PRELIMINARY DRAFT
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MANAGEMENT OF THE TRAFFIC CRASH RISK:
A Conceptual Framework

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The contents of this report reflect the views of the authors. They are responsible for the accuracy of the facts and the data presented.

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FOREWORD

This paper has been prepared as part of a larger examination of past and future directions in highway safety sponsored by the Motor Vehicle Manufacturers Association under a grant of unrestricted funds to The University of Michigan's Highway Safety Research Institute. It has also evolved from work conducted under the sponsorship of the U. S. Department of Transportation in a study entitled "A Systems Analysis of the Traffic Law System," completed in 1972.

This paper was originally scheduled for release for review by our colleagues in the field of highway safety in early 1978. Current discussions on the future of highway safety now being conducted in the public and private sector(e.g., the Automobile Assessment Study conducted by the Office of Technology Assessment) have led us to release the document earlier than scheduled. We do so in the hope that some of the issues we raise will receive more scrutiny because of the current interest in the topic and that our conceptual approach will be strengthened by the comments of the readers.

Early release of this document has not allowed us to complete a rigorous internal review process. Thus, the paper exhibits stylistic flaws, and some of the discussions are not as complete as we expect the final version to present. We welcome suggestions for improvement of both the substance and presentation approach of the paper.

The paper is being circulated for comment within the highway safety research and policy communities. In light of the preliminary nature of the document and the probability that it will be

substantially revised may we ask that any use of the content, for other than review purposes, be discussed with us in advance of such use.

We thank the readers for their consideration.

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1.0 INTRODUCTION

The Highway Transportation System and the omnipresent automobile are as much a part of American life as apple pie. The societal mobility provided by the auto, as a personal transportation unit, has shaped our society for better and for worse. Along with the mobility that the auto has provided, auto use has resulted in death, personal injury, and property losses because of traffic crashes. These traffic crashes represent a societal risk that must be managed.

This paper examines general concepts and theories developed to explain traffic crashes and support efforts to reduce crashes and crash losses. We are concerned with the macro-theory that support the broad concept of highway safety, as opposed to micro-theories that explain some special aspect of the crash problem or a societal response. We are interested in identifying and examining the general explanations that link the micro-theories to provide direction for the highway safety effort.

This examination has been undertaken to develop a more systematic frame of reference for evaluation of past approaches and for development of future approaches to management of the traffic crash risk.

1.1 Background

This paper developed from a more general inquiry that is examining what has been done in the field of highway safety. The objectives of the inquiry are to develop recommendations for the direction of future programs and to identify the research necessary to support future highway safety efforts.

As a first step in this inquiry, a general literature review was undertaken. As the literature base was amassed, it became apparent that some conceptual scheme would be necessary to organize and synthesize past research findings and program activities. Thus, we focused on identifying existing theory to develop a conceptual framework for organizing existing knowledge and identifying gaps that should be addressed by further research.

While our search revealed many micro-theories (e.g., math models of vehicle dynamics) that follow generally accepted scientific practices to explain and describe specific aspects of highway safety, we did not find a well-developed body of literature describing a macro-theory of highway saftey. As we noted the absence of formally stated general theory, we became aware simultaneously of the general disorder of the field. In view of the function that theory performs for inquiry and action, such disorder might be viewed as predictable. Nonetheless, the magnitude of the disorder came as a surprise. We concluded that many inconsistencies could be explained by the lack of a general, formal, theoretical foundation for the field. If this conclusion is valid, it follows that unless a general conceptual framework is developed, the future is apt to be as disordered as the past.

It is appropriate here to discuss a moment the function that theory performs for a field of endeavor. Theory is a concern of the researcher and the academician, but it is not their province alone. Theory has significant implications for the practitioner and for the public. Theory has been spoken of as a map to guide both inquiry and action. Without theory, inquiry and action move blindly, inefficiently, and often ineffectively.

The basic function of theory is explanation. *A theory may be thought of as a generalization that explains statements or organizes those statements to provide explanation.* So the theories not only explain but usually also allow prediction.

Theories are not simply approaches for research or action. They are more than a framework for investigation. By positing relationships that can be verified or denied by empirical findings, theories provide an efficient means of advancing our understanding of the phenomena in question.

The broader understanding that flows from a macro-theory or a conceptual framework has significant practical import. The conceptual framework provides (1) a method of organizing existing knowledge; (2) principles and rules for making decisions; (3) a way to focus inquiry; (4) a common communication system, and (5) order and direction for activity. These are all needed in the field of highway safety.

We do not suggest that the field of highway safety is devoid of theory. Limited conceptual frameworks exist and are used. Macro-theories have been suggested in the past but are not in use today. What is lacking is a rigorous discussion of the theoretical underpinnings of the research and program efforts that form the field of highway safety today.

This paper has been developed to draw together the basic literature on highway safety theory, discuss its limitations, and raise for discussion a conceptual framework that may be useful in ordering present knowledge and suggesting future directions. The primary objective of this paper is to stimulate discussion of highway safety theory and its applications.

1.2 Scope and Approach

This paper has been deliberately limited to discussion of top-level concepts. Any attempt to deal inclusively with all issues of highway safety, assuming the task could be accomplished, would have produced an unworkable document. Therefore, this paper leads a reader through the major theoretical issues, and, at the same time provides some factual information on traffic crash risk and approaches for managing that risk.

The remainder of this paper is divided into three major parts. The first, which includes chapters 2 and 3, presents a summary of existing theories of highway safety and discusses their limitations.

The second part, chapters 4, 5, and 6, introduces a new theory and important related concepts. Chapter 4 presents a new conceptual framework for explanation and examination of the highway safety process. Chapters 5 and 6 present related theory and information from other fields. We believe an understanding of these concepts is necessary to improve the management of the traffic crash risk.

The third part discusses the application of the new framework and related theory to the problems of highway safety (chapter 7), and some implications for future research and action (chapter 8). Chapter 9 presents our conclusions and recommendations.

We must emphasize that this paper is presented in the context of discovery. It is intended to raise issues and stimulate discussion, and not necessarily to resolve questions or prescribe solutions. We hope that it may contribute to some short-term solutions, but, more important, we hope that it will produce more rigorous conceptual frameworks that, in turn, will permit development of more effective ways to manage the risk of traffic crashes.

2.0 HISTORY OF HIGHWAY SAFETY THEORY

This chapter presents brief descriptions of the major "theories" of highway safety that have appeared in the literature of the last fifty years.

The role of theory was discussed briefly in the introduction. Additional information is presented in the following section to emphasize the importance and relevance of theory for the field of highway safety.

Next, a review of the literature is presented. Many of the models and conceptual frameworks discussed were not presented by their authors as general theories of highway safety. They were offered to aid in the explanation of the traffic crash problem and to guide action to reduce crash losses. While they may not have been formally labeled "theory", they have performed that role for the field. Thus, we present and examine them as theory because they constitute the existing highway safety theory.

2.1 The Need for Theory

In any field, theory is necessary to provide a rational, consistent basis for analysis and action. In highway safety, theory is especially important because of the complexity of problems that touch almost every aspect of daily life and contain a bewildering array of interrelated economic, social, political, and technological factors.

When we examine the way in which highway safety programs develop, it appears that conventional wisdom prevails. Beliefs in the effectiveness of certain approaches are held too tenaciously from the perspective of experience or perhaps intuition. In many cases programs are continued simply because they seem reasonable. Unfortunately, reliance on experience and intuition, which appear to be the basis for conventional wisdom, has a predictable outcome. New ideas will "look" like old ones.

A rigorous application of theory can address many of the problems that arise from the application of conventional wisdom. First, the use of theory leads to a better understanding of the problem. This understanding provides more objective criteria for testing the reasonableness of proposed programs as well as suggesting new approaches and new ideas. The value of such a systematic or scientific approach is well established.

A fundamental use of theory is in organizing existing knowledge. With highway safety, this means knowledge about the causes, conditions, and consequences of crashes and about ways of dealing with the problems of crashes. Knowledge must be organized so that elements involved in the generation of crashes and crash losses are related to elements involved in the reduction of the frequency and severity of crashes. As will be seen later in this paper, past paradigms of highway safety have not combined these two categories of knowledge into a single, integrated conceptual framework.

A second role of theory is in generating principles and rules for making decisions. A practical theory provides a basis for deciding what actions should be taken to achieve desired results. This flows from the ability of a theory to explain and predict. In highway safety, a theory should help decide how best to deal with a given type of crash brought about by a particular set of circumstances under a specified set of conditions. In a similar sense, theory should provide guidelines for establishing priorities among problems and courses of action for resolving problems. Theory cannot be expected to provide a foolproof recipe for dealing with traffic crashes. It may be expected to provide a set of principles for efficiently developing detailed prescriptive measures.

Another important use of theory is in directing inquiry. A theory that is both problem-oriented and action-oriented assists in determining the information required to develop the knowledge base necessary for decision-making. It will suggest new areas of research and new programs. This focusing effect of theory makes both research and action more efficient.

Theory also helps by improving communication. It provides a common set of terms, definitions, and relationships. This allows researchers, practitioners, and policymakers to speak to each other and to other concerned individuals in a common language. There is a great need for improved communication in the field of highway safety. Existing knowledge must be effectively shared and a more common understanding of problems developed.

In summary, theory is essential to bring order into a field which at times appears to be almost hopelessly complex. Theory is a necessary requirement for action programs as well. Without adequate theory, one is reduced to shooting in the dark at an undefined target with an unknown weapon. With theory, one can productively direct activity toward established goals.

One other attribute of a good theory must be mentioned. A "good" theory provides for testing of its content. A good theory is dynamic. It promotes evolution, even when the testing process results in replacement of the theory with another. In contrast, a bad theory does not facilitate testing or rejection.

One could read the foregoing and conclude that nothing happens without theory. In a sense that is true. The problem is that things happen with "bad" theories--theories that have not been tested, that are not well founded, and that promote disorder and confusion. Highway safety activities have not stopped for lack of a body of sound theory. However, development and use of sound theory will significantly improve the direction and effectiveness of future efforts.

2.2 Formation of Highway Safety Theory

Although official concern over highway safety in the United States had been expressed since the early 1920s, not until the mid-1960s were attempts made to develop comprehensive theories for understanding and attacking the problem. Six National Conferences on Street and Highway Safety (in 1924, 1926, 1930, 1934, 1946, and 1949) had failed to produce even an adequate foundation for a nationwide program in Highway Safety (1), although some topics of major concern were identified and described. In reviewing the state of knowledge in the field circa 1952, the National Academy of Science's Highway Safety Research Correlation Conference (2) observed that despite a need for "large-scale research involving systematic study of interrelated variables," most research had been relatively small-scale efforts "to solve an immediate problem, or isolated studies carried on by individual investigators with relatively small resources to call upon." The report recommended several broad areas of driver-oriented research, but the areas were not comprehensive and no structure was presented for generating the integrated program called for. An additional stimulus for an organized attack on the problem resulted from a 1958 meeting of the President's Committee for Traffic Safety, but most of the recommendations followed a "shopping list" format and were not explicitly related to any overall strategy of research and action (3).

Meanwhile, highway crash losses continued to mount. By 1966, annual traffic deaths exceeded 53,000, (4) and the President requested Congress to initiate an "aggressive highway safety program" (1). The immediate response was in the form of two pieces of legislation, the Highway Safety Act of 1955 (P.L. 89-564) and the National Traffic and Motor Vehicle Act of 1966 (P.L. 89-563). The Acts created two federal agencies to administer a national program of highway safety. The agencies were first established within the Department of Commerce, but the Department of Transportation Act of 1966 (P.L. 89-670) redesigned the two agencies as bureaus and assigned them to the new Department of Transportation (DOT). In 1967 two bureaus were combined into a single National Highway Safety Bureau (NHSB) and placed under DOT's Federal Highway Administration (FHWA) where it remained until 1970. In 1970 NHSB was organized as the National Highway Traffic Safety Administration (NHTSA), a separate element of DOT.

This flurry of federal activity was accompanied and followed by a variety of separate efforts to "re-think" the entire problem of highway safety. In 1966 the Motor Vehicle Manufacturers Association (MVMA) sponsored the landmark "An Analysis of the State of the Art of Traffic Safety," by Arthur D. Little, Inc.(5). The automobile industry and the insurance industry established new programs of extramural research (6, 7), and the RAND Corporation was commissioned by NHSB to develop a comprehensive approach to highway safety (8). Numerous conferences were held to define future programs of research and action (10, 11).

As a result, several conceptual frameworks and theories of highway safety began to emerge. The first of these grew out of a simple classification scheme that had been implicitly accepted since the 1920s but had not been formally articulated until the late 1940s when the concept of highway safety as a public health problem began to gain support (12). Types of factors related to highway crashes were likened to types of factors considered in the epidemiologic approach to the control of diseases by actions against the host, the agent, and the environment. In the public health metaphor, the "disease" of highway crashes could be dealt with by measures aimed at the driver (the host), the vehicle (the agent), and the highway (the environment).

In 1966 Haddon and Brenner of NHTSA added another dimension to the public health conceptualization of highway safety, asserting that losses from highway crashes result from a sequence of three phases of interactions of the driver-vehicle-highway factors (13). The three phases were defined as the time period preceding the crash, the time period during the crash, and the time period following the crash. The categories of factors were generalized to include human, vehicle and equipment, and environment. Those were matched against the three phases to form a nine-cell matrix (Figure 2-1). This formulation was offered as a paradigm for highway safety in classifying present knowledge, research, or "countermeasures" to reduce crash losses (14).

While Haddon and Bremner were developing their framework in the 1960s, other researchers were recommending that highway safety adopt a "systems approach,"* a term that was not fully understood at the time and was often used as a synonym for "comprehensive." Frequently, these systems approaches were vague, incompletely stated, and oversimplified. Many of their originators were operations research specialists and engineers fresh out of the aerospace and defense sectors, and the tools of these professions were confidently offered as ready-made solutions to a largely analogous set of problems.

Arthur D. Little, Inc. (5, 15) advocated a systems analysis "methodology" that first focused on defining the objectives of highway safety, next considered alternative approaches to achieving those objectives, and then applied cost-effectiveness techniques to selecting preferred alternatives (See Figure 2-2). The selection of objectives was seen as the "simplest task," the major difficulty being the identification and selection of alternatives for achieving those objectives (the objective was stated to be a reduction in "a mix of fatalities, injuries, and property loss"). The immediate need was to "determine causes of crashes," and the resulting review

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* The Williamsburg Conference in 1958 (3) also recommended a "systems approach to traffic flow and driver behavior" but did not describe what was meant by the terms and did not present a conceptual framework for applying it.

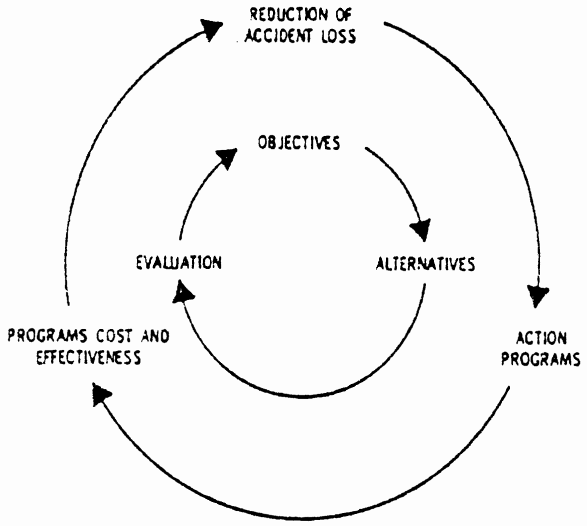
FIGURE 2-1: GENERALIZED VERSION OF THE HADDON-BRENNER MODEL

FACTORS

		Human	Vehicle and Equipment	Environment
	PreCrash			
PHASES	Crash			
	PostCrash			
	Results ⇨			

Source: Reference 14

FIGURE 2-2: ARTHUR D. LITTLE CONCEPTUAL FRAMEWORK FOR HIGHWAY SAFETY



Source: Reference 15

of crash causation research by Arthur D. Little (15) used the Haddon-Brenner scheme for classifying current knowledge about causal factors. An additional category ("Regulatory and Legal Factors") was used for classifying knowledge about methods of reducing crash losses.

As noted above, the National Highway Safety Bureau (NHSB) commissioned the RAND Corporation to perform a "preliminary study of highway safety measures." The results of the study were published in seven volumes in 1968. The first three volumes (16, 8, 9) were explicitly directed toward development of a "conceptual framework for a systems model." The framework ultimately developed in the study dealt principally with the events immediately surrounding a crash and was primarily concerned with the driver and his interactions with the vehicle (Figure 2-3). In the RAND framework, the sequence of events became the "Pre-Accident Stage," the "Intra-Accident Stage," and the "Post-Accident Stage," and each stage was broken down into smaller "phases." Although a variety of factors involved in the stages and phases were discussed, the factors were not explicitly categorized as human, vehicular, and environmental in the conceptual framework.

The most comprehensive of the theories and conceptual frameworks generated by the systems analysts of the mid-1960s were developed at The University of Michigan in the course of activities conducted to establish the Highway Safety Research Institute. In a 1967 report (6), Bonder focused on the nation's highway transportation <u>systems</u> and a hierarchy of its subsystems (e.g., the vehicle, the human operator, the highway, the casualty recovery facilities) and its <u>components</u> (e.g., such vehicular components as engines, transmissions, etc.). Highway safety was to be achieved through design, operation, and control of this system (Figure 2-4). The primary "control strategist" in the existing system was said to be the human operator who decided, for example, when to pass, how fast to travel, and how to avoid hazards.

