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# MANAGING THE TRAFFIC CRASH RISK

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## ABSTRACT

Traffic crashes result in thousands of fatalities and billions of dollars in losses annually, and constitute a leading public health and safety problem. Society has responded to this problem by spending large sums of money and employing many people in traffic-safety programs; however, these efforts have been unguided by any well-developed body of theory. Prevailing highway safety theory has focused on the crash event itself, to the exclusion of more remote but nonetheless important factors that lead to traffic crashes.

More effective management of the social risks posed by traffic crashes requires development of a body of theory that accounts for the role of society and its systems in managing social risks such as traffic crashes. A conceptual framework applying societal risk-management systems to the disutilities produced by the Highway Transportation System is presented. The conceptual framework applies concepts drawn from the disciplines of systems analysis and risk management. It is presented to describe the highway safety process and to provide the basis for further development of highway safety theory. Strategies for further research in highway safety based on the conceptual framework are described, and directions for further activity within the highway safety field are identified.

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# INTRODUCTION

This paper grew out of an inquiry into the conceptual tools that have been used to guide highway safety efforts. During this inquiry it became apparent that there exists a considerable amount of literature dealing with **micro-frameworks** of highway safety--that is, conceptual frameworks oriented to limited and highly specialized problems, such as mathematical models of vehicle dynamics. On the other hand, there is no well-developed body of literature dealing with the **meta-frameworks** of highway safety as a whole. Meta-frameworks are comprehensive frameworks developed to explain the overall phenomenon of traffic crashes and associated losses, and used to support efforts to reduce both crashes and crash losses.

This is not to suggest that the field of highway safety is without meta-frameworks; broad frameworks exist and are in wide use. What the field of highway safety lacks is systematic discussion of the need for such meta-frameworks, careful review of existing frameworks, and well-developed proposals for further conceptual development.

The lack of well-developed literature dealing with the meta-frameworks used to guide highway safety efforts is a matter of serious concern. It implies that large-scale programs of action and research are set in motion without benefit of systematic study, and without proper means to guide and assess that effort. In view of the significant human and economic resources involved, and the acknowledged role that conceptual development plays in any complex field, efforts to correct these deficiencies deserve a high priority.

This paper takes a modest step in that direction. It examines the need for a well-developed meta-framework in the field of traffic safety; reviews general concepts and meta-frameworks developed in the past to explain traffic crashes and to support efforts to deal with them; presents a new framework for ordering present knowledge and suggesting directions for future action; and describes applications of the proposed framework as well as recommendations for public policy that flow from its use.

## TRAFFIC CRASHES: HOW SERIOUS A PROBLEM?

Measured in absolute terms, traffic crashes and associated losses present a social problem of great magnitude. During 1979, the most recent year for which complete data are available, there occurred some 18.1 million traffic crashes, in which 51,900 persons were killed and another 2 million persons suffered disabling injuries. By one estimate, traffic crashes generate a total annual cost to society of $35.8 billion, a figure that includes property damage, loss of wages, medical expenses, and insurance costs (National Safety Council 1980). Because traffic crashes range from the minor "fender-bender" to multi-vehicle crashes in which many casualties occur, no single statistic adequately represents the overall risk, or problem, that traffic crashes present to members of society. The term "risk" often denotes the traffic-crash problem. More precisely, though, **risk** means the probability that an undesired event, or **hazard,** will occur. Risk thus has several different measures: what hazards are of interest; what persons are exposed to the hazard (that is, what is the **population at risk**); what are the conditions under which the exposure occurs; how long the population at risk is exposed to the hazard.

The closest approximation of a global measure of "traffic crash risk" can be obtained by treating the crash itself as the hazard, and by treating the entire population of the United States as the population at risk. From the total number of crashes that occurred in 1979 (18.1 million), and the estimated U.S. population for that year—in round figures, 220 million (U.S. Department of Commerce 1979)--the so-called **hazard rate** can be determined. Hazard rate is the probability that a member of the population at risk will be involved in a specific undesired event during a certain period of exposure to it. Here, the event is a traffic crash, and the period of exposure is one year. However, not all traffic crashes are single-vehicle crashes; clinical studies indicate that the average crash involves about two persons, including passengers and pedestrians. Thus the number of crash involvements is approximately twice the reported number of crashes, or about 36.2 million per year. Thus the traffic crash hazard rate for 1979 for a typical U.S. resident was 36.2 million divided by 220 million, or .165—a one-in-six chance. This in a sense represents the annual risk of being involved in a traffic crash during 1979. Of course, that risk would differ if the time period were specified differently, such as December 1979 or Christmas Day 1979.

Experiencing a hazard becomes more likely as one is exposed for a longer time to the hazard. Assuming that the annual hazard rate for a traffic crash remains constant at .165, and that the annual lifespan of the typical American is 75 years, the risk of being involved in at least one crash during that time approaches certainty, and the expected number of crashes during one's lifetime becomes approximately twelve. These hazard rates are comparatively high, since most traffic crashes involve nondisabling injuries, or property damage without injuries. For the more serious crashes, the hazard rates are much smaller but nonetheless significant. During 1979 the hazard rate for disabling injury was .009 (2 million divided by 220 million), and the hazard rate for death was .0002 (51,900 divided by 220 million). Again assuming constant annual hazard rates and a 75-year lifespan, the average American faces a 50 percent probability of suffering a traffic-related disabling injury and a two percent probability of being killed in a crash.

Again, these figures represent oversimplified, global estimates of traffic crash risk for the entire population of the United States. Subpopulations will have varying risks. Persons who do not drive and do not ride in motor vehicles (for example, prisoners or hospitalized persons) have hazard rates approaching zero. On the other hand, male drivers aged 15 to 24 years have a fatal crash hazard rate three times that of the general population, and outranking all other causes of death combined (National Safety Council 1980). Drivers with severe drinking problems likewise have higher crash risks than the population as a whole (Jones and Joscelyn 1979).

## Traffic Crash Risk Compared to Other Risks

The hazard most consistently used as the basis for comparing different kinds of risk is loss of life. Its selection no doubt reflects the difficulties of finding a common denominator for the many kinds of undesired events that can afflict humans.

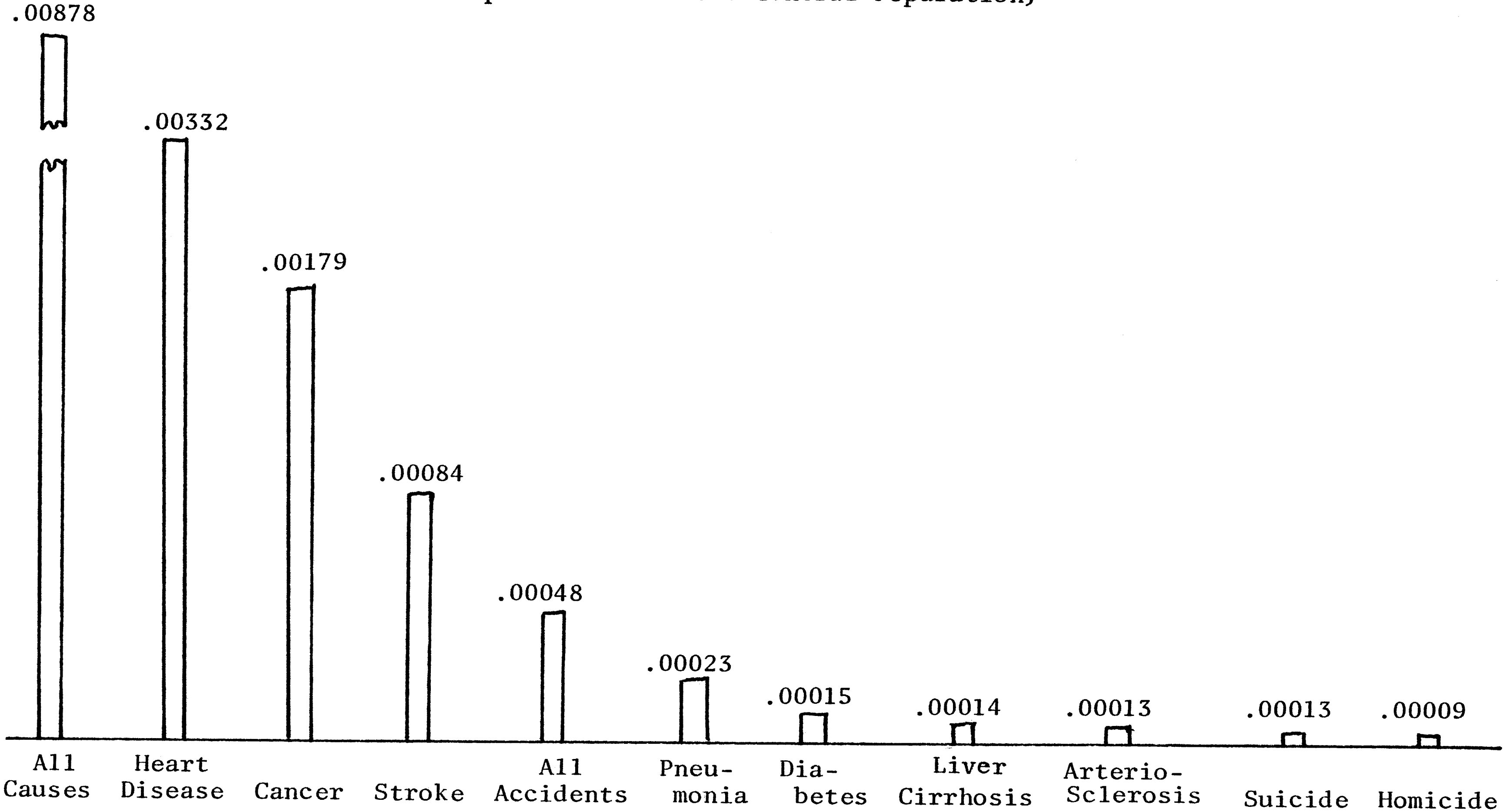
For 1977, the most recent year for which data are available, the overall death rate for the United States was about .0088. That was the annual hazard rate for deaths from all causes (National Center for Health Statistics 1980). Heart disease was the largest single cause of death for the population as a whole, accounting for more than a third of all deaths; it was followed by cancer and stroke. Accidents of all kinds ranked fourth, ahead of such well-publicized causes of death as pneumonia, diabetes, cirrhosis of the liver, arteriosclerosis, suicide, and homicide (see Figure 1). Among accidents, traffic crashes were by far the largest single cause of accidental death, accounting for about as many deaths as all other accidents combined (see Figure 2).

Not all traffic crashes kill, but even nonfatal crashes are enormously costly to society. Hartunian, Smart, and Thompson (1980) sought to determine how serious a public health problem is posed by traffic crashes. To measure more realistically the benefits and costs of preventive measures against the costs of the crash problem, they treated the costs of crashes as if they all occurred during the "year of incidence," that is, the year in which the traffic crash occurred. The authors applied this same analysis to three other major killers: heart disease, cancer, and stroke. Even though there are fewer traffic casualties than cases of other, "natural" illnesses, this is balanced by the earlier incidence of crashes (that is, more young people experience them) and the greater likelihood that a crash victim will be disabled. Thus the costs of traffic crashes—including lost earnings, treatment costs, insurance, and legal expenses—ranked second behind those of cancer, and ahead of heart disease and stroke.

While traffic crashes present a significant risk of death or serious injury to the general population, they account for an even larger portion of the death rate among adolescents and young adults, especially among

FIGURE 1

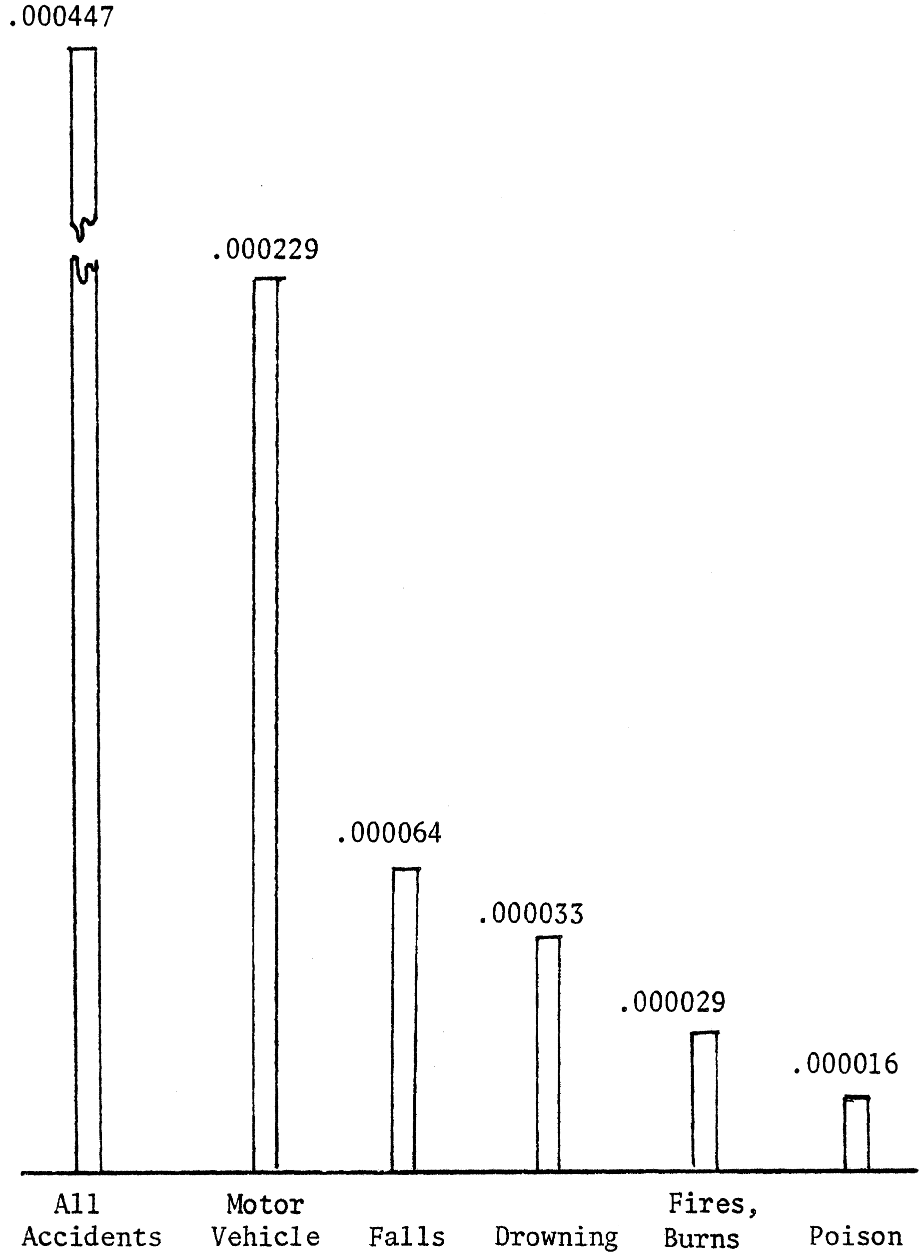
LEADING CAUSES OF DEATH IN THE UNITED STATES, 1977
(Numbers Shown Are Death Rates per Year
per Member of the General Population)




Source: National Center for Health Statistics (1980)

FIGURE 2

LEADING CAUSES OF ACCIDENTAL DEATH IN THE UNITED STATES, 1977
(Numbers Shown are Death Rates per Year per Member of the General Population)



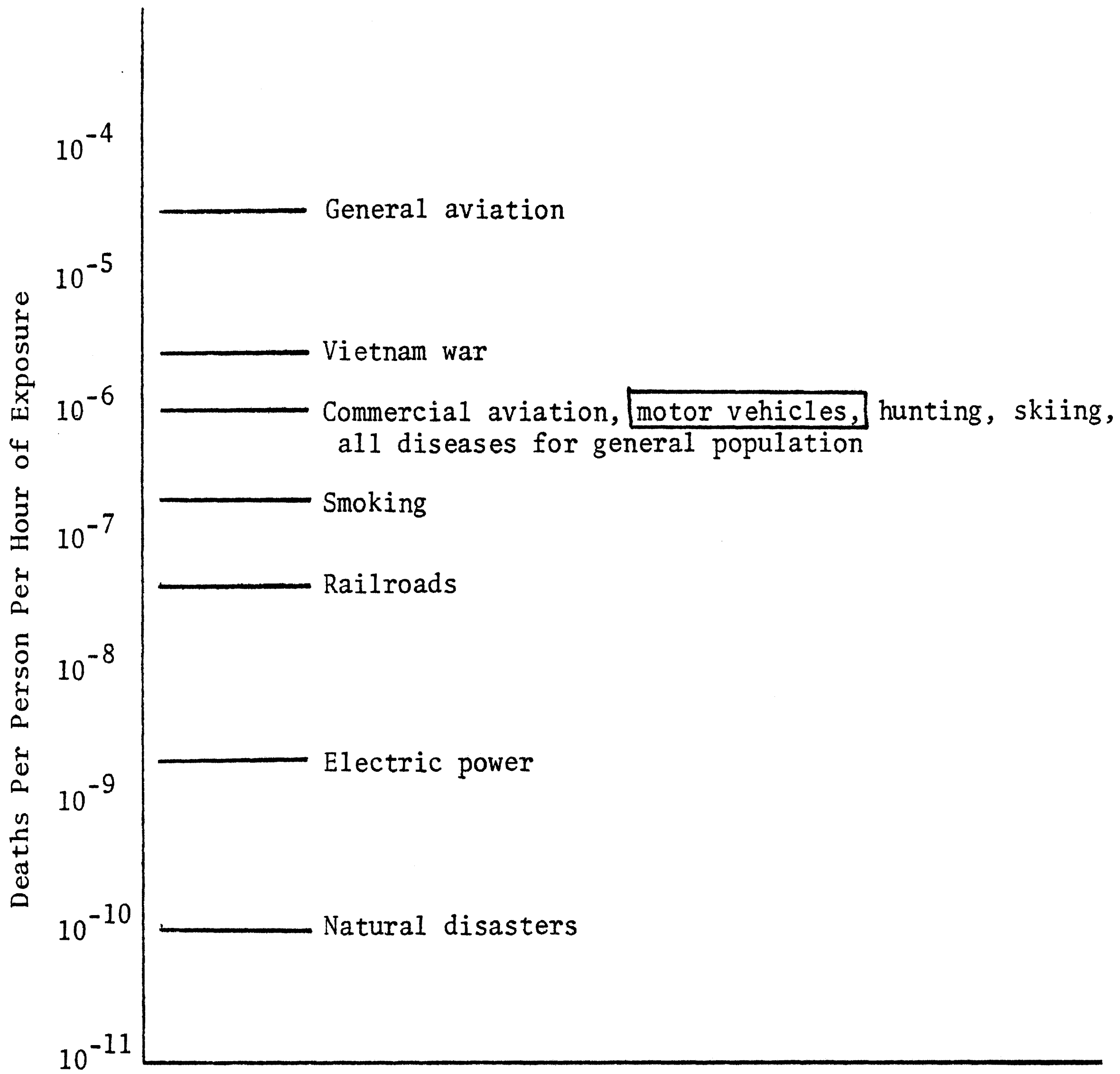

Source: National Center for Health Statistics (1980) males. The motor vehicle death rate for persons aged 15 to 24 is twice that of persons of all ages and, as already mentioned, the death rate for males in that age group is even larger. Traffic crashes are the leading killers of persons aged 15 to 24. They account for 38 percent of all fatalities, and persist as the leading cause of death until about age 35, when cancer surpasses it (National Center for Health Statistics 1980). The prevalence of traffic deaths and injuries among younger persons is especially significant in terms of long-term rehabilitation for the disabled, and the loss of huge amounts of potential earnings by those who are killed or incapacitated.

