Problems in Estimating Comparative Costs of Safety and Mobility

By Frank A. Haight*

Introduction

This paper is designed to emphasise the desirability of discussing safety and mobility in a unified context, and to highlight some of the difficulties in doing so. There is no suggestion that the data given are more than illustrative. In particular, unless otherwise specified, they refer to the United States. Although much of the discussion applies to industrialised countries in general, it is not the purpose of the paper to search out and compare data from a wide variety of sources. That task must be left to research workers with more time, more staff and a more substantial research budget.

Traffic Safety

It is fair to assume that personal safety has been a concern of road users as long as there have been roads, and there is some evidence to suggest that a specific risk — risk of injury from a collision — was no less before the invention of the car than it is today. Nevertheless, it has only been with the widespread use of motor vehicles in the present century that concern over this particular hazard has been translated into substantial organised research and government intervention. In the United States, for example, the largest percentage growth in the population of vehicles (accidents were not systematically recorded), which occurred in the year 1917, was soon followed (in 1921) by the establishment of the Highway Research Board and subsequently by state traffic authorities. By the mid-1960s the federal government had entered the safety field with massive funding, at first with respect to vehicle design and performance but later in virtually all aspects of safety (see, for example, Mashaw and Harfst, 1990, and Graham, 1989, for the political and social history of one aspect of the problem: occupant protection).

Most of today's safety countermeasures were known 25 years ago (Arthur D. Little, Inc., 1966) and many even 50 years ago (Halsey, 1941): drink-driving programmes; improving vehicle design; controlling speed; building better roads; driver testing before

* Institute of Transportation Studies, University of California, Irvine. The author gratefully acknowledges the helpful suggestions of Andrew Evans, H. Laurence Ross and several anonymous referees.
licensing; provision of emergency medical services; separation of pedestrians from traffic; investigation and record-keeping of accidents; removing roadside obstacles; driver education in schools; and so on. Even the recommendation for passengers to use seat belts, often considered part of the “Haddon revolution” of the mid-60s, was contained in a federal government report published several years earlier (Secretary of Commerce, 1959).

In addition to these specific safety initiatives, many changes in the transport system contributed to reduced risk. Traffic control devices, for example, were designed to improve the flow of vehicles, but incidentally made the flow safer. Many similar improvements in roads and vehicles, intended to improve mobility, contributed also to safety. A recent example of this serendipitous “piggybacking” effect of safety on other programmes, is the 55 mph speed limit, hastily introduced in 1973-74 with a view to conserving fuel.

Social and demographic changes can also have an effect on traffic safety. For example, an ageing population implies a smaller percentage of high-risk young drivers. (Although the very old also have high accident rates, the preponderant effect is produced by the very young.) Similarly, increasing urbanisation implies lower average travelling speeds with the consequence of less severe collisions.

Although it is difficult to quantify exactly the effect of any specific factor, it is possible to gain an impression of the aggregate changes in traffic safety by analysing changes in certain key parameters. In doing so, we are limited by the type of data which are systematically collected. This may include the annual number of fatalities, the number of injuries reported to the police, hospitals or insurance companies on one hand, and on the other the total resident population, the number of registered vehicles, and the number of vehicle-miles of travel. The resulting data — especially the calculation of ratios between safety measures and mobility measures — form the basis for myriad research papers, popular articles and books.

There are, of course, many other statistics that would be helpful in understanding traffic safety in detail, but which are not generally available. One might wish to see, for example, the number of passenger-miles of travel disaggregated by region and by date; the number of ton-miles of freight similarly disaggregated; to have socio-economic profiles of those injured or killed; and to have better measures of pedestrian exposure to traffic. Nevertheless, by manipulating the data which are conveniently available, some useful information can be obtained. It appears that traffic is safest in Sweden (fatalities per vehicle), or in the United States (fatalities per vehicle-mile of travel) or even in China (fatalities per resident population). It is certainly not the purpose of this paper to tease out all the comparisons that might be made.

One thing does deserve emphasis, however: the constantly falling fatality rate per vehicle mile of travel. Figure 1, line (a), shows that travel over an average fixed distance on the roads of the United States is now substantially less likely to result in the death of a road user than it was fifty years ago (National Safety Council, 1991).

The interesting aspect of this steady decline is that similar changes have been experienced in all jurisdictions for which adequate records are kept, both in individual
states and in the industrialised countries of the world (Oppe, 1989, 1991). Since the active safety programmes have been different — in timing, in magnitude, in emphasis — in different countries, the nearly parallel reduction in fatality risk suggests that "the cause" is in large part the gradual maturation of road transport as a system. This includes better traffic law, better traffic engineering, better road and vehicle design, and especially the increasingly mature behaviour of road users, including, above all, drivers. In motorised societies, driving to test vehicle capabilities (distance, speed, acceleration) seems to belong to an adolescent stage of motorisation.

The other side of the picture, which is masked by the discussion of rates, is the total cost of road accidents. In fatalities alone the most authoritative estimates (Center for Disease Control, 1991) forecast approximately 45,000 US traffic fatalities in the year 2000, at least one thousand more than in 1989. The total for the 44 most motorised countries is slightly over 150,000 in the latter year (National Safety Council, 1991). This list omits China,
India and the Commonwealth of Independent States, suggesting that the estimate of Trinca et al. (1988) that the total number of fatalities worldwide may be as much as half a million annually may not be greatly in error. Furthermore, as we will see in a later section, fatalities, although relatively reliably measured, comprise only a portion of the total cost.

In parenthesis, one may reasonably ask how all these factors promoting safety (including programmes of countermeasures) of long standing, well conceived in many cases, often with massive funding from state and federal sources, have had only a marginal effect on the annual number of fatalities. There appear to be two answers. First, programmes, however good, have to be put into practice in an extremely complex environment, namely the road transport system (described in the following section) with many constraints: social, economic, legal and political. Thinking of countermeasures is easy; applying them in real traffic is usually difficult, and often costly as well. The complexity of factors affecting any one crash and its outcomes is so great that any programme, however well conceived, can be expected to affect only a very small percentage of hazardous situations.