A subsequent HSRI study for the Insurance Institute for Highway Safety (IIHS) described the Highway Transportation System (HTS) as

FIGURE 2-3: RAND CONCEPTUAL FRAMEWORK FOR HIGHWAY SAFETY

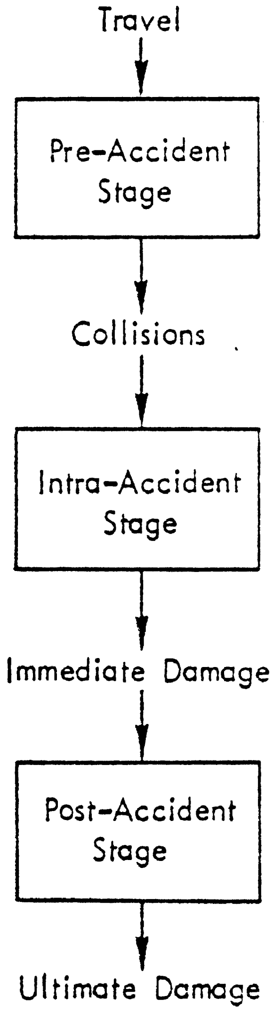


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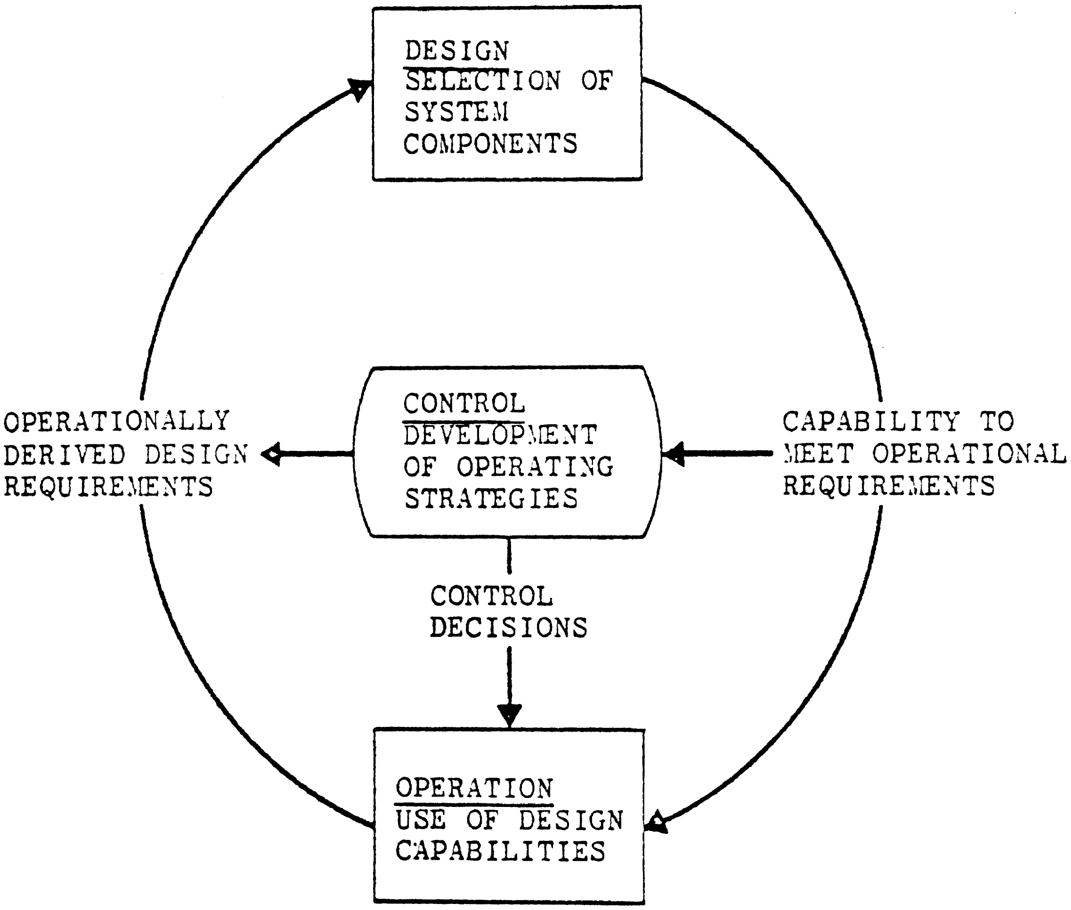
FIGURE 2-4: BONDER CONCEPTUAL FRAMEWORK FOR HIGHWAY SAFETY



Source: Reference 6

a complex of four interacting subsystems: drivers, vehicles, roads, and pedestrians (7). The phases were expanded from the precrash, crash, and postcrash trichotomy of Haddon-Brenner to (1) conditioning (preparation for normal functioning), (2) traffic (actual normal function of HTS elements), (3) accident initiation, (4) collision, and (5) post-accident. The HTS was then described in relation to its physical and social environment and to a "Highway Services System" which facilitates the use of the highways in emergencies and for purposes other than normal operations (Figure 2-5). A concurrent study by the Stanford Research Institute (17) produced a somewhat similar but less comprehensive and rigorous framework for highway safety (Figure 2-6).

No further large-scale conceptualizing was documented in the literature until 1972, when a NHTSA-sponsored study by Joscelyn and Jones presented a conceptual framework that viewed the problem of highway safety from a new perspective (18, 19). In essence, their formulation envisioned highway safety as a closed-loop control process which attempts to maintain the negative outputs (called "disutility") of the HTS at some level that will be tolerated by society (Figure 2-7). The framework treated the HTS in much the same way as earlier constructs, but added as areas of equal emphasis, (1) elements of society that must be influenced to reduce crash losses, and (2) elements that originate and apply measures to bring about loss reduction. Particular attention was given to the process by which crash risks to society were controlled, and terminology (e.g., "risk management") drawn from the new discipline of systems safety analysis (20) and from the insurance industry (21) was used in describing that process. Later papers by Wilde (22, 23) applied the framework in analyzing individual driver behavior vis-á-vis crashes.

At present, there is little evidence to indicate that any of the theories that are based on systems approaches have been widely

FIGURE 2-5: HSRI CONCEPTUAL FRAMEWORK

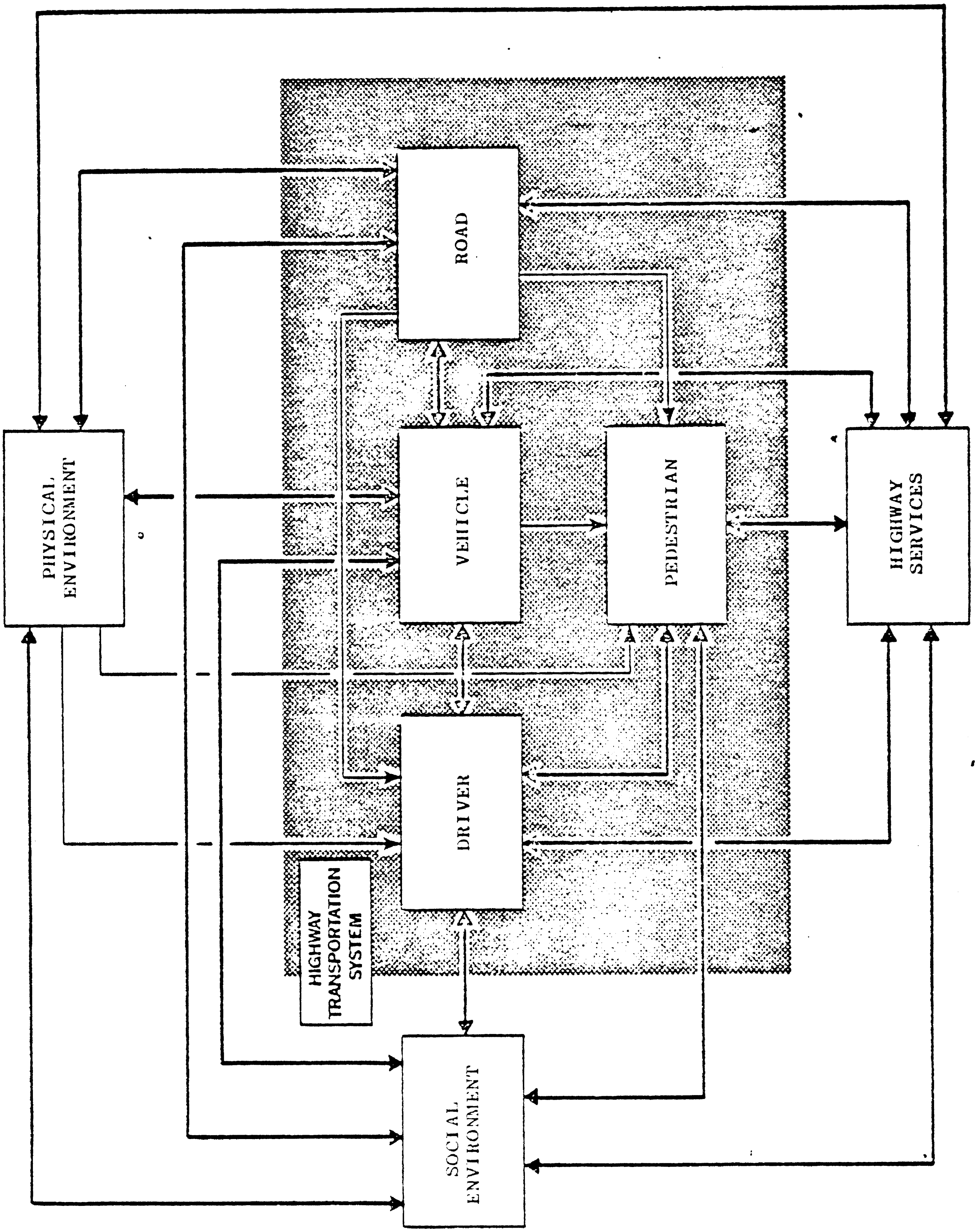


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FIGURE 2-6: SRI CONCEPTUAL FRAMEWORK

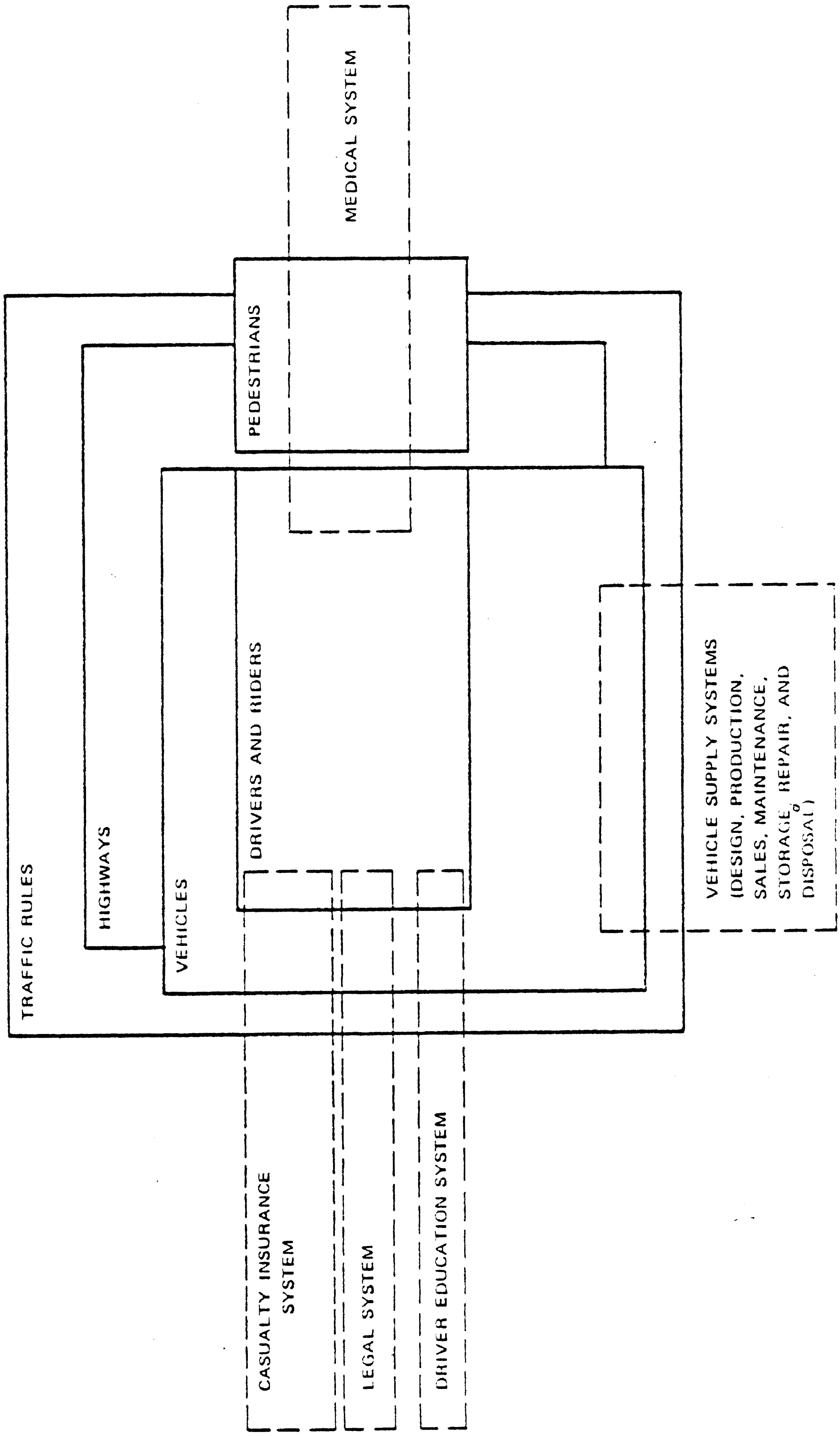

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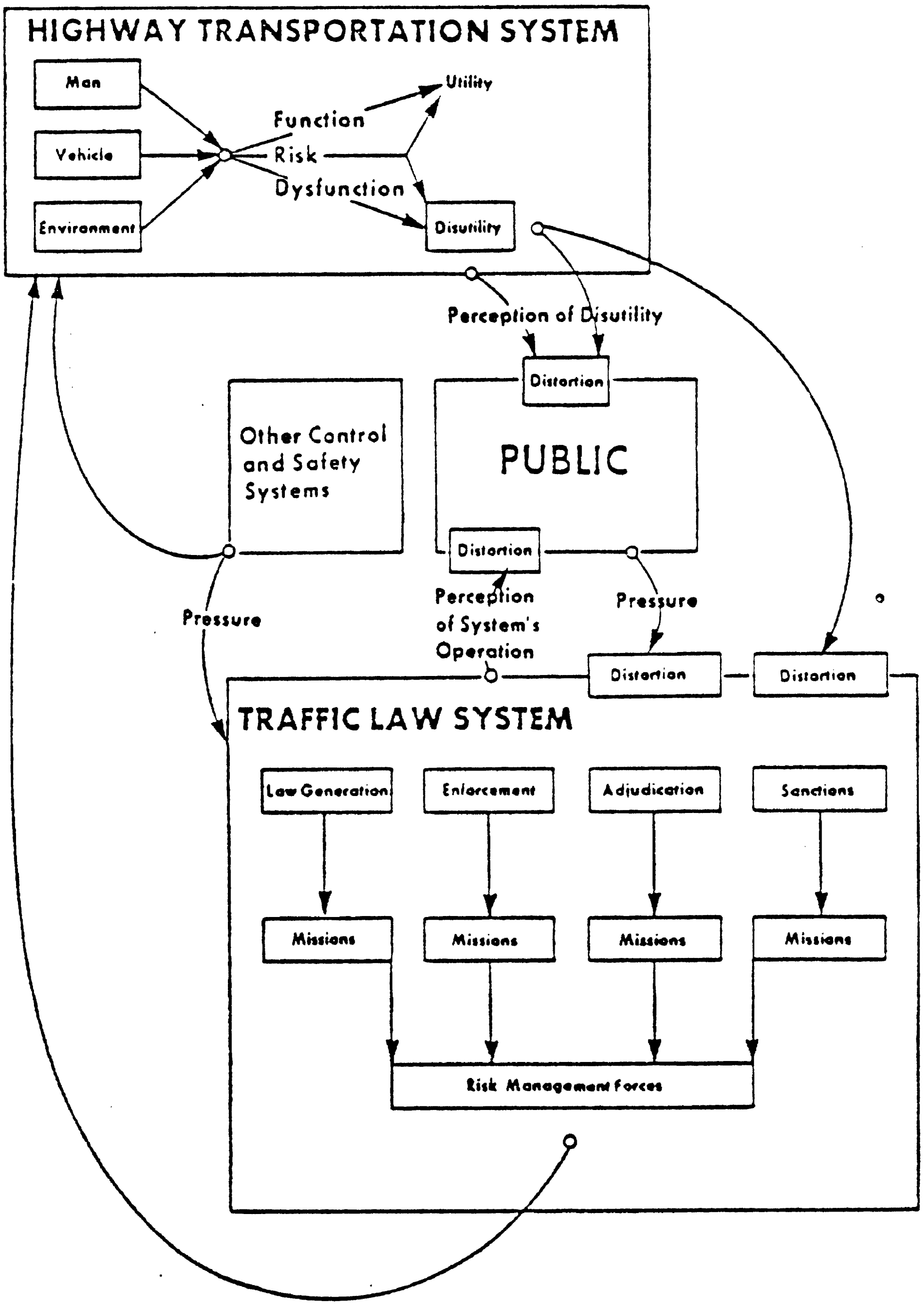
FIGURE 2-7: JOSCELYN-JONES CONCEPTUAL FRAMEWORK FOR ANALYZING THE TRAFFIC LAW SYSTEM



Source: Reference 18

adopted for planning highway safety research on a global scale. The Joscelyn and Jones model has been used in analyzing, designing, and supporting improvements to legal approaches to modifying driver behavior, but has not been widely applied to other areas of highway safety. Other constructs described above have been used in developing theories of crash causation and in developing data requirements for analyzing highway crashes. For the most part, the public health approach expounded by Haddon and associates has been accepted as the fundamental framework for analyzing highway safety problems and solutions.

2.3 Summary and Conclusions

In highway safety, theory is essential for organizing knowledge and bringing order into a very complex field. Particularly important is the need to relate knowledge about the nature of highway crash losses. Theory is needed for determining in advance how to make the right decisions about current responses to crash risks and for directing inquiry to improve future responses. Theory is also valuable for improving communications among individuals engaged in risk-reduction activities (e.g., researchers, legislators, police officers).

The history of highway safety indicates that there has been little effort to create a comprehensive theory of highway safety to meet these needs and that promising theories have either not been sufficiently developed for universal application or have not been widely accepted and applied. The Haddon-Brenner model, based on a public health approach, is currently the most commonly used theory or conceptual framework.

3.0 PROBLEMS WITH EXISTING THEORY

This chapter discusses the problems with existing theories from two perspectives. First, the conceptual limitations of the theories are examined. We look to see if the descriptions are complete, if known relationships are defined, and if an adequate explanation of how crashes are created and controlled is presented. The primary focus of this examination is on the structure of the model, conceptual framework, or theory--not its use.

Second, the consequences of using existing theory are examined. As the Haddon-Brenner model has been used almost exclusively in the past ten years, it is the focus of this discussion and criticism. The discussion is negative because we are discussing problems and there are problems that reliance on their model has created.

Two points must be considered to place this discussion in perspective. First, their model has contributed to the field of highway safety. Second, it fits the requirements of a "good" theory in that its structure has provided for its testing, its rejection and the development of new conceptual frameworks.

3.1 Limitations of Existing Theory

A review of the underlying principles of the conceptual frameworks and theories described in the literature reveals two major deficiencies.

- Existing theories concentrate on events closely associated with traffic crashes.
- Existing theories largely ignore interrelationships among factors that produce crashes, control forces that attempt to reduce crashes and crash loss, and society as a whole.

It is almost axiomatic that solution of a problem requires that the problem be adequately defined. Thus, the focus of most of the theories on the traffic crash problem is not inherently wrong. It is only when the focus becomes exclusive or so narrow that other important factors in managing crash risk are excluded from consideration that the conceptual base of the theories weaken. Unfortunately, this appears to be the case with most of the theories examined.