As noted earlier, **risk** is the probability that a given hazard will occur. Risk is directly related to exposure, and that exposure is not the same throughout the population. Some members of the population spend more time in vehicles than others, and some more frequently operate vehicles under conditions—such as intoxication or fatigue—that make a crash more likely. That being the case, it is preferable to specify more clearly the conditions under which exposure to hazard occurs. The term **conditional risk** is used to denote the probability that an event will occur given one or more conditions. A specified condition might be driving in excess of the speed limit; being less than 18 years old; or having a blood alcohol concentration higher than the legal limit.

Starr (1969) developed order-of-magnitude estimates of the **conditional hazard rate**—the probability that a specified hazard, a fatality, will occur during a given period of exposure to the hazard—associated with a number of deadly activities, including vehicular travel. He found that general aviation presented the greatest conditional risk, with a hazard rate of about .00003 fatalities per hour of exposure. This was about thirty times the hazard rate of automobile travel which, in turn, was about fifty times that of railroad travel and about 10,000 times that of natural disasters (see Figure 3). On the basis of conditional hazard rates, one hour of automobile travel was estimated to be only slightly less risky to life than one hour on a military assignment in Vietnam. Starr's figures should be qualified, however, in that the average person is exposed to traffic crashes

FIGURE 3

ESTIMATED CONDITIONAL HAZARD RATES
ASSOCIATED WITH DEATH DUE TO SELECTED CAUSES, CIRCA 1969




Source: Starr (1969)

only for an hour or two per day, as opposed to around-the-clock exposure for a combat soldier or in the case of natural disasters. Still, Starr's findings show that traffic crashes present a significant risk to members of society, and they are sufficiently large to expect an allocation of resources commensurate with other risks. This, however, has not been the case. Consider that the death rate due to traffic crashes is about eight times that due to fires (National Center for Health Statistics 1980). Most communities, though, have fire departments funded and staffed at a level nearly equal to police departments. Consider also the relative problem of crime versus traffic crashes. The police, who deal with traffic control, are also responsible for preventing crime and performing community services. In recent years, public perception of the dangers of violent crime has resulted in the diversion of police resources away from traffic duty and toward general law enforcement. Igleberger (1969) reported that the Dayton, Ohio police department reviewed its priorities, basing the review in large part on perceived citizen needs as reflected in requests for service and complaints; as a result, the department reduced the manpower allocation to traffic control. The citizens of Dayton perceived crime to be a more important social problem than traffic crashes. Their perception of social problems probably cannot be disputed; the accuracy of that perception is more debatable.

Heller and McEwen (1973) conducted a study in St. Louis, Missouri, designed to improve the allocation of police resources. The researchers examined a series of crimes and rated their seriousness based on criteria such as whether the victim was injured, whether a weapon was used, and how much property loss occurred. They then used the same set of criteria to rate the seriousness of traffic crashes. Even though most traffic crashes lack one component of crime, intimidation, the injuries and property losses in crashes were serious enough that the average traffic crash was 50 percent more serious than the average serious crime. The

Heller and McEwen study, while not definitive, strongly suggests the inaccuracy of society's perception of the relative, aggregate risk of crime and traffic crashes.

The data show that the problem of traffic crashes is great, in absolute terms, and that it is also serious when compared with other public health and safety risks. The relative importance of traffic crashes as a societal risk, given present public perceptions, is apparently not well understood. This suggests that the relative risk of traffic crashes must be better defined and communicated so that more accurate public perceptions can be developed. So long as society perceives the risk of traffic crashes as less important than other risks, society's efforts to control those risks will be limited.

## WHAT CAUSES TRAFFIC CRASHES?

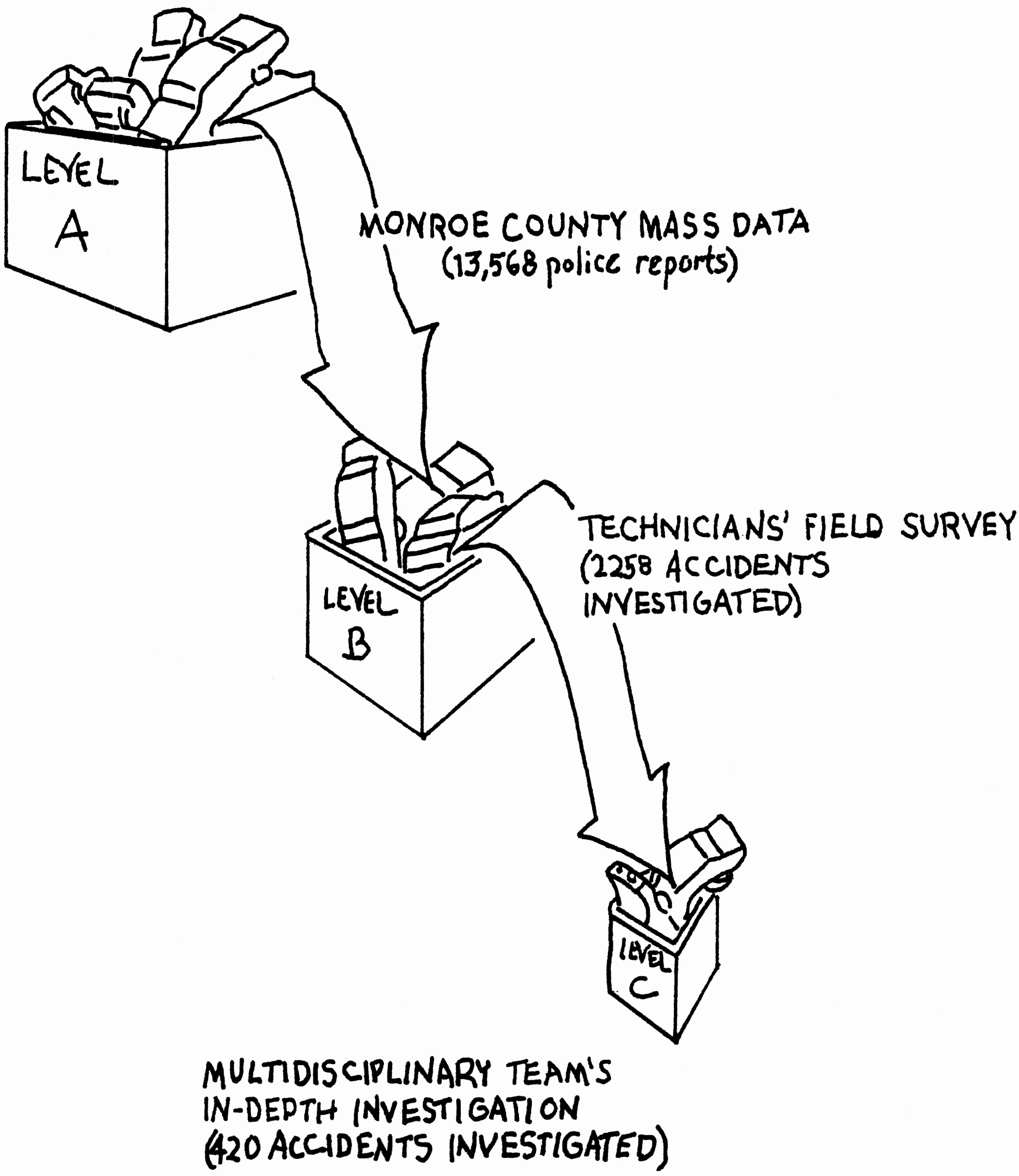
To reduce the risk of traffic crashes and associated losses, it is necessary to know what causes traffic crashes. The state of the art of knowledge about injury-producing mechanisms and the dynamics of the crash phase are advanced relative to knowledge about crash causation; yet, not enough is known about either area. It is nonetheless important to have some measure of understanding about what causes crashes, since efforts to solve the traffic crash problem are highly influenced by perceptions about how and why crashes occur.

### Human, Vehicular, and Environmental Factors

Treat et al. (1977) reported the findings of a study on traffic crash causation conducted by the Indiana University Institute for Research in Public Safety. That study occurred in Monroe County, Indiana, over a period of more than five years. The general objective was to satisfy national needs for data regarding crash causation and crash avoidance. Data were collected on three levels of detail, as shown in Figure 4. At level A, police reports of crashes, driver license data, and vehicle registration data were collected. At level B, technicians were sent to

FIGURE 4

LEVELS OF DETAIL IN THE DATA COLLECTED
IN THE INDIANA TRI-LEVEL STUDY




SOURCE: Treat et al. (1977)

crash scenes shortly after crashes occurred, and they conducted an independent, on-the-scene evaluation. Level C investigations were conducted after the crashes; these involved a multidisciplinary team of professionals. At level C, quantitative measurements were made, the crashed vehicles were physically examined by automotive engineers, involved drivers received vision and knowledge tests, and accident reconstruction specialists made drawings of the scene and assisted in obtaining and interpreting physical evidence. Following the data collection process, the multidisciplinary team convened as a group to develop a clinical assessment of the causes of the crash.

Causative factors were listed in three primary categories: human, environmental, and vehicular. The classes of causal factors were not mutually exclusive; it was possible for two or more factors to play a causative role in a crash.

A rating system was developed to express the investigators' degree of confidence in their conclusions that a factor played a role in the crash: "certain," when there was no doubt; "probable," when it was highly likely although not certain; and "possible," when potentially relevant although the evidence did not substantially support its existence or involvement. Failure to assign even a "possible" rating to a factor reflected a judgment that its involvement was highly unlikely.

The findings of Treat and associates are presented in overview form in Figure 5. Among the major classes of causative factors, human factors played at least a probable role in as many as 93 percent of all traffic crashes, environmental factors in up to 34 percent, and vehicular factors in up to 13 percent. Among specific human factors examined by Treat and associates, improper lookout ranked first; it was at least a probable factor in 23 percent of all crashes involving a human causative factor. Other frequent human factors included excessive speed (17 percent), inattention (15 percent), and improper evasive action (13 percent).

Caution should be taken in interpreting the crash causation data. Although human factors were found to be the predominant class of causative factors, it is not correct to assume from this finding that the

## FIGURE 5

# CAUSATIVE FACTORS IDENTIFIED BY INDIANA TRI-LEVEL STUDY

### IN-DEPTH TEAM FINDINGS

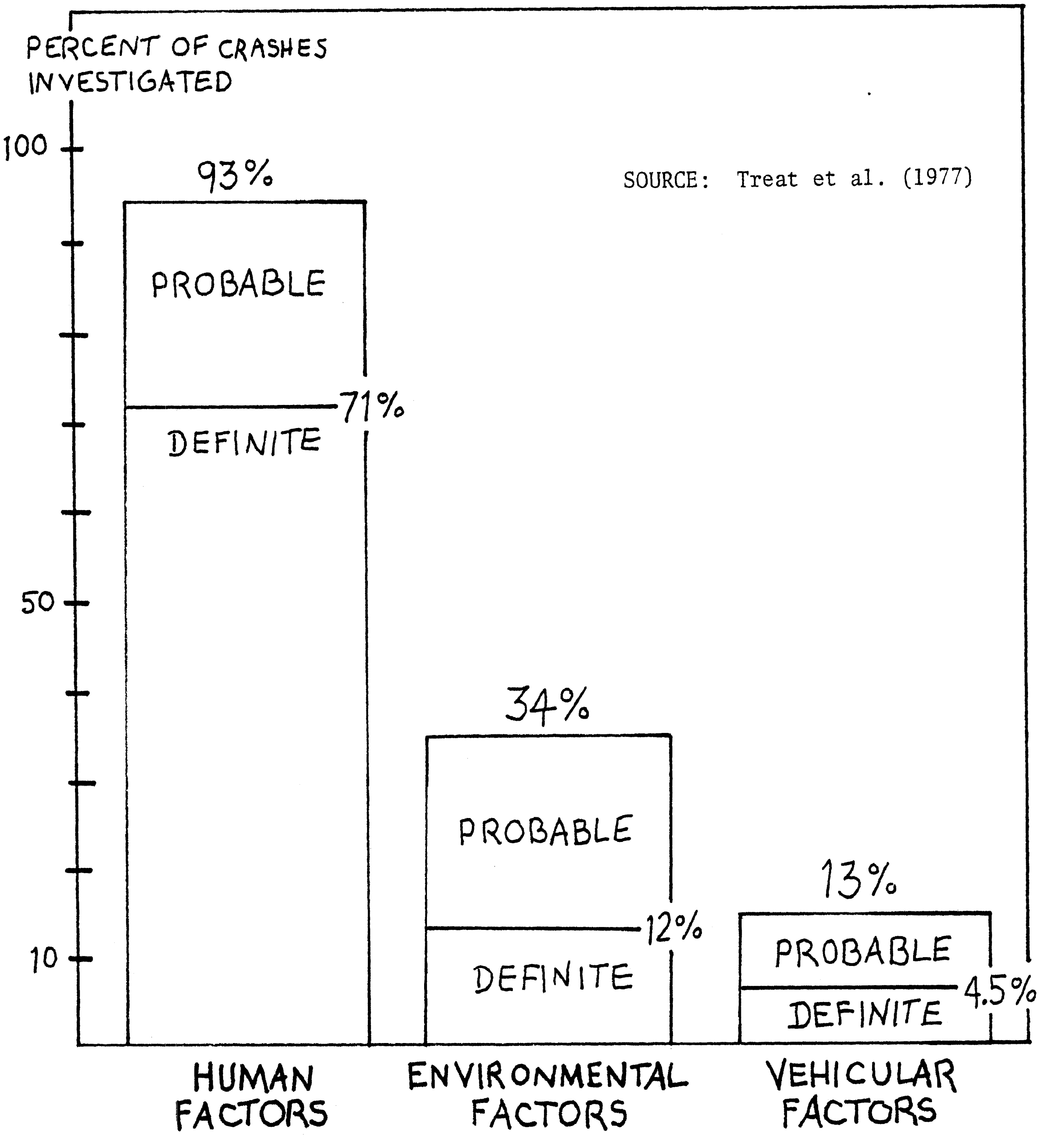
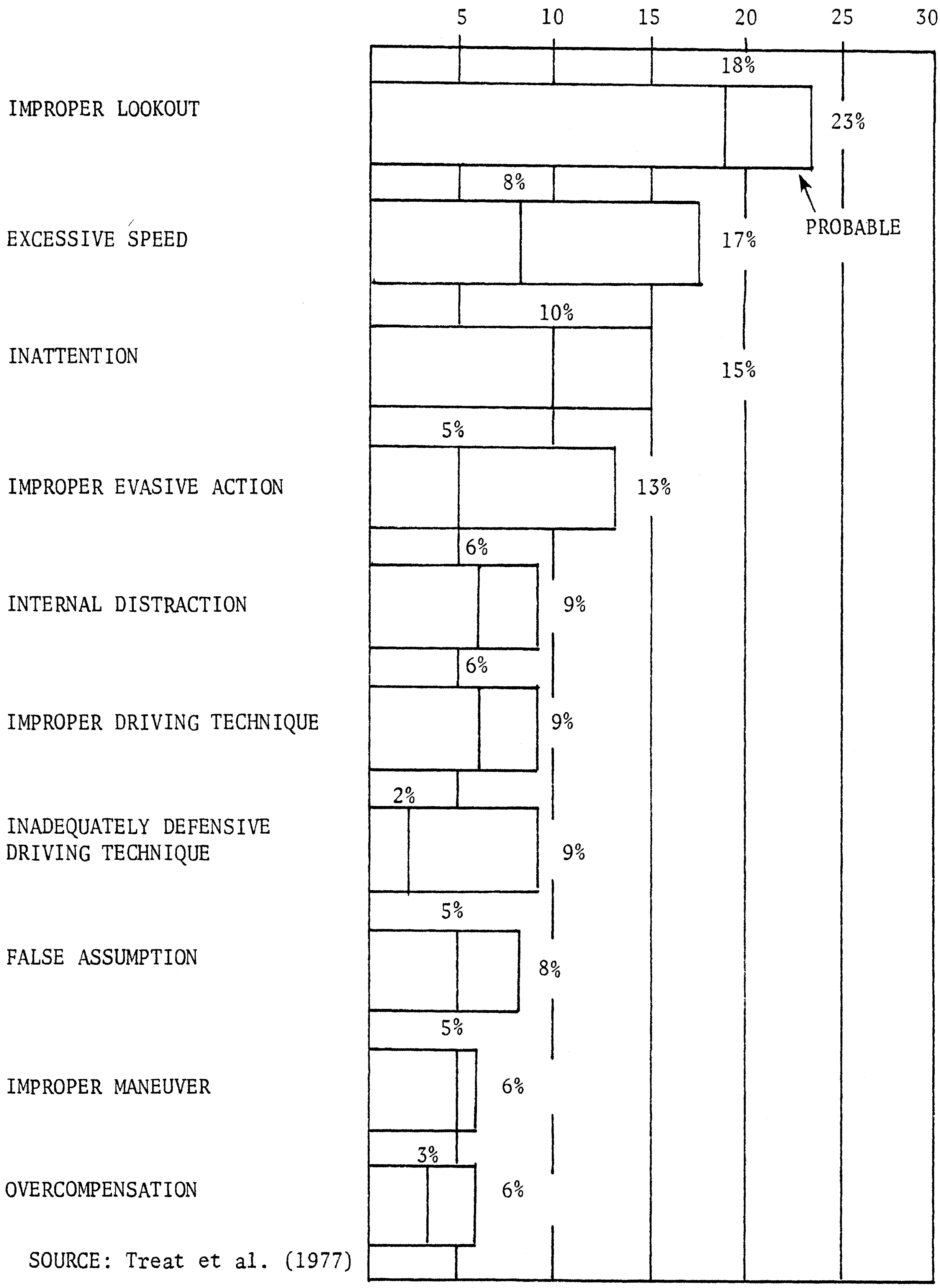


FIGURE 5 (cont'd)

MAJOR HUMAN CAUSES OF TRAFFIC CRASHES




SOURCE: Treat et al. (1977)

only response to a human failure should be directed at the driver. Some underlying conditions that lead to human failure may be addressed more effectively by modifying the vehicle, the roadway environment, or both. On the other hand, most of the vehicular factors noted were maintenance-related rather than manufacturing defects; thus the best way to address some vehicle defects would be to direct responses at the owner or operator.