Secondly, and more importantly, as travel has become safer per mile, the number of miles travelled has increased. Figure 1, line (b), shows that the per capita rate, although mostly declining since the mid-60s, is now only slightly lower than it was in 1943. One might conclude that much of the improvement in the vehicle-mile rate has been “used up” in providing for increased mobility. Not only that, but the increase both in vehicle ownership and vehicle use shows very little sign of moderating; even in areas with the highest density of vehicles per capita, there is only a slight indication (see Haight, 1984) that saturation may be approaching in the near future. Indeed Evans (1991) argues that there is no more reason to expect a limit to the proportion of cars than there is a limit to the proportion of any other consumer product.

**Mobility**

The road transport system of an industrialised country such as the United States is a structure of massive size and complexity. Whether measured in ton-miles of freight carried, in passenger-miles, in percentage of the gross national product (GNP) consumed or in proportion of time involved in travel, the magnitude of the figures is impressive. It may be difficult to state the exact value of road transport in maintaining an industrial society; in the United States its cost is often estimated at about 15 per cent of the total GNP. Approximately 90 per cent of passengers and freight go by road. If one can accept the various estimates which have been made, the cost of road transport exceeds the cost of road accidents by a considerable factor; some estimates are as low as 8:1, some as high as 25:1.

Mobility in an industrialised society is therefore not a trivial concern such as skydiving or football that could, if necessary, be restricted or even abolished in the interests of safety with no consequences except for petty inconvenience. Neither can other modes of travel (chiefly air and rail) substitute for most road travel; the reasons are various, but may be generally summarised as flexibility and consumer choice. (There have, however,
been two industrialised countries having transport systems based on rail, without a modern road network: pre-1950 Japan and pre-1980 Soviet Union.)

The concern of this paper, however, is not the size of the transport system, but its complexity. The operation of traffic is accomplished by means of a continuous sequence of individual road-user decisions, day and night, city and country, summer and winter, by a wide variety of drivers and pedestrians. Driving is not restricted to those who are educated, or polite, or those who have perfect eyesight and motor skills, or to those with good judgement and lacking hostility. The population of drivers will include some individuals who have consumed alcohol (perhaps even beyond the legal threshold) or who are in a desperate hurry, or who are experiencing an unexpected physical or medical difficulty.

In earlier days when "motoring" was a luxury or a hobby, it was possible in many jurisdictions to restrict licensing to "expert" drivers, but in industrialised countries in the late twentieth century, one must exhibit some gross incapacity to be denied a driver's licence.

It is primarily in this respect that the control of road transport differs from that of all other modes and it is therefore also in this respect that traffic safety problems differ from safety issues in rail, air, sea, pipeline, and so on.

Road-user behaviour is based on attitudes, perceptions and decisions, which are constantly varying and by no means infallible. However, it is not based solely on these personal qualities. Many other factors, including traffic engineering, law and social norms attempt to control, or at least influence, the behaviour of road users. Unfortunately, no system is absolutely foolproof. Some people at some times in some situations can and do disregard traffic lights, evade police surveillance, drive while in an inappropriate physical or mental state, neglect vehicle maintenance, take unreasonable chances, or engage in similar deliberately risky behaviour. Beyond that, and perhaps more importantly, ordinary road users, in ordinary circumstances, sometimes fail to see, register, process or comprehend information and then fail to react, and take appropriate action. These failures in traffic may be attributed to any number of causes, some "wilful" and some inadvertent; what is important is to recognise that they do exist and that, in spite of any sanctions we can reasonably imagine, they will in some measure continue to do so.

Furthermore, the "errors" of road users, real though they may be, could in many instances equally be attributed to deficiencies in the traffic systems and road conditions which permit the errors to occur. So-called "black spots" in the road network (that is, places experiencing many accidents) have their counterpart in black spots in traffic law, or black spots in police procedures. A notorious case was the advice given to drivers to stay one car-length behind a leading vehicle for each 10 mph of speed. (Another difficulty with "driver error" as a concept is that it provides an ideal justification for errors in road construction and administration. For a farcical example, see Haight, 1973.)

Finally, there is undoubtedly a large random component in accident experience, which is difficult to attribute to anyone’s error. The more sophisticated the traffic system, the larger the random component will be, simply because the easily identifiable causal factors have been gradually discovered and treated.
Thus, the very operation of the road system creates simultaneously mobility and risk, and it is unreasonable to consider mobility and risk to be separate problems. Whether for discussion or for intervention, treating safety without regard for mobility is bound to be incomplete and probably unsuccessful. One might as well try to separate education from thought, or war from violence as to separate safety from mobility.

This view is not novel; the link was recognised over 50 years ago in the following terms:

"They [accidents] are important inefficiencies that should be reduced or eliminated, just as delays are important inefficiencies that should be minimised ... Accidents not only cause untold suffering and grief, but they are also a symptom of inefficiency in the function of transportation, which is the orderly movement of traffic." (Halsey, 1941)

**Safety and Mobility**

We now describe in more detail how safety and mobility interact with one another. Although both are important social goals, unfortunately they are goals which are in some respects conflicting, and in any case seem — at first — to be incommensurable.

Before discussing these two issues, it is worth mentioning that measures taken primarily to facilitate mobility are often justified by reference to their effect on safety. Some important examples are: driver education; traffic rules and their enforcement; and engineering of roadways. In promoting these classical "three E’s", safety is often the most persuasive argument, simply because failures in safety may have more heart-rending consequences than failures in mobility.

Where safety and mobility are affected simultaneously by a single programme, it may be that both are improved: technical improvements in vehicles and in roadway standards are outstanding examples.

On the other hand, where mobility and safety are in conflict, the conflict is substantially related to speed: speed limits, travelling speeds, interruptions in free speed, and so forth. Some things which promote safety, such as traffic lights, speed limits, or sobriety checkpoints, also impede mobility.

For a more complete discussion of mobility-safety relationships, see Evans (1991, chapter 14) and Campbell (1991). While one may not agree with all the items in Evans's lists (he is not entirely persuasive with respect to measures supposedly neutral to mobility; manufacturing costs are omitted, and small delays belittled), one must agree that mobility and safety are not necessarily antithetical; the situation is far more complex than simply safety versus mobility. Campbell gives a 3x3 table showing measures which are safety/mobility positive, neutral or negative. For example, the cell representing safety neutral, mobility positive contains "high occupancy vehicle lanes, larger fuel tanks on vehicles". The cell which is safety positive, mobility neutral contains "belt laws, vehicle crashworthiness".