This situation is somewhat paradoxical, because the literature is replete with discussions of the importance of systematic consideration of all issues, with emphasis placed on the inclusion of "societal" aspects of the traffic crashes and their management. In 1949 Gordon (12) described "socioeconomic" factors as comprising a major component of the environment in which traffic crashes occur and "which come into play through association of man with his fellow man." Said Gordon:

> "Whatever the kind or nature of mass disease or injury, the part exerted by the socioeconomic environment probably is the most neglected of any epidemiologic influence, and accidents are not different in this respect from any other causes of damage."

The importance of the socioeconomic environment to safety was reemphasized in 1962 by McFarland and Moore (24) in another paper on the epidemiologic approach to accidents.

The Williamsburg Conference (3) was sufficiently concerned with the societal aspect of highway safety to designate it as one of three major areas for discussion (along with the systems approach and the psychology of driver behavior). The Conference recommended that the place of the automobile in American life, highway driving as a social activity, and use of the automobiles as an economic activity be major topics for future research. With respect to the last topic, the conference observed that:

> "An automobile trip by its very logic tends to differ from ordinary economic good in several respects--e.g., there are

> numerous external economics and diseconomics; consumer preferences interact; there is uncertainty, risk, and misperception of risk; there are other kinds of consumer ignorance. The usual market mechanism fails in this area to allocate the burden and to encourage the economizing of human life, time, and money. Research should aim at specifying an ideal solution and, once this is done, uncover the most profitable next steps public and private policy must take. The problem of the economics of traffic safety is akin to the economics of public health and public goods in general; for instance, schools, courts, defense, etc."

In 1967 Bonder (6) also recognized the need to include "social and legal factors" in a conceptual framework for highway safety, but assumed that these factors would be of primary importance only as they affected the behavior of the "vehicle controller" (i.e., the driver). However, Bonder stated that:

> "Later models must include the effect of social and legal factors on design characteristics of the vehicle and other subsystems and their effect on various aspects of the operations model."

The HSRI conceptual framework of 1967 (7) also included a niche for the "social environment," which was described as "aspects of the organizational system of society, as a whole, which influence the HTS." Highway safety "research gaps" in the area of the social environment were said to include knowledge about the effects of traffic laws, police enforcement, legal sanctions, driver education, driving regulations, and public information on the driver, and knowledge about the impact of social structures and values on the driver.

Despite these repeated expressions of concern for the societal aspects of traffic crashes and highway safety programs, the theory which appears to have dominated activity within the field for the last ten years fails to include these aspects explicitly. We refer to the public health approach that was articulated by Haddon and Brenner in an expanded form.

Their concept focuses on the crash problem. It is best suited for describing crash processes and for identifying targets for programs designed to control crash losses. If taken at face value, this theory implies that the crash problem as defined through application of the theory is something dealt with by some undefined external group or forces. These undefined forces somehow will be stimulated to the correct course of action once the nature of the problem is understood. The general domains of countermeasure design, implementation and evaluation are not explicitly treated by the theoretical framework. As it appears in the literature, this theory is the archetypal example of the second deficiency noted above.

Several other problems also exist with the theory as it has been set forth. It is difficult, in retrospect, to ascertain from the literature whether these problems arise from the underlying concepts of the theory or the way in which the concepts have been operationally stated or defined.

The first problem is the first deficiency noted above. The conceptual framework narrowly focuses on the crash problem. While one may carry a causal chain to absurdity, it seems clear that many events not immediately associated with the crash sequence (i.e., pre-crash, at crash, and post-crash) influence crash causation and consequent loss. The focus on the crash sequence, to the exclusion of more general examination of HTS operations, often has as its consequence too narrow closure. This results in loss of information important for risk reduction. For example, direct application of the theory would lead us to examine why people drove badly in situations that resulted in crashes but not why people drove well and avoided crashes. Our point is that the emphasis is on the problem to the exclusion of other information that may provide insights to the solution.

A second problem with the theory has its genesis in the way the theory is graphically presented. The 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. Apparently one must assume that people not involved in crashes and operating within the HTS are in a pre-crash state, post-crash state, or both. Given the relatively large number of people not involved in crashes compared to those who are, one must either conceive of the pre-crash and post-crash elements of the matrix as inordinately large in comparison to the at-crash elements (see Figure 3-1) or, alternatively, think of the HTS as containing a series of Haddon-Brenner matrices with drivers transitioning among them as a function of time (see Figure 3-2). Regardless of the construct, the problem is that the cells are not equal. One has much more time to implement preventive countermeasures in the pre-crash phase than in the at-crash or immediate post-crash phases.

The conceptual framework, as graphically presented, simplifies a very complex problem. The focus is on the crash and leads to the suggestion of countermeasures that equally focus on the crash. This is an error only to the extent that such a focus precludes other avenues of inquiry that might have greater effectiveness. One is reminded of the parable of the drunk and the lamppost. Even though the dime was lost in the alley the drunk preferred to look for it near the street lamp, where there was light. The primary impact of the Haddon-Brenner theory is to shine a bright light on one aspect of highway safety.

One can speculate on why this theory has been so widely accepted. The literature, in both theoretical discussions and operational applications, has used this conceptual framework almost to the exclusion of others. Those who follow the personality theory of policy analysis may point to the fact that Dr. Haddon, after a significant

Figure 3-1

EXPANDED H-B MODEL ILLUSTRATING ADDITIONAL TARGETS FOR CONTROL ACTION

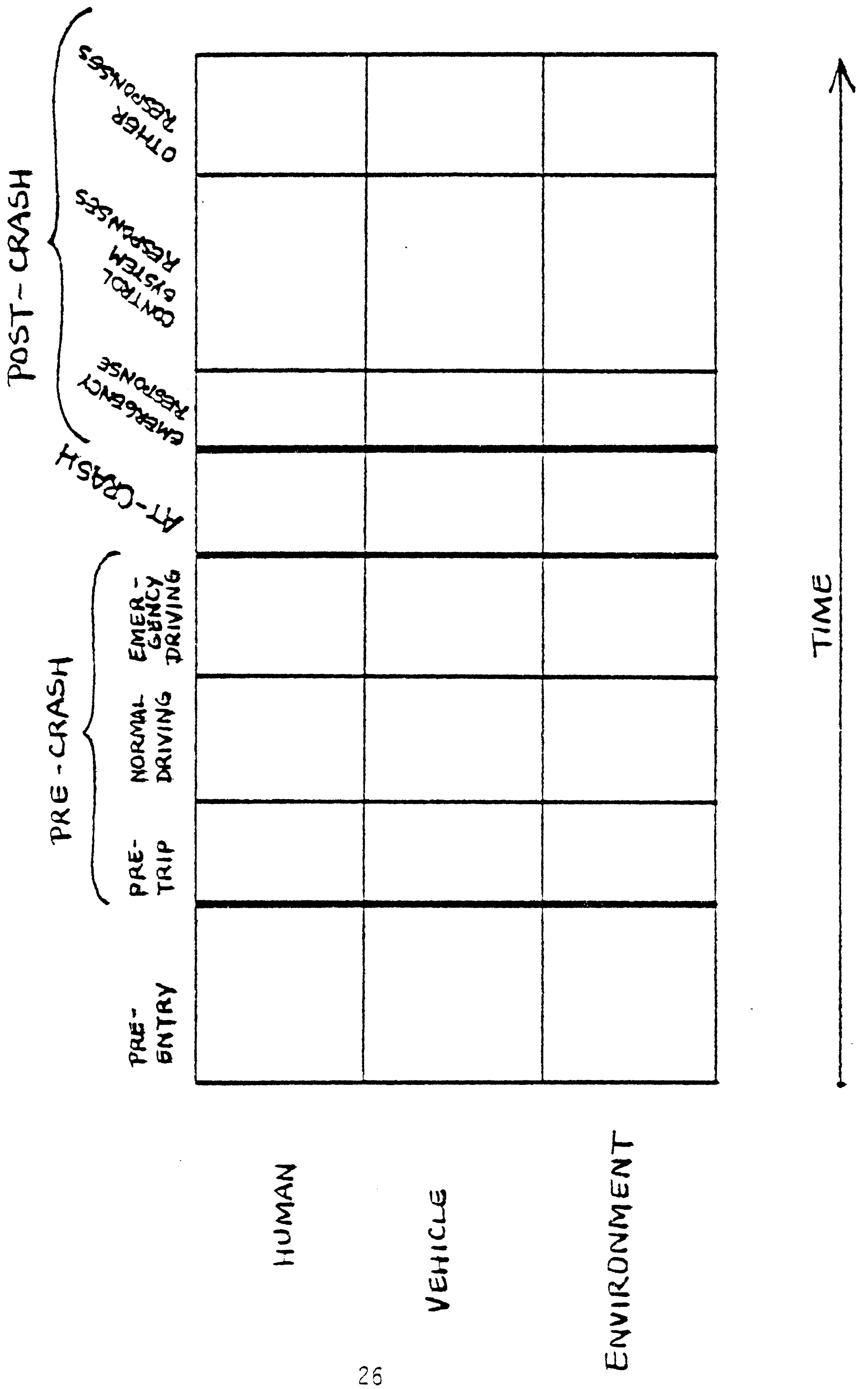
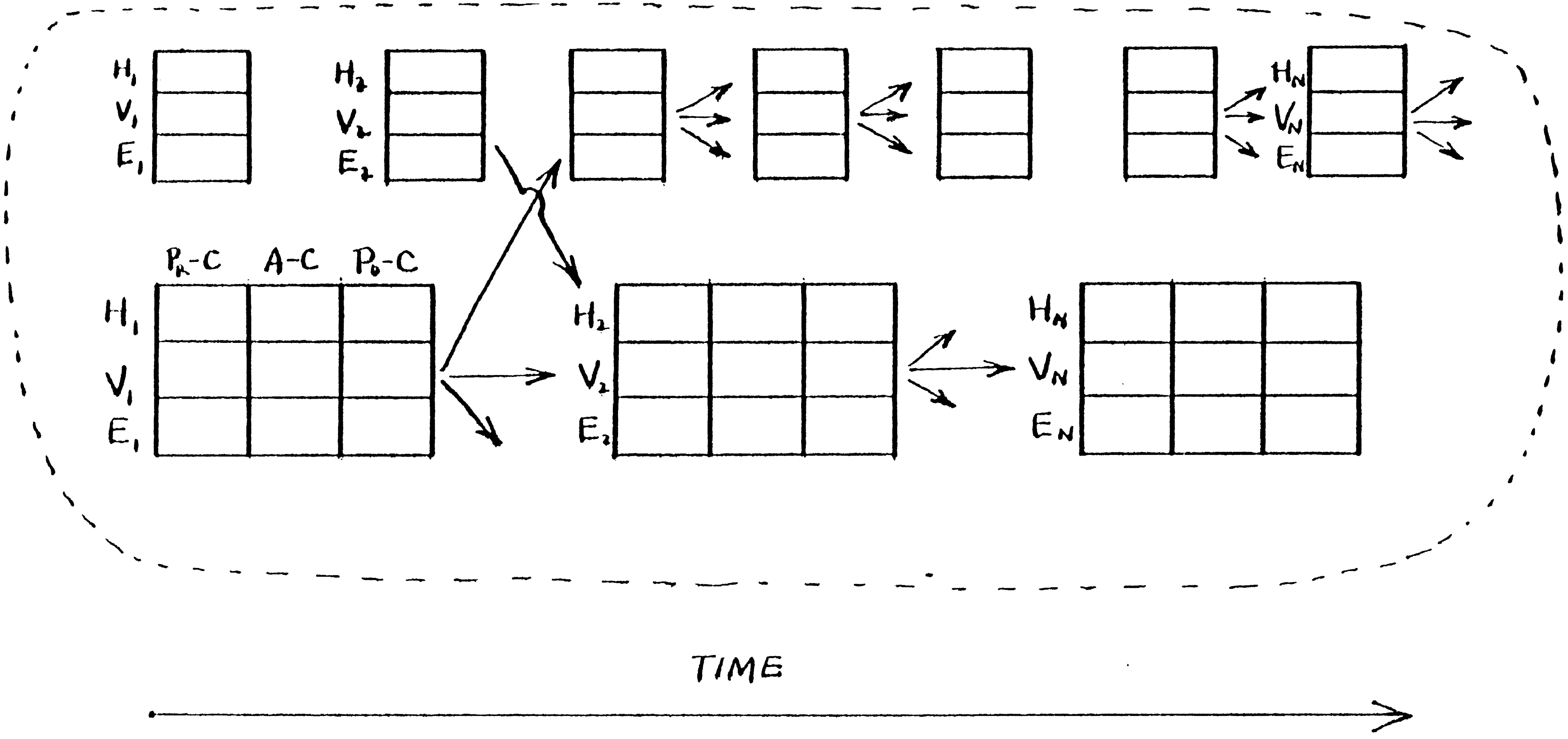


ILLUSTRATION OF NON-STATIC NATURE OF HTS DEMONSTRATING LIMITATIONS OF HADDON-BRENNER MODEL



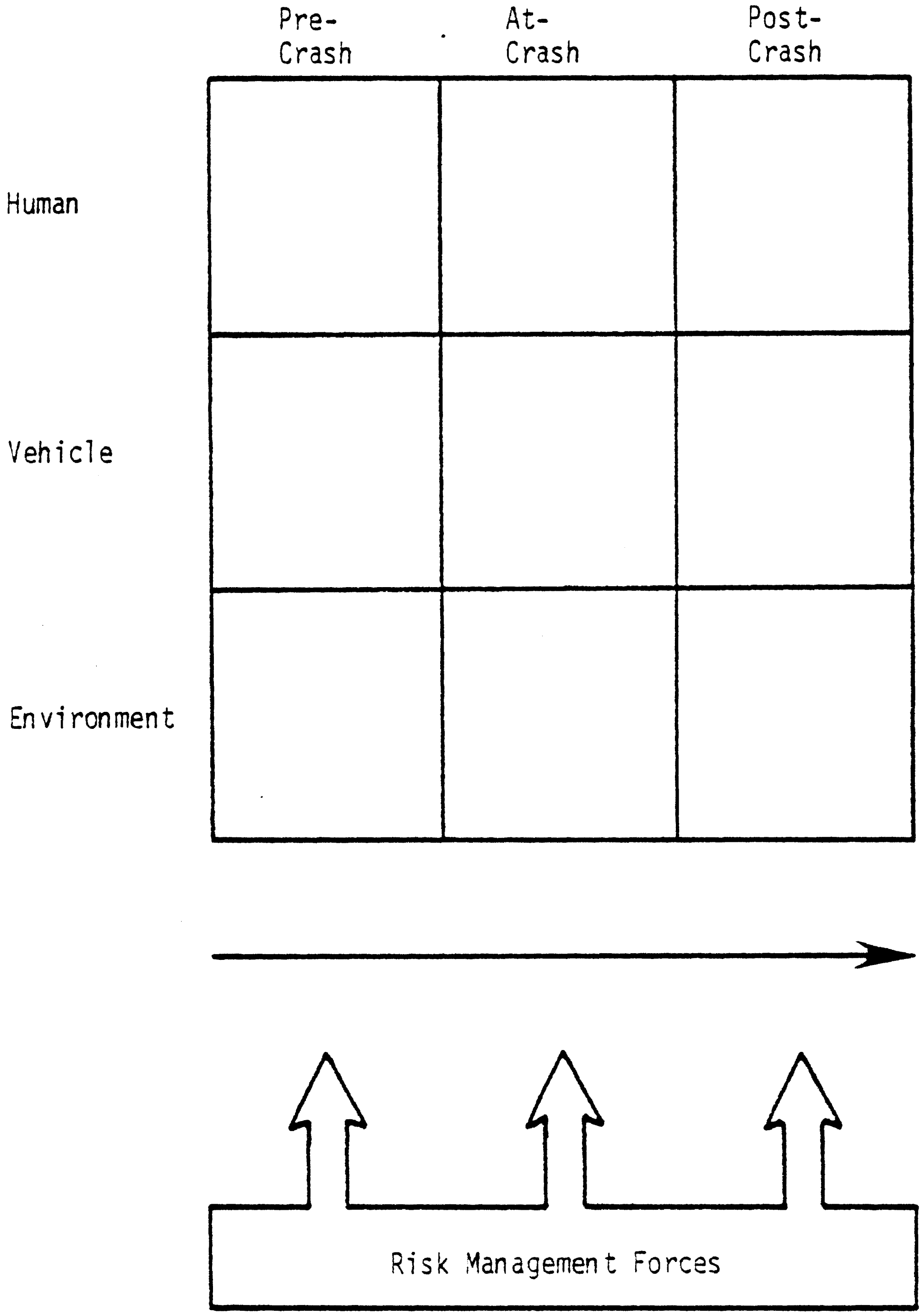
career as a researcher, became the first director of NHSB, where he was joined by Robert Brenner. The Haddon-Brenner model was frequently referenced in public presentations and could be viewed by observors as reflecting NHSB doctrine. It is probable that the position of Haddon and Brenner and the exposure the concept received promoted its widespread adoption. However, this was probably not the overriding reason for its acceptance. The theory was presented at a time when society generally perceived traffic crashes as a problem. Thus, a problem-oriented theory fit the mood of a society that was in a hurry to move forward with action programs. The theory also was comfortable for widespread elements of the highway safety community. Many of these individuals grew up with faith in the three E's (education, engineering, and enforcement) as the cure for traffic crashes. The Haddon-Brenner theory was compatible with these concepts and provided a convenient and more rigorous method of target selection. (In fact, one can simply expand the model by illustrating this target concept (see Figure 3-3)).

The theory was also expressed in familiar terms. It did not use the jargon of the "systems approach," nor were complex ill-defined relationships postulated and expressed in almost incomprehensible diagrams. It allowed conventional wisdom to proceed. In particular, it allowed free reign to those who believed that the traffic safety problem could be solved by more resources doing more of the same thing. Unfortunately, the theory did not provide explicitly for measurement of effectiveness, so that even though more was done the effect is largely unknown.

In a sense, the major limitation of this theory is that it is too simple. It provides too broad brush a treatment that is not sensitive to changes within society or interrelationships among elements of the highway transportation system. As noted previously, this appears to flow as much from the way the theory has been

Figure 3-3

Risk Management Forces and the 9-Cell Matrix



operationally expressed or defined as from the way in which the concept was originally conceived. It is clear that both Drs. Haddon and Brenner are scientists with a much broader view of society and highway safety than may be seen from their expression of this conceptual framework. It must also be remembered that the framework has been used operationally by thousands of individuals who have had no communication with the authors of the concept and do not have their background and experience in research or highway safety.

3.2 Consequences of Existing Theory

As discussed in the previous section, the macro-theory that has dominated policymaking for research and action programs in highway safety has been the Haddon-Brenner model. Several consequences of following this general theory appear to conflict with both logic and recommendations that appear in the highway safety literature.