The findings reported here are the product of a relatively large study and reflect perhaps the best available information regarding crash causation. Still, they are not definitive. They should not be extrapolated to the entire United States and should not be used to support general statements such as a conclusion that "93 percent of traffic crashes are caused by human failures." The data reported by Treat and associates, however, are remarkably consistent with other, more limited studies in the United States and in other countries as well. **The studies indicate that human factors take precedence among the causes of traffic crashes.** The relative involvement rates of human, vehicular, or environmental factor, should be kept in mind as general trends when developing, implementing, and assessing strategies to control crash losses.

## Human Causes: Unsafe Driving Acts

Prior study of traffic crash causation has consisted of **statistical assessments** that seek to determine if a factor is overrepresented in the crashed population as opposed to a comparable noncrashed population; and **clinical investigations** that examine individual crashes to determine the factors that led to their occurrence. Data obtained from clinical studies are useful because they permit estimates of the relative involvement of various crash-producing factors. Clinical studies include the Indiana University Tri-Level Study reported by Treat et al. (1977); similar studies conducted in England (Sabey and Staughton 1975); and examinations of unsafe driving actions conducted at the University of North Carolina (Lohman et al. 1976; Hiett et al. 1975) and at The University of Michigan (Treat et al. 1980). In many cases the various clinical studies point to roughly the same involvement by selected factors in crashes.

Human factors were found by Treat and associates (1977) to be the predominant cause of crashes; they are at least potential causal factors in as many as 93 percent of all crashes. With respect to human factors, the various studies have provided a relatively consistent picture of the driving actions and errors that cause crashes. Three principal classes of driver behavior predominate: intentional risk-taking behavior (especially excessive speed); delays in perception resulting from inattention or distraction; and inadequate search and detection activity before entering or crossing the flow of traffic. These broad categories may sometimes overlap; for example, failure to search and detect, or even excessive speed, may be the result of preoccupation. On the other hand, delays in perception may be caused by impairment. Using a somewhat more specific classification of human factors, Treat and associates found that improper lookout was the most frequent human error; it appeared in 23 percent of the crashes in which human factors played a causal role. Excessive speed is the next most frequent error, followed by inattention, improper evasive action, internal distraction, improper driving technique, and inadequately defensive driving technique (Treat 1980). This taxonomy, however, does not readily translate into measurable and observable driving behaviors. Most efforts to reduce the incidence of behaviors that increase the risk of a crash depend upon externally observing and measuring the behaviors. This is especially true when efforts to reduce unsafe driving take the form of law enforcement strategies.

One behavior that is both observable and measurable, and is frequently implicated in traffic crashes, is speeding. Excessive speed—both in excess of posted limits and too fast for conditions—is one of the leading crash-causing behaviors, accounting for approximately twenty percent of crashes of all severities and a considerably higher percentage of fatal and other serious crashes. Inappropriate speed selection also includes driving too slow, which may account for another ten percent of traffic crashes (Treat et al. 1980). The North Carolina study (Lohman et al. 1976) identified two other unsafe actions—following too closely and driving left of center—that are not only leading causes of traffic crashes but capable of external observation. However, subsequent clinical analysis shows that while left-of-center driving appears to be causally involved in ten percent of all crashes and an even higher percentage of fatalities, it is either unintentional or is prompted by a decision to avoid an obstacle in the road (such as a jogger or a pothole) and most of the remaining actions are the product of fatigue or impairment and thus not conscious and deliberate. Following too closely is believed to be the cause of 14 percent of all crashes, if a broad definition of following too closely is used. This, however, is misleading. Even though one crash in four is a "rear-end" collision, most such crashes are caused by delays in perception and response to the lead vehicle braking, and not a conscious decision to follow at a dangerously close distance. Treat and associates (1980) report that other leading observable unsafe driving actions identified by the clinical investigations include:

- pulling in front of oncoming traffic (involved in 14 percent of all crashes);
- failure to stop at a stop sign or signal (seven percent);
- turning left in front of oncoming traffic (five percent); and
- unsafe lane change or merge (four percent).

Preventing some of these actions is more difficult than others, because a driver usually does not decide in advance to "daydream," become distracted, or even fall asleep. Thus, left-of-center driving and what is widely but not always accurately called "following too closely" are different from such behaviors as improper speed selection, disobeying a traffic signal, or passing a stopped school bus. We emphasize that conscious **decision-making** by a driver is an important criterion in identifying unsafe behaviors that can be reduced through societal action. Thus, conscious decision-making is essential to the definition of an unsafe driving act. The distinction between conscious and unconscious behavior, while it is not free from ambiguity in practice, does focus attention on general risk-management strategies that attempt to change a driver's decision from risk-taking to risk avoidance. Since a driver's decision whether to commit an unsafe driving action is hypothesized to flow from a balancing of the perceived utilities and disutilities likely to follow the decision, risk-management strategies attempt to manipulate either the actual or perceived consequences of a driver's decisions. Speeding is a leading driving behavior that flows from a conscious decision to do so. Unconscious behaviors, such as many cases of inattention, are presumed not to flow from decision-making and might not be changed by the use of traffic sanctions and other efforts to change actual and perceived consequences. Thus driving behavior that is most amenable to risk-management strategies is both conscious and observable, such as speeding. Societal actions are best directed at behaviors that involve decision-making and the presence of which can be measured externally. This paper therefore will focus primarily on conscious decisions to drive unsafely.

Decisions with respect to risk vary from one decision-maker to another. The decision is actually a two-step process. The first is **risk assessment,** an objective determination of how probable a given hazard is; the second is a **safety determination,** or a subjective determination of whether the risk is small enough under the circumstances to justify exposing oneself to the hazard (Lowrance 1976). Individuals may differ with respect to their risk assessments for a variety of reasons, including a lack of information, incorrect information, or incorrect perceptions based on available information. Safety decisions are subject to even greater variation, even when individuals have relatively reliable information, for individual thresholds of acceptable risk will vary, as will individuals' valuations of the benefits of a certain risky behavior. Some individuals will choose to take risks that society has determined are too great to tolerate, such as hunting without an orange colored jacket or using marijuana or cocaine. In many such cases society has passed laws to discourage such risk-taking and in effect has created the "surrogate" risk of legal punishment to accompany the actual risk of engaging in the behavior. In other cases, society does not react to risky behavior by prohibiting it, but instead by providing the would-be risk-taker with information about its consequences with the intent that such information, if known, would prompt a decision to avoid certain risky behavior. The familiar warning labels on cigarette packages are an example of the latter strategy. In a sense, too, placing a patrol vehicle in a visible location on an interstate highway "informs" drivers of the risk of speeding. Still other societal strategies attempt to change the way individuals value certain kinds of behaviors, such as by portraying excessive drinking as the mark of a "slob" rather than "macho" behavior. All of these have in common the goal of changing the outcomes of decisions about risk.

To explain how decision-makers choose between risk-taking and risk avoidance, it is necessary to examine the body of theory that explains the decision-making process.

## Decision-Making Theory

A variety of theories and models in the social science literature seek to explain the conscious behavior of individuals and groups. Perhaps the best known of those theories are found in the empirical and theoretical literature in **decision theory**, the origins of which lie in mathematics. The first theory of decision-making was based on the concept of **expected values.** This was originated to facilitate better decisions about gambling. A gambler faced with a decision about how to bet on uncertain events should bet on the event that, on the average, maximizes winnings (Edwards 1968). This assumes that the gambler knows the probability of each possible outcome, and the monetary value, or payoff, associated with each outcome. The expected value of a decision is the probability of an outcome multiplied by its payoffs; the rational gambler will compute the expected value of each outcome and choose the course of action with the largest expected value. From its origins in gambling, expected value theory was soon applied to other aspects of human decision-making.

Experimental investigations soon indicated that human decision-makers did not always behave in a manner consistent with that which was predicted by expected value theory; instances could be cited in which most persons consistently preferred choices with lower expected value over those with higher expected value. It was evident that human decision-makers responded to factors aside from the mere computation of probabilities and payoffs (Marks et al. 1981). Thus expected value theory was modified to account for **expected utility**, one's personal or subjective preference, rather than some objectively defined value (see Slovic, Fischhoff, and Lichtenstein 1977). In the context of transportation and traffic safety, it has been substantiated that drivers assign large utilities to fulfilling transportation needs by driving one's own vehicle (Finkelstein and McGuire 1971). In fact, there is evidence that some view accepting risk itself as a utility--"flirting with death" is considered valuable to some persons (see e.g., Andriessen 1972). While expected utility theory helped explain why otherwise "rational" persons' choices could vary given similar sets of alternatives, anamolous results continued to occur: choice situations could be constructed in which subjects consistently preferred alternatives with lesser expected utility than other available ones. Again the data indicated that the dimensions of human decision-making were more numerous and less simple than those found in the model.

A decision-maker computing the expected utility of an alternative considers both the size of the payoff (its utility) and the probability of its occurrence. It has been found that individuals are poor at estimating probability (e.g., Slovic, Fischhoff, and Lichtenstein 1977), and this tends to be especially true in the case of extreme probabilities, those near zero or near certainty (Phillips and Edwards 1966). Since the probability of a traffic crash or citation on any particular trip is extremely small, the probability of these events is especially likely to be misjudged. Some individuals appear to focus on the magnitude of the loss in a crash and expend more effort and resources than is warranted; others take the "it won't happen to me" attitude and exercise very little caution (Slovic 1978). Given no guidance, most individuals are very suboptimal in their allocation of resources for crash prevention; they need specific information regarding how to minimize the probability of a crash.

Not only are individuals relatively unskilled in handling probability, but their estimates of probability are subject to a variety of distorting influences. The probability of events that are easily visualized, or that have happened to the decision-maker before, tends to be overestimated: Fischhoff et al. (1976) found this to be the case with respect to fatal traffic crashes in comparison to "natural" causes of death; in another study, most of the drivers responding to a survey grossly overestimated the probability of their being apprehended for a traffic law violation (Joscelyn and Jones 1972a). Assessments of probability are also subject to the perceptions of others; for example, subjects estimated the probability that an event would occur, and were asked some time later to recall their probability estimates. Those who were told the event in fact occurred "recalled" higher probabilities than they first offered; those who were told it did not occur "recalled" lower priorities (see Marks et al. 1981). Impairment by alcohol, other drugs, or fatigue may affect one's assessments of probability; some research suggests that many persons are more likely to take risks after drinking (Cutter, Green, and Harford 1973; Goodwin, Powell, and Stein 1973; Wallgren and Barry 1970).

Not only do perceptions of probability differ from individual to individual, but individual utility assignments differ as well. For example, most people view a vehicle as a means of transportation, but Klein (1972) points out that some adolescents view the car as a recreational facility and assign utilities accordingly. Wilde (1976) and Shor (1964) have analyzed the effect of social norms on driver decision-making; they found that the norms of the group to which the driver belongs have a substantial effect on decision-making. The driver's own attitudes and values likewise determine what utility assignments are made in driving decisions. There exists in most humans a tendency to "discount" delayed or long-term effects of risk-taking behavior, a phenomenon that may account for low levels of seat belt usage in the United States. Finally, impairment may prevent a driver from recognizing a potentially disutility-producing situation, for example, by diminishing visual acuity (Newman and Fletcher 1941) or the ability to concentrate (Moskowitz 1974).

Although this paper stresses conscious behavior that results from a decision-making process, a portion of driving behavior is not conscious. For example, speeding because the driver follows the pace set by other traffic and does not realize his or her own speed, is not conscious. Some drivers act from internalized "scripts" and fail to process information relating to the magnitude and probability of hazards and payoffs; for example, they drive fast because a favorite actor does so in his motion pictures. Other drivers, while they are not script-followers, nonetheless make decisions without considering certain critical items of information, or fail to use all the information at their disposal.

In sum, then, human decision-making is much more complex than was suggested by earlier mathematical models of expected value or utility. Human beings make decisions on the basis on incomplete information or fail to use all available information. Studies show that most individuals are not skilled in applying probability concepts, especially in the case of rare events such as serious traffic crashes. Prior experiences and the influence of others also can distort probability assessments. Regarding the assignment of values and utilities, drivers differ from one another, and utility assignments are determined by personal beliefs and attitudes as well as the influence of others. Some driving behavior is not the product of conscious decision-making at all. Nevertheless at least some risky driving flows from a conscious decision that can be controlled by societal action directed at the decision-making process; and, in many cases of unsafe driving, the specific behavior can be measured externally and the effectiveness of many societal strategies can be measured by external observation.

## DEVELOPMENT OF HIGHWAY SAFETY THEORY

A traffic crash problem was doubtlessly perceived by the public early in this century, when large numbers of automobiles began to appear on the nation's highways. Crashes were one of a variety of problems associated with motor vehicles; others included noise and pollution, problems that also persist to this day. Early concern over the dangers resulting from improper driving took the form of legislation prohibiting excessive speed, drunk driving, and other unsafe actions; and setting down the rules of the road.

Official concern over the traffic crash problem has been expressed in the United States since the early 1920s; however, it was not until the mid-1960s that serious efforts were made to develop a comprehensive theory for understanding and solving the problem. Six National Conferences on Street and Highway Safety, held between 1924 and 1949, identified and described safety issues of major concern, but failed to produce even an adequate foundation for a nationwide program in highway safety (U.S. Department of Transportation 1975). In 1952 the National Academy of Sciences' Highway Safety Research Correlation Conference reviewed the state of knowledge in highway safety, and observed that despite a need for "large-scale research involving systematic study of interrelated variables," most research had consisted of relatively small-scale efforts "to solve an immediate problem, or isolated studies carried on by individual investigators with relatively small resources to call upon" (National Academy of Sciences 1956). The National Academy of Sciences report recommended several broad areas of driver-oriented research, but those areas were not comprehensive, nor was any structure presented for generating the integrated program the report called for. Additional stimulus for an organized attack on the highway crash problem resulted from a 1958 meeting of the President's Committee for Traffic Safety, called the Williamsburg Conference, but most of that meeting's recommendations followed a "shopping list" format and were not explicitly related to any overall strategy of research and action (Joscelyn and Jones

1977).

With increases each year in the number of vehicles using the highways and in miles traveled, highway crash losses increased. In 1966, when the annual death toll stood at 53,000 (National Safety Council 1980) then-President Johnson asked the Congress to initiate an "aggressive highway safety program" (U.S. Department of Transportation 1975). The immediate response was in the form of two acts of Congress: the Highway Safety Act of 1965 (Public Law 89-564); and the Motor Vehicle Act of 1966 (Public Law 89-563). These acts created two federal agencies to administer a national program of highway safety. One of these agencies was absorbed into the Federal Highway Administration within the U.S. Department of Transportation (DOT); the other has become the National Highway Traffic Safety Administration (NHTSA), also within the DOT.

The federal activity during the 1960s was accompanied and followed by other efforts to solve the problem of traffic crashes. Under sponsorship of the Motor Vehicle Manufacturers Association, Arthur D. Little, Inc. (1966) conducted the landmark study, "An Analysis of the State of the Art of Traffic Safety." The automobile and insurance industries established new programs of extramural research (Highway Safety Research Institute 1968; Bonder, Cleveland, and Wilson 1967); and the RAND Corporation was commissioned by the federal government to develop a comprehensive approach to highway safety efforts (Wohl 1968a,b). Numerous conferences were held to define future programs of research and action (e.g., Insurance Institute for Highway Safety 1968; Miser 1967).