Although the effect of mobility and safety on each other is not entirely conflictual, it is that conflict, to the extent that it exists, which is the subject of this paper.
The problem of comparing "time saved" with "lives saved" (to express the question in popular if inaccurate jargon) has seldom been seriously addressed. Transport engineering textbooks sometimes ignore safety (Manning and Kilareski, 1990; Wright and Ashford, 1989; Papacostas, 1987). Where safety is recognised as significant to transport, it is usual to assume that mobility demands are given, and then to attempt to maximise safety for whatever engineering facilities are needed (Garber and Hoel, 1988; McShane and Roess, 1990; Khisty, 1990). Of course, the transport engineers' assignment is normally to promote mobility, and sometimes to consider levels of safety as criteria of success. A more broadly-conceived assignment would permit consideration of the simplest way to increase safety: decrease mobility. Although the most spectacular improvement in traffic safety in recent years came as the result of mobility reductions concomitant with the 1973 energy panic, the 1991-1993 Highway Safety Priority Plan (National Highway Traffic Safety Administration, 1991) of the federal government includes no proposals to reduce travel. It is also interesting that the current emphasis on promoting mass transit — apart from the fact that it is currently fashionable — comes more from the need for energy savings, for air quality improvement and for the reduction of congestion than from considerations of traffic safety.

If the transport community treats safety superficially, it is true a fortiori that the safety community treats transport issues — if at all — with contempt. At best, authors writing about traffic safety brush mobility aside as being of no consequence. For example, in a table "Examples of Injury Control Countermeasures with Known Effectiveness" (Rice, Mackenzie and Associates, 1989) no mention of mobility cost is given in recommending various interventions. Occasionally we may see a rhetorical question: "After all, what does a few seconds mean to anyone, when their life is at stake?" But never, it is safe to say, do safety analysts and especially safety advocates take seriously the economic role of road traffic in maintaining an industrial society.

Some analysis verges on the absurd. For example, it has been pointed out (Robertson, 1980; Karpf and Williams, 1983) that if teenagers are not taught to drive in high school, they will be less likely to be killed in traffic; a true observation, certainly, but a fanciful suggestion. Another author has suggested that speed limits in metropolitan areas should be 5 kilometres per hour; still another that journeys of less than 5 kilometres be done by walking, or on bicycles. There are two principal difficulties with these ideas. First, only passenger travel is discussed, and moreover by able-bodied adults in good weather. Are the contents of heavy trucks to be sent on bicycles? Second, if one is going to deal in such inane terms, one might as well add to the list: "cancel licence after first offence"; "put speed bumps on the freeways"; "drive only in daylight"; "put median barriers in every street"; "forbid children to ride bicycles"; and so on. The simple observation that none of these suggestions would be taken seriously is a sufficient indication that we do not in fact consider life to be priceless or time to be without value.\footnote{It is not only mobility which is ignored: the arguments leading to a 21 year old drinking age were based on traffic safety consequences and inter alia failed to refute the earlier arguments in favour of an 18 year-old drinking age.}
A realistic approach to the problem of reconciling mobility and safety must, to begin with, acknowledge that both are social goods which have value. In very simple terms, we may think of three-way optimisation: maximise safety, maximise mobility, minimise cost. A little reflection will show that any two parts of this triad can be reasonably well satisfied at the expense of the third. The goal of public policy is to optimise all three; this seems to be nearly impossible.

Indeed, the problem need not (and probably cannot) be approached simply as a computational exercise. But lack of a clear-cut method leading to a specific answer does not mean that the question is beyond rational analysis, or that it can in any reasonable way be ignored. To begin with, we should make a serious attempt to provide a framework for evaluating programmes on both safety and mobility scales.

To do so is an immensely complex project, which can be only sketched in the present paper. We intend no more than to provide some of the groundwork, and a discussion of earlier research. As a start, we will face squarely two of the most difficult components of any mobility/safety balance: estimates of the value of life (for safety) and of the value of time (for mobility).

The Value of a Life to Society

In this section we review the literature on the value of life to society, and make some calculations to reconcile the enormously varying conclusions. Obviously it is impossible to consider the value of a given individual’s life to him/herself, or to his/her friends and relatives. Value-of-life studies properly refer to the value of a statistical life.

The subject is divided conveniently in two ways. First, we distinguish between costs which can be calculated in monetary terms and those which cannot. The latter are often called “pain, grief and suffering” (PGS). Second, we can divide costs between those which are borne by society as a whole, such as legal and administrative costs and loss of productivity, and those which can, with reasonable accuracy, be assigned elsewhere: the individual, hospitals, local authorities, and so on. PGS is not borne by society, so we are left with three categories: monetary social cost, PGS personal cost, and monetary personal cost.

Many attempts have been made to calculate the monetary costs, dating back to the seventeenth century in a reference given by Landefeld and Seskin (1982). By now it seems to be generally agreed that there are two possible approaches. The first, called human capital (HC) is to treat a human being as an element in the production process, and value his/her death or incapacitation in terms of the estimated future loss to that process, sometimes minus the victim’s estimated future consumption. This procedure has the merit of being reasonably easy to assess, and as Arthur (1981) points out, it is actuarially sound in using age-specific accounting. However, by using only loss in GNP, it may lead to the result that certain lives — those of the elderly, or those otherwise unproductive — may be given a negative value if their consumption is expected to exceed their contribution. Although we must be reluctant to conclude that society is truly improved by the death of
any member, the HC approach does permit the possibility of such economic improvement. The method has been widely used, and may be thought to give a minimum value.

One technical difficulty with an actuarial approach to valuing life is in the choice of a discount rate for obtaining present values. This is a problem with any forecasting, and is usually avoided by using several feasible rates. In application to traffic fatalities, the conclusion is especially sensitive to choice of discount rate, simply because the age distribution of injuries is skewed towards youth, with correspondingly longer life expectancies.