The most general impact of following the theory has been to focus research and subsequent actions narrowly on the crash process and events that closely precede or follow the crash in time. Thus, one finds research describing the dynamics of crashes with significant emphasis on the at-crash phase and action programs concentrated on minimizing loss after crashes rather than preventing crashes. More limited examinations of pre-crash events (in the sense of traffic crash causation) and post-crash events have been undertaken.

In contrast, research on the general driving task has been limited. Perhaps more critical, research examining the complex relationships that create and support management systems intended to reduce crashes is extremely limited. Examination of traditional services such as enforcement, adjudication, and emergency medical services has been undertaken, but in highly traditional contexts. The research has, in general, not questioned standing goals but has focused on improving the efficiency of service delivery.

Action programs have also been narrowly developed. In general, they have tended to reflect extensions of pre-existing concepts (pre-1965). Control force relationships are presumed to exist. Emphasis has been placed on increased levels of effort and better management of service delivery, as opposed to questioning basic assumptions of either objectives or service delivery methods.

This does not suggest that all approaches that have been followed are wrong. What is suggested is that alternatives have not been explored adequately and the approaches followed have not been rigorously evaluated.

The research and action program record also reflects a strong tendency to concentrate on efforts expected to have an immediate impact on traffic crashes. There has been a tendency to look for solutions in the "light," as did the drunk looking for the lost dime. This may stem more from the basic human drives of policymakers, who seek to make an impact that can be realized during their tenure in office, than from careful application of sound highway safety theory. Theory should direct policymaking toward effective research and action programs. It should establish the unreasonableness of programs that are not well founded. The narrowness of the Haddon-Brenner theory has not provided this important function for policymakers.

It has been easier to focus on technological solutions (e.g., engineering changes) with emphasis on the vehicle and the highway rather than the driver. Unfortunately once this trend starts it is difficult to alter. The body of knowledge increases in areas that are the focus of study. New research areas are suggested and new programs started in those areas. Areas ignored do not advance. In fact, in comparative terms they recede. This is largely the case today with research and programs focused on the human factor. This human factor appears in a narrow sense in the form of individual driver behaviors and in a broader form in the societal and institutional responses to traffic crash risk. Rigorous, large-scale research programs examining these complex issues in a comprehensive structure do not exist. Action programs dealing with the human factor reflect a collage of conventional strategies focused on current targets of interest.

This lack of balance flows from the lack of an underlying body of theory that can frame the area of highway safety, describe the dimensions of the process, and establish a body of rules for decision-making.

It is both interesting and informative to reflect on the safety impact of the energy crisis, which produced reduced driving and lower travel speeds. The reduction in fatalities is dramatic evidence of the "human" factor. In contrast, technology has provided the lap-torso restraint, which has significant potential for injury reduction. Yet, it is not used by a large portion of the population. Our research does not tell us why this is or suggest how it may be changed. The solution of passive restraints, an example of looking in the light, bypasses basic concerns about the role of the human factor.

3.3 Summary and Conclusions

Existing highway safety theory concentrates on traffic crashes. This narrow focus is a major limitation. Factors that manage the crash risk are either excluded or inadequately treated. The roles of society in creating traffic crashes and reducing crash loses are largely ignored.

The most widely used theory, the Haddon-Brenner model, is useful for describing crash processes and for identifying targets for risk management action, but is inadequate for dealing with the interactions between the loss-generating elements of the Highway Transportation System and the elements of society that wish to reduce those losses.

Specifically, forces that provide motivation for individual or group action to create or reduce crash losses are not treated explicitly by this theory. This has resulted in the removal of many fundamental areas of concern from the mainstream of highway safety research and action. Clearly, a more comprehensive theory is needed to relate the elements of society that generate and are affected by crash losses.

4.0 A NEW CONCEPTUAL FRAMEWORK FOR HIGHWAY SAFETY

This chapter presents a new descriptive theory of highway safety. The theory is presented in the form of a conceptual framework describing the highway safety process. The framework develops the relationships between societal objectives for safety in highway transportation and functional means of achieving those objectives.

In preceding chapters we did not differentiate between the terms <u>theory</u>, <u>conceptual framework</u>, and <u>model</u>. We use the term <u>conceptual framework</u> to describe the new "theory" because it is not presented in sufficient detail to warrant its being called a model. The conceptual framework is useful for understanding the highway safety process. It is a step toward formal theory. We urge its examination in that context.

The conceptual framework has three basic elements:

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

The highway safety process entails interactions among those elements for purposes of reducing crashes and crash losses.

The following sections define the elements, their interrelationships, and fundamental constraints on the highway safety process.

4.1 The Highway Transportation System

The first element of our conceptual framework is the Highway Transportation System (HTS). We define the system to include the highway network, vehicles, system users, and supporting components. This definition of the HTS is essentially the same used in several other theoretical discussions of highway safety (6, 7, 17, 18, 19).

Figure 4-1 depicts the HTS. (This illustration and similar illustrations of other elements are later combined in a graphic representation of the conceptual framework--the highway safety process.)

HTS

- System Users
- Vehicles
- Highway Environment
- Support Components

The primary objectives of the HTS are to provide mobility with safety. Many secondary objectives also exist, such as providing recreation and pleasure for system users, providing a market for the automobile transportation industry, 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 of its constituent parts. In this sense, the system is defined in a broader context than in some prior theoretical frameworks.

The HTS was created and has grown in our society because it provides benefits for society in the course of performing its four top-level functions. The term "utility" describes all positive outputs of the HTS. These include individual mobility, rapid transportation of goods, and the social economic well-being that flows from the HTS operations. The HTS operations also produce negative outputs in the form of traffic crashes with associated deaths, injuries, and property losses. Other negative outputs include environmental degredation and depletion of natural resources. The term "disutility" is used to describe these negative outputs.*

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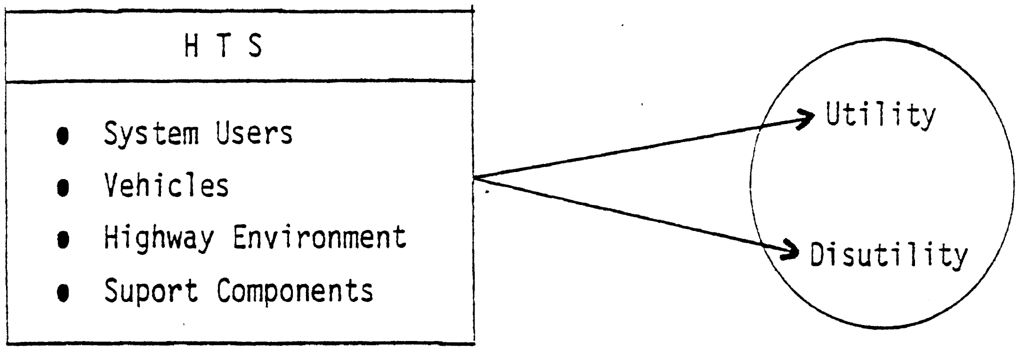
*Some disciplines consider "utility" as a term having both positive and negative values. In this sense, disutility is equated with negative utility.

Figure 4-2 illustrates the HTS and its outputs.



The concept of disutility may be operationally defined in a number of ways. In this discussion, we describe it as the negative output associated with a particular event (i.e., a traffic crash). Thus, from a highway safety perspective, we may describe traffic crash losses as disutilities. Society is concerned with minimizing the occurrence of events that produce disutility, and, if they occur, with minimizing the loss. This perspective requires that we think of future action about future events. We use the term risk to aid in thinking about future events that will produce loss. More explicitly, we define risk as a probability.

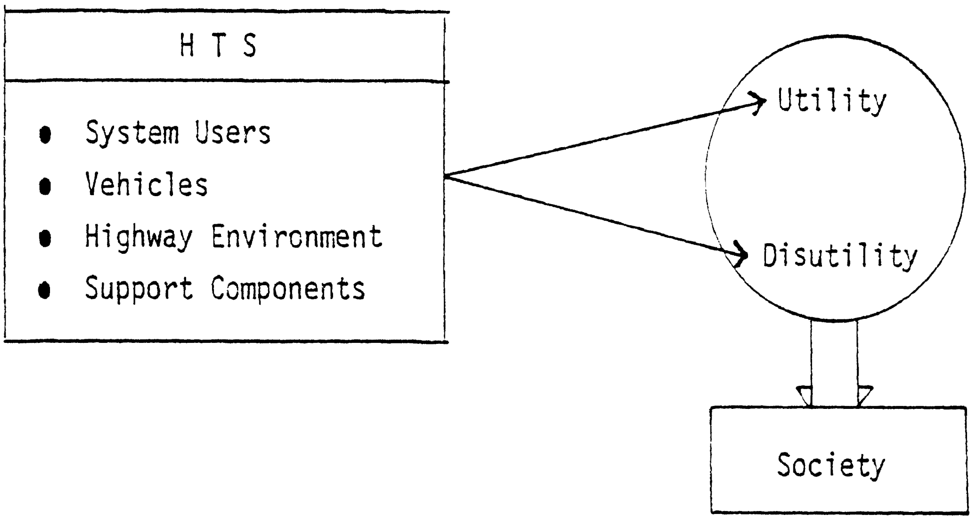
> Risk is the probability of the occurrence of an event that will produce disutility.

In the simplest highway safety context we could speak of the risk of a crash that would have associated with it some specific loss. Actually, we are concerned with a series of risks: the risk of a crash of a vehicle, the risk of an occupant impacting on the interior of the vehicle, the risk of additional loss because an injury does not receive prompt attention, etc.

The concepts of risk and disutility are important because they form the basis for societal concerns that lead to societal action.

4.2 Society

We identify society as the second major element within our conceptual framework. Society is broadly defined to include all individuals and institutions, both public and private, that have a role in making decisions about the operations of the Highway Transportation System. These decisions may be individual choices of a system user (e.g., a driver), public policy enacted by a legislative body, or decisions of other participants in the system. Society observes the operations of the HTS and the utility and disutility generated. This is illustrated in Figure 4-3.



If the magnitude of the disutility is large enough compared to the utility to evoke societal concern, formal actions are taken in an attempt to reduce the risk that creates the disutility. These risk-reduction actions are safety actions. In this context, it is useful to think of society as representing the market for highway safety.

In our earlier work on the Traffic Law System (18, 19) we suggested the concept of a level of disutility that would produce formal public responses. We defined this level as the <u>maximum tolerable disutility</u>. Disutility in excess of this level produces societal pressure for highway safety activity. As disutility increases above this maximum tolerable level the pressure for highway safety action increases. Conversely, as the level of disutility drops below the maximum tolerable level, societal concern decreases and support for highway safety also decreases.

When disutility is in excess of the maximum tolerable level, society creates and supports systems to reduce the risk. We call these entities risk-management systems.

4.3 Risk-Management Systems

The risk-management systems form the third element of our conceptual framework. These systems are formal and informal structures created by society to exert control forces on the Highway Transportation System to reduce risk. This is illustrated in Figure 4-4. (This illustration presents our conceptual framework in its most basic form.)

The risk-management systems actually do not seek to eliminate risk, although they may purport to. They operate to reduce risk to a level less than or equal to the maximum tolerable disutility .

These risk-management systems are very numerous and not well defined. They include formal systems (e.g., the Traffic Law System), parts of formal systems focused on broader aspects of society (e.g., the health care delivery systems), and less formalized systems (e.g., the media used for public information and education). Many societal influences (e.g., customs, ethics, mores, folkways, family structures, peer pressures, etc.) also exert control forces that have not been systematically defined. In fact, significant components of the risk-management element of the conceptual framework have not been formally defined or their effect established. There are, however, many references to their existence throughout the literature of highway safety and the more general literature on management of societal risks (e.g., crime, public health, defense, etc.).

Viewed in a broad perspective, the conceptual framework represents a process. The object of the process is to control disutility in a specific societal system, in this case the Highway Transportation System. The highway safety process is a disutility-control process.

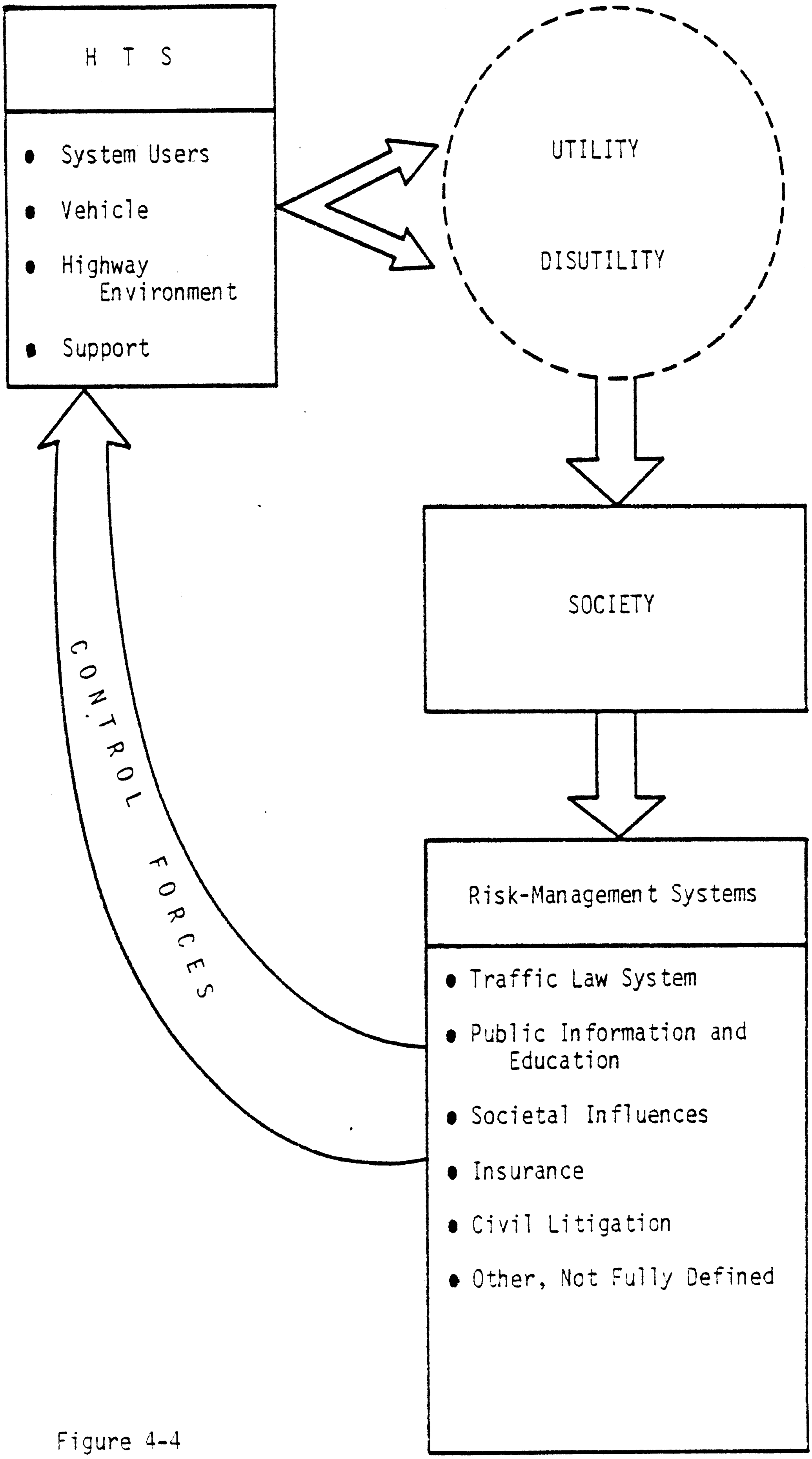

H T S
• System Users
• Vehicle
• Highway Environment
• Support
UTILITY
DISUTILITY
SOCIETY
Risk-Management Systems
• Traffic Law System
• Public Information and Education
• Societal Influences
• Insurance
• Civil Litigation
• Other, Not Fully Defined
CONTROL FORCES

Figure 4-4

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.

An analogy can be made between the highway safety process and closed-loop control systems used to regulate physical systems. In both cases, the objective is to maintain the output of the regulated system within specified tolerances or, stated in another way, to reduce the difference between the desired output and the actual output (i.e., the system error) to zero. Signals that measure the system error are sent to a control system that generates control forces that are applied to the prime system to reduce the error. The control forces increase in magnitude as the magnitude of system error increases. Continuous measurement of error and the control forces provides information for adjusting the strength of the control forces to reduce the error. In physical systems, the continuous monitoring and adjustment eventually reduce the error to some insignificant amount near zero and the system is said to be in equilibrium.

In the Highway Safety Process (HSP), society serves as the monitoring device, measuring both the system error and the strength of the control forces. The error is the excess of disutility over utility. In this sense, our term <u>maximum tolerable disutility</u> must be thought of as a <u>net</u> term reflecting the outcome of the societal balancing of utility and disutility generated by HTS oeprations. The strength of the control forces is a function of the operations of the risk-management systems. Society in monitoring these operations also balances the positive and negative benefits. Society will not tolerate a risk-management activity that produces more negative benefits than positive. The cure that is worse than the illness will not be tolerated. The monitoring function is shown on an expanded version of the basic conceptual framework (see Figure 4-5) by arrows indicating the information flow paths. The information is used to make decisions about risk and risk management.

Thus, the crucial role that society plays within the highway safety process can be seen as a fundamental limitation of the process.