In the course of addressing the problem of highway crashes, several theories and conceptual frameworks of the highway safety process began to emerge. The first of these grew out of a simple classification scheme, implicitly accepted in the field since the 1920s but not formally articulated until the late 1940s when the characterization of traffic crashes as a public health problem gained wide support (Gordon 1949). Under the public health approach, factors related to crashes were likened to factors considered in the epidemiologic approach to the control of diseases, namely actions against the host, the agent, and the environment.

Applied to the control of highway crashes, actions were directed against the driver (host), the vehicle (agent), and the highway (environment).

The public health approach was further developed by Haddon and Brenner, who asserted that highway crashes resulted from a three-phase sequence of interactions among the driver, the vehicle, and the highway (Haddon 1968). The Haddon-Brenner model was a nine-cell matrix, matching the three phases of precrash, crash, and postcrash against the three factors of the human, the vehicle (including vehicle equipment), and the environment. The Haddon-Brenner model is depicted in Figure 6. This model was offered as a paradigm for the highway safety process in classifying existing knowledge, research, and "countermeasures" to reduce crash losses (Haddon 1970). The Haddon-Brenner approach remains predominant in the field of highway safety, and remains the most commonly used conceptual framework for reducing highway crashes.

At the same time the public health approach was developed, other researchers were recommending that the so-called "systems approach" be adopted. They urged the application of systems analysis, a discipline that developed during and after World War II. to manage large and complex aerospace projects. The National Academy of Sciences (1956) called for a systematic study of the highway crash problem but offered no structures for so doing. The Williamsburg Conference also used the term "systems approach" but did not describe the term or present a conceptual framework for applying it. Arthur D. Little, Inc. (1966) advocated a systems analysis framework that first defined the highway safety objectives (reducing crashes and losses), next considered alternative approaches to achieving those objectives, and then applied cost-effectiveness techniques to select the preferred alternatives. The Arthur D. Little study found that identifying and selecting alternative means of reducing crash losses presented the greatest difficulty; it identified determining causes of crashes as an immediate need. In 1968 the RAND Corporation published a three-volume preliminary study of highway safety measures (Goeller 1968; Wohl 1968a,b), directed toward developing a conceptual framework dealing with events immediately surrounding a crash and primarily concerned with

FIGURE 6

GENERALIZED VERSION OF THE HADDON-BRENNER MODEL

FACTORS

| | | Human | Vehicle and Equipment | Environment |
|---|---|---|---|---|
| PHASES | Precrash | | | |
| | Crash | | | |
| | Postcrash | | | |
| | Results ⇨ | | | |

SOURCE: Haddon (1970)

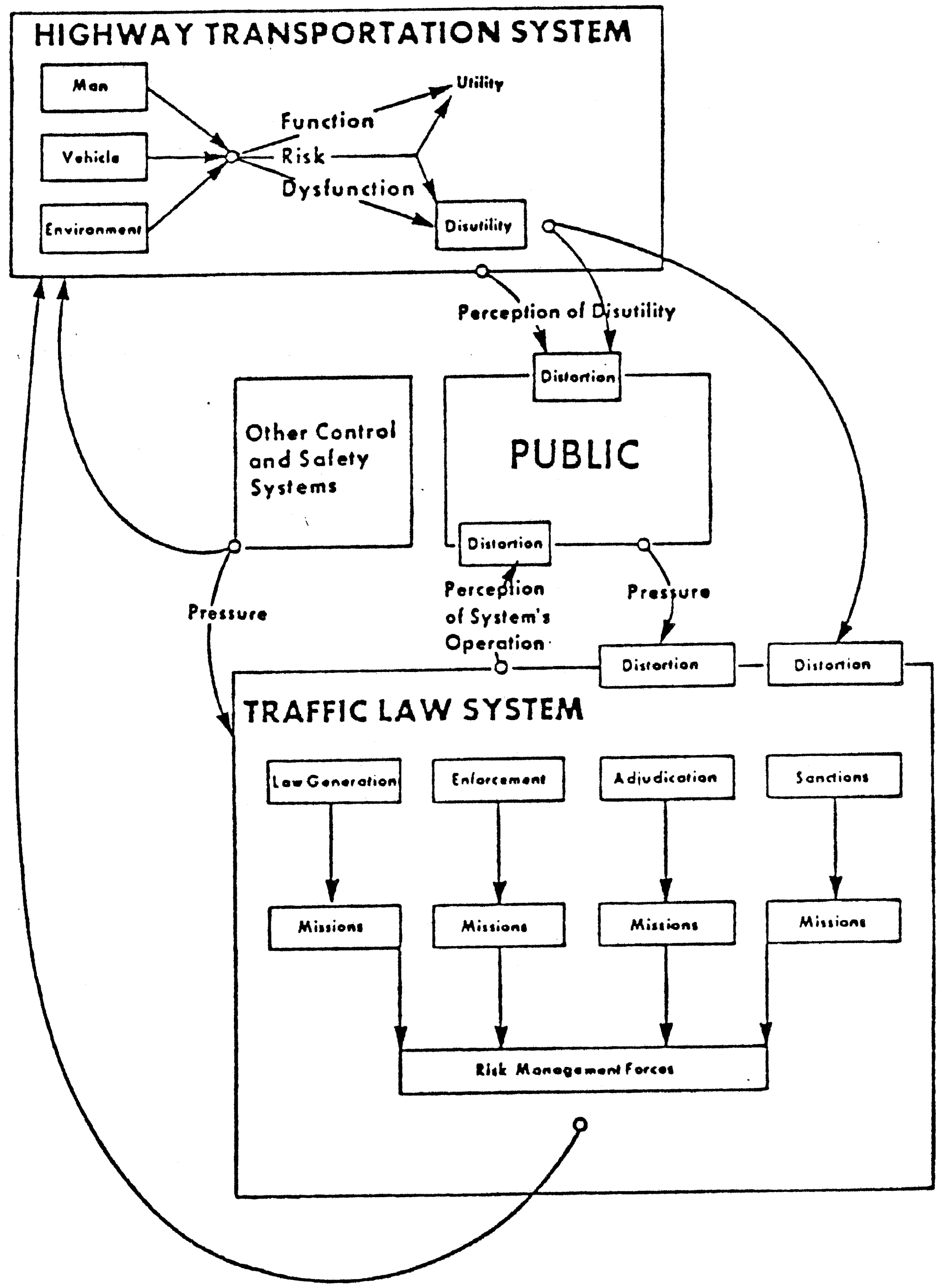
the driver and the driver's interactions with the vehicle.

The most comprehensive conceptual framework of the early systems analysts was developed by Bonder, Cleveland, and Wilson (1967) at The University of Michigan in the course of activities conducted to establish the University's Highway Safety Research Institute (HSRI). Bonder and associates focused on the nation's highway transportation systems; a hierarchy of its subsystems, such as the vehicle, the driver, highways, and casualty recovery facilities; and its components, including, for example, such vehicular components as engines and transmissions. Highway safety was to be achieved through design, operation, and control of the highway transportation system. The primary "control strategist" in the system was the driver, who decided, for example, when to pass, how fast to travel, and how to avoid hazards. A 1968 study conducted by HSRI described a Highway Transportation System as a complex of four interacting subsystems: drivers, vehicles, roads, and pedestrians. The 1968 HSRI report expanded the Haddon-Brenner framework to include two more phases, namely "conditioning" or preparing the system for normal functioning; and "traffic," or normal system functioning. The Highway Transportation System was also described in relation to its physical and social environment as well as to a so-called "highway services system" that facilitated the use of the highways in emergencies and other extraordinary purposes. A concurrent study by the Stanford Research Institute (Gray et al. 1968) produced a similar but less comprehensive and rigorous framework.

We first presented a conceptual framework (Joscelyn and Jones 1972a) that viewed the problem of highway safety from a new perspective: that highway safety was a closed-loop control process, analogous to processes used to control physical systems. This framework is depicted in Figure 7. The objective of this process was to maintain the Highway Transportation System's "negative outputs" (such as crashes) at a level low enough to be tolerated by society. Two areas of emphasis that did not appear in earlier systems frameworks were added: first, elements of **society** that must be influenced to reduce crash losses; and second, elements that originate and

FIGURE 7

JOSCELYN-JONES CONCEPTUAL FRAMEWORK
FOR ANALYZING THE TRAFFIC LAW SYSTEM




SOURCE: Joscelyn and Jones (1972)

apply measures, or **risk-management forces,** to reduce those losses. Particular attention was paid to the process by which society controls crash risks, and the terminology was drawn from the new discipline of systems safety analysis (e.g., Reed 1972) and from the insurance industry (e.g., Snider 1964). Later work by Wilde (1976, 1975) applied the systems framework to analyze the role of individual driver behavior in causing crashes.

Despite the work that has been done in applying systems principles to solving the traffic crash problem there is little evidence to indicate that any of the systems frameworks have been widely adopted in planning highway safety programs. For the most part the public health model of Haddon and Brenner remains the fundamental framework for analyzing highway safety problems and for generating solutions (Joscelyn and Jones 1977).

## PROBLEMS WITH EXISTING HIGHWAY SAFETY THEORY

It is almost axiomatic that to solve a problem, one must first adequately define it. In the case of highway crashes, billions of dollars are expended annually on police traffic services, highway improvements, courts and licensing authorities, and traffic safety research, all of which are directed at reducing the severity of the traffic crash problem.

For years, a systematic approach to solving the traffic crash problem has been recommended. The highway safety literature is replete with discussions of the systematic consideration of all issues, emphasizing "societal" aspects of traffic crashes and their management. Gordon, whose 1949 analysis of the traffic crash problem was the ancestor of the Haddon-Brenner public health approach, described "socioeconomic" factors as a major component of the environment in which traffic crashes occur, and characterized it as the most neglected influence of crashes. McFarland and Moore (1962) reemphasized Gordon's statement regarding the importance of the socioeconomic environment in analyzing traffic safety. The Williamsburg Conference was sufficiently concerned with the societal aspect of traffic safety to designate it one of three priority areas for discussion (the others were the systems approach, and the psychology of driver behavior). Bonder, Cleveland, and Wilson (1967) also recognized the need to include social and legal factors in a conceptual framework for highway safety, as did the HSRI study (1968).

In spite of the repeated expressions of concern for the societal aspects of traffic crashes and highway safety programs, the dominant framework within the traffic safety field remains the public health approach of Haddon and Brenner. That framework does not explicitly include societal aspects; rather, it focuses on the crash problem alone. Such a focus is therefore too narrow. It implies that the traffic crash problem will be dealt with by some undefined "external forces," but the relevant systems producing those forces are nowhere represented. Many events not immediately associated with a traffic crash can nonetheless influence crash causation and produce losses. Focusing on the crash to the exclusion of more general examination of Highway Transportation System operations has resulted in too rapid closure, resulting in the failure to seek information that is important for crash reduction. For example, accident investigation studies to determine why people drove badly in situations that resulted in crashes are common, but few studies examine why people drove well and avoided crashes. Emphasis is placed on the crash problem to the exclusion of other information that may provide insight. Aside from its narrow focus, a second problem of the Haddon-Brenner framework is in its graphic presentation (see Figure 6). Its precise three-by-three matrix, with each cell the same size, conveys the impression of equality among the cells. In reality this is not so.

In sum, the dominant framework in highway safety oversimplifies a very complex problem. Because its focus is on the crash alone, it suggests countermeasures that similarly focus on the crash, and may divert attention from other avenues of inquiry that might be effective. One can only speculate on why the Haddon-Brenner framework has gained such wide acceptance. Being problem-oriented, the framework perhaps fit the mood of a society that perceived traffic crashes themselves as the problem and that was eager to move forward with action programs to solve it.

Perhaps, too, those who have a strong faith in the traditional "three E's" of education, engineering, and enforcement as the cure for traffic crashes found the framework compatible with their beliefs. Perhaps the framework was appealing because it was simple to understand and visualize, was expressed in familiar terms, and allowed conventional wisdom—that the traffic crash problem can be solved by allocating more resources to do more of the same--to proceed. Unfortunately, the Haddon-Brenner framework does not provide a mechanism for measuring its effectiveness, so that even though more of the same was done, the effect is largely unknown.

The public health framework has dominated recent research and action programs in highway safety, even though this approach appears to conflict with both the logic and the recommendations that appear in the highway safety literature. The most obvious consequence has been the narrow focus of research and safety programs on the crash process and on events that closely precede or follow the crash. In contrast, research on the general driving task has been limited. Perhaps more critical is that research examining the many relationships that create and support management systems that can reduce crashes is extremely limited. Past research has in general focused on more efficient delivery of police and other services but has failed to question standing goals. Action programs also have been narrowly developed; they too have emphasized increasing the level of effort and better managing service delivery, rather than questioning basic assumptions about objectives or methods of delivery.

This recitation of the weaknesses of the present framework does not suggest that all traffic safety efforts implemented to date have been wrong. What is suggested is that accepted approaches have not been rigorously evaluated and that there exist alternatives that have not been explored adequately. Research and action programs have so far concentrated on efforts expected to have an immediate impact on crashes, especially technological solutions emphasizing the vehicle and the highway rather than the driver. Research and programs focused on individual driving behaviors, and on institutional and societal responses to traffic crash risk, have been largely ignored. Because the latter areas are ignored, in comparative terms they recede rather than advance. The need exists for rigorous, large-scale research programs examining driver behavior and societal responses in a comprehensive structure, as well as for action programs that deal with the human factor in a broader fashion than today's conventional strategies.

## A NEW CONCEPTUAL FRAMEWORK FOR HIGHWAY SAFETY

The lack of balance in highway safety efforts flows from the lack of an underlying body of theory that can frame the highway safety process, describe its dimensions, and establish a body of rules for decision-making. In short, a new meta-theory is needed to describe the highway safety process.

Traffic crashes and associated losses cause hundreds of thousands of casualties, and generate social costs totaling billions of dollars each year. Society, responding to this problem, has spent billions of dollars on measures to reduce its magnitude. Many of those efforts reflect an overly narrow focus, emphasizing traditional "solutions" at the expense of measures directed at the driver and taking into account society's existing systems for managing risks. This reflects continued reliance on the Haddon-Brenner public health framework for defining and solving the traffic crash problem, a framework that conflicts with authority calling for a systematic consideration of all issues, especially the societal aspects of traffic crashes and ways to reduce losses. There exists the need for a new meta-framework for describing the highway safety process. Such a framework should relate the loss-generating elements of highway transportation to the elements of society that attempt to control those losses.

We have developed a conceptual framework that responds to this need (Joscelyn and Jones 1977). It is purposely called a conceptual framework—and not a theory—for in its present form it is not presented in sufficient detail to warrant its being labeled a formal theory or model. It is the first step toward development of a theory, and in its present form it is useful for describing how the highway safety process operates. Our proposed framework should be examined in that context.

The conceptual framework, which is presented in overview form in Figure 8, has three basic elements:

- The Highway Transportation System,
- Society, and
- Risk-Management Systems.

In the highway safety process these elements interact to reduce crashes and resulting losses.

**The Highway Transportation System**

The first element, the Highway Transportation System (HTS), consists of the highway network, vehicles, system users (such as drivers), and supporting components. The HTS, thus defined, is similar to that found in previous conceptual frameworks, although it is defined in a somewhat broader context.

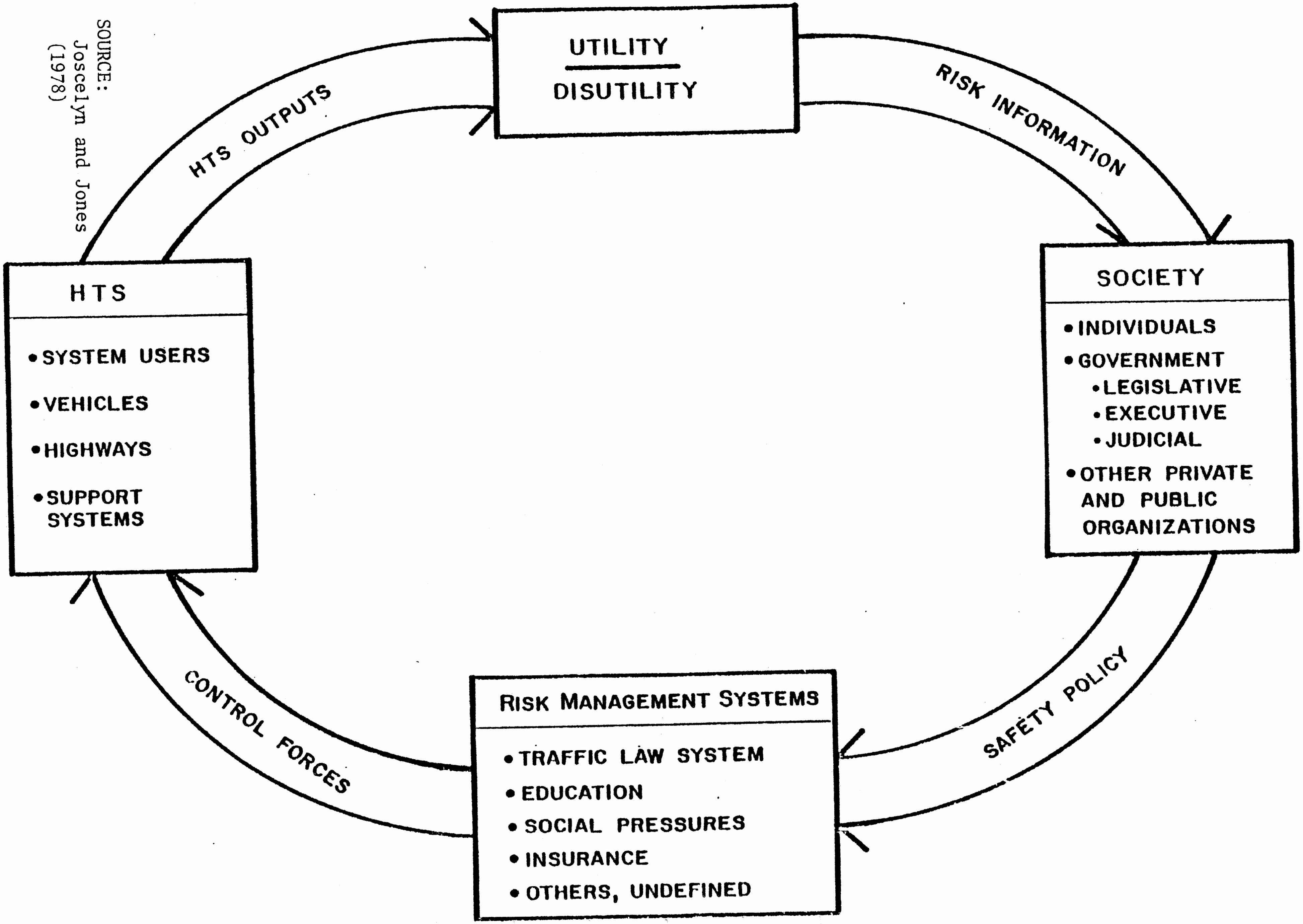
The primary **objectives** of the HTS are to provide mobility with safety. Many secondary objectives also exist; these include, for example, providing recreation and pleasure for system users, providing a market for the automobile and transportation industries, and supporting the national economy. The top-level **functions** of the HTS may be described as the design, construction, operation, and support of the system as a whole and the constituent parts of the system.