One of the earliest evaluations using the HC procedure is the work of Rice (1967) who, using mainly loss of productivity, found a figure of less than $60,000 per fatality. A more contemporary estimate along the same lines (Miller, Luchter and Brinkman, 1989, 1991; see also Andreassen, 1991) uses six categories of cost (property damage, medical costs, loss of productivity, emergency services, legal and court costs, other administrative costs) and gives the value of $425,406, of which 90 percent is contributed by loss of productivity.

The second approach to valuing life, originally proposed by Mishan (1971), is called "willingness to pay" (WTP). WTP is based on a principle which economists call "potential Pareto improvement" and which is also used in other areas of cost-benefit analysis. The following example (given in Landefeld and Seskin, 1982) shows in simple terms how the value of life can be found from WTP.

Suppose that in a town with a population of 100,000, each person is willing to pay $25 for a countermeasure which would reduce the probability of death from 0.0009 to 0.0008. This would mean a reduction in the expected number of fatalities from 90 to 80 at a cost of $2,500,000, or $250,000 per life saved. This calculation (essentially $25/(0.0009 - 0.0008)) is independent of the size of the town. If people were willing to pay $50 for the same improvement, the value of life would be increased to $500,000.

There are obvious difficulties with WTP. Not everyone in town may be able to assess the risk, either before or after the countermeasure is implemented, or to state exactly the amount he/she would be willing to pay to reduce that risk by a given factor. Also assuming the question refers to their own risk, people may say that they would be willing to pay any amount of money to stay alive. (If true, this type of response would tend to inflate the average value.)

Nevertheless, some rather sophisticated techniques have been developed to implement the WTP method. These are of two types: survey responses and "revealed preferences". A summary of various survey results is given by Landefeld and Seskin (1982), who also discuss in detail the various difficulties with the method. For example, one study found that individuals would be willing to pay $76 for construction of a coronary care unit that would reduce the probability of death from heart attack by 0.002, leading to a value of life of $37,000 (in 1973 dollars). Other surveys cited lead to values of life exceeding $1,000,000. The method has been especially associated with the work of Jones-Lee (for example 1976, 1982), who has also applied his results to death in traffic (1969).

In the other method for assessing WTP, the results of investment in safety already made are used. For example, one may compare the price of smoke-detectors with their probable life-saving effects or the wage premium paid for high-risk jobs with the degree of risk.
Jones-Lee (1976) gives an extended survey of earlier work in the area, covering some
dozen important publications. Much of Jones-Lee’s work is mathematical, and designed
to overcome some of the theoretical objections to the WTP method. However, one recent
paper (Hills and Jones-Lee, 1983) deals in simple terms with the problem of investment in
safety projects, and the value of life they imply. The authors show that earlier investment
decisions (from the United States and from the United Kingdom) are remarkably
inconsistent, implying as they do a value of life ranging from three thousand dollars to
sixty million dollars. Hills and Jones-Lee also discuss the merits of different approaches
to value-of-life calculations, depending on the purposes to which the results are to be put.

As a result of such extreme variation in values obtained by WTP methods, even
averaging results may be statistically suspect.

In the literature, the WTP method is often associated with the procedures used by
economists, and HC with those of engineers, although the reason is not really very clear.
In any event, in the publications surveyed for this paper, the WTP values seem to be much
larger than those obtained by HC calculations, and it would be a reasonable guess that the
difference is substantially accounted for by inclusion of PGS in WTP. (Since PGS is not
given a monetary value by the HC method, it is assumed that it is implicit in results based
on WTP.)

Beginning in the mid-1980s a series of studies by T. R. Miller (Miller, Reinert and
Whiting, 1984; Miller, 1986; Miller and Luchter, 1988; Miller, Whiting, Kragh and
Zegeer, 1988; Miller, Luchter and Brinkman, 1989) revisited the work of Hartunian,
Smart and Thompson (1981) (which is discussed in a later section of this paper) and
proposed certain modifications. In the most recent of these papers, using a calculated value
of a life of $425,406 (1986 dollars, 6 per cent discount rate) Miller, Luchter and Brinkman
calculate the “rational investment levels for enhancing the safety and health of the
American public,” and find that to avoid one fatality, it is rational to invest $2,000,000,
that is about 470 per cent of the previously accepted HC value of a life. The argument is
based on the results of various WTP surveys (Miller, 1986) and on re-computing “those
that involved discounting or valuation of travel time” and adjusting “to correct an endemic
problem with these studies, namely that people behave in accordance with risk levels they
perceived, not actual risk levels.” This appears to define “rational investment level” as
WTP with some unspecified adjustments, or juggling (in Miller, Luchter and Brinkman,
1989).

Miller et al. (1989) also estimate the value of PGS for some extremely severe injuries
(called “fates worse than death”). This calculation seems to be based on percentage utility
loss scaled for various such fates (ranging, for example, from 106 per cent of death for
paraplegia to 139 per cent for severe burn) combined with sample survey results and jury
awards. The general conclusion of Miller et al.’s 1989 analysis is summarised as follows:

“This paper has introduced the concept of rational investment levels as a basis for
benefit-cost analysis of highway safety issues. This concept is consistent with
universal federal practice in benefit-cost analysis. Unfortunately, only a few states
are using this concept in their economic analysis of safety issues. Instead, most
states inappropriately base investment decisions on the economic costs of crashes to society. For fatalities, for example, they misuse the $225,000 cost per life estimated by the National Safety Council or the $358,000 cost estimated by NHTSA (1983). The appropriate value per life saved to use in resource allocation and benefit-cost efforts is an order of magnitude larger, approximately $2,000,000.”

Miller’s figure has now been widely cited and used by several agencies in project evaluation. It is reasonably consistent with the 1990 value (Department of Transport, 1991) for Great Britain of £664,940, perhaps bearing in mind the inflated medical costs in the United States. It is, however, quite different from the Australian figure (Andreassen, 1992) of $A 625,000, or something like half a million US dollars.

While the order of magnitude leap may have economic validity, it appears nevertheless that the motive for the recalculation and the use to which it is put are both political. Miller believes that the difference between the WTP and HC is not one of convenient choice of a metric, but rather between right and wrong methods.