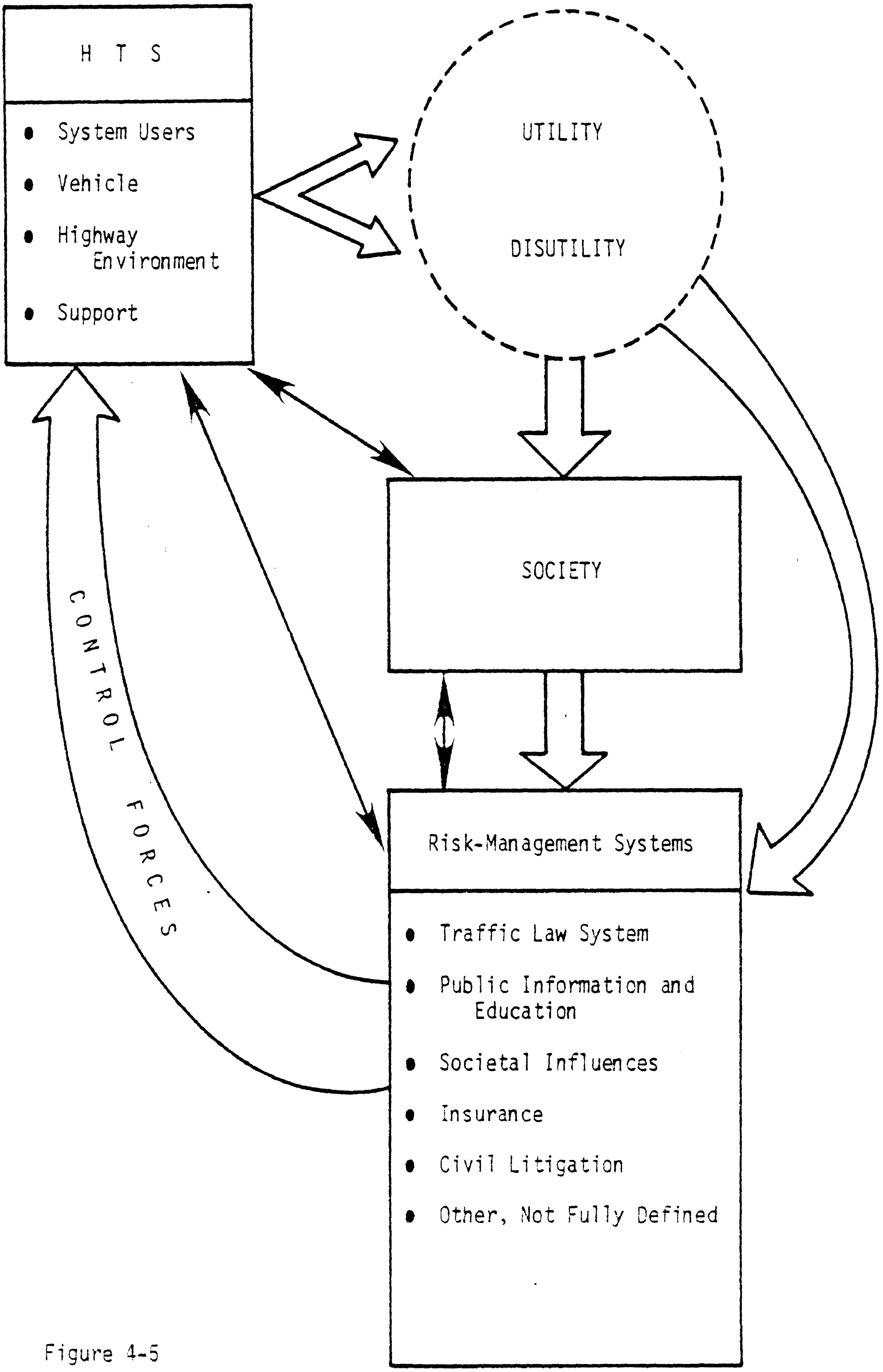

H T S
System Users
Vehicle
Highway Environment
Support
UTILITY
DISUTILITY
SOCIETY
CONTROL FORCES
Risk-Management Systems
Traffic Law System
Public Information and Education
Societal Influences
Insurance
Civil Litigation
Other, Not Fully Defined

Figure 4-5

This fundamental limitation has its foundation in two basic contraints: (1) perception of risk and risk-management operations; (2) information on risk and risk-management operations. These constraints are interrelated; perception is a function of information, but it also has quite independent attributes. These constraints are discussed in the following section.

4.4 Fundamental Constraints on the Highway Safety Process

In the preceding section the role that society plays in monitoring net disutility and control force strengths was noted. The discussion was in absolute terms, as if the actual values of disutility and the control forces were known and used by society in decision-making. It is evident that the actual values of disutility and the nature and effects of the risk management operations are not known. This information is not available today in the quantity or quality necessary to support informed decision-making. The lack of information does not invalidate the conceptual framework.

The highway safety process can operate optimally only if perfect risk-management information is communicated to each of its elements and components. Perfect risk-management information is complete and accurate information on (1) the structure, components, functions, inputs, and outputs of the highway safety process, and (2) the factors and processes that govern decision-making within the highway safety process. The term communicated, in the sense the word is used above, is a concept that implies not only accurate transmission but also accurate reception of the required information. We emphasize that accurate reception must include accurate understanding.

It is this last element, understanding, that forms a major portion of another fundamental constraint on the highway safety process-societal perceptions. 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. Thus, society acts on the basis of perceived disutility, perceived risk, perceived benefits and disbenefits of risk management, rather than on the basis of actual values. The societal perceptions are formed as a result of a complex shaping of individual perceptions. The perception formation process is ill-defined and ill-understood. Available evidence suggests that a <u>perception gap</u> exists (18, 25, 27). Perceived risk appears to be lower than actual risk, but this is not clearly established. It is clear that perceptions of risk and of the value of risk-management action govern the highway safety process. Thus, in a theoretical sense of optimizing the process, one would seek to reduce the perception gap to zero so that perceived risk equalled actual risk.

In the real world one cannot realistically expect to reduce the perception gap to zero. First, it is doubtful that information will ever be available in sufficient detail to accurately establish actual risk in every case.

Second, the process of risk perception is highly complex and varies greatly from individual to individual. When we speak of perceived risk or maximum tolerable disutility we speak of individual values combined in a societal position. At any point in time those individual values represent a distribution, or many distributions. Individuals vary not only in how they perceive risk but in how much risk is acceptable. Risk is not a single item in this context but many. Individuals are likely to hold quite different perceptions about different risks and what ought to be done about them.

Third, all the perceptions change with time. The perception of risk is a dynamic and not a static process. These changing perceptions affect societal acceptance of risk management practices.

The objective, then, is to attempt to narrow perception gaps as much as possible.

If perception gaps were narrowed, society as a market force would appropriately determine the level of safety desired. A maximum tolerable disutility (net disutility) with a corresponding risk value could be established. In turn, the nature and extent of risk-management operations required to reach that risk level could be defined. Safety measures beyond that point would not be supported. In fact, personal risk-taking might increase the level of risk to the tolerable level if it were artificially depressed. This concept has been suggested by Wilde (22, 23) as it relates to individual risk behaviors and by Peltzman (34) in a broader societal context. Peltzman in effect argues that, currently, the level of risk is equal to that which is tolerable, and that this explains the lack of success of recent efforts to reduce HTS risk. The mathematical methods Peltzman used to support this hypothesis have been severely criticized (35). Some data tend to support his hypothesis that risk equilibrium has been reached. For example, one indicator of HTS risk, fatal crashes per 100,000 of population, has remained at a fairly constant level for the past fifty years (see Figure 4-6).

While his hypothesis may be supported, its basic validity rests on the accuracy of societal perception of risk. If the present perception of risk is lower than the actual risk and can be altered to a value nearer to the actual value, it would follow, from our conceptual framework, that society would support increased control action and engage in personal risk avoidance until an equilibrium state with lower disutility was reached consistent with the new perception of risk.

Thus, the importance of societal perceptions of risk and risk management can be seen. These perceptions form fundamental constraints on the highway safety process.

Despite the ease in stating this proposition, the concept is difficult to adopt in practice, if we can accept the validity of past experience. Societal perceptions were either ignored or mis-read in the development and promulgation of regulations requiring the seatbelt-ignition interlock system (28). As a result, Congress, presumably reflecting the public perception of the negative value of this

Figure 4-6

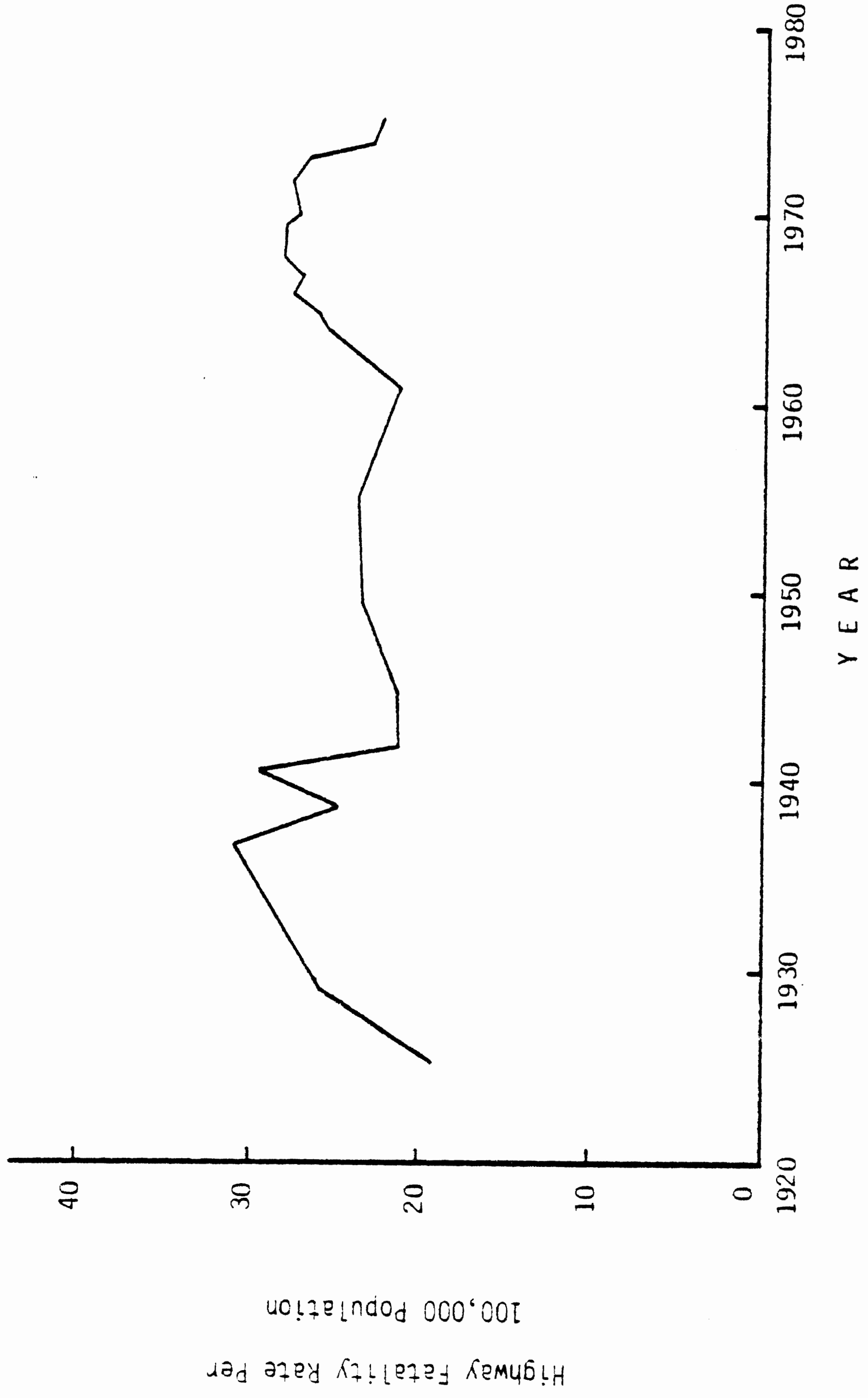


Figure 4-6: Highway Fatality Rate Per 100,000 Population

1925 - 1975

risk-management strategy, overruled the Secretary of Transportation and rescinded the requirement. Similar public resistence has been noted in the case of "get tough" traffic law enforcement campaigns (29). Societal perceptions must be considered in design and development of risk-management strategies.

Perceptions flow from information but are modified or altered by biases inherent in the receiver or the sender. The Highway Safety Control process is a complex of information transmission and reception networks. Many social mechanisms act as filters serving to attenuate or suppress the actual information being transmitted. These same mechanisms also generate spurious information or false signals which also affect perceptions. At every linkage, communication is inhibited by "noise" which masks the content of information being transmitted. This "noise" is a basic constraint on communication of information and formation of accurate perceptions. It limits the highway safety process. These filtering mechanisms are incorporated in Figure 4-7 to reflect a more complete representation of our conceptual framework.

The critical need for accurate information, accurate societal perceptions, and elimination of "noise" within the communication systems must be understood if the highway safety process is to be improved.

4.5 Highway Safety Principles

The following principles are basic statements that summarize and explain the highway safety process described in the conceptual framework:

1. The Highway Safety Process is the process society uses to control disutility within the Highway Transportation System to produce a state of equilibrium.
2. The Highway Transportation System is in a state of equilibrium when its operations produce a level of disutility equal to or less than a maximum tolerable disutility.
3. Maximum tolerable disutility is the maximum net HTS disutility acceptable to society. Society determines this limit by balancing the utilities and disutilities resulting from HTS operations.

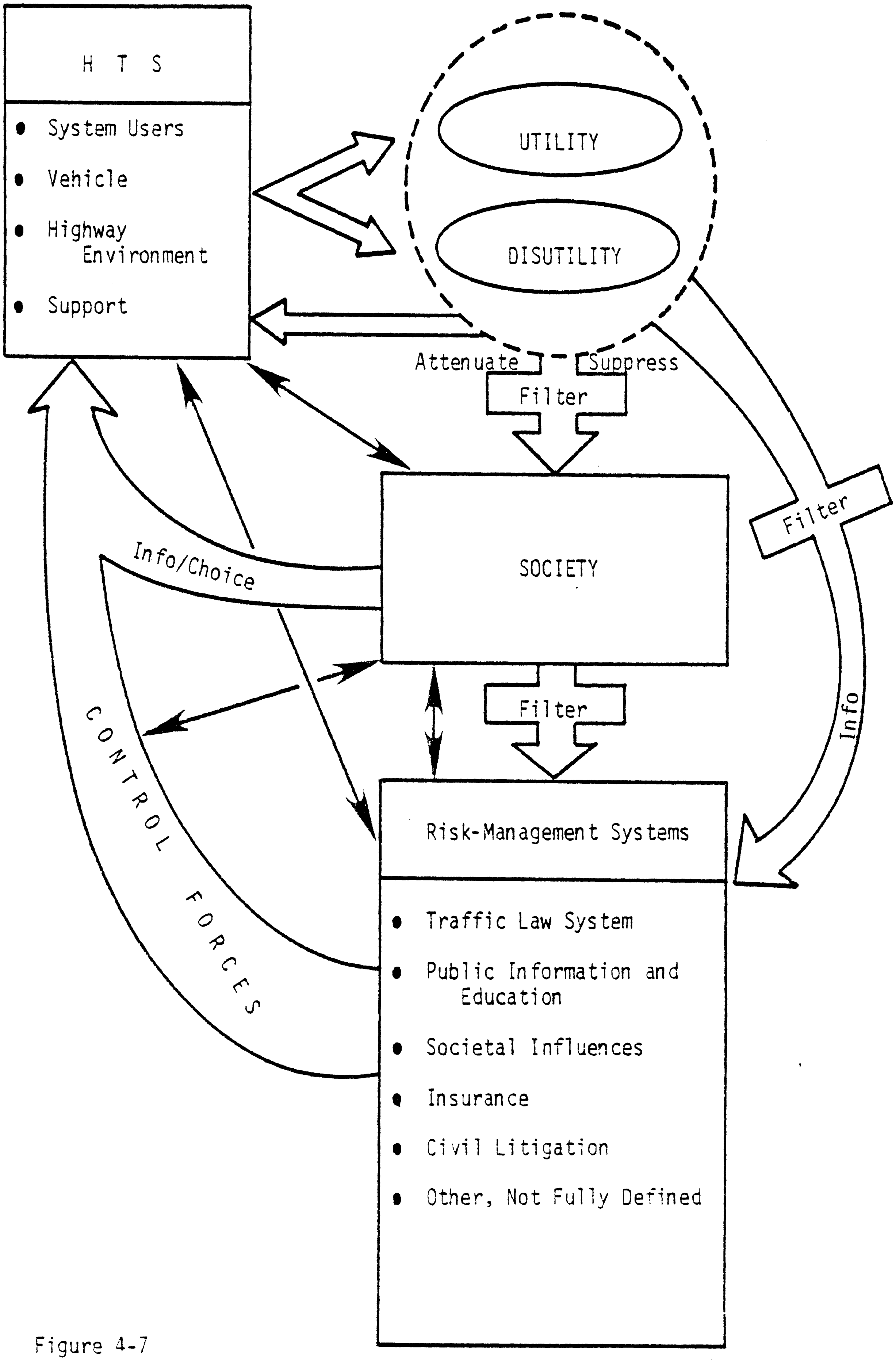

H T S
System Users
Vehicle
Highway Environment
Support
UTILITY
DISUTILITY
Attenuate
Suppress
Filter
SOCIETY
Info/Choice
Filter
Info
Filter
CONTROL FORCES
Risk-Management Systems
Traffic Law System
Public Information and Education
Societal Influences
Insurance
Civil Litigation
Other, Not Fully Defined

Figure 4-7

4. The highway safety process is limited by the quantity and quality of information available for decision-making and the perceptions of society about risk and risk-management system operations.

5. Risk is the probability of occurrence of an event (e.g., a traffic crash) that will produce disutility (e.g., death, injury, property loss, etc.).

6. Risk-Management Systems are formal and informal mechanisms created by society to exert control forces on the HTS to reduce disutility to a tolerable level.

7. Society's demand for and support of risk-management activities increases as (1) the perception of magnitude of risk increases (i.e., perception of the excess of disutility above the tolerable level) and (2) the perception of the net benefits of risk-management operations increases.

8. Society will not demand or support risk-management system action if the Highway Transportation System is perceived to be in equilibrium (i.e., perceived net disutility is less than or equal to maximum tolerable disutility).

4.6 Summary and Conclusions

A conceptual framework that describes the highway safety process as one of society's disutility control processes has been introduced. The framework includes three major elements: the Highway Transportation System, Society, and the Risk-Management Systems. The risk-management systems generate control forces to reduce risk within the Highway Transportation System. The nature and extent of control forces depends upon society's perceptions of (1) risks and associated net disutilities and (2) net benefits of the risk-management actions. Society will support risk-management actions if risk exceeds a level society views as tolerable, and if society believes the control actions of the risk-management systems are appropriate. Society decides how much safety is enough by balancing these equities. The balancing is critically dependent upon the quality and quantity of information that describes risks and operations of the risk-management systems. The way in which society forms perceptions from this information is also critical, because it is the perceptions rather than facts that govern societal decision-making.

5.0 THE IMPORTANCE OF UNDERSTANDING HOW PEOPLE MAKE DECISIONS ABOUT RISK

The development of the conceptual framework in the preceding chapter highlighted the critical role that individual and group decisions play in the highway safety process. The decisions individuals make determine the magnitude of the risk of traffic crashes. The decisions groups make determine how effectively the traffic crash risk is managed.

These decisions basically deal with risk and risk management. A decision may be to take a risk, to avoid a risk, or to ignore the whole issue. Risk-taking, risk-avoidance, and inaction all flow from individual and group understandings and perceptions.

If we are to reduce traffic crash losses, we must understand how these decisions are made by individual system users, policymakers, risk managers, and society as a whole.

In the same sense that we need general theory to structure and guide the highway safety process, we need theory that explains how decisions within that process are made.

This chapter briefly reviews decision-making theory. It presents major theories and explanations that are useful in understanding risk and risk-management decisions.