The Highway Transportation System was created and has grown in American society because it provides benefits, or **utilities**, for society in the course of performing its four top-level functions. Utilities are the positive outputs of HTS operation, and include individual mobility, rapid transportation of goods, and social and economic well-being. HTS operations also produce **disutilities**, or negative outputs (sometimes called negative utilities in the literature). Chief among them are traffic crashes with associated deaths, injuries, and property losses. Other disutilities include environmental degradation and depletion of natural resources.

The concept of disutility may be operationally defined in a number of

FIGURE 8

THE HIGHWAY SAFETY PROCESS




SOURCE: Joscelyn and Jones (1978)

ways. This framework describes disutilities as negative outputs, including lost productivity, welfare costs, and use of emergency services associated with a particular event such as a traffic crash. From a highway safety perspective, traffic crash losses are disutilities. Society is concerned with minimizing the occurrence of events that produce disutilities and, should they occur, with minimizing the loss. Such a perspective requires the consideration of future action about future events. To aid in thinking about future events that will produce loss, the term "risk," the probability that a disutility-producing event will occur, is used.

In the case of a traffic crash one is concerned with a series of risks, such as the risk of a traffic crash, the risk of a crashed occupant impacting on the interior of a vehicle, the risk of incurring fatal or disabling injury, and the risk of additional loss because an injured person does not receive proper postcrash attention.

Disutility and risk are important because they form the basis for societal concerns that lead to societal action.

**Society**

Society, the second major element, is broadly defined to include all individuals and institutions, both public and private, that have a role in making decisions about Highway Transportation System operations. Those decisions may be individual choices of a system user (such as a driver's choice of speeds), public policy enacted by a legislative body (such as a maximum speed limit), or decisions by other participants in the system (such as that of an owner of an apartment complex to place speed bumps in the driveways). Society observes the operations of the HTS and the utilities and disutilities it generates. When the magnitude of the disutility is so large when compared to the utility that it evokes societal concerns, **formal** actions are taken to reduce the risks that create the excessive disutilities.

Our earlier work on the Traffic Law System (Jones and Joscelyn 1976; Joscelyn and Jones 1972b) suggests that there exists a level of disutility that would produce formal public responses. We define this level as the

**maximum tolerable disutility.** Disutility in excess of this level produces societal pressure for highway safety activity; conversely, when disutility falls below this level, societal concern and support for highway safety actions decrease.

Societal systems that reduce risk may be formal or informal. All such entities may be termed **risk-management systems.**

### Risk-Management Systems

Risk-management systems are formal or informal structures created by society to exert control forces on the Highway Transportation System to reduce risk. Risk-management systems operate to reduce risk to a level less than or equal to tolerable disutility. They do not eliminate risk, even though some systems may purport to.

These systems are numerous and not well defined. They include formal systems such as the Traffic Law System, elements of which generate laws, enforce them, adjudicate guilt or innocence, and sanction offenders. Also included are parts of formal systems focused on broader aspects of society, such as health care delivery systems; and less formalized systems such as communications media used for public information and education. Aside from these more or less formal systems, there exists a wide variety of societal influences--such as customs, mores, ethics, folkways, family structures, and peer pressures--that also exert control forces; however, most of these influences have yet to be formally defined or their effects established. Still, many references are made to their existence in the highway safety literature as well as in the more general literature dealing with the management of such social risks as crime and disease.

### The Highway Safety Process

Viewed in a broad perspective, the conceptual framework represents a process. Its object is to control disutility in a specific societal system, in this case, the Highway Transportation System. The highway safety process is one of disutility control. It can be thought of as one of several disutility control processes that act to reduce societal risks in the broadest sense. These processes compete for society's resources to carry out control activities as exemplified by the competition, cited earlier, between traffic and crime-control activities within the Dayton Police Department.

An analogy can be made between the highway safety process and closed-loop control systems used to regulate physical systems—for example, thermostats. The objective is to maintain the output of the primary system within specified tolerances; in other words, to reduce the difference between desired and actual output (the system error) to zero. The control system monitors system error and applies control forces to the primary system to reduce error; the control forces increase in magnitude as the magnitude of system error increases. Continuous monitoring of system error and control forces allows for adjusting the strength of the control forces to reduce error. In physical systems, such continuous monitoring and adjustment eventually reduce the error to near zero, at which point the system is said to be "in equilibrium."

In the highway safety process, society serves as the monitoring device, measuring both the system error and the strength of the control forces. System error is the difference between actual disutility and the maximum tolerable disutility. Control forces are supplied by the operations of risk-management systems. Society will act when the disutility level is higher than is tolerable. On the other hand, society will not tolerate a risk-management activity that produces unacceptable negative effects, such as the loss of mobility that would result from a national speed limit of 30 miles per hour.

Unlike a thermostat that objectively monitors a single physical property, society—human beings and institutions—monitors the functioning of the highway safety process. Thus the role that society plays is a fundamental limitation on the process. This fundamental limitation has its foundation in two basic constraints: first, the quality and communication of **information** on risk and risk-management operations; and second, society's **perception** of risk and risk-management operations. These constraints are interrelated, since perception is a function of information; however, the constraints have quite independent attributes.

Performance of the highway safety process depends first upon the quality of risk management information. That information must be available and useful, and must be **communicated** to each element of the system for use in **decision-making** about risk. Such information describes, first, the structure, components, functions, inputs, and outputs of the highway safety process; and second, the factors and processes that govern decision-making within the highway safety process. As used here the term "communicated" means not only transmission of information but also its reception and understanding.

Understanding information constitutes a major portion of the second constraint on the highway safety process, which is societal perception. Even if complete and accurate information were available, society would continue to be guided by its understanding or perception of risk and risk-management activities in making decisions about the highway safety process. Society acts on the basis of perceived rather than actual values.

Societal perceptions are the result of the shaping of many individual perceptions, not all of which are alike. Although the process of perception formation is ill defined and ill understood, available evidence suggests that a "perception gap" exists (e.g., Joscelyn 1975b; Worden 1973). Thus one ideal way of improving the highway safety process is to reduce the perception gap to zero, so that perceived risk equals actual risk. While one cannot realistically expect to eliminate the perception gap, any narrowing of the gap would provide society with a better basis for determining the level of safety efforts it desires. A new value of maximum tolerable disutility with a corresponding risk value would be established as the perception gap narrows. In turn, the nature and extent of risk-management operations required to maintain risk at or below that level would be better defined.

In general, perceptions are based on information but are altered by biases inherent in the receiver or the sender. The highway safety process consists of many information transmission and reception networks. Many societal mechanisms act as "filters" that amplify or suppress the information that is transmitted. These same mechanisms also generate spurious information that affects perceptions. At every linkage, communication is inhibited by "noise" that masks the content of information being transmitted. This noise inhibits the communication of information and the formation of accurate perceptions. That, in turn, reduces the quality of decisions about risk. Fliters and "noise" are basic constraints. These filtering mechanisms are shown in Figure 9. The critical roles of information, societal perceptions, and noise must be understood if the highway safety process is to be understood.

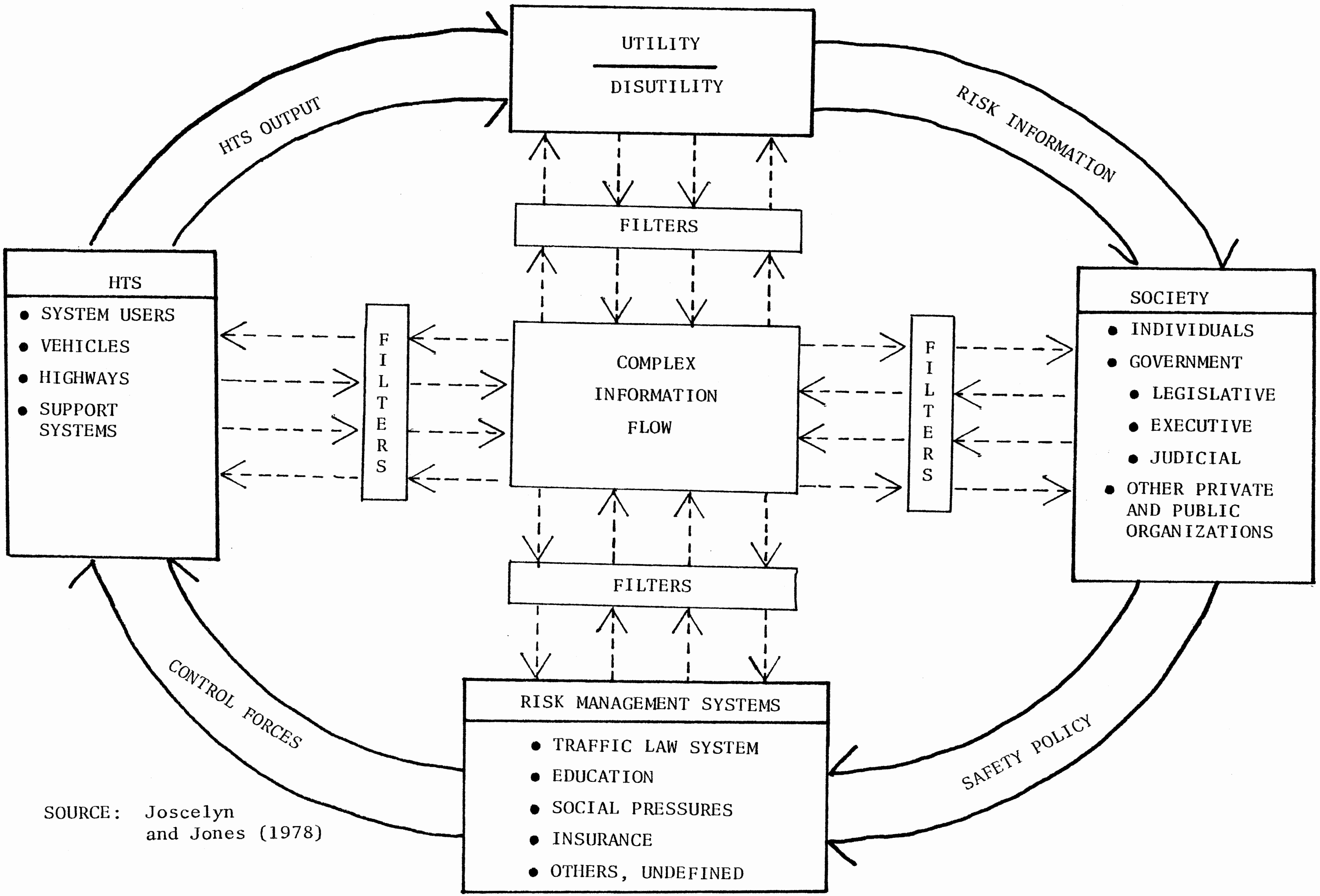
## HIGHWAY SAFETY AND RISK MANAGEMENT

The conceptual framework presented in this paper describes a process by which individuals and societal forces control the risk of traffic crashes and associated losses. **Risk**, the probability that a hazard will occur, is objectively determined from such data as the frequency and severity of accidents. On the other hand, **safety** is a subjective judgment regarding the personal or social acceptability of a particular risk. While individual judgments concerning safety differ, they are determined in part by such considerations as whether a hazard is avoidable; whether its effects are immediate or delayed; what alternatives exist to a specific risky behavior; how widely the hazard affects the population; whether the hazard is common or "**dread**"; and whether the effects are permanent (Lowrance 1976). Societal judgments concerning safety are roughly the sum total of individual judgments; however, such factors as social traditions, the presence of vested interests, or the actions of powerful advocates of a particular viewpoint may distort the overall societal response (Withey and Cole 1980).

Society does not act to eliminate risk; rather, it seeks to reduce risk to a "safe," or socially acceptable level. This process has been termed **risk management**, an approach to decision-making under risk conditions. It emerged from an awareness that decisions and subsequent acts can affect the probability, the type, and the extent of potential losses. Ideally, risk management is based on a comprehensive understanding of those systems that interact to produce and affect losses, their magnitude,

FIGURE 9

INFORMATION FLOW AND FILTERING MECHANISMS WITHIN THE HIGHWAY SAFETY PROCESS




SOURCE: Joscelyn and Jones (1978)

and their probability. It stresses evaluating the expected costs and benefits of alternative decisions with respect to their expected effects. Applied to human activity as a whole, the goals of risk management are, first, to reduce uncertainty (or reduce the negative results of uncertainty); and, second, to optimize some set of benefits in light of uncertainty.

The term "risk management" apparently was coined by corporate insurance managers beginning in the mid-1950s (Gyory 1964); consequently the insurance industry is an appropriate starting point for a discussion of risk management. During the 1920s corporate insurance buyers formed associations that resulted in formation of the National Insurance Buyers Association and later, the American Society of Insurance Management. At the same time, there was a trend toward separate insurance management and, for example, fire prevention departments within railroad, oil, or food corporations. These trends signaled a change in businesses' attitudes toward loss. Previously businesses assumed that losses resulting from fire, accident, and injury were inevitable; they simply bought enough insurance to cover projected losses. Managers responsible for obtaining insurance began to experiment with a combination of strategies—including prevention--to reduce overall losses. This required a more active role in assessing risks, insurance costs, and savings, using proper coverage.

Still, the definition of risk was narrow. The corporate risk manager's function was restricted to managing financial risks. In many cases risk analysis began and ended with a consideration of the corporate balance sheet; under this approach personal injuries were relevant risks only to the extent of their economic repercussions (Gallagher 1964). Managers further limited the scope of their activity to minimizing the so-called "pure" risks, those resulting from the ownership of property, but not the so-called "business" risks taken in the hope of making a profit (Parrett 1964). Finally, preventive efforts to abate or reduce risks remained separate functions from those of the risk manager; these were entrusted instead, for example, to the manager in charge of fire prevention or industrial safety.

During the 1960s the scope of corporate risk management expanded as the insurance and safety responsibilities were merged. At that time more formal procedures were developed for assessing and managing a wider variety of risks, such as loss of time, damage to corporate good will, and the interruption of services. The risk management literature stressed careful analysis and quantitative evaluation of risks and alternative management strategies (Rennie 1961). These developments reflected the influence of operations research and the increasing use of systems analysis.

By 1970 risk-management theory had developed as a relatively comprehensive process reflecting the emerging "systems philosophy." Since then risk management has undergone few radical changes. There has been an increased understanding of, and insistence upon using, a systems approach that considers all relevant aspects of risk. Management by objectives--which requires a delineation of top-level organizational objectives or goals, in turn divided into more specific and action-guiding objectives--has come into wide use. In recent years measurement techniques have been refined to account for deaths and injuries, and mathematical models have been used. In general, risk-management techniques have experienced tremendous growth in the military and aerospace industries as well as in solving such policy issues as those involving waste disposal and energy systems. There has been increasing interest in the application of broad, systematic analysis to more amorphous social problems such as urban decay, public education, and traffic safety (Joscelyn and Jones 1977).

Risk-management procedures were originally developed in the context of insurance. From this relatively narrow beginning, risk management has become a broad management strategy in situations where uncertainty exists. Although it makes use of a body of methods that are closely identified with systems analysis, decision analysis, and operations research, risk management should not be viewed only in methodological terms. Rather, it is an approach to managing and organizing efforts given the presence of risk. It is therefore applicable to efforts to manage the traffic crash risk.

## IMPROVING THE MANAGEMENT OF RISK

Management of risk is a process that is analogous to other management processes. The body of theory that describes risk management can be applied to management of the traffic crash risk. Application of basic risk-management principles can improve the operation of the highway safety process.

### THE RISK-MANAGEMENT PROCESS

In the insurance industry, a stepwise process of risk management has developed (see, e.g., Snider 1964). We further defined that process in the specific context of traffic safety. The process consists of six discrete but interrelated steps. These may be taken by an individual in making personal decisions about a course of action to follow; by institutions in developing formal control actions; by public entities in generating formal public policy; and by society in generating demand for and support of the highway-safety process.

The steps may be succinctly stated as follows:

- Identify the risk;
- Establish priorities among risks;
- Determine the allocation of resources;
- Select risk-management strategies and tactics;
- Implement risk-management actions; and
- Evaluate outcomes in terms of risk reduction (Joscelyn and Jones 1978).