In this brief overview of issues and methods, no exact “answer” to the problem of life valuation is given. But it is shown that, depending on the situation at issue and on the purpose of the exercise, there are available certain well thought out approaches to the problem. To place a cash value on human life may seem improper (see Hauer, 1994) but it is certainly not impossible. In addition, we argue also that it is a necessary prerequisite to rational discussion of safety measures.

The Value of Time to Society

Just as the study of the value of life has roots in public health research, so the study of the value of travel time has roots in transport research, and has always been considered to be an important variable in transport planning (see Guttman, 1975). In attempting to put a cash value on time, however, the difficulties are numerous and complex. Obviously some time may be as valuable as life itself, while other time — leisure time is usually cited — has a much lower value.

In the 1960s studies relied principally on travellers’ stated value of time, which was used in analysis of choice of modes (car, bus, train, or other) (for example, Moses and Williamson, 1963), and in travellers’ choice of toll road versus free road (Thomas, 1968). The former publication gives the value of $1.55 per hour (a little over the minimum wage at the time of publication); the latter states that the “traditional value” is $0.86 per hour, but recommends that this be increased to $2.82 per hour, again slightly more than the minimum wage at the time. For a tabulation showing methods and results for nineteen studies before 1974, see Keller (1975).

In the following decade, more sophisticated concepts were introduced into value-of-time studies. Also, instead of giving a dollar value, some authors (for example, Lisco, 1967) expressed their results explicitly in terms of the prevailing wage rate (50 per cent in this case). For business trips by air, the question of “employer’s time” as against “employee’s time” was raised, and a value of 150 per cent of average salary obtained
(Hensher, 1977). The concept of “traders” (those willing to sacrifice cash for time or vice versa) was introduced (Beesley, 1974) with values of 30-43 per cent of income given for traders. One author (Gronau, 1974) distinguishes between “value of time” (VOT), the amount of money that a traveller would pay to gain a unit of time, and “price of time” (POT), the amount of money a traveller would forgo for one time unit. Most writers made some attempt to disaggregate the problem, some by family income, some by trip purpose: personal, business, social/recreational, vacation, school, work (see Thomas and Thompson, 1971). In one study (Reichman, 1973, 1974), travellers implied value of time was estimated by asking those already on a journey by various modes how long they estimated the same trip would have taken by alternate modes. The results showed that a difference existed between the true and estimated time savings, tending to throw some doubt on people’s answers to surveys asking for their value of travel time.

Most significantly, the language of economics, with its associated mathematics, began increasingly to be found in the value-of-time literature, as the following quotation shows:

“If travelling carried with it no marginal utility or disutility, theory suggests that the value of travel time would simply be the opportunity cost of travelling, which is the value of leisure time.” (Guttman, 1975)

Guttman, incidentally, finds that peak-hour work trip time has a value of $5.17 per hour, off-peak work trips a value of $1.91, and off-peak social and recreational trips a value of $2.08.

In 1982, an ingeniously devised experiment was conducted in the Toronto subway system. People waiting for trains were offered immediate cash bribes to miss their train, and travel by a later train (Hauer and Greenough, 1982). By varying the amount offered, and the delay demanded, it was possible to calibrate the implied value of time. The variables used were time of travel (morning peak, midday, afternoon peak), sex, and income level. For those who were just on time or late for their trip, the implied median value of an hour was $55 at the morning peak, $59 at the evening peak. For those who were early, or who had no fixed arrival time, the values were respectively $30 and $17. It is interesting that all the values obtained in this experiment were (although in Canadian dollars) far in excess of those found by traditional means, such as questionnaires.

In the mid-1980s a large research project was carried out in the United Kingdom, with a view to estimating the value of travel time in a wide variety of circumstances. The five-year project, involving a twenty-person study team, resulted in a comprehensive book (MVA Consultancy, 1987) of over 200 pages. Six major surveys were carried out, with the variables: trip purpose, mode of travel, and urban versus inter-urban. Both “stated preference” and “revealed preference” methods were used. It was shown that although value of time increases with income, the trend is not linear, so that the increase is less than would be expected. Time spent waiting and walking were valued more highly than time spent in vehicles. There was confirmation for the difference between POT and VOT: “individuals will need to be compensated more for an increase in travel time of x minutes than they will be prepared to pay to save x minutes.” When income groups were compared, a threefold difference in income led to a difference of only 40 per cent in value of time.
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In view of the complexity of the study plan, and the multitude of results, it is not feasible here to summarise all the conclusions. One extract, however, will give the flavour: in the lowest income group (< £5,000 per annum) “approximate values for persons from two-person households, who are neither retired nor students, and who, if working are not working ‘variable’ hours” are given as follows:

- Urban bus: 1.5 p/min (about $1.62 per hour)
- Long-distance bus or train: 3.4 p/min (about $3.67 per hour)
- Long-distance car: 3.5 p/min (about $3.78 per hour)
- Commuters: 3.0 p/min (about $3.24 per hour)
- Leisure: 4.5 p/min (about $4.86 per hour)

If one assumes a median income for this group of £4,000, a 40-hour working week and a 50-week working year, the overall value suggested for value of time of about $3.89 would still be slightly in excess of the average hourly wage of $3.60.

Before leaving this topic, we should also mention the conjecture often expressed, that “small packets” of time have no value and should not be aggregated, but rather ignored. This notion, while possibly amusing, seems to suffer from several defects: (a) it does not specify how small the time packets should be to deserve oblivion; (b) it usually refers to someone’s time other than the speaker; (c) no evidence is offered that the statement is true, or if there is, it is in the form of a rhetorical question (“why should anyone mind if two seconds are lost in traffic?”); and (d) drivers in traffic certainly seem to act as if they valued small gains of time. Experience with central door-locking in cars and touch-tone telephones (among other things) confirm the impression that small packets of time have monetary value.

For the purposes of the present paper, we will use the minimum wage as the metric for valuing time.