5.1 History of Decision-Making Theory

A variety of theories and models extant in the social science literature seek to explain the purposive, planned, or conscious behavior of individuals and groups. Such theories attempt to explain and predict such behavior. Perhaps the best known of the theories of planned or purposive behavior is found in the empirical and theoretical literature in the area known as decision-making.

Decision theory has its origins in the branch of mathematics known as probability theory. Questions posed in a decision-theory context stimulated advances in the mathematics of probability theory. So closely are these two fields allied that one can regard decision-theory as a branch of applied probability theory.

5.1.1 Expected Value Theory. The first theory of decision-making was based on the concept of expected values. The theory originated to facilitate better decisions about gambling. It states, in effect, that a gambler faced with a decision about how to make bets on uncertain events with different payoffs should bet on the event that, on the average, maximizes his winnings. The expected value model may be formally specified as follows: a decision-maker must select one alternative course of action out of a set of alternatives. Through some independent random process, a "state of the world" is determined or selected from a set of all possible states. The selection by the decision-maker of an alternative, and the occurrence, by random process, of a particular state of the world determines an "outcome" which can be represented as a monetary payoff (or loss) to the decision-maker. Further, it is assumed that the decision-maker knows the probabilities with which each of the possible states of the world can occur, knows the monetary values associated with each possible outcome, and knows the sets of possible courses of action and possible states of the world. The expected value model of decision-making states that the "rational" decision-maker will make his choice by computing the "expected value" or average return of each alternative available to him, and then select that alternative whose expected value is largest. This maximizing of expected value is referred to in decision theory as a strategy.

This model of "rational" decision-making, developed within the context of gambling choices, was soon proposed as a theory of human decision-making. Under the prevailing belief that humans were essentially guided by reason and rationality, the normative expected value decision model was proposed, and for a time accepted by some, as a descriptive model of human decision-making.

As with other models and theories of human behavior, it was not long before experimental investigations indicated that human decision-makers did not in fact comply with the predictions of behavior generated by the expected value model. For example, instances could be constructed in which most persons would prefer certain choices with lower expected value over those with higher expected value. Thus, it was evident that human decision-makers were responding to aspects and dimensions of decision-making situations that went beyond the mere computation of probabilities and monetary payoffs.

As is often the case in the history of scientific investigations and theory building, experimental evidence which contradicts the prevailing theory of the day resulted in modifications of the theory so as to accommodate the new data, rather than outright rejection of the theory. What typically occurs when data challenges theory is an elaboration of the theory--the addition, for example, of more free parameters, the construction of more "special cases," or the specification of limiting conditions which circumscribe the domain of the theory, so that data incompatible with it are held not to be relevant. When a theory is popularly held it can prove to be surprisingly resistant to contradicting experimental results. Often a scientific theory is rejected only when it has become so elaborated with "special cases" and conceptual elaborations that it collapses under its own intellectual weight. A classical example of this is found in the case of the Ptolemaic theory of the solar system, which fixed the earth at the center of the universe and had the various stars and planets orbiting around it at various speeds and distances. With the growing accumulation of astronomical observations, ever more elaborate celestial patterns of orbital movement had to be devised to maintain the geocentric assumption of the theory. Only when the theoretical orbits of movement bordered upon the preposterous did the Ptolemaic theory yield to the far simpler and conceptually more economical heliocentric Copernican theory. When one traces the history of theory and modelling in the area of decision-making, a similar resistance to theoretical innovation can be noted.

5.1.2 Utility Theory and Subjective Probability. Upon the failure of Expected Value theory to adequately describe the decision-making behavior of actual decision-makers, the theory was modified by introduction of the concept of "utility." Without going into the technical and mathematical properties of utility theory it is sufficient here to define it as an index of an individual's personal or subjective preference for an outcome, object, or event. By replacing the objectively defined concept of "value" (measured in monetary units) with the subjectively defined concept of "utility," it was hoped that the rationality assumption of human decision-making could be retained by the simple expedient of proposing that individuals were guided in their decision-making by those choices which maximized expected utility rather than expected value.

Though expected utility theory fared better than its predecessor in the experimental laboratory in explaining and predicting the choice behavior of human subjects, anomolous experimental results continued to be produced for which the revised model was inadequate to explain. For example, certain choice situations could be constructed in which subjects consistently preferred an alternative that provided lesser expected utility. Again, the data indicated that the dimensions of decision-making were more numerous and complex than those of the explanatory model.

The disparity between theory and data then led to further refinement of the rational theory of decision-making. It was next proposed that the objectively defined probabilities of previous models be replaced by what might be called "subjective probabilities." The idea was that individuals, in their decision-making, deal in probabilities in a personal way, judging likelihoods in ways that well might differ from some objectively defined standard. People could be expected to make their decisions upon the basis of their own personal and subjective feelings about probabilities, rather than upon some externally defined measure of likelihood. Further, this modification in the theory allowed for individual variation in choice behavior and decision-making. So it was possible, under the theory, for two decision-makers with identical preferences for outcomes to be both "rational" and arrive at different decisions simply because they differed in their appraisal of the probabilities of various outcomes. This concept of subjective probability originated long before decision theory was defined as a separate discipline, but was not incorporated into decision theory until fairly recently.

What has evolved is essentially a psychological theory of decision-making, rather than a truly "rational" theory. With abandonment of the index of monetary value to appraise the worth of alternatives, and replacement of objectively defined probabilities with personal or subjective ones, the burden of understanding and predicting the decision-making behavior of individuals and groups has shifted from mathematicians and decision theorists to social and behavioral scientists. That actual human decision-makers do not conform to neat rational models of decision-making has become obvious. To understand how decisions are made, attention must now be directed to the social and psychological factors which affect human decision-makers.

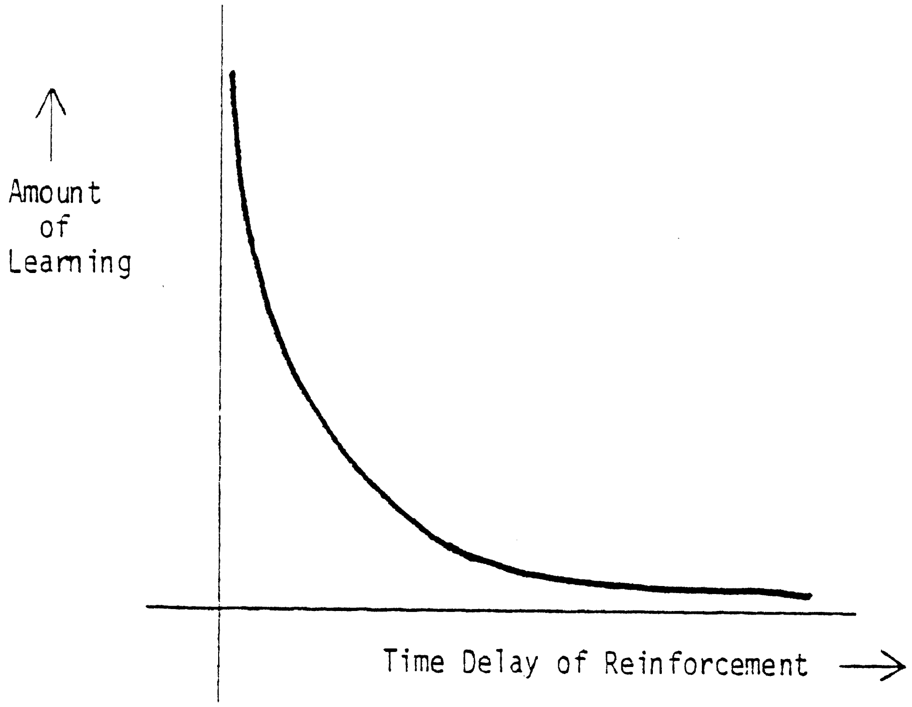
5.2 Social and Psychological Factors in Decision-Making

Some social and psychological factors have already been identified by research, though their mode of operation is not yet well understood. Other variables affecting decision-makers will be discovered through empirical research into such topics as human information processing, risk perception and outcome evaluation, cognitive biases which affect various types of decision-makers, interactions between the motivational states of decision-makers and relevant dimensions of particular decision problems, perceived reliability and source of information and its impact upon outcome and risk evaluation, and several related questions that address the human-nature aspects of decision-makers and the constraints and limitations that psychological and social realities impose upon the decision-making process.

Along with the realization that formal and "rational" models of decision-making are inadequate as descriptive theories of actual decision-making, it has begun to be accepted that social factors also play an important role in the behavior of decision makers. The individual does not function in a vacuum, but instead is part of a social and institutional structure which tends to shape perceptions and values in systematic ways. Thus, to understand and predict the decision-making process, one must also study the social milieu in which it takes place. An adequate theory of decision-making, unlike theories of the past, must consider the influences of societal factors upon individual and group decision-makers.

5.2.1 Learning Processes and Decision-Making. Knowledge of human behavior gleaned from other areas of the behavioral sciences can be of great help in understanding the underlying psychological and societal factors that affect human decision processes. One area deserving further study in values is the manner in which fundamental principles of the human learning process interact with bias and place constraints upon decision-making. Although it appears obvious that a decision-maker is also a "learner," there is little in the empirical or experimental literature which deals with changes in behavior during the decision-making process. Traditional models of decision-making typically conceptualize the world as made up of statistically independent events, and hence have relied upon mathematics which embody independence assumptions. Behavioral scientists, however, recognize that there is a marked statistical dependency in real-world events which is often mirrored in the laws describing human behavior. Unlike ideal decision-makers, human decision-makers are affected in their perception of the present by experiencing the consequences of their past decisions. In some situations this may be appropriate, as when the fisherman who was successful at a particular bend in the river in the past returns there in the expectation of again being successful. In other situations, however, this very "human" characteristic works to the detriment of decision-makers, as when the gambler, having experienced a string of losses at roulette, increases his wagers, falsely reasoning that his probability of a win must have been increased by his past losses. To adequately understand the dynamics of decision-making, the natural propensities of humans to perceive the world in a particular manner and the plasticity of behavior subject to past events or "reinforcers" must be incorporated in our theoretical formulations.

5.2.2 Recency and Time Delay. Another important aspect of human behavior that plays a part in the decision-making process relates to the dimension of recency. According to some learning theorists, learning takes place when the consequences of various behavioral acts provide "feedback" to the individual in the form of rewards and punishments. Behaviors that produce consequences rewarding to the individual have an increased probability of a future occurrence, while behaviors that produce punishing consequences have a lessened probability of future occurrence. Through this "reinforcing" mechanism the consequences of various behaviors serve to strengthen certain behaviors while eliminating others. The recency phenomenon, well established through experimental studies on both humans and infra-human species in the psychological laboratory, plays an important role in the learning process. Put simply, the recency effect states that the amount of learning produced by a reward or punishment will depend upon the time delay between it and the behavior which produced it. When there is a long delay, rewards and punishments do little to alter them; when the delays are minimal, rewards and punishments have their greatest impact upon learning. Graphically, the relationship between time delay and amount of learning looks somewhat as shown in the figure below.



This fundamental principle of human learning has profound effects upon how persons make decisions. It follows from this principle, for example, that individuals will tend to underestimate and undervalue the impact of future events, and correspondingly overvalue the immediate consequences of their behaviors. This very human sort of bias is reflected in such sayings as "A bird in the hand is worth two in the bush," or "Let us eat and drink; for tomorrow we shall die."

Now, in some instances of decision-making, this sort of bias may not be harmful; to a certain degree it may be justified, in the economist's words, to "discount" the future. However, there are a number of situations in which this aspect of human nature leads decision-makers to seek short-run gains at the expense of objectively more desirable long-range ones. In other words, the recency effect associated with the learning process can exercise a systematic bias upon a decision-maker's evaluation of alternatives, leading him to overestimate the value of immediate rewards and underestimate the value of delayed rewards. Similarly with punishments; the immediate ones are overvalued, the delayed ones undervalued. For example, the immediate discomfort or inconvenience of wearing a seat belt causes some people not to use them, thereby increasing the risk of much more severe consequences (e.g., death, serious injury) in the future. Only after a crash has occurred, and the injury is an immediate event rather than a remote one, does one regret not wearing a seat belt.

The bias in decision-making caused by the time-delay effect can have specially deleterious effects when a particular behavior produces a mixture of consequences, as, for example, an immediate small reward and a delayed but severe punishment. In this instance the time-delay effect may well lead the decision-maker to ignore the future punishment in his preference for immediate gain or reward. For example, a decision to drive after drinking too much alcohol produces an immediate reward in the form of readily available transportation, but increases the risk of a future crash and its accompanying "punishment."

5.2.3 Perception of Risk and Probability. In the preceding discussion of the time-delay effect, attention was directed toward a cognitive process which, in decision-making language, affects the subjective evaluation of outcomes. It will be recalled that the decision-making models used to describe choice behavior are comprised of two classes of variables: those dealing with outcomes and their evaluation by the decision-maker, and those involved with the appraisal of probabilities, likelihoods, and risk. Behavioral science can contribute a great deal to our understanding of both of those classes of variables.

In the probability or risk-appraisal dimension of the decision-making process, one deals primarily with a perceptual/cognitive aspect of behavior. This involves an aspect of human behavior in which there is a complex interaction between physiological, social, and environmental factors. It is almost a truism to say, from a perceptual standpoint, that "objective" reality exists only as an idealized state. For example, studies conducted in the social psychological laboratory have shown that an individual's perception of so simple an event as the movement of a light source in a darkened room is greatly affected by prior reports of movement made by other persons present. Similarly, the motivational states and pre-existing attitudes and beliefs of an observer can greatly affect his perception of a situation (hungry persons tend to see food items in the ambiguous perceptual field of a Rorschach card). Everyone is also familiar with the phenomenon captured in the folk wisdom of the proverb, "The grass is always greener on the other side of the fence," or the Aesop's fable of the "sour grapes." In these examples the perception of particular events or states of the world is affected by the individual's probability of achieving a sought-for outcome. (The proverb and the fable constitute competing "theories" of behavior; the former predicts that unattainable outcomes are enhanced in attractiveness, while the latter predicts that we deal with our setbacks by minimizing them.)

Several other behavioral phenomena which can bias our appraisal of "reality" have been discovered in the psychological laboratory but have not yet been integrated into our theories of decision-making. For example, it has been established that individuals, when shown a random sequence of binary events (say, a string of red and blue lights) almost invariably report detecting a "pattern." That is, people automatically attempt to find and impose an orderly rule or explanation for observed phenomena or an event when, in a statistical sense, such order is absent. A converse effect has also been observed. Subjects in a psychological experiment have been asked to attempt to generate a random sequence of events--for example, to simulate the behavior of a fair coin and state the outcomes of 100 hypothetical flips of the coin. When these humanly generated "random" events are analyzed by statistical tests of randomness, they are almost invariably found to be highly non-random--that is, very different from what would be generated by a truly random device.

These two aspects of the human response to randomness have significant implications for the study and modelling of human risk behavior. What they say is that humans deal quite poorly with random events because they don't recognize randomness when they see it, and what they do recognize as "random" (as for example, self-generated sequences) is generally in fact not random. It is obvious to one observing this aspect of the perceptual process that it cannot but influence the decision-making process by introducing systematic bias and certainly less than optimal performance.

Another very human foible which affects decision-makers when they deal with probabilities is their susceptibility to selective distortions of memory when evaluating their own prior performances. This has been demonstrated in studies where subjects are asked to give estimates of the probability of occurrence of particular future events. Sometime later (weeks or months), the subjects are brought back and some are informed that the particular events had in fact occurred, while others were told they had not. Each group of subjects is then asked to recall their previous probability estimations. Subjects told the events had occurred "recalled" larger probability estimations than they had actually made; those told the events hadn't occurred "recalled" smaller estimations than they had actually made.

This "hindsight" effect is not really surprising to observers of human behavior. We are all prone to recall the past in ways which enhance our self-esteem. However, when we wish or need to rely upon the past to provide us with information and lessons upon which to base present or future decisions, the "hindsight" effect can bias our probability estimations, causing the decision-making to be less than optimal.

Most humans have this "hindsight" bias partly because most humans misunderstand and misapply the concept of "probability." Although most persons have an "intuitive" theory of probability, in many cases it varies so much from the objective theory that the performance of untrained individuals in probability estimation tasks falls far below optimal levels. For example, in tasks where humans are asked to estimate the probability of alternative hypotheses, based upon samples of data that pertain to those hypotheses, humans are far less able to make optimal use of the available probabilistic information than are statistical decision-making models. People generally tend in such situations to be what is called "conservative"; that is, they change their estimates of the probabilities at a slower rate than is called for by the available evidence. Put another way, human decision-makers, at least untrained ones, do not make full use of all the information available to them in probability-estimation tasks.

The time-delay effect and biases related to perception and cognitive processes provide important illustrations of some of the shortcomings of contemporary decision-theory, and point out a possible synthesis of behavioral theories of learning on the one hand and decision-theory on the other. Most existing theories of decision-making disregard certain important psychological and social dimensions of human behavior which play a crucial function in the decision-making process--for example, the above-noted tendency for persons to "discount" the future in their appraisal of choices or alternative courses of action. Behavioral-learning theories, for their part, typically fail to take account of the purposive planning and goal-seeking behavior of humans engaged in such highly organized complex tasks as information processing and problem solving. A theoretical approach to decision-making that uses behavioral science knowledge as well as the theoretical power of formal mathematical models might well serve to remedy the shortcomings of our present ability to affect the decision-making processes of persons engaged in a variety of activities. Certainly, taking account of certain human "limitations" which make us less than ideal decision-makers may make it feasible to formulate decision-making aids to improve our ability to make good decisions or assist us in avoiding some of the more obvious shortcomings.

5.3 Summary and Conclusions

The theory of human decision processes has evolved to a point where the underlying social and psychological factors in decision-making are of central concern. At first, simplistic notions about what constituted "rational" behavior dominated the field, leading to models that, while appealing, did not reflect the actual behavior of most decision-makers. These early theories dealt with what were believed to be the two major ingredients in decision-making: the probabilities of various events associated with a decision alternative, and the values associated with the occurrences of those events. It was found that real decision-makers often do not, as theory predicted they should, combine these two ingredients so that the decision is made on the basis of maximum expected value across all alternatives.

Substitution of subjective probabilities for actual probabilities and utilities for values resulted in more realistic theories but shifted the emphasis from the mathematical sciences to the social sciences. At present, the major concern in the study of human decision processes is how to determine subjective probabilities and utilities rather than how to manipulate them.

The tendency of individuals to "discount" the future is an example of a psychological factor that influences decision-making but cannot be described in sufficient rigor for use in present mathematical models. The way past experience is used in forming perceptions of the present is another example of an important but insufficiently understood psychological factor affecting decision-making.

With respect to risk perception, the literature on human behavior identifies several factors relevant to highway safety. For example, in perceiving probability or risk, people tend to:

- make insufficient use of available information,
- be influenced by pre-existing attitudes or beliefs,
- have selective distortions of memory when evaluating their own performance,
- be influenced by others in a group, and
- have difficulty in understanding concepts of randomness and probability.

