as follows:

$$\text{Benefit} = X(V_1 + V_2 + V_3) \tag{5.7}$$

This is the value that will be compared to the cost of a lifesaving program. If Conley's theory concerning the inclusion of discounted earnings in a self valuation is correct then a double counting will occur in equation 5.7. The discounted earnings appear in the values V_1 and V_3. Depending upon the analyst's degree of belief in Conley's assertions, the discounted earnings in V_1 can be retained or deleted from the overall benefit computation.

Jones-Lee has made the point that the component V_3 has often been neglected in the analysis of government lifesaving programs. This is significant because his preliminary work has indicated that V_3 appears very large when compared to V_1 and V_2. If this is the case then it is indicated that the government resources committed to safety are much too small and the value of lifesaving has been greatly underestimated.

VI. APPLICATION TO COAST GUARD ANALYSIS

A. GENERAL COMMENTS

When applying the procedure for determining lifesaving benefits to Coast Guard problems useful data sources must be identified. Table 6.1 lists possible sources of data that can be used in computing the various components of total program benefit. The accounting procedures are straightforward and have reliable sources of data for computation. The Coast Guard sponsored study [13] recommends the use of these procedures alone for benefit computation. While this study's approach yields an underestimate of the true benefit, it is computationally valid. The results of the study are summarized in Appendix A. The values obtained using all aspects of this procedure should be periodically updated to assure validity.

The computation of V_3 poses a few difficulties for the analyst. Necessary for this value computation are the perceptions and values of various individuals concerning risk and risk reduction. The simplest way to quantify these perceptions is through the use of an interview or questionaire technique. Before conducting an interview it is necessary to have a clear definition of the risks and risk changes that are involved. Without these figures an individual is unable to make valid judgements concerning the worth of changes.

TABLE 6.1

DATA SOURCES

	PROCEDURE ELEMENT	SOURCE
V_1	Wages - National Average Opportunity Costs Population Data on Boaters	Census Bureau Estimated - can use values from NHTSA Coast Guard Annual Boating Survey 1976
V_2	Legal Fees Funeral Costs Probate Costs Insurance Admin Property Damage and repair	National Safety Council and NHTSA Coast Guard Data Base CG-357
V_3	Boating Risk Levels Risk of other Activities Value of Risk Change	Coast Guard Boating Statistics CG-357 FAA Statistics Interview Techniques

The exact degree of risk faced by a boater is difficult to estimate but the Coast Guard has made considerabel progress toward that objective. The Nationwide Boating Survey [12] has provided considerable information concerning the profile of the boating population. The survey does have a deficiency for SAR program analysis in that it does not distinguish between those areas of Coast Guard SAR responsibility and areas that there is no responsibility. Due to this a reasonable estimate of boating activity in areas of Coast Guard SAR jurisdiction might be suspect. This deficiency is one that can be remedied by making this distinction in the next survey.

Information provided by the survey includes the total operating hours of various recreational boat classes. By coupling the operating hours with known fatalities a risk for a specified time of exposure can be estimated. A risk per time exposed is superior to risk per population since the population is not homogeneous in their boating activity. The lack of similarity in boating habits would necessarily imply that the same degree of risk is not faced by all boaters.

B. COMPUTATION OF $V(\overline{p})$

Computations for $v(\overline{p})$ can be accomplished in the following manner. Before proceeding, though, the following values need to be obtained:

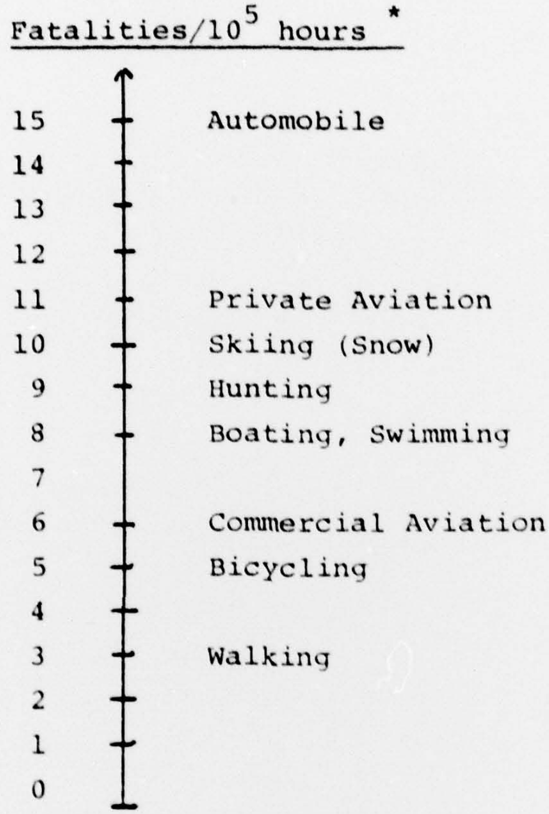
1. Cost/hour of operation of boating
2. Risk/hour of exposure during boating

The first step is to produce a scale to be used in comparing the various risk levels of activities that individuals participate in. An interval scale, as shown in Figure 6.1, is useful for facilitating the comparisons. The risk levels displayed are for demonstration only and are not the actual risk levels encountered.

Once the scale has been completed it can be presented to individuals comprising a sample of the boating population. The people would then be able to compare the risks of various activities. Once presented with this information the individual is informed that the risks of boating can be changed through the introduction of various programs. The present level of risk and the cost associated with that level are now presented. The individual is given an opportunity to make decisions concerning the reduction (or increase) of risk for a price (compensation) that would be reflected as changed operating costs. The decision process can be facilitated through the use of a format similar to that in Figure 6.2. Again it should be noted that the figures used are contrived data.