Reduced Safety as a Cost of Mobility

In this section, we discuss only one aspect of transport costs, namely those resulting from deaths, injuries and property damage (and, in some studies, pain, grief and suffering) in collisions involving at least one motor vehicle on public roads. (Agricultural and recreational collisions are excluded.) There are, of course, many other costs associated with road traffic, ranging from those produced by environmental deterioration to various personal aggravations. We will survey published results dealing with costs of mobility, omitting, for example, the purchase price of vehicles and fuel, and the cost of road construction.

One of the most difficult aspects of such an assessment is, of course, the value of a human life, and for this reason that subject has been discussed separately in an earlier section.

It may be surprising to learn that very few publications before 1980 make any mention of monetary costs of accidents, and fewer still make a serious attempt to put a dollar value on the total. The exception is the National Safety Council (NSC) annual publication
Table 1

Annual Cost of Road Accidents
(United States, Selected Years)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost (current $M)</th>
<th>Cost (1989 $M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>1,350</td>
<td>12,919</td>
</tr>
<tr>
<td>1943</td>
<td>1,250</td>
<td>8,960</td>
</tr>
<tr>
<td>1953</td>
<td>4,300</td>
<td>19,932</td>
</tr>
<tr>
<td>1963</td>
<td>7,700</td>
<td>31,178</td>
</tr>
<tr>
<td>1973</td>
<td>20,200</td>
<td>56,350</td>
</tr>
<tr>
<td>1983</td>
<td>43,300</td>
<td>53,878</td>
</tr>
<tr>
<td>1985</td>
<td>48,600</td>
<td>56,006</td>
</tr>
<tr>
<td>1987</td>
<td>64,700</td>
<td>70,573</td>
</tr>
<tr>
<td>1989</td>
<td>72,200</td>
<td>72,200</td>
</tr>
</tbody>
</table>

Source: National Safety Council

Accident Facts (various years), which gives yearly estimates beginning with the 1933 calendar year.2

Table 1 shows some typical values. The costs are based on the human capital approach, using wage losses, medical costs, insurance claims, and property damage.

One may suspect that some of the remarkable growth in these costs is connected with the growth in travel. To illustrate the relationship, the costs per NSC reported vehicle-miles of travel (vmt) are shown in Figure 2 for the period 1940-1989, in 1989 cents.

It appears from Figure 2 that the seemingly huge increases in cost shown in Table 1 are, apart from inflation, primarily due to increased mobility.

The costs given by the NSC have been widely (and until the 1980s unquestioningly) used, and crop up in many official sources. For example, 1959 Federal Report to Congress on Highway Safety (Secretary of Commerce, 1959), although covering over 200 pages of small type, mentions costs in half a page. This page quotes the National Safety Council figure of $5,400 million and the Associate of Casualty and Surety Companies' figure of $7,250 million. The remainder of the discussion is mainly devoted to showing how much this would be per mile, per registered vehicle, per capita, per gallon of gasoline, and so on. It does mention, however, a study in Massachusetts which showed that 56 per cent of costs were attributable to property damage, a figure somewhat in excess of that given in contemporary studies. Later, James R. Hoffa, in testifying before Congress (US Senate, 1966) mentions "8.5 billion loss last year caused by highway accidents", a figure quite consistent with the NSC estimate.

2 The NSC warns that "cost figures are not completely comparable through all years. As additional or more precise cost data have become available... they have been used... but previously estimated figures have not been revised". Beginning with the 1986 edition, the figures are no longer given for the whole series, but only for the current year.
Apart from the NSC procedures, the earliest serious attempt to assess the total cost of US motor vehicle injuries is by Hartunian, Smart and Thompson (1981). It is important to remember that this volume, which has been widely quoted, does not include property damage, but only injury and death. The statistic which has proved most popular shows that the cost of injuries in traffic is roughly equal to that associated with coronary heart disease, and is something like 61 per cent of that of cancer. Funded primarily by the insurance industry (through its Insurance Institute for Highway Safety) the authors’ methods are now generally accepted as technically correct. Considerable care was taken with such details as the discount rate (using 2, 6 and 10 per cent), with choice between “prevalence approach” (assigning costs to the year of payment) and “incidence approach” (assigning cost to the year of injury), and with avoidance of “transfer payments” (which do not represent a real cost to society, but only a transfer from one sector to another).

The methodological chapters especially make this book a significant advance on earlier studies. Decisions relating to valuation of productivity, deduction of personal consumption, and valuation of non-market productivity in connection with the HC approach are clearly delineated. Recognising the advantages and disadvantages of both
HC and WTP, the authors choose the former as being more straightforward and more commonly accepted (for example, by the United States Public Health Service).

As the book deals not only with injuries resulting from road transport, but also with coronary heart disease, strokes and cancer, the emphasis is medical so that the principal areas of disaggregation (in addition to age and sex) are those of degree and type of injury. In addition to national transport-related data files, the authors make considerable use of actuarial tables for specific types of injury for various Maximum Abbreviated Injury Scale (MAIS) levels (see Association for the Advancement of Automotive Medicine, 1985). Even such costs as those arising from criminal and civil action, emergency services, and forgone earnings are disaggregated by MAIS level and in several instances specific sub-levels (for example, “paraplegic complete”) are included.

The final tabulation follows, for estimated direct and indirect costs of death and injury from traffic in the United States, in millions of 1975 dollars at a discount rate of 6 per cent:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cost (1975)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers</td>
<td>23,148</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>13,714</td>
</tr>
<tr>
<td>Stroke</td>
<td>6,456</td>
</tr>
<tr>
<td>Motor vehicle injuries</td>
<td>14,435</td>
</tr>
</tbody>
</table>

In millions of 1989 dollars, the figure for motor vehicle injury would be

Motor vehicle injuries 33,248 (1989 M$)

This figure omits property damage, whether in property damage only (PDO) accidents or in injury accidents. For that estimate, we turn to the publications of the Federal Government. The National Highway Traffic Safety Administration (NHTSA) of the US Department of Transportation has issued a series of reports (NHTSA, 1972, 1983; see also Faigin, 1976) which proceed in a vein similar to that of Hartunian et al., except that the value of life is omitted as “the value of a human life cannot be measured in monetary terms” and that delay and property damage are included. The 1983 report gives the “reported property damage” at 16,650 million (1980) dollars in PDO accidents and 3,999 million (1980) dollars for property damage in injury accidents. This total, in 1989 dollars, would add to the figure given above:

Motor vehicle property damage 31,065 (1989 M$)

and result in:

Total traffic accident costs: 64,313 (1989 M$)

This total is somewhat less than the NSC value (1989 M$ 72,200), and considerably less than the 1976 calculation of the NHTSA figure of M$ 37,590, which in 1989 dollars would be M$ 86,583. In the 1983 NHTSA version the total calculated costs are given by severity level in Table 2.