The first step, **risk identification**, is the most critical, since it determines whether society and its risk-management systems will respond at all. Identifying a risk means determining its magnitude, and also effectively communicating it to all persons affected by the risk. Once the risk is identified and communicated, and that information is received by the intended audience, perceptions of risk are created. Increased perception of risk leads individuals to engage in risk avoidance; to support the creation, funding, and operation of risk-management systems; and to cooperate with risk-management systems as their risk-management strategies are implemented. Not only must information regarding risk be communicated, but it must be communicated in enough detail to support further risk-management action. Specifically, information must exist concerning how risk is created and what disutilities result, and when and why.

As we already pointed out, existing information describing the traffic crash risk and comparing it with other societal risks is apparently not well understood. Society appears to view traffic crashes as less of a societal problem than other risks that create less loss. Also, the crash causation data indicate that human factors are the leading cause of traffic crashes. This suggests that greater efforts are warranted to identify, and effectively communicate, the magnitude of the traffic crash risk. Further, it suggests that human factors must be examined in greater detail to develop information to support risk-management activities. Many failures appear to warrant action directed at the driver—but not all such failures dictate human-oriented action.

After crash risks are identified, the second step is to **establish priorities** among them. This involves ranking specific crash risks, or classes of risks, in order of the magnitude of the threats they pose to society. To deserve priority, risks must be associated with a reasonably high probability of occurring and, should they occur, the disutility must be sufficiently undesirable. A major requirement of highway safety research is to provide operational definitions of "reasonably high" and "sufficiently undesirable." Frequent events that create great disutility when they happen deserve the highest priority, rare events with very low disutility the lowest priority. Establishing priorities among risks is actually the first of three steps that are closely interrelated. The other two steps, determining the allocation of resources and selecting risk-management strategies and tactics, involve designing comprehensive programs of risk reduction and dealing with unacceptably great risks.

**Allocation of resources**, the third step, takes place in two contexts. The first reflects society's general decision to allocate resources to a given class of risks relative to other classes of risks, such as highway safety versus cancer. The second context relates to how resources are allocated to strategies and tactics aimed at a particular class of risks, such as how highway safety resources are to be spent.

The fourth step, **selecting strategies and tactics,** must be a systematic analysis. The nature, magnitude, dynamic characteristics, costs, and societal acceptability of control forces associated with expected effects must be considered. This systematic process is generally not followed today, even though claims are made by a multitude of system managers that they in fact apply such methods. If used, a systematic analysis is likely to identify some risks that cannot be reduced to desired levels by using existing strategies. These risks must be addressed through research to identify and evaluate new control forces.

After risks have been identified and ranked, and after programs are developed to deal with them, the fifth step is to **implement risk-management actions.** Here, all activities needed to operate a risk-management program are performed. These range from providing funds to actually applying control forces and include, for example, recruiting and training personnel, monitoring operational methods and procedures, and purchasing equipment. Implementing programs, like selecting strategies and tactics, should follow a systematic process: personnel, equipment, facilities, and other resources should be allocated on the basis of how much they contribute to the effectiveness of the total risk-management system. Presently the systemwide coordination necessary for such an approach seldom occurs (Joscelyn and Jones 1972b).

The final step, **evaluating outcomes,** is intended to identify effective control forces and risk-reduction programs so that they may be more widely applied; and to identify forces and actions that have not worked, so that they may be improved or discarded. An evaluation must be related in some reasonable way to the reduction of risk. Reliance on such ultimate measures as the actual reduction of crash losses is probably not feasible for most programs, especially local ones. It is instead more reasonable to focus on a particular category of risk (such as the proportion of drivers traveling 15 or more miles per hour above the speed limit) and measure change in that risk (such as the reduction in the excessive speeder population). Results of evaluations must be communicated to risk-management systems and to society. Whether society is willing to tolerate and support risk-management activity depends on its perceptions of benefits. Frankness in sharing information of a program's successes and failures is a necessity. This also requires that programs not be oversold, for evaluations that show no reduction in risk can produce disastrous consequences for program managers who have promised too much. It is necessary to develop a clear societal understanding of how complex the traffic crash risk and the highway safety process really are, and that simple, societally acceptable solutions to the crash problem are unlikely to be found soon.

## THE TRAFFIC LAW SYSTEM: AN ILLUSTRATION

The Traffic Law System (TLS) is the best known formal risk-management system within the highway safety process. It is society's formal mechanism for applying law to manage the traffic crash risk. Law is applied in a variety of ways. In a positive sense, it provides guidelines for normal operations of the Highway Transportation System. These guidelines provide a series of common expectations (for example, that all drivers will use the right-hand side of the road) that facilitate daily activity. These guidelines, drawn from theoretical understanding of risk, suggest or require conduct that reduces risk.

The law is also used in a negative sense to prohibit actions that create increased risk. The law provides a formal system for dealing with individuals who violate the prohibitions. This use of the law stems mainly from the legal concept of **deterrence:** undesired behavior can be prevented by the threat of punishment. Most theories of deterrence are based on the hypothesis that a person contemplating a prohibited activity will refrain from acting if the expected benefits of that activity are outweighed by the expected costs resulting from threatened punishment (Andenaes 1974, 1966; Zimring and Hawkins 1973). The literature distinguishes between two forms of deterrence: **special deterrence,** which prevents the punished parties themselves from engaging further in the prohibited activity; and **general deterrence,** which discourages members of a group from engaging in the activity even if they are not caught and punished (Zimring and Hawkins 1973).

Within the Highway Transportation System, the formal means of creating deterrent threats to unacceptably risky behavior is the Traffic Law System. The threats of fines, license suspension, and confinement to jail are the **control forces** of the TLS, these are applied as the TLS performs its four top-level functions of **law generation, enforcement, adjudication,** and **sanctioning** (Joscelyn and Jones 1972b). The objectives of these functions are depicted in Figure 10.

A wide variety of governmental agencies and institutions are involved in performing these functions. Because the American system of government is based on separation of powers, no single agency or institution is in charge of the entire system, and there is no "system manager" for the Traffic Law System for any other formal control system. No "system specification" exists for describing what the TLS--or any of its components—should perform. In reality, the TLS is a "system of systems," each operating more or less independently but all loosely bound together by a set of common principles.

**Law Generation** is performed by federal, state, and local governments operating under legal constraints imposed by constitutions, federal and state laws, and court decisions. Legislative bodies create formal statements, called statutes, of what risks are prohibited and what the penalties are for engaging in risky behavior. Other statements, called regulations, are generated by administrative agencies in the executive branch of government. In addition to prohibiting risky behavior and specifying punishments, laws also authorize the operation of other system components, such as driver-licensing authorities and police departments, and provide direction for and constraints on their operation, such as arrest and citation procedures. De facto laws are generated by other instrumentalities of the government, for example, by setting speed limits

FIGURE 10

THE FOUR TRAFFIC LAW SYSTEM FUNCTIONS
AND THEIR OBJECTIVES

**Law Generation**

- Define risk precisely;
- Prohibit behavior that creates risk;
- Prescribe behavior that reduces risk; and
- Provide for operation of the TLS through procedural guidelines, creation of the necessary entities, and funding them.

**Enforcement**

- Detect and apprehend risk-takers for further system action;
- Manipulate human behavior to reduce risk; and
- Collect basic data to identify risk.

**Adjudication**

- Determine if risk-taking occurred in the case of individuals apprehended by Enforcement;
- Determine validity of risk prohibitions by Law Generation;
- Provide fundamental fairness essential for system operation.

**Sanctioning**

- Provide ultimate system response designed to ensure that the sanctioned individual will not engage in risk-taking in the future (special deterrence); and
- Provide a pattern of responses to individual risk-taking that influences all potential risk-takers to refrain from such action (general deterrence).

Source: Jones and Joscelyn (1976); Joscelyn (1975a).

and posting stop signs. More informal—but nonetheless real—laws are created by individuals, for example, when a police officer directs traffic at an intersection (Joscelyn 1975a).

**Enforcement** is performed by state and local police agencies. Primary operational subfunctions include detecting law violators, apprehending violators, observing the suspect to help decide whether to arrest or issue a citation, and arrest and postarrest processing of the suspect. An important secondary subfunction of enforcement is to provide a deterrent threat to potential risk-takers simply through the presence of police or police symbols. Research suggests that police presence influences some driver behaviors, such as speeding, that are associated with some crash losses (Joscelyn, Bryan, and Goldenbaum 1978). Enforcement also supports operation of the entire Traffic Law System by providing information—such as arrest and citation records or accident reports—on the nature of the risk.

**Adjudication** is most commonly associated with traffic courts, where the rules of criminal procedure are followed to determine the guilt or innocence of individuals accused of violating traffic laws. Major subfunctions of this process are determining the charge to be made against the suspect, and conducting a proceeding to inform the accused violator of the charge and his or her rights, and to determine the guilt or innocence of the accused violator. The latter subfunction, commonly referred to as the "trial" when conducted by the judiciary, has as its objective the finding of fact and law related to a particular event and individual.

It must be emphasized that the adjudication function is not always performed by a court or the judicial branch of government. Driver-licensing authorities often hold administrative hearings in which findings of facts are made by a hearing officer. In some jurisdictions, such as New York and Rhode Island, some offenses have been "decriminalized" to expedite the processing of less risky violations. Decriminalization means the removal of jail as a possible penalty, the relaxation of criminal procedures, and sometimes the transfer of the adjudication function from the courts to an administrative agency, such as the Department of Motor Vehicles. Still less formal adjudication processes often occur. For example, a police officer may decide after stopping a driver not to arrest or cite and to issue a warning instead, thus precluding further action by formal adjudication components of the system. Similarly, a prosecutor may decide not to charge or to reduce a charge in exchange for the offender's promise to undergo treatment for some condition, such as alcoholism, that led to the offense. In most instances, however, it is the driver who self-adjudicates after receiving a citation by pleading guilty or forfeiting bail (Joscelyn 1975a).

**Sanctioning** provides the ultimate deterrent threat of the Traffic Law System. It can be performed by the judiciary (e.g., imposing a fine), by an administrative agency (e.g., by suspending a driver's license), or by a police officer (e.g., by issuing a warning). The purpose of the punishment is to prevent the punished individual from engaging in the risky behavior, and to influence other individuals, who wish to avoid punishment, not to engage in that behavior.

The risk-management process is applicable in both "meta" or system sense and in a "micro" or individual agency sense. The basic steps of risk management are performed within each functional area of the Traffic Law System. Each individual or agency should deliberately go through each step to effectively and efficiently discharge the risk-management mission. In addition, each functional area has responsibility for performing some of the steps for the TLS as a whole. For example, the enforcement component has special responsibilities to develop information on risks and share them with other components of the system. In a similar sense, the law generation component must translate general information on risk into operational definitions of prescribed and prohibited behaviors.

We have previously analyzed the performance of the Traffic Law System as a risk-management system (Joscelyn and Jones 1972b). We found that it was conceptually sound but had insufficient resources to manage Highway Transportation System risk effectively. The low level of resources available to the Traffic Law System reflected the public's misperception of the net disutility produced by the Highway Transportation

System. We concluded that this misperception was caused by a lack of precise knowledge about risk and a lack of communication to the public of existing knowledge. Our study also found that risk-management principles often were not being applied by the TLS. Consequently, existing resources were not being effectively used. Minimal coordination among its various elements was found, resulting in a lack of common purpose and in actions that were counterproductive to achieving the system's ultimate objectives, namely to reduce crashes and associated losses. The failure of the TLS to "operate as a system" resulted in serious inconsistencies in the Traffic Law System's interactions with the Highway Transportation System, society, and other risk-management systems. It has even resulted in nonperformance of major risk-management functions, especially risk identification, at the system level. **The function of risk identification is most critical, because the entire decision process revolves around an understanding of the nature of risk and the effects of control force actions on reducing risk. In general, the free flow of accurate information about risk and risk-management is the most fundamental and important requirement for the operation of the highway safety process.**

## MANAGEMENT PROBLEMS AND NEEDS

The conceptual framework we present in this paper can be used to analyze overall highway safety problems and needs in a more orderly and meaningful way than was previously possible. We have applied it to develop a top-level statement of management requirements to serve as a point of departure for more extensive analyses.

Our analysis focuses on management problems and needs, in particular, the decision-making process. Our framework for risk management places great emphasis on individual and societal decision-making. Decisions rest on information and perceptions. Perceived consequences of a decision affect the decision process as much as the actual consequences. Good decisions are more likely to be made if the decision-maker has accurate information. Communication of information within the highway safety system is necessary for management. Understanding how information flows within a system requires an understanding of the system. We have been unable to identify any major research or action programs that systematically describe the highway safety process.

Thus, we identify three general categories of management problems: **describing** the highway safety process; improving **decision-making** within the process; and facilitating **communication** within the process.

These **problems** are described in greater detail in the following sections. The descriptions are used as an analysis tool to develop **need** statements that articulate the requirements for future analytical work and program development.

## DESCRIPTION OF THE HIGHWAY SAFETY PROCESS

**Problems.** The highway safety literature records no attempt to describe the entire highway safety process **as a whole.** The lack of a comprehensive theory has, in fact, precluded such a global presentation of the process. Researchers have yet to even describe all the elements and their components. The result has been fragmented, piecemeal descriptions of elements believed to be important to a given restricted analysis. Any analysis of the performance of the highway safety process as a whole has been impossible for the most fundamental of reasons: not all of the parts of the system have been identified. As a consequence of the fragmented conceptual frameworks used in past highway safety activities, the most neglected components of the highway safety process have been those related to control of crash disutility. While many major system components (such as drivers, vehicles, and roads) have been dissected to identify their constituent parts in great detail, very few studies have attempted to isolate and classify the societal and risk-management system components of the highway safety process. No effort to identify **all** of the significant parts of the societal and risk-management system components has ever been made.

Similar problems exist in describing the **functions** of the highway safety process. Several studies have analyzed selected functions of the Highway Transportation System and risk-management systems, but few studies have attempted to develop hierarchies of functions in relation to top-level system and subsystem objectives. Not only has there never been a functional analysis of the entire highway safety process, but there has been no formal attempt even to identify all of these functions. With respect to the HTS, only the operational function has received much attention in the highway safety literature. Some detailed analyses of lower-level HTS functions involving interactions between driver and vehicle (called task analyses) have been conducted, but related functions that must be performed in the course of total driving "missions" (for example, a trip to the office on a busy expressway) have not been described in the same degree of detail. Some functions of some risk-management systems (such as emergency medical or police traffic services) have also been identified, and in one case (the Traffic Law System) a formal functional analysis has been performed (Jones and Joscelyn 1976). However, the functions of many risk-management system components (for example, private safety foundations and insurance companies) have not been described in sufficient detail in the literature, and few functional descriptions have been related to the functions of risk management.

Without a comprehensive list of components and functions of the highway safety process, the requirement for a **structure** interrelating the functions and their performance cannot be met. Thus there is no way of knowing exactly how any given function contributes to accomplishing risk-management objectives, or how that function affects the accomplishment of the objectives and functions of other components. As a result, control forces cannot be evaluated in terms of the functions that produced them, and the design and development of new forces are hindered by the lack of information about what works and what does not work in controlling crash disutility.

With respect to the **outputs** of the highway-safety process, one requirement—describing the disutilities of the Highway Transportation System--has been addressed most frequently by past highway safety research. However, such research has identified events immediately prior to, during, and following crashes, and has developed a variety of descriptions of the resulting disutilities. Thus risks and disutilities have not been adequately examined with respect to events or conditions that occur or exist far in advance or long after a crash; hence many potential opportunities for interdicting the series of events leading to disutility have not been identified.

An additional problem is that crash disutilities that have been studied have not been adequately described in terms that will support risk-management actions, that is, with respect to the risk associated with the disutilities, to other non-HTS risks, and to normative values of factors related to disutilities. Utilities of the HTS have received even less attention than the disutilities. Particularly, no attempt has been made to compare the utilities and disutilities associated with particular activities or collections of activities, and to relate the resulting net utility or disutility to "risky" or "safe" driving behavior.

Much more attention has been given to identifying the outputs of the Highway Transportation System than the outputs of the risk-management systems. In general, neither the effectiveness nor disutilities of risk-management system control forces are known. The result is that resources are commonly wasted on ineffective safety programs, and potentially effective programs are rejected because their disutilities are perceived as greater than the crash disutilities they seek to reduce. The repeal of federal seatbelt-interlock regulations, and the repeal of mandatory helmet use laws for motorcyclists in some states, are examples of public refusal to accept "cures" they perceived as worse than the "illnesses" they were directed against.

Figure 11 summarizes existing major problems in developing a description of the highway safety process to support risk management. The problems are shown relative to the three major elements of the highway safety process: the Highway Transportation System, risk-management systems, and society.

**Needs.** The first specific need is that each element of the highway safety process, and their **components** be identified and described. Our conceptual framework identified top-level components and gave examples of lower-level components. Additional groupings and classifications of components need to be developed and expanded to include each component whose activities are believed to have any significant impact on highway safety process operations.

Next, the **functions** of the highway safety process need to be identified in hierarchical form. Top-level functions include providing fast, convenient transportation and maintaining Highway Transportation System disutility at a societally acceptable level. Lower-level functions include the design, construction, operation, and support of automobile equipment and highways. The primary functions of risk-management systems are identifying risks; setting priorities among risks; allocating resources; developing strategies and tactics; implementing and operating programs; and evaluating them. We identified the functions of one specific risk-management system, the Traffic Law System, discussed them briefly, and related them to the primary functions of risk-management systems in general. Similar but more detailed descriptions of highway-safety process

FIGURE 11

## SUMMARY OF MAJOR PROBLEMS IN DESCRIBING THE HIGHWAY SAFETY PROCESS

| Problem Area | Elements of the Highway Safety Process | | |
|---|---|---|---|
| | Highway Transportation System | Risk-Management System | Society |
| 1. Identification and Description of Components | Inadequate identification of components involved in nonoperational functions (e.g., design and support) | Incomplete identification of components, especially in private sector | Incomplete identification of public sector and external elements that interact with the Highway Safety Process |
| 2. Identification and Description of Functions | • Inadequate identification of nonoperational functions<br>• Lack of hierarchies of functions related to objectives | Functions of most risk-management systems not identified explicitly | Highway safety-related functions not identified |
| 3. Definition of Structure | No rigorous structure interrelating components and functions | Intersystem structures not defined. Intrasystem structures defined for only a few systems | No structural analysis exists |
| 4. Identification and Description of Outputs | • Utilities and disutilities not described in operational terms<br>• Utilities and disutilities associated with all functions and operational modes not described<br>• Net utility or disutility of functions and operational modes not known | • Effectiveness of control forces not known<br>• Disutilities of control forces not known | Societal demands for disutility control not known |

Source: Joscelyn and Jones (1978)

functions must be developed so that all significant activities that pertain to the generation and control of disutility are known and related to the objectives of the highway safety process.