Once the forms have been completed by the people comprising the sample a validity check can be performed to assure a logical sequence in the values. The values can then be tabulated and used to estimate the functional relationship between risk and compensation. While this is not the only procedure that could be used for this type of estimation it is relatively straightforward and easy to apply.

FIGURE 6.1



* The figures presented are not actual risk levels encountered in the activities. These are presented for demonstration only.

FIGURE 6.2

FATALITY RATE * (per 10^5 op hours)	COST (per op hour)
15	______
14	______
13	______
12	______
11	______
* Present Level * 10	$100
9	______
8	______
7	______
6	______
5	______

* The risk levels presented are not actual risk levels faced in boating activities. This is for demonstration only.

The procedure for computing V_3 as outlined in Chapter V can now be completed and the function $v(\overline{p})$ for each sample member estimated.

VII. CONCLUSIONS

The necessity of life valuation underlies a logical determination of the Coast Guard's SAR budget. Benefits of lifesaving cannot be measured in terms of dollars without placing a value on the final product, a saved life. If life valuation procedures are not used explicitly, then a tacit procedure has been utilized. Any level of spending for lifesaving will automatically place a value on life, whether it is admitted or not.

As the Coast Guard moves into a period of restricted SAR budgets and potentially diminished response capacities, difficult decisions have to be made. The decisions involve either more cost-effective approaches to maintain the present level of services or a redefinition of SAR program objectives. Any decision made will have an impact on the risk faced by the boating public. This impact can be manifested as increases or decreases in the present risk levels. The procedure detailed in Chapters V and VI would be useful in determining the increase or decrease in safety benefits through SAR program changes. While not mentioned previously, the reduction in benefits can be obtained by determining the additional lives lost through the elimination of specific programs and using the same procedures given but going the opposite direction in computing V_3.

Before fully implementing this procedure the analyst should be aware of two potentially troubling aspects of it. The first of these is the difficulty in estimating the function of risk versus costs for specific individuals, $v(\bar{p})$. The ability of people to properly evaluate low level risks has been called into question by Zeckhauser [17]. He feels that estimates gained using this approach are highly unreliable. Mishan [5] on the other hand implies that it is better to have a poor estimate of a valid approach than a good estimate of an invalid approach. This author concurs with Mishan's analysis since continued research in utility estimation techniques will provide more reliable estimates for use in life valuation. The risk scaling approach of the previous chapter allows an individual to compare the risks of risky activities with other risky activities and thus make value judgements of changes to achieve his desired safety levels.

Another troubling aspect applies to risk reduction in general. Conley [1] has shown that making an activity safer will induce more people to participate in it. This increase in the demand for an activity such as boating could potentially invalidate the estimates of total activity and expected risk levels. It is difficult to quantify the exact increase in demand and the effects of that increase. Nevertheless the decision maker should be made aware that this effect could occur.

Jones-Lee's [5] research has shown that the value obtained for V_3 may very well be far greater in magnitude than the values obtained for V_1 or V_2. If this is the case then the use of only $(V_1 + V_2)$ as a measure of benefit may be underestimating the value of a lifesaving program by a considerable amount. If the cost of a program is relatively small when compared to $(V_1 + V_2)$ then an ultimate decision for or against a program would most likely be the same regardless of the value obtained for V_3. On the other hand if the cost of a program was close in value to the value $(V_1 + V_2)$ then by not making use of the value for V_3 in the analysis, the program may be rejected when in fact the benefits far outweigh the costs. If a decision is made not to utilize V_3 in the analysis of a program then it should be kept in mind that benefits are being overlooked that may have had an influence on the final decision made. Another consideration may be that if Conley's assertion is true, that the discounted future earnings are a lower bound on an individual's self value, then $(V_1 + V_2)$ would be a valid lower bound on the value of a life and could be used as such until more experience is gained in self valuation techniques.

APPENDIX A

The values in this table have been drawn from the report, A Survey of Methods For Estimating The Cost Value of a Human Life, completed for the Coast Guard in 1976. The values tabulated are for the accounting value of life recommended for use by the Coast Guard in program analysis.

METHODS AND COST ELEMENTS	Scope of Costs & Benefits: VICTIM	FAMILY	EMPLOYER	COMMUNITY	SOCIETY	Avail-ability and Quality of Data	EXPECTED RANGE OF VALUES (Based on rough estimates from Coast Guard Data)
1. ACCOUNTING METHODS							
. Wage Loss		X				High	About $140K-275K
. Family/Opportunity		X				Low	About $35K
. Community/Opportunity				X		Low	$5000-$10,000
. Employer Loss			X			Low	$1500-$4500
. Insurance Admin.					X	Low	About $5000
. Legal & Court		X				Low	$1000-$3000
. Pain & Suffering	X					Low	$10,000-$15,000
. Hospital/Medical		X				High	Probably Negligible
. Funeral Costs		X				High	$1000-$1500
. Others Time/Money		X		X		Low	$1000-$1500
. Property Damage					X	High	$900-$1000/Fatality
. Misc. Accident					X	Low	Probably Negligible
. Victims Assets	X	X				Low	About $5,000
. Fringe Benefits	X		X			High	About $1500-$2000
. Income Tax				X	X	High	About $2000-$4000
. Victims Consumption					X	High	About $3500
TOTAL							About $200K-$365K

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