The United States was not the only country in which an attempt to cost traffic injury and property damage was being made in the early 1980s. Atkins (1981) gives a survey of
total accident costs in Australia in 1978, using a 10 per cent discount rate, and including PDO. The total is given as $A 1,591 millions, or approximately M$US 1,241. This represents about 3 per cent of the US cost in a country with a population of about 6 per cent of the US. The same publication also summarises studies in Canada, Japan and New Zealand.

In another report to Congress (Rice et al., 1989), the “economic losses caused by motor vehicles” is assessed at $49,000 million. This value, although seemingly consistent with the 1983 NHTSA figure (for 1980) of $42,053 (bearing in mind inflation) is in fact quite different, because it omits property damage, and includes a significant proportion of transfer payments (said to be economically incorrect by Hartunian). Apart from a chapter explaining with greater clarity Miller’s WTP calculations, the remainder of the volume is anecdotal didactic, and contains little new material (and rather startling errors in the foreword).

A more recent study by the Centers for Disease Control (Panel on Motor Vehicle Injury Prevention, 1991) cites a value of $75,000 million, without specifying whether PDO is included, and without providing an explanation of the method used.

All these figures are substantially consistent with the (WTP) value obtained for Great Britain in 1990. The official (Department of Transport, 1991) estimate was £6,770, which at the current rate of exchange would be a little over one-fourth of the NHTSA figure for the United States, with a population about one-fourth as large.

On the basis of the recent revaluation of non-fatal injury based on willingness-to-pay (Department of Transport, 1993), this figure would have been about £11,000 (Editor).
Reduced Mobility as a Cost of Safety: An Example

For an analysis symmetric with the preceding section, we should now try to assess the cost in terms of mobility of traffic safety interventions. This, unfortunately, is impossible. One reason, of course, is that many if not most safety measures have never been evaluated for their mobility effects. Evaluation procedures in traffic safety are characteristically conducted to assess (and frequently to justify) some safety intervention, and not to discover non-safety effects, important though they may be (an exception may be Heckard et al., 1976).

An example may help to emphasise this point. In a manual designed by the Federal Highway Administration (FHWA, 1981) to teach evaluation procedures, the cost-benefit analysis of a stop sign is based on costs to government only (the expenditure to buy and install the sign) and then compares this rather negligible cost with safety benefits. The stop sign, however, exacts a small penalty in time lost, in fuel consumed and in vehicle wear each time it induces a vehicle to stop. Since these costs are borne by the owners of vehicles, they are not evaluated by FHWA and not counted in the cost-benefit ratio.

More importantly, safety interventions are so various, conducted at so many different levels of government, supported in so many different ways, that it is hardly feasible to discuss or evaluate "safety" as a single concept. For these reasons, it is not rewarding even to speculate on the mobility effect of "safety" in the abstract. In order to reach any sensible conclusion, we must narrow the scope of the inquiry to some specific safety programme. But even then, if we succeed in estimating the cost in travel time for this particular safety project, it will be pointless to preserve the answer with a view to aggregating it with that obtained by studying other projects. Since we can never list all safety measures, we have no choice but to make the safety/mobility comparison on each measure individually, to the extent that the necessary data are available.

The simplest case of all is speed control, which in the United States is almost always approached by means of speed limits and their enforcement (although not necessarily; see Jørgensen, 1992). Speed limits are directly linked to safety (through travelling-speed distributions and thence to injury-severity levels) and to mobility (through travel time changes).

Our example is the national 55 mph speed limit, which has been thoroughly researched. Some of the necessary information is available in a comprehensive study (Transportation Research Board, 1984) written by a team of experts under the sponsorship of the National Research Council. As such it carries the presumption of authority and precision. On the subject of travel time and cost impacts, the figure of 1,037,560,000 "additional passenger hours of travel" due to the 55 mph speed limit is given for the year 1982, that is, eight years after the speed limit was enacted. For the year 1974, another study (Keller, 1975) gives the additional vehicle-hours of travel as 755,000,000 at a cost of M$ 3,321.6 using a cost per hour of $4.20 for cars and $6.00 for trucks. (The two figures would agree if average vehicle occupancy was 1.37.)

4 Oddly enough, I have been unable to find a formula for the delay caused by braking from speed $x$ to a stop and then accelerating to speed $x$, expressed as a function of $x$. 

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It is more difficult to determine the savings due to reduced death, injury and property damage from the TRB volume, owing to some deficiencies in the data. In its Table 16, the "Direct Costs of Motor Vehicle Accidents Reduced by the 55 mph Speed Limit" are given as:

- Medical: M$ 50-90
- Legal: M$ 20-55
- Property damage: M$ 52-95 (from injury accidents only)

There are several problems with this information. First, it is not quite precise. Second, it is not clear which year is referred to — probably 1974 — and so it is not quite comparable with the 1982 data for passenger delay. Third, it seems to omit fatalities, as they are not given in the Appendix Tables from which TRB Table 16 is constructed. Fourth, "lost productivity" is specifically exempted from the table, as "impossible to estimate", although this was published three years after the appearance of Hartunian, Smart and Thompson (1981).