Once the components and functions of the highway safety process are defined, they must be interrelated to form a detailed **structure** of the process. Each top-level function must be related to every other top-level function, and the components involved in performing that function must be identified. Similarly, interfunctional relationships must be developed among lower-level functions, so that, ultimately, a network of functions can be created. Such a network would, among other things, enable one to determine how any given activity performed by any given component might affect other activities and components. This would provide a major tool for the practice of risk management.

The last major need for describing the highway safety process is to define its **outputs.** In the case of the Highway Transportation System, this means stating the utilities and disutilities associated with its various modes of operation, its components, and its function. For example, driving at a high speed in a large "luxury" car on an interstate highway has a positive utility, not only to the driver and passengers who want to minimize travel time, but to the manufacturer of the vehicle and those who build and maintain the highway. Even a direct disutility (such as a serious crash) may have utility to some segments of society, for example, automobile repair companies and hospital workers. It is essential to risk management that the significant outputs associated with HTS operation be specified in relationship to what individuals and organizations that receive the utilities and disutilities. Understanding crash causation, while it is an important element of this "output definition" requirement, is clearly only one of many elements. It is necessary to state disutilities not only in terms of the losses associated with a particular event but in terms of the probability (risk) that the event will occur. Further, to produce an effective risk-management response, disutilities must be described in relation to other disutilities (such as fire or disease) and their associated risks.

The outputs of risk-management systems are control forces designed to maintain acceptable Highway Transportation System disutility. Control forces are more difficult to describe than the outputs of the HTS, because it is necessary to define not only their nature and origin but their purposes, effects, and costs. For example, a control force in the form of a driver license suspension must be examined to identify its purpose (such as preventing crashes involving teen-aged drunk drivers), its effectiveness in accomplishing its purpose, and the total cost of resources expended in applying that force. It is also important to identify any negative effects associated with application of that force, for example, the violation of fundamental constitutional rights by denying due process.

Finally, the specific nature of society's "outputs" must be known. These should be described in terms of required reductions in specific risks as well as what constitutes acceptable control forces for such risks.

Meeting the above needs will produce a comprehensive and detailed description of the highway safety process. Kept up to date, the description will provide a running history of the highway safety process' constituents, objectives, and outputs; such a description will comprise the first basic ingredient for designing, operating, and evaluating programs of risk management.

## DECISION-MAKING WITHIN THE HIGHWAY SAFETY PROCESS

**Problems.** Considerable progress has been made in recent years in developing theoretical models of decision-making and in understanding psychological and social factors involved. Still no single, integrated theory of decision-making is available for rigorous application to the field of highway safety.

Major difficulties exist in translating existing knowledge from the behavioral sciences into terms that can be used to improve operational decision-making. For example, it is known that most people do not use information efficiently in estimating risk. But it is not clear how that knowledge can be used to better present information about crash risk to police officials. Moreover, it is known that human decision-makers tend to "discount" the future. But is not clear how that knowledge can be used to stop legislators from responding only to short-term highway safety pressures and ignoring problems that will create far greater pressures later. Nevertheless, the greatest deficiency with respect to decision-making is the lack of effort to translate knowledge into operational terms. Thus, much potentially useful knowledge is not being used to improve perceptions and decision-making within the highway safety process. Failure to use existing knowledge is a major current problem.

Research efforts to gather new knowledge in the area of human decision processes are inadequate. A recent study in England revealed only a handful of publications about decision-making that were relevant to highway safety. In the United States, no federally sponsored programs are concerned with describing current perceptions about risk within the highway safety process could be identified. Only a limited amount of research examining how perceptions about crash risk are formed and how decisions about risk responses are made was found. Thus, present knowledge about decision-making is not being used, and there are essentially no programs to promote the use of this knowledge or to develop new knowledge.

**Needs.** Important factors in deciding how to deal with Highway Transportation System risk must be identified and described. Three specific needs are germane to decision-making within the highway safety process.

The first need relates to formation of **perceptions** about the outputs of the Highway Transportation System and risk-management systems. We noted earlier that perceived risk often does not equal actual risk and that perceptions about utilities of the HTS and disutilities of risk management system control forces may also be inaccurate. Thus, there is a need to determine the nature of these perceptions, and to understand how those perceptions are formed. It would be useful to know, for example, how perceptions of crash risk due to speeding vary with demographic characteristics and whether speed "traps" are more effective deterrents to some groups of drivers than to others.

The concept of **maximum tolerable disutility** due to crashes is an essential element of highway safety. This reference value of disutility must be described for different groups of individuals from the Highway Transportation System, risk-management systems, and society in general. The need for such knowledge is fundamental because it forms the basis for determining specific risk-management system objectives. Such information, combined with information about actual and perceived disutility, allows one to ascertain if society's safety requirements are being met and the extent to which control forces should be applied to meet those requirements.

For example, if the maximum acceptable risk of an average driver's being killed in a crash over a driving lifetime is one chance in 1,000, and the actual risk is actually closer to 20 chances in 1,000, this knowledge could have very significant implications for risk management. Such knowledge would indicate that risk-management systems are not satisfactorily accomplishing their objectives, for actual risk greatly exceedes acceptable risk and perceived risk is much lower than actual risk. On the other hand, a finding that drivers who use a heavily patrolled roadway during nighttime hours can expect to be involved in some kind of serious crash once in every 1,000,000 trips, when their safety requirement is no more than one serious crash in 100,000 trips, **might** indicate a misallocation of police resources. In either case, maximum tolerable disutility must be known to measure the performance of risk-management systems.

The last need in this category is to understand how **decisions** about responses to risk are made. In the case of the Highway Transportation System, this means, for example, that one understand why one driver will respond to a given perceived risk by avoiding it, while another driver's response will be to accept the same risk. By the same token, the public in one jurisdiction may demand immediate action against a given perceived risk, but the same risk in another jurisdiction may leave the public apathetic. Finally, one police agency may respond to a given increase in perceived risk by allocating more patrol cars to a specific location; but a police agency in another, apparently similar, jurisdiction may take no action at all to deal with the same increase in risk. Thus, there is a need to know the significant factors that lead to such wide differences in responses to the same perceived risk, and to know how to manage these factors to obtain optimal responses from the decision-makers.

## COMMUNICATION WITHIN THE HIGHWAY SAFETY PROCESS

**Problems.** No system-wide information system has ever been designed for the entire highway safety process, and there is no record of any analysis of what content, form, or method of delivery of information is needed by various components of the process. Formal information "systems" that do exist are mainly repositories where information is stored rather than disseminated. These repositories are usually designed to meet the needs of specialized user groups, most frequently researchers, and are most often located at the facilities of the user groups. Such repositories include the National Highway Traffic Safety Administration's Fatal Accident File; The University of Michigan Highway Safety Research Institute's Library; and repositories maintained by such safety foundations and associations as the National Safety Council, the Motor Vehicle Manufacturers Association, the American Association of Motor Vehicle Administrators, and the Transportation Research Board. A few information "services," for example, the Transportation Research Information System (TRIS), exist for the benefit of those who seek highway safety information; however, some familiarity with both the literature and the organization of the retrieval systems is necessary for effective use of these services.

The most serious problem in communication is in meeting information needs of the public and of operational components of the Highway Transportation System and risk-management systems. There is not and has never been any ongoing, integrated program to provide these components information about risk and control forces.

Efforts to communicate with the public have mainly taken the form of sporadic public information and education "campaigns" supporting countermeasures aimed at particular behaviors associated with crashes, such as speeding and drunk driving. The effectiveness of most of these campaigns in modifying behavior has not been demonstrated. The highway safety literature provides no evidence that studies have been performed to determine what kinds of information, provided in what form to what groups, are required to enhance risk perceptions and to support rational decision-making regarding risk.

With respect to risk-management systems, the major communications problem is in providing information that now exists in a form suitable for risk management at state and local levels of government. At these levels, operational risk-management strategies and tactics are developed, most resources are expended, and most control forces actually applied. However, state and local units of government have the least access to information needed for these functions. Unmet needs of these risk-management system components include concise state-of-knowledge reviews about risk, manuals for operating countermeasure programs, and surveys of the results of evaluations of past programs.

Examination of past highway safety efforts leads to the conclusion that information that is currently available is frequently not used in the design or development of highway safety programs.

The risk-management process has been described in some detail. This is not a new concept; it has been a part of the general management literature for many years. Still, one does not find such management concepts specifically incorporated within the literature on highway safety program management.

Current highway safety program literature refers to a three-step process—problem identification; program development and implementation; and evaluation--that, in a general sense, resembles the risk-management process. The difference lies in the emphasis the risk-management process places on identifying risk, establishing priorities, and evaluating implemented strategies and tactics in terms of risk reduction. Actual practice in the agencies and institutions that implement programs appears to ignore even the management concepts in the existing highway safety literature as well as basic risk-management concepts. Programs are started as extensions or expansions of existing activity. Risk identification is not accomplished, and effective evaluation is a rarity.

A major reason for this is the failure of state and local units of government to understand the systematic nature of their highway safety efforts. Sufficient attention is not given to the organization and management of highway safety programs or to the institutions that implement programs. This lack of system management contributes to a failure to use existing information, and a failure to develop new information through risk identification and evaluation.

Part of this failure can be attributed to a general tendency of the public, policymakers, and highway safety specialists to ignore existing information on risk. Basic information on traffic crash causation has been reinforced by more recent, more detailed studies. Despite this information, resources are still allocated to engineering or technological solutions focused on the highway and the vehicle, with only limited resources available to examine the human element. We do **not** suggest that vehicle safety or programs designed to improve the highway environment cease or be reduced; rather, as priorities for allocation of resources are established, sufficient attention should be paid to the human element. In the next twenty years the Highway Transportation System will experience major transitions. Whether those can be accomplished with minimal disruption of our society will depend not only on technological solutions but on increased understanding of patterns of human behavior.

The past practice of underestimating the human factor is reflected also in the design and development of programs that focus on drivers and other system users. Conventional wisdom has prevailed; most new programs are remarkably similar to the old. Policymakers have relied on the Traffic Law System as a risk-management mechanism. The TLS has been expected to be a deterrent to unsafe driving action. Drivers have been expected to perceive sanctions resulting from enforcement action as surrogate risks. Drivers, in making "rational" decisions about courses of action, have been expected to consider the unfavorable outcomes. Since the risk of a crash has apparently not been sufficient to influence the behavior of many drivers, the risk of legal action has been used as an additional decision factor. The success of this strategy has been limited, because the level of enforcement is generally so low that the surrogate risk is not significantly more important than the crash risk in the human decision process.

A more fundamental problem exists. Using the traffic law system is basically a negative reinforcement strategy, one of increasing disutility of risky behavior. A significant body of psychological literature establishes that humans respond more effectively to positive than negative reinforcement. Alternative strategies for driver control, that rely more on incentives than disincentives, should be considered. There are limits on the use of the criminal sanction. General and unrestricted use of the legal system for all aspects of driver control is likely to exceed those limits. Alternatives to the classic operations of the traffic law system are needed. Since that system has been the primary risk-management strategy at the state and local level, alternative strategies are needed for highway safety in general, not just for legal system activity.

Figure 12 summarizes the major problems of communication within the highway safety process. The problems of describing the Highway Transportation System, improving decision-making within the system, and improving communication within the system, all stem from a lack of theory to focus action. They are direct products of the failure to use existing information and knowledge effectively.

**Needs.** A body of knowledge about the nature and effects of the highway safety process is of little use unless the knowledge is disseminated and understood by the components of the process. Effective means of accurately communicating information are thus a basic requirement for risk management.

Three specific needs are generated by this general requirement. First, it is necessary to determine the **nature** of information needed by each component of the highway safety process. In general, each component will need at least some of each type of information defined by the above

FIGURE 12

SUMMARY OF MAJOR PROBLEMS
IN COMMUNICATING WITHIN THE HIGHWAY SAFETY PROCESS

| Problem Area | Elements of the Highway Safety Process | | |
|---|---|---|---|
| | Highway Transportation System | Risk-Management System | Society |
| 1. Determination of what information is needed | Done on a formal or deliberate basis only for selected Highway Transportation System components. Not done systemwide. | Not done on a formal or deliberate basis for most risk-management systems. Greatest deficiency at local and state level of government. | Not done on a formal or deliberate basis except in conjunction with isolated public information and education "campaigns." |
| 2. Determination of the form and method of delivery of needed information | Done on a formal or deliberate basis only for selected Highway Transportation System components. Not done systemwide. | Not done on a formal or deliberate basis for most risk-management systems. Greatest deficiency at local and state levels of government. | Not done on a formal or deliberate basis except in conjunction with isolated public information and education "campaigns." |
| 3. Development and operation of continuing information programs | ● No formal programs except those for researchers and for individual organizations.<br>● No systemwide programs. | ● Appropriate information not provided to units of local and state governments.<br>● No systemwide programs. | Done only sporadically in support of specific programs. |

Source: Joscelyn and Jones (1978).

specific requirements, but the depth and scope of the information will vary greatly among components. For example, the information that traffic court judges need to identify the risk due to drunk driving is different from the information needed by an automobile designer. Both need to know about the magnitude of the risk associated with various blood alcohol concentrations: the designer needs more detailed and precise information about how alcohol affects vehicle-driver interactions and thereby increases crash risk; on the other hand, the traffic court judge needs a more in-depth explanation of the effects of a given treatment regimen for alcoholic drivers.

Individuals and organizations that are often not considered part of the highway safety process should also be provided information about highway safety and their role in it. For example, physicians should be aware that certain types of injuries are more likely to appear than other injuries and should be prepared to identify and treat those injuries when examining a crash victim.

Secondly, the appropriate **form and method of delivery** of the information must be determined for each component of the highway safety process. For example, the automobile designer might best be reached through technical reports and journal articles, while traffic court judges might respond better to an intensive seminar involving colleagues and other peers who have specialized knowledge about alcohol-related crashes and treatment methods for alcoholism. The mass media would be a better vehicle for informing segments of the general public about alcohol-crash risk and what responses risk-management systems will take to that risk.

Finally, continuing communications **programs** must be designed and implemented. The programs must provide needed information in effective form to all components of the highway safety process.

# CONCLUSIONS AND RECOMMENDATIONS

The prior sections contain many findings, suggestions, and conclusions as the natural work products of an analysis. Our purpose here is to present some of the more important conclusions and recommendations as a point of departure for colleagues, researchers and practitioners alike, who we hope will critically carry forth the development and application of highway safety theory.

## RECOMMENDED MANAGEMENT STRATEGIES

Society, through individuals and their institutions, attempts to manage risk-producing factors to reduce the frequency of hazards or disutility-producing events, and to minimize losses when hazards do occur. Through this process of risk management, society seeks to reduce risk to a tolerable level, at or below maximum tolerable disutility. How much disutility is tolerable is a complex balance between perceived utilities and perceived disutilities.

Our conceptual framework identified a set of public and private institutions of greater or lesser formality that practice risk management of a more deliberate basis than private citizens, or society as a whole. Some of these institutions are linked together by working arrangements to form discrete and identifiable risk-management systems, such as the Traffic Law System.

Formal risk-management systems—of which the Traffic Law System is one—attempts to reduce the disutility of the Highway Transportation System by exerting control forces on it. Control forces include, but are not limited to, legal system actions such as apprehending violators. The strength of these forces depends on whether society perceives that disutilities have exceeded the maximum tolerable level. Control forces operate under a fundamental constraint, namely that forces may not themselves generate more disutility than utility.

Strategies to reduce traffic crashes and associated losses should begin with an understanding of the factors that create the risk. Analysis of the factors involved in traffic crashes identify human factors as a definite, probable, or possible cause in over 90 percent of all traffic crashes (Treat et al. 1977). However, vehicle and environmental factors are significant in traffic crash causation, and vehicle- or environment-oriented countermeasures may be superior means of responding to some human behaviors. Hiett and associates (1975) developed initial definitions of unsafe driving actions, or UDAs, that are both observable and measurable, and that can be managed by appropriate legal or social strategies. Lohman and associates (1976) at the University of North Carolina attempted to assess the relative priority among the various UDAs in the context of their rate of involvement in crashes. These studies led to the identification of three UDAs—speeding, following too closely, and driving left of center—for more detailed examination. These were characterized as "priority UDAs" on account of their prevalence as traffic crash factors. Treat and associates (1980) at the University of Michigan continued the UDA analysis. They developed more rigorous definitions of UDAs based on nationwide data on crashes involving UDAs.

Our definition of a UDA requires an act resulting from conscious decision-making by the driver. That decision process encompasses a balancing of the perceived utilities and disutilities associated with committing the UDA. If the perceived utilities outweigh the perceived disutilities, the driver decides to commit the UDA. A driver's balancing process is not necessarily deliberate or even "rational" in the usual sense of the word. Also, the utilities and disutilities associated with a given act are not necessarily the same for all individuals. In deciding whether to commit an unsafe driving act, a driver's decision-making process is influenced by information on the outcomes of his or her past unsafe driving (such as whether a crash or traffic citation occurred), the outcomes of unsafe driving actions of other drivers (for example, seeing a driver stopped by a police officer) and risk-management actions taken prior to his or her unsafe driving act (such as the number of violation points on the driver's record).