Efforts to narrow the gap between perceived risk and actual risk in the Highway Safety Process would clearly be enhanced by taking cognizance of what already is known in the field of decision-theory and the behavioral sciences. Further reduction of the "perception gap" will become possible when contributions of mathematical modelers and statisticians are combined with those of behavioral scientists to form an integrated theory of human decision processes.

While an integrated theory of human decision processes is not available, existing theory can be applied in the management of the traffic crash risk. Existing concepts suggest new approaches for risk management that have their foundation in an understanding of how decisions to take risk or avoid risk are made. For example, past approaches have relied heavily on increasing the perceived negative consequences associated with an unsafe act (e.g., prohibiting the act and sanctioning the offender). Decision theory suggests that we should also consider reducing the benefit associated with the act, so that an individual would be less likely to place himself at risk.

A major conclusion, drawn from an understanding of decision theory, is that highway safety should be approached in a far broader context in the future than it has in the past. Understanding how and in what contexts people make decisions should be a goal. Technology will continue to play an important role in the reduction of the crash risk. The use of technology should flow from an understanding of the decision process. Technology cannot replace the need for such understanding.

6.0 IMPROVING THE MANAGEMENT OF RISK

This chapter presents basic principles concerning the management of risk. The conceptual framework set forth in Chapter 5 described risk-management systems as an essential element of the highway safety process. In reality, the entire highway safety process is a risk-management process. The formal actions that one associates with management, however, take place in institutions that exert controls on the highway transportation system.

Management of risk is a process analogous to other management processes. A body of theory that describes management exists and may be applied to the management of the traffic crash risk. In this chapter, basic management theory is used to describe the risk-management process. Application of these basic principles can improve the operations of the highway safety process.

Risk Management is a process that requires completion of six discrete but interrelated steps. These steps 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.

These steps, discussed in the following section, may be succinctly stated as follows:

- Risk Identification;
- Establishment of Priorities Among Risks;
- Determination of Allocation of Resources:
- Selection of Risk-Management Strategies and Tactics;
- Implementation of Risk-Management Actions; and
- Evaluation of Outcomes in Terms of Risk Reduction

6.1 The Process of Risk Management

Of these steps, risk identification is the most crucial, since it determines whether there will be a response at all by society and its risk management systems. First, the magnitude of risk must be determined and effectively communicated to all persons affected by it. This identification, communication, and reception creates perceptions of risk that govern both individual and societal behavior. Increased perception of risk leads individuals to:

- engage in risk avoidance;
- support the creation, funding, and operation of risk-management systems; and
- cooperate with risk-management systems as risk-management strategies are implemented.

Second, the nature of risks must be described in sufficient detail to support further risk-management action. Information must exist concerning how risk is created and what disutilities result, when, and why.

Existing information on the traffic crash risk is limited and apparently not well understood. Appendix A briefly compares the disutility of traffic crashes with disutility resulting from other societal risks. The Appendix also summarizes data on traffic crash causation drawn from the most recent NHTSA study. The major points that can be drawn from these summaries are:

- Society appears to view traffic crashes as less of a societal problem than other risks that create greater disutility.
- Human factors are the predominant cause of traffic crashes. Environmental (including highway related) and vehicle factors follow in that order.

This information 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. (Note that the fact that a human failing caused a crash does not mean that the only response should be directed against the driver. A change in the vehicle, the highway, or both may be more effective. Many failures, however, appear to warrant action directed at the driver.)

A basic part of the risk-identification process is the determination of risk identification requirements. The content of information needed by users to perform risk-management functions must be specified. Effective methods of communicating this information must also be specified. While risk-identification requirements cannot be specified in detail a priori, a minimal requirement is that both the magnitude and likelihood of various types of crashes be described in terms that can be understood by individual citizens and by institutions that must establish and implement policies for managing the traffic crash risk.

After particular traffic crash risks have been identified, priorities among them need to be established. This step involves ranking specific crash risks and categories of risks in order of the magnitude of the threats they pose to society. Extremely rare events with very low disutility receive the lowest rank, while frequent events that create great disutility receive the highest rank.

Thus, highway safety risks, to be non-trivial, must be associated with a "reasonably high" likelihood of occurring, and when the events occur, the disutility must be "sufficiently undesirable." Clearly, a major requirement of highway safety research is to provide operational definitions of "reasonably high" and "sufficiently undesirable."

Establishing priorities among risks is actually the first of three steps that are closely interrelated. In the other two steps, determination of allocation of resources and selection of risk-management strategies and tactics, comprehensive programs of risk reduction are designed to deal with risks ranked unacceptably high.

Allocation of resources takes place in two contexts. The first reflects the general societal decision allocating resources based on the relative importance of a particular class of risks among all other classes of risks. The second context relates to allocation of assigned resources among the strategies and tactics selected for dealing with risks within the specific class.

The selection of 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 not generally followed today, even though claims are made by a multitude of system managers that such management methods are applied.

Such a systematic analysis is likely to identify risks that cannot be reduced to desired levels by applying existing countermeasures. These risks must be addressed through research to identify and evaluate new control forces.

After risks have been identified, ranked, and programs developed to deal with them, the next step in the risk-management process is <u>implementation of risk-management actions</u>. Here, all activities necessary for operation of risk-management programs are performed. Such activities range from provision of funds for programs to actual application of control forces (e.g., arrest of an offender by a police officer, or treatment of an injured person). Included are such diverse activities as recruitment and training of operational personnel (e.g., ambulance drivers), the monitoring of operational methods and procedures (e.g., suspension of a driver license), and the purchase and maintenance of equipment (e.g., police cars). Ideally, the determination of functional requirements for implementing risk-management strategies should follow a systematic process whereby the personnel, equipment, facilities, and other resources are allocated on the basis of their contribution to the effectiveness of the total risk-management system. Unfortunately, the systemwide coordination necessary for such an approach seldom occurs in the real world (18).

The final step in the risk-management process is the evaluation of outcomes in terms of risk reduction. The purpose of this step is 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 they may be improved or discarded. The concept of risk-management requires that evaluation must be related in some reasonable way to the reduction of risk. Reliance on ultimate measures such as actual reduction of crash losses is probably not feasible for most programs, particularly local ones. It is more reasonable to target a risk-management approach on a particular category of risk and then measure change in that risk (e.g., reduction in the frequency of a particular unsafe driving act).

It is critical that evaluations be conducted and the results communicated to the risk-management systems and society. Society's willingness to tolerate and support risk-management activity depends on societal perceptions of benefits. Frankness in sharing information on successes and failures is a necessity. This requires that programs not be oversold. The consequences of evaluations that show no reduction in risk are often disastrous for program managers who have promised too much. We need to develop a clear societal understanding of the complexity of the traffic crash risk and of the highway safety process. Simple solutions (that are societally acceptable) are not likely to be found in the near future.

6.2 The Traffic Law System--An Illustration

The preceding section discussed the risk-management process in the context of the conceptual framework of the highway safety process. This section describes the Traffic Law System, which is one of the formal risk-management systems within the highway safety process. Examination of the functions and operations of this risk-management system will help to clarify the concepts and principles developed in prior sections.

The Traffic Law System may be described as society's formal mechanism for applying law to management of the traffic crash risk. Law is applied in a variety of ways. In this limited examination we focus on operations of the law system that deal with the system user --predominantly the driver, although general provisions of the "rules of the road" also deal with other users (e.g., owners, pedestrians, bicyclists, etc.).

The use of the law may be seen in several contexts of equal importance. Law is used in a positive sense to provide guidance for normal operations of the Highway Transportation System. These guidelines provide a series of common expectations (e.g., we will all drive on the right side of the highway) that facilitate daily activity. These guidelines, drawn from theoretical understanding of risk, suggest or require conduct that reduces risk.

The law also operates to prohibit actions that create increased risk. The law provides a formal system for dealing with individuals who violate the proscriptions. This use of the law is embedded in the concept of deterrence.

The premise of deterrence is that a 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 benefit derived from the activity is less than the expected cost resulting from some threatened punishment (30). The literature distinguishes between two forms of deterrence, so-called "special deterrence," which prevents the <u>punished parties</u> from engaging further in the undesired activity, and "general deterrence," which discourages <u>all</u> members of a given group from engaging in the activity even if they are not caught and punished (31).

The formal means for creating deterrent threats to risky behavior within the HTS is the Traffic Law System (TLS). In effect, such threats (e.g., driver license suspension, fines, jail) are the control forces of the TLS and are developed as the TLS performs its four top-level functions: law generation, enforcement, adjudication, and sanctioning (18). See Figure 6-1. The objectives of these functions may be stated as follows (19,32):

Law Generation

- Define risk precisely;
- Proscribe 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.

Enforcement

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

Adjudication

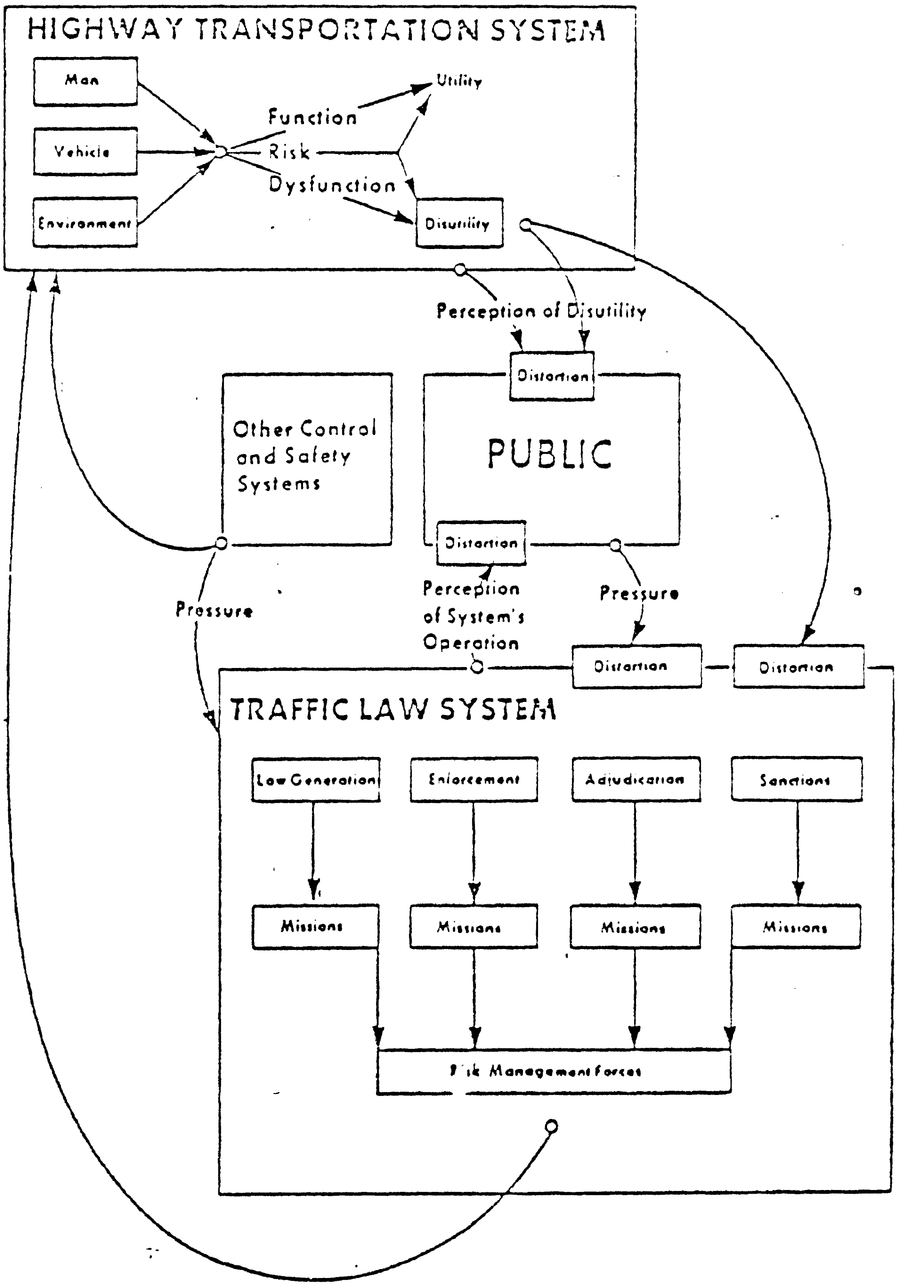
- Determine if risk-taking occurred in the case of individuals apprehended by Enforcement;
- Determine validity of risk prescriptions by Law Generation; and
- Provide fundamental fairness essential for system operation.

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).

A wide variety of governmental agencies and institutions are involved in performing these functions. Because our system of government is based on the doctrine of separation of powers, no single agency or institution is in charge of the whole system. There is no "system manager" for the TLS or for any other formal societal

FIGURE 6-1 JOSCELYN-JONES CONCEPTUAL FRAMEWORK FOR ANALYZING THE TRAFFIC LAW SYSTEM



control system. No "system specification" exists for describing what the nationwide TLS must do or how it must do it, nor are there nationwide "subsystem specifications" that tell how the components of the TLS should perform in relation to each other and to the whole system. In reality, the TLS is a "system of systems," each unit operating in varying degrees of independence from the other, but all loosely bound together by a set of principles that encompass the entire spectrum of human values, ranging from those implicit in our culture to those explicitly addressed in our federal Constitution.

The Law Generation function is performed by federal, state, and local governments operating under legal constraints imposed by federal and state laws, constitutions, and judicial precedents. Legislative bodies create formal statements (i.e., statutes) of prohibited HTS risks and the penalties for engaging in risky behavior. Laws, in the form of regulations, are also generated by administrative agencies in the executive branch of government. In addition to proscribing risky behavior and punishments, laws also authorize operation of other components of the TLS (e.g., agencies for licensing drivers, police departments) and provide direction and constraints on operations of those components (e.g., procedures for the arrest of a driver for risky behavior). More informal, de facto laws are generated by other instrumentalities of government through, for example, creation of speed limits and posting of stop signs. Still more informal, but just as real, laws are created by individuals--for example, the police officer who makes a regulation through directing traffic (32).

The Enforcement function is performed by state and local police agencies. Primary operational sub-functions include:

- Detection of law violators;
- Apprehension;
- Observation of the apprehended suspect to help decide whether or not to arrest or issue a citation; and
- Arrest and post-arrest processing of a suspected law violator.

An important secondary sub-function 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 (e.g., speeding) associated with some crash losses (33). Enforcement also supports operation of the entire TLS by providing information on the nature of risk (e.g., from arrest/citation records, from accident reports).

The <u>Adjudication</u> function of the TLS 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 sub-functions of this judicial adjudication process are:

- Determination of the charge to be made against the suspect; and
- Conduct of pre-trial hearing to inform the accused violator of the charge and his rights, and to determine the guilt or innocence of the accused violator.

The last sub-function, 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 of the judicial branch of government. Driver license agencies often hold administrative hearings where findings of facts are made by a hearing officer. Further, in order to expedite the processing of violations of lower risk, some offenses have been "decriminalized," lessening the due process requirements (e.g., New York) wherein minor traffic cases are handled by an agency of the executive branch of government (i.e., the Department of Motor Vehicles).

Still less formal adjudication processes often occur. For example, a police officer may decide whether a driver he has stopped is guilty of an offense and decide not to arrest or decide to issue a warning, thus precluding futher action by formal adjudication components of the TLS. Similarly, a prosecutor may decide not to charge or to reduce a charge in exchange for a promise to undergo treatment for some condition (e.g., alcoholism) that led to the offense. In most instances, however, it is the driver himself who adjudicates after receiving a citation by pleading guilty or forfeiting bail (32).

The Sanctioning function provides the ultimate deterrent threat of the TLS. Again, it is performed by the judiciary (e.g., imposing a fine), by an administrative agency (e.g., suspending a driver license), or by a police officer (e.g., issuing a warning). The purpose of the punishment is to prevent future occurrences of the risky behavior by the punished parties and by other individuals who wish to avoid punishment.

The basic steps of risk-management are performed within each of the functional areas of the TLS. 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 performance of some of the steps for the TLS as a whole. For example, the enforcement function has special responsibilities to develop information on risks and share them with other components of the system. In a similar sense, Law Generation must translate general information on risk into operational definitions of prescribed and proscribed behaviors. The risk-management process is applicable in both a macro or system sense and in a micro or individual agency sense.

In 1970, we analyzed the performance of the TLS as a risk management system and found it conceptually sound but with insufficient resources to manage HTS risk effectively. The level of resources available to the TLS was seen as a reflection of the public's misperception of the net disutility of the HTS. We concluded that this was due to a lack of precise knowledge of risk and a lack of communication to the public of existing knowledge about risk. Our study also found that the principles of risk-management often were not being applied by the TLS and that, as a result, existing resources were not being effectively utilized. Minimal coordination among the various elements of the TLS was found, resulting in a lack of common purpose and in actions that were counter-productive to achievement of ultimate system objectives. The failure of the TLS to operate as a system was seen to result in serious inconsistencies in TLS interactions with the HTS, society, and other RMSs, and even in non-performance of major risk-management functions at the system level (e.g., risk identification). Thus, significant violations of all steps of the risk-management process were found to be commonplace in the TLS.

6.3 Summary and Conclusions

The method by which the risk-management systems operate is described as the risk-management process. This process is also used for individual and societal decision-making about the highway safety process. Basic steps in the process are:

- Risk Identification;
- Establishment of Priorities Among Risks;
- Determination of Allocation of Resources;
- Selection of Risk Management Strategies and Tactics;
- Implementation of Risk-Management Actions; and
- Evaluation of Outcomes in Terms of Risk Reduction

All of these steps are critical for proper operation of the risk-management systems and the highway safety process.

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.

7.0 ANALYZING HIGHWAY SAFETY NEEDS: AN APPLICATION OF THE NEW CONCEPTUAL FRAMEWORK

The preceding sections of this paper have demonstrated the need for treating the problem of highway safety within the context of the societal systems that generate and attempt to deal with disutilities caused by highway crashes. A conceptual framework for analyzing these systems and their interrelationships was presented, and the processes through which people make decisions about risk were discussed. Some major problem areas and needs in risk-management were mentioned.

The purpose of this section is to show how our conceptual framework can be used to analyze overall highway safety problems and needs in a more orderly and meaningful way than has previously been possible. The analysis leads to a concise statement of top-level requirements for managing highway crash risk and serves as a point of departure for future, more extensive analyses.

7.1 Problem Analysis

Our conceptual framework suggests that problems in managing crash risk may be placed in three general categories. The categories contain problems pertaining to:

(1) the description of the Highway Safety Process (HSP),
(2) decision-making within the HSP, and
(3) communication within the HSP.

The term "Highway Safety Process" describes the complex of interacting societal systems that create and control highway crash disutility (see Chapter 4.0). Some of the more obvious risk-management problems within these categories are discussed below.