We first attempt to remedy some of these deficiencies by using information from other sources. NHTSA (1983) gives the proportion of cost due to property damage in injury accidents as 0.1936655. Applying this ratio, we obtain:

- Property damage: M$ 268.5-490.5 (all accidents)

Next, we would like to include lost productivity, as given by Miller (1989) in the calculations. This in turn will depend on severity levels. The savings in each level (except fatality!) are given in TRB Table A-25: "Estimated Reductions in Injuries by AIS Level" as follows (for 1974 in comparison with 1973):

- AIS 1: 79,214
- AIS 2: 17,184
- AIS 3: 6,191
- AIS 4: 610
- AIS 5: 231

but with no value given for AIS 6 (fatal). In Chapter 3, the question of number of fatalities is treated much more vaguely than for other AIS levels:

"Together, this experience indicates that the effect of the 55 mph speed limit on motorist behaviour was a major contributor to the reductions in the fatality rate in 1974, accounting for 3,000 to 5,000 fewer fatalities that year." (TRB, p.33)

Taking into consideration that fatalities are generally reported with greater accuracy than less severe outcomes, it seems paradoxical to see such precision in estimates of savings in lower AIS levels and such wide variation in the fatality reduction estimates. We can shed some light on the situation by comparison with published frequencies of AIS levels. Miller (1989) gives frequencies as shown in Table 3, in comparison with the frequencies given by TRB.

Although changes in travelling speeds will probably have greater effect on fatalities than on other levels of injury, nevertheless the remarkable discrepancy in column 3 of this table between fatalities and other injury levels suggests strongly that the figure of 3,000-5,000 fatalities forgone is incorrect. For this reason, we will take the nominal value of 3,000 (probably too high) instead of the wide band cited. It is now possible to estimate the savings in lost productivity as depending on level of injury, as in Table 4. This indicates that an additional M$ 583 should be added to the TRB Table 16.

5 Perhaps because fatalities are more salient in the popular imagination; this may also explain why the fatality figure is omitted from Table A-25.
Table 3

**Comparison of Severity-Level Proportions as Given by TRB (1984) and Miller (1987) (Number of Cases)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>74,214</td>
<td>2,895,000</td>
<td>36.55</td>
</tr>
<tr>
<td>AIS 2</td>
<td>17,184</td>
<td>370,000</td>
<td>21.53</td>
</tr>
<tr>
<td>AIS 3</td>
<td>6,191</td>
<td>127,000</td>
<td>20.51</td>
</tr>
<tr>
<td>AIS 4</td>
<td>610</td>
<td>15,500</td>
<td>25.41</td>
</tr>
<tr>
<td>AIS 5</td>
<td>231</td>
<td>9,500</td>
<td>41.13</td>
</tr>
<tr>
<td>Fatal</td>
<td>3,000-5,000</td>
<td>43,600</td>
<td>14.5-8.72</td>
</tr>
</tbody>
</table>

Table 4

**Productivity Savings from 55 mph Speed Limit in the United States**

<table>
<thead>
<tr>
<th>AIS Level</th>
<th>55 mph Savings 1974 M$*</th>
<th>Lost Productivity per case 1974 M$*</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>79,214</td>
<td>126</td>
<td>9,980,964</td>
</tr>
<tr>
<td>AIS 2</td>
<td>17,184</td>
<td>745</td>
<td>12,802,080</td>
</tr>
<tr>
<td>AIS 3</td>
<td>6,191</td>
<td>2,035</td>
<td>12,598,685</td>
</tr>
<tr>
<td>AIS 4</td>
<td>610</td>
<td>24,785</td>
<td>15,118,850</td>
</tr>
<tr>
<td>AIS 5</td>
<td>231</td>
<td>64,974</td>
<td>15,008,994</td>
</tr>
<tr>
<td>Fatal</td>
<td>3,000</td>
<td>172,384</td>
<td>517,152,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total: 582,662,000</td>
</tr>
</tbody>
</table>

*Transportation Research Board, 1984

*Miller et al., 1989

Further savings due to the 55 mph speed limit are given in TRB Table 17: " Savings due to the 55 mph Speed Limit" from direct public programme costs of motor vehicle accidents (for example, social security payments, food stamps, medicare and medicaid, aid to families with dependent children, and so on) as M$ 55.66. Adding this total gives the savings for 1974 as shown in Table 5.

It is now possible to compare this amount with the value of time lost. Valuing time at the minimum 1982 wage rate expressed in 1974 dollars, the cost of the speed limit in 1982 (the year for which passenger delay was given by TRB) was M$ 1,776 (1974 dollars) in comparison with a saving in safety effects of M$ 1,130 (1974 dollars).
Table 5

Savings Produced by the 55 mph Speed Limit
(1974 M$)

<table>
<thead>
<tr>
<th></th>
<th>Range (M$)</th>
<th>Average (M$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>50-90</td>
<td>70.0</td>
</tr>
<tr>
<td>Legal</td>
<td>20-55</td>
<td>37.5</td>
</tr>
<tr>
<td>Property damage</td>
<td>268.5-490.5</td>
<td>383.5</td>
</tr>
<tr>
<td>Lost productivity</td>
<td>583</td>
<td>583</td>
</tr>
<tr>
<td>Public programmes</td>
<td>55.66</td>
<td>55.66</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>1,129.66</strong></td>
<td></td>
</tr>
</tbody>
</table>

Several remarks should be made regarding this calculation:

1. No attempt has been made to assess the reliability of the original sources of data. It appears that some information came from The National Highway Traffic Safety Administration and presumably from state records, some from The National Safety Council.

2. Although the cost in travel time exceeds the savings in safety, this does not mean that the speed limit should or should not be considered desirable. After all, many non-safety benefits have been omitted from the calculation, especially benefits from fuel saving, which was what the speed limit was originally designed to accomplish. We have confined the calculation strictly to mobility/safety.

3. Even in this "simplest" case (speed control) with the help of official documents, the cost balance between mobility and safety was troublesome to calculate, and would be even more difficult to verify exactly. There may be some reluctance to make calculations based on data which is inherently imprecise. There is no novelty here: the history of statistical reasoning contains many examples of just such hesitation in the face of uncertainty. Neither is the situation unique to traffic safety; many conclusions in modern social analysis are based to some extent on potentially unreliable information. This is hardly a valid excuse for failing to make the best use of the data which are available.

4. Finally, the reluctance to undertake such calculations may often be more political than scientific. Instead of discourse based on science and reason, we often find slanted, misleading or tendentious arguments designed to promote a particular course of action.
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Problems in Estimating Comparative Cost of Safety and Mobility


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