Risk-management actions are directed at changing driver decisions from risk-taking to risk avoidance. These may be general or special. Special risk-management actions are those taken by society to discourage a driver from engaging in risky behavior in the future; the best known action is issuing the driver a traffic citation that the driver will remember later on. General risk-management actions are taken to discourage all drivers—whether or not they were the targets of special risk-mangement actions—from engaging in risky behavior; a good example of this is the "halo" effect a parked patrol vehicle has on traffic in its vicinity. Both special and general risk-management actions provide drivers additional information to use in deciding whether to commit an unsafe driving act.

Because a "go, no go" decision regarding an unsafe driving act is the product of balancing perceived utilities against perceived disutilities, driver decisions may be influenced by reducing the total utility of engaging in risky behavior (in which case it is termed a positive strategy) or by increasing the total disutility of the behavior (a negative strategy). Past approaches to highway safety have focused almost entirely on increasing the disutility of unsafe driving. This is because society's principal approach to managing the traffic crash has been to use the Traffic Law System. Operation of that system is based primarily on the legal principle of deterrence, or establishing a threat of punishment that is so certain, so severe, and so immediate that it discourages individuals from engaging in the prohibited conduct. Thus legal sanctions such as fines, violation points, license suspension or revocation, and even confinement to jail, are the predominant means of reducing the incidence of driving behavior that is likely to cause traffic crashes.

The threat of law system action is only one of a range of disutilities that a driver considers in making a decision whether to commit an unsafe driving act. There are many other disutilities that are not usually considered by risk managers in developing highway safety countermeasures. Applying basic concepts of decision-making and social control, we identified a series of general risk-management strategies directed against one specific unsafe behavior, namely speeding (Joscelyn and Jones 1981). Most of these did not rely on the Traffic Law System. Presuming that UDAs are the product of a conscious decision-making process in which the driver balances the perceived utilities and disutilities that are likely to result, we identified four broad strategies of controlling the risks posed by unsafe driving behavior. They are:

- Decrease the utility of driving unsafely,
- Increase the utility of driving safely,
- Increase the disutility of driving unsafely (the predominant strategy today), and
- Decrease the disutility of driving safely.

By "utility" and "disutility" are meant **perceived** utility and disutility, respectively. A driver who believes that the chances of being stopped for drunk driving are one in three will likely decide not to drive while impaired, even though the actual probability of apprehension is believed to lie somewhere between one in 200 and one in 2,000 (Jones and Joscelyn 1978). Changing a driver's perception of what consequences will likely follow a decision whether to drive safely can be as effective as—or even more effective than—changing the consequences themselves or their likelihood.

The first strategy calls for **decreasing the utility of committing an unsafe driving act.** The reduction must be large enough so that the net disutility of unsafe driving now exceeds that of its net utility, with the result that the driver changes from a "go" to a "no go" condition. For example, if a commercial trucker speeds to reduce travel time and is thereby rewarded with money or approval from his superiors, this strategy calls for reducing or eliminating the reward, such as ceasing to praise speeding employees or even changing the company's pay policies. Even if the **actual** decrease in the utility of speeding is small, information and education countermeasures can create in the driver the perception that the decrease in utility is large enough to create the desired effect, namely a decision not to speed.

The second strategy involves **increasing the utility of not**

**committing an unsafe driving act.** In effect, rewards are offered to those who drive safely, such as company bonuses for drivers with crash-free records. Again, the reward--actual or perceived--must be large enough to change a decision to drive unsafely to a decision to drive safely. Information and education are especially instrumental in changing perceptions regarding the increased utility of safe driving.

The third strategy, **increasing the disutility of committing an unsafe driving act,** is the classical negative approach to behavior modification and is the operating principle of the Traffic Law System. When this strategy is applied by the TLS, it is called deterrence. The punishment, or threat of punishment, for committing a prohibited unsafe driving act is a "surrogate" risk added to the inherent risks of speeding, disobeying traffic-control signals, and the like. Negative approaches do not have to rely on the Traffic Law System. Other risk-management systems have appeal because they are not bound by such constraints as fundamental rights guaranteed by the federal and state constitutions, and legal requirements of proof and procedure, the way the Traffic Law System is constrained. For example, insurance "systems" can impose punishments, in the form of rate increases, following an at-fault accident without following all of the legal formalities needed to find legal fault. Whatever system is relied on to apply punishments, both actual and perceived, can be used to influence driver decisions. Deterrence theory (and common sense) dictate that the negative approach will be most effective when both actual and perceived consequences are presented to the driver.

An example of the final strategy, **decreasing the disutility of not committing an unsafe driving act,** might involve the driver who believes she will be dismissed because of reporting late to work and who therefore attaches a high disutility to complying with the speed limit. Applying this strategy, a possible countermeasure might be to persuade the employer to find means other than firing tardy workers to encourage their punctuality.

Applying these four strategies, and relying on risk-management systems other than the Traffic Law System alone, we offered a number of countermeasures directed at the specific unsafe behavior of speeding.

These included:

- informing drivers that the time savings resulting from speeding are small, especially when compared to the possible costs of a crash or citation;
- encouraging drivers to report violators to governmental authorities or to corporate owners of offending vehicles;
- installing on-board equipment that would inform vehicle owners (such as parents or car rental companies) when vehicles were operated at high speeds;
- automated speed detection equipment, perhaps coupled with a scheme by which vehicle owners rather than drivers are penalized for speed offenses; and
- offering rewards to drivers and corporate fleets with exemplary records of compliance.

Other human-oriented countermeasures have been developed by Murdoch and Wilde (1980), who used a similar research approach.

In sum, then, risk management provides a useful set of tools for reducing the incidence of unsafe driving actions that cause traffic crashes. Our conceptual framework indicates that human-oriented strategies should be aimed at changing drivers' assessments of the perceived utilities and disutilities associated with a decision to engage in risky behavior. Most strategies today focus on increasing the disutility of committing an unsafe driving act, typically by imposing legal sanctions on drivers caught violating the law. Other strategies are available to change utility and disutility perceptions, and systems other than the Traffic Law System can be used to do so.

## RECOMMENDATIONS FOR RESEARCH

One of the most striking results of assessing research efforts against the conceptual framework presented here is how narrow research has been in the field of highway safety. Recommendations of past studies almost invariably suggest more research of the same nature and scope. Use of the conceptual framework shows that significant areas of the highway safety process have received only limited attention. The scope of past research has not been adequate. Thus it is important to broaden the **scope** of inquiry of highway safety research.

As part of this broadening of scope, consideration must also be given to developing a **balance.** Research has tended to concentrate on the highway environment and the vehicle. Only limited research attention has been given to the human component of the Highway Transportation System. Examination of past funding indicates, at a first look, that a relative balance has been maintained among the components of the Highway Transportation System. The funding for human-oriented research, however, has been heavily biased toward "demonstration programs" such as the Alcohol Safety Action Projects sponsored by the National Highway Traffic Safety Administration (NHTSA) rather than basic research. These programs have consumed significant funds with insignificant results. They cannot be viewed in the same context as past vehicle and highway research efforts. Thus, emphasis on human-oriented research should increase. Demonstration programs should follow developmental research projects, not preempt them.

A comment must be made as well on the **quality** of research. The present research funding process of NHTSA encourages low bidders and discourages researchers interested in addressing non-obvious but seminal problems. Typically, NHTSA conducts research procurement by competitive contract solicitation. Approximately four weeks are allowed from the announcement of a procurement, called a Request for Proposal, until the due date for the proposal. Some of the procurements have work statements that could cover research efforts ranging in magnitude from one to one hundred years of professional effort. This produces a bidding "jungle" and attracts the segment of the research industry that can afford to invest in proposal writing and discourages the research community that operates from universities or other non-profit organizations. The result has been a lack of continuity in many programs. Work started by one group is continued by a second. Lessons learned in the first effort must be relearned by the second group. Work products of extremely uneven quality have been produced and disseminated. If the conclusions fit the policy objectives of the moment, the research may be used to support action programs or defend past efforts. The relatively small research community in highway safety has made it difficult to obtain the type of critical comment that is common in broader research areas. Individuals are reluctant to openly criticize the NHTSA program and the work products of their colleagues because of the perceived consequences. It is very important for the future of highway safety research that quality control methods be developed and implemented.

Another area of concern is research **sponsorship.** Initial examination indicates that the vast majority of human-oriented highway safety research is sponsored by governments. At least 75 percent of the total funding in this area comes from federal sources. Private sector funding represents only a small portion of the whole--probably about ten percent. It is important to review present funding levels. When all factors are considered, the expenditure of additional funds for research in highway safety is justified and necessary. This suggests increased expenditures by both the public and private sectors.

The respective research roles of the public and private sectors should be examined. It is likely that under both present and future funding patterns the vast majority of research will be funded by the federal government. It then becomes very important to ensure that the policy issues of scope, balance, and quality are adequately addressed within the federal program.

This suggests that an important role for the private sector is to help ensure that these objectives are met. The private sector can be far more influential and effective by funding efforts to produce better quality federal research. The private sector should place greater emphasis on funding basic and applied research to develop policy directions for general highway safety research and on funding the evaluation of federal research programs to ensure that proper attention is given to scope, balance, and quality.

We suggest a series of general strategies for research that address the needs of better description of the highway safety process, improved decision-making within the process, and improved communication within the process. General research strategies include:

- **Develop an organized body of highway safety theory.** Such a framework will help organize existing knowledge, establish rules for decision-making, focus inquiry, provide a common way to communicate, and provide order and direction for risk-reduction actions.

- **Broaden the scope of highway safety research to include all aspects of the highway safety process.** It is necessary to address the full breadth of the highway safety process and consider all factors that create risk within the Highway Transportation System. Present research is too narrow and ignores significant areas, such as the role of societal perceptions of risk.

- **Broaden the nature of research activity to include all research relevant to reducing the crash risk.** An examination of past highway safety research reveals that very little basic or applied research related to human-oriented highway safety is being conducted.

- **Balance highway safety research to give attention to all priority areas of the highway safety process.** Human factors, despite having been identified as the major cause of crashes, have not been given the same attention as highway- and vehicle-oriented research emphasizing the crash phase. Highway crash countermeasures likewise stress the highway and vehicle. Human-oriented research should determine why people drive safely, or what utility drivers associate with committing unsafe driving acts. Alternatives to present negative approaches directed at the driver should be examined.

- **Make deliberate efforts to increase the quality of highway safety research.** A more flexible approach by sponsors, especially the National Highway Traffic Safety Administration, would lead to research designs that do not unnecessarily hamper the quality of highway safety research.

- **Make deliberate efforts to increase the usefulness and actual use of research findings.** Program decisions are often made without using available information, in part because it is difficult to gain access to past research that is not made widely available or is poorly indexed and stored.

- **Increase the level of effort devoted to highway safety research.** The losses due to highway crashes constitute a significant public health problem comparable to that presented by

> diseases to which large-scale efforts are directed. Efforts should be concentrated on increasing understanding of what produces crashes, increasing the use of technology to reduce crashes, and promoting public understanding of the magnitude of the highway crash problem.

It is not only important that priority areas and strategies in the highway safety field be addressed, but that the research proceed in a logical and organized fashion. Joscelyn and Jones (1978) presented four major program areas paralleling their conceptual approach to highway safety. These areas include the highway safety process in general as well as its respective elements: the Highway Transportation System, society, and risk-management systems. Within each of these program areas there are the specific topic areas, identified earlier in this paper, of description, decision-making, and communication, plus risk management as a whole. Thus a structured program of highway safety research might follow a four-by-four matrix. Specific projects addressing these sixteen research programs need to be systematically developed. Also, the programs themselves should be defined in more detail in a more in-depth program of "research on research." Finally, a set of priorities should be developed for specifying which programs and projects should be conducted, in what order, and in which time periods. Joscelyn and Jones (1978) made initial observations and insights about research priorities and related issues. Regarding priorities, the preceding discussion in this paper suggests three broad priority areas of near-term research in the field of highway safety: perception of risk and risk management; information utilization and technology transfer; and development of new risk-management approaches.

The first of these, **perception of risk and risk management,** is important because subjective perceptions about traffic crash risks and the value of risk-management appraches form both the basic constraints on, and the sustaining forces for, the highway safety process. How these perceptions are formed, how they change, and what factors influence perceptions are basically unknown. Until more objective perceptions can be developed, the highway safety process will likely follow the direction suggested by the most persuasive voice.

The second area, **information utilization and technology transfer,** is significant because studies have shown that the use of existing knowledge and technology in the field of highway safety is relatively low. This is particularly true at the local government level. The ways in which information is transmitted and used are now well known. The individuals who should be using research findings are not adequately identified. Methods for disseminating information, well known within the fields of education and communication science, have been applied only to a limited degree in highway safety. As critical as it is to expand the existing knowledge base, it is equally critical that existing, valid knowledge is used.

The third area, **developing new risk-management approaches,** flows from the observation that conventional risk-management systems, especially the Traffic Law System, are heavily relied on to manage the traffic crash risk. Existing risk-management approaches are primarily negative in nature, relying on the substitution of a present threat, such as a traffic arrest, for the more indefinite risk of a traffic crash. Consideration needs to be given to more positive approaches, such as reducing the benefits associated with risk-taking.

## RECOMMENDATIONS FOR ACTION

This paper has detailed the magnitude of the traffic crash risk, and has examined existing conceptual frameworks in the field of highway safety. It has described and illustrated a new conceptual framework, based upon this analysis and on a reexamination of the goals of the highway safety process.

The highway safety process is oriented to the control or management of risk. Therefore, conceptualization has involved describing the systems involved in this process. Prescriptively, the problem has been defined as one of improving the system's capacity to control risk, a problem that was pursued in the specific context of the formal organization of the risk-management system. This led to an examination of the critical role of knowledge and information, and the use of risk-management principles.

This paper raised and discussed highway safety issues, reached conclusions and made recommendations related to those issues. When used to examine past and current problems in highway safety, the conceptual framework was found to be useful in identifying research questions that need to be pursued. Nonetheless, this paper should be viewed primarily as a policy study. What follows is a limited set of top-level conclusions and accompanying recommendations that the authors believe are most important for immediate consideration.

- **Immediate emphasis should be placed upon in-depth consideration of the goals of highway safety.** The goals of highway safety are only valuely defined, and are not based upon a thorough analysis of highway safety processes.

  It is therefore recommended that well-defined mechanisms for the intensive analysis of goals be instituted. Not only should goal determination processes be encouraged at every level of risk management, but systemwide goal determination processes, emphasizing broad participation, should be undertaken.
- **A better specification and articulation of knowledge, information and action objectives is needed.** The goals of highway safety are frequently stated in terms of action objectives. What knowledge and information are required is seldom specified as an explicit objective and articulated with a particular program of action objectives. Effective action on complex safety problems requires effective generation and use of knowledge; therefore, an action system not only requires action objectives, but an articulated set of knowledge and information objectives.

  It is therefore recommended that major action objectives be thoroughly examined with respect to the implied knowledge and information requirements, and the necessary support—resources, time and willingness to create developmental and experimental exceptions to standard practices—must be provided.

• **Immediate emphasis should be placed on developing an organized body of theory of highway safety.** The lack of order, conflicting demands for resources, and absence of an organizing framework for decision-making evidence the need for a general theory and model. The conceptual framework presented here is a starting point, but much more must be done.

It is therefore recommended that formal programs, designed to develop theory, be started by the public and private institutions concerned with highway safety. Cooperation should be encouraged, but it is likely that the field will benefit from multiple as opposed to monolithic programs. The research community should lead in encouraging the start of a research program and in critically reviewing its progress.

• **Priority should be given to improving the use of existing knowledge about the traffic crash risk and methods for managing that risk.** Available evidence indicates that societal peceptions of the traffic crash risk are inaccurate. Traffic crashes appear to be viewed as less important than other societal risks that produce less loss. A more accurate perception of risk is likely to result in risk reduction and improvement of risk-management operations.

It is therefore recommended that formal programs be established at the federal, state, and local level to disseminate information on risk and risk management to decision-makers. It is not enough to simply transmit information; it must be transmitted in forms that help to assure that it is understood and thus applied to reduce risk.

• **Emphasis should be placed on understanding the role that human factors play in crash causation and crash losses. Risk-management strategies that effectively deal with these factors should receive priority attention.** Available information on the traffic crash risk indicates that human factors are predominant in traffic crash causation. These factors have received only limited attention in the last ten years—in the sense of rigorous systematic examination of risk, and development of risk-management responses.

Further identification of "human" risk may well result in risk-management strategies that focus on changes in the vehicle or highway environment or both.

It is therefore recommended that the responsible federal agency allocate significant resources for research on risk identification and development of risk-management strategies focused on the human factor. Funding efforts to establish a base for effective action should take priority over funding conventional demonstration programs.

- **The general concept of highway safety should be broadened and more disciplines encouraged to study problems of crashes and crash losses.** The conceptual framework identified many new areas that must be described and studied to elucidate the highway safety process. This inquiry should involve individuals from disciplines other than those traditionally involved in highway safety research or programs, such as decision theorists and social psychologists.

  It is therefore recommended that public and private institutions establish and fund programs designed to apply the best minds from a wide range of disciplines to an examination of crash risk and its reduction. In turn, the research and academic community should formally recognize, to a greater extent, the importance of managing the traffic crash risk. Understanding how the traffic crash risk is created, and how it can be managed, can lead to a broader understanding of how to manage risk in society.

This paper has been written to raise issues and stimulate discussion, and not necessarily to resolve questions or prescribe solutions. It is hoped that this work will contribute to some short-term solutions. More important, it is hoped that this will lead to development of a more vigorous conceptual framework that, in turn, will permit development of more effective ways of managing the risk of traffic crashes.

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