7.1.1 Description of the Highway Safety Process. The literature on highway safety contains no record of an attempt to develop a description of the entire HSP. The lack of a comprehensive theory has, in fact, precluded such a global presentation of the process. Researchers have yet to identify all of the HSP 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 HSP as a whole has been impossible for the most fundamental of reasons: all of the parts of the system have not been identified. As a consequence of the fragmented conceptual framework used in past highway safety activities, the most neglected components of the HSP have been those related to control of crash disutility. While many of the major components of the HTS (e.g., drivers, vehicles, 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 HSP. No effort to identify all of the significant parts of the societal and RMS components has ever been made.

Similar problems exist in describing the functions of the HSP. Several studies have analyzed selected functions of the HTS and RMSs, but few studies have attempted to develop hierarchies of functions in relation to top-level subsystem and system objectives. There has never been a functional analysis of the entire HSP, nor any formal attempt even to identify all of these functions. With respect to the HTS, only the operational function seems to have received much attention in the highway safety literature. Analyses of lower-level HTS functions involving interactions between driver and vehicle in a particular driving scenario (called task analyses) have sometimes been conducted in detail, but related functions that must be performed in the course of total driving "missions" (e.g., a trip to the office on a busy expressway) have not been described in the same degree of detail. Some functions of some RMSs (e.g., emergency medical services, police traffic services) have also been identified, and in one case (the Traffic Law System) a formal functional analysis has been performed. However, the functions of many components of RMSs (e.g., private safety foundations, 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 HSP, 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 the accomplishment of risk management objectives, or how that function affects the accomplishment of the objectives and functions of other components. As a result, RMS 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 HSP, the requirement to describe the disutilities of the HTS has been addressed most frequently by past highway safety research. Such research has identified events immediately prior to, during, and following crashes, and has developed a variety of descriptions of the resulting disutilities. However, the 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, so that 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, i.e., with respect to the risk associated with the disutilities, to other non-HTS risks, and to normative values of factors related to disutilities. The same situation exists with respect to utilities of the HTS, which have received far less attention than the disutilities. Particularly, no attempt has been made to compare the utilities and disutilities associated with particular HTS activities and collections of activities i.e., missions, 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 HTS than the outputs of the RMSs. In general, neither the effectiveness nor disutilities of RMS 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 rescinding of federal regulations requiring seatbelts to be interlocked with a car's ignition system and the repeal of mandatory helmet use laws for motorcyclists in some states are examples of public refusal to accept RMS "cures" perceived as worse than the "illnesses" they were directed against.

Figure 7-1 summarizes existing major problems in developing an HSP description to support risk-management. The problems are shown relative to the three major elements of the HSP, i.e., the HTS, RMSs, and society.

7.1.2 Decision-Making in the Highway Safety Process.

Considerable progress has been made in recent years in developing theoretical models of decision-making and in understanding psychological and social factors that enter into the applications of such models. However, at present, 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 useful for improving operational decision-making. For example, it is not clear how the knowledge that most people do not use information efficiently in

Figure 7-1: 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 non-operational 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 HSP
2. Identification and description of functions	● Inadequate identification of non-operational functions ● Lack of hierarchies of functions related to objectives	Functions of most RMSs not identified explicitly	Highway safety-related functions not identified
3. Definition of structure	No rigorous structure interrelating components and functions	Inter-RMS structures not defined. Intra-RMS 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 ● Utilities and disutilities associated with all functions and operational modes not described ● Net utility or disutility of functions and operational modes not known	● Effectiveness of control forces not known ● Disutilities of control forces not known	Societal demands for disutility control not known

estimating risk can be used to better present information about crash risk to police managers. Neither is it known how to use knowledge about the tendency of human decision-makers to discount the future to stop legislators from responding only to short-term highway safety pressures and ignoring problems that will create far greater pressures in the future. Nevertheless, given the difficulty of the task, the greatest deficiency in meeting HSP requirements with regard to decision-making is that there has been an insufficient effort to attempt this translation. Thus, much potentially useful knowledge is not being used to improve perceptions and decision-making in the HSP. The failure to use existing knowledge--a major current problem--is discussed later in section 7.1.4.

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. No federally sponsored U.S. programs are concerned with describing current perceptions about risk within the HSP. No known research in this country is examining how perceptions about crash risk are formed and how decisions about risk-responses are made. 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.

7.1.2 Communication Within the Highway Safety Process.

No system-wide information system has ever been designed for the entire HSP, and there is no record of any analysis of the content, form, or method of delivery of information needed by various components of the HSP. 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 user groups include the federal government (e.g., NHTSA's Fatal Accident

File), universities (e.g., HSRI's Information Center), and private safety foundations and associations (e.g., the National Safety Council, Motor Vehicle Manufacturers Association, and the American Association of Motor Vehicle Administrators). A few information "services" (e.g., the Transportation Research Information System or TRIS) exist to assist persistent seekers of highway safety information, but some familiarity with 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 needs of the public and of operational components of the HTS and RMSs. No ongoing, integrated program to provide to these components information about risk and RMS control forces has ever existed at the national level.

Efforts to communicate with the public have mainly been in the form of sporadic public information and education "campaigns" in support of countermeasures aimed at particular behaviors associated with crashes (e.g., speeding, drunk driving). The effectiveness of most of these campaigns in modifying behavior has not been demonstrated. The literature on highway safety provides no evidence of studies 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 in dealing with risk.

With respect to RMSs, the major communications problem is in providing information from existing repositories of knowledge in a form suitable for risk-management at state and local levels of government. It is at these levels, where operational risk-management strategies and tactics are developed, that most resources are expended and control forces are actually applied. Yet, state and local units of government have the least access to information needed for these functions. Unmet needs of these RMS components range from concise state-of-knowledge reviews about risk, to manuals for operating countermeasure programs, to surveys of the results of evaluations of past programs.

Figure 7-2 summarizes some major communication problems in managing highway crash risk.

7.1.4 Use of Existing Information. Examination of past highway safety efforts leads to the conclusion that information and knowledge that are currently available are 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. We state it in specific terms but it has been a part of the general management literature for many years. Yet, 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: (1) problem identification; (2) program development and implementation; and (3) evaluation. In a general sense this is close to the risk-management process. The difference lies in the emphasis the latter places on risk identification, establishment of priorities, and evaluation of implemented strategies and tactics in terms of risk reduction. The 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 the risk-management concepts. Programs are started as extensions or expansions of existing activity. Risk identification is not accomplished, and effective evaluation is a rarity.

We believe a major reason for this is the failure of states and local units of government to understand the system nature of their highway safety efforts. There is not sufficient attention given to the organization and management of highway safety programs or to the institutions that implement programs. This lack of system management contributes to (1) failure to use existing information, and (2) failure

Figure 7-2: Summary of Major Problems in Communicating Within the Highway Safety Process

Problem Area	Elements of the Highway Safety Process		
	Highway Transportation System	Risk-Management Systems	Society
1. Determination of what information is needed	Done on a formal or deliberate basis only for selected HTS components. Not done system-wide.	Not done on a formal or deliberate basis for most RMSs. Greatest deficiency at local and state level of government.	Not done on a formal or deliberate basis except in conjunction with isolated PI&E "campaigns."
2. Determination of the form and method of delivery of needed information	Done on a formal or deliberate basis only for selected HTS components. Not done system-wide.	Not done on a formal or deliberate basis for most RMSs. Greatest deficiency at local and state levels of government.	Not done on a formal or deliberate basis except in conjunction with isolated PI&E "campaigns."
3. Development and operation of continuing information programs	● No formal programs except those for researchers and for individual organizations. ● No system-wide program.	● Appropriate information not provided to units of local and state governments. ● No system-wide program.	Done only sporadically in support of specific programs.

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 the highway safety community to ignore existing information on risk. Basic information on traffic crash causation has demonstrated the importance of the human element. This has been reinforced by more recent, more detailed studies. Despite this information, the tendency has been to allocate resources 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. We do suggest that as priorities for allocation of resources are established, sufficient attention be given the human element. In the next twenty years the Highway Transportation System will experience some 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 look remarkably like 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. Sanctions resulting from enforcement action have been expected to be perceived by drivers 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 as to make the surrogate risk not significantly more important than the crash risk in the human decision process.

A more fundamental problem exists. The use of the legal system is basically a negative reinforcement. A significant body of psychological literature establishes that humans respond more effectively to positive than negative reinforcement. We need to look for alternative strategies for driver control that rely more on incentives than disincentives.

There are limits on the use of the criminal sanction. General and unrestricted use of the law 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 use of the Traffic Law 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.

The problems discussed above stem from a lack of theory to focus action. They are direct products of the failure to use existing information and knowledge effectively.

7.2 Needs Analysis

This section outlines what needs to be done to overcome the risk-management problems identified in the preceding section. The resulting statement of highway safety needs is a first step toward development of a set of top-level requirements for managing crash risk. Further analyses of problems and needs are necessary to develop more comprehensive and detailed statements of requirements. The needs discussed below address the three categories of problems that were described above, i.e.:

(1) the description of the Highway Safety Process (HSP)
(2) decision-making within the HSP, and
(3) communication within the HSP.

7.2.1 Description of the Highway Safety Process. The HSP and its individual parts should be described with respect to its composition, functions, and outputs. A conceptual framework such as the one presented in chapter 4.0 of this paper is the first step in development of such a system description, but more detailed descriptions are needed.

The first specific need is that each element and its components be identified and described. The conceptual framework described in chapter 4.0 identifies classes of components (e.g., the HTS, RMSs) and gives examples of lower-level components (e.g., drivers, automobile manufacturers, driver licensing agencies). 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 HSP operations.

Next, it is necessary that the functions of the HSP be identified in hierarchical form. Some top-level functions identified elsewhere in this report include the provision of fast, convenient transportation and the maintenance of HTS disutility at a societally acceptable level. Lower-level functions of the HTS were said to include the design, construction, operation, and support of automobile equipment and highways. The primary functions of RMSs were identified as risk identification, risk prioritization, resource allocation, development of strategies and tactics, implementation and operation of programs, and evaluation. The functions of one specific RMS, the Traffic Law System were identified, discussed briefly, and related to the primary functions of RMSs in general. Similar but more detailed descriptions of HSP functions must be developed so that all significant activities pertinent to the generation and control of HTS disutility are known and related to HSP objectives.

When the components and functions of the HSP have been 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 the performance of 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, and would thus provide a major tool for the practice of risk management.

The last major need for describing the HSP is to define its outputs. In the case of the HTS, 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 his passengers who want to minimize travel time, but to organizations that manufacture and support the equipment and facilities involved in such usage of the HTS. Even a direct disutility (e.g., a serious crash) that sometimes occurs as a consequence of this mode of operation may have utility to some segments of society (e.g., automobile repair companies, hospital workers). It is essential to risk management that the nature of the significant utilities and disutilities associated with the operational modes of the HTS be specified in relationship to the various classes of individuals and organizations that receive the utilities and disutilities. The etiology of crashes is an important element of this "output definition" requirement vis-a-vis the HTS, but it is clearly only one of many elements.

It is necessary that HTS disutilities be stated not only in terms of the losses associated with a particular event but in terms of the probability (i.e., risk) that the event will occur. Further, to evoke an effective risk-management response, HTS disutilities must be described in relation to other disutilities (e.g., fire, disease) and their associated risks.

The outputs of RMSs are control forces designed to maintain acceptable HTS disutility. As such, they 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. Thus, for example, a control force in the form of a driver license suspension imposed by an administrative agency must be examined to identify its purpose (of, say, preventing crashes involving teen-aged drunk drivers), its effectiveness in accomplishing its purpose, and the total cost of RMS resources expended in applying that force. It is also important to identify any negative effects associated with application of that force (e.g., the violation of fundamental constitutional rights by denial of 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 and in terms of 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 constituents, objectives, and outputs of the HSP, and thus will comprise the first basic ingredient for designing, operating, and evaluating programs of risk-management.

7.2.2 Decision-Making Within the Highway Safety Process.

Factors important in deciding how to deal with HTS risk must be identified and described. Three specific needs are germane to decision-making within the HSP.

The first need relates to formation of perceptions about the outputs of the HTS and RMSs. It was noted earlier in this report that perceived risk often does not equal actual risk and that perceptions about utilities of the HTS and disutilities of RMS control forces may also be inaccurate. Thus, there is a need to determine the nature of societal, HTS, and RMS perceptions of the risks and utilities of the HTS and RMS control forces, and to understand how those perceptions are formed. It is necessary to know, for example, how perceptions of crash risk due to speeding vary with demographic characteristics and whether speed "traps" are more acceptable to some groups of drivers than to others.

The concept of maximum tolerable disutility due to crashes was introduced in Chapter 4.0 as an essential element of highway safety. There is, therefore, a need to describe this reference value of disutility for different groups of individuals from the HTS, RMSs, and society in general. The need for such knowledge is fundamental because it forms the basis for determining the specific objectives of RMSs at any point in time. Combined with information about actual and perceived disutility, it 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, knowledge that, all things considered, the requirement that an average driver's chances of being killed in a crash over a driving lifetime not exceed one in 1,000, when they are actually more than 25 in 1,000, could have very significant implications for risk-management. Such knowledge would indicate that RMSs were not satisfactorily accomplishing their objectives, since actual risk greatly exceeds that which is acceptable, 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 one serious crash in 100,000 trips, might indicate a misallocation of police resources. In either case, maximum tolerable disutility must be known in order to measure RMS performance.

The last need in this category is to understand how decisions about responses to risk are made. In the case of the HTS, this means, for example, that one understand why one driver's response to a given perceived risk will be risk avoidance, while another driver's response will be to accept the 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 given stretch of highway; but a police agency in another, apparently similar, jurisdiction may take no action at all to deal with the same amount of 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 so as to obtain optimal responses from the decision-makers.

7.2.3 Communication Within the Highway Safety Process.

The accumulation of a body of knowledge about the nature and effects of the HSP will be of little use unless such knowledge is disseminated and understood by the components of the process. Effective means for accurately communicating needed information within the HSP is thus a basic requirement for risk-management.

Three specific needs are generated by this general requirement. First, there is the necessity to determine the nature of information needed by each component of the HSP. In general, each component will need at least some of each type of information defined by the above specific requirements, but the depth and scope of the information will vary greatly among components. For example, the information needs of traffic court judges with respect to identification of risk due to drunk-driving are different than the information needs of the automobile designer. Both need to know about the magnitude of the risk associated with various blood alcohol concentrations, but the designer needs more detailed and precise information about how alcohol affects vehicle-driver interactions and thereby increases crash risk. However, traffic court judges need a more in-depth explanation of the effects of a given treatment regimen for alcoholic drivers.

Individuals and organizations that are often not considered to be a part of the HSP 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 HSP. 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 with 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 the responses of RMSs 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.

7.3 Summary and Conclusions

Our new conceptual framework has been used to analyze major problems and needs in managing crash risk. Examination of the past operation of the HSP reveals a range of problems inhibiting the effective management of risk. The problems fall within the following three categories:

(1) the description of the societal process (i.e., the Highway Safety Process) through which the disutilities of highway crashes are generated and controlled,

(2) decision-making within the Highway Safety Process (HSP), and

(3) communication within the HSP.

Major problems contained in these three categories may be listed as:

Description of the HSP

- The components of the HSP are not identified and described.
- The functions of the HSP are not identified and described.
- A detailed structure relating the components and functions has not been developed.
- The outputs of the process are not defined.

Decision-Making

- The nature of perceptions about the HSP and its outputs have not been determined and it is not understood how these perceptions are formed.
- Maximum tolerable disutility due to highway crashes has not been described.
- The process through which decisions about how to respond to crash risk has not been described and it not understood.

Communication

- The nature of the information needed by each component of the HSP has not been determined.
- The appropriate form and method of delivery of needed information has not been determined.
- Continuing communications programs to provide needed information in effective form to all components of the HSP have not been developed.

Major needs in highway safety have been identified. With respect to the HSP as a whole, these needs may be stated as:

- A comprehensive theory of highway safety should be developed.
- The perception of highway crash risk should be made more accurate.
- The HSP and its components should be adequately described.
- Existing knowledge should be used.
- RMS actions should be evaluated.

With respect to the Highway Transportation System (HTS), major needs in risk management are:

- Components should be more fully identified and described.
- Operations should be more fully identified and described.
- User decisions should be understood.
- Utilities should be described in operational terms (e.g., the reasons for risk-taking or safe driving).
- Disutilities due to crashes should be adequately identified and described in operational terms that will support risk-management actions.

Within the Societal component of the HSP, major needs are:

- Risk perception should be made more accurate.
- The processes through which perceptions are formed should be described and understood.
- Methods for changing perceptions should be developed.

Major needs of Risk-Management Systems have been identified as:

- RMSs should be identified and defined.
- RMSs should engage in system management.
- Risk-management action by state and local units of government should be increased.
- The process of risk management should be followed.
- Information on the effectiveness of risk-management strategies and tactics should be provided to RMSs.
- A wider range of risk-management strategies should be considered and less reliance placed on traditional countermeasures.
- The effectiveness of the control forces of RMSs should be determined and made known to the public.
- Public support of control actions should be increased by developing control forces that do not in themselves generate excessive disutility.

It is concluded that there is also a clear need for a more formalized and extensive analysis of risk management needs, and for the development of focused programs to meet those needs. That such an analysis has not been conducted in the past is due in large part to the lack of an adequate theory or conceptual framework as a basis for identifying needs.

8.0 IMPLICATIONS OF THE CONCEPTUAL FRAMEWORK

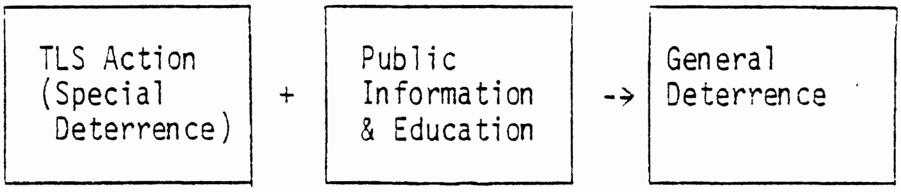
Prior chapters have examined the theoretical framework of the highway safety process and discussed top-level problems and needs. These discussions are necessarily general and somewhat abstract. However, the conceptual framework and associated theory from related fields are not mere abstractions or methodological toys. They have import and application for the practitioner.

This chapter presents some brief examples to illustrate the implications of the conceptual framework for the field of highway safety. The illustrative examples are intended only to stimulate thought. They do not represent the breadth or depth of the conceptual framework. They are glimpses of what can be developed in the future by thinking more broadly about the highway safety process.

8.1 How About Decreasing Utility?

As we examine the conceptual framework, it can be seen that the operations of the Highway Transportation System are influenced by the utility they provide society. Trips and driver behaviors are associated with the perceived utility associated with the trips or behavior. These trips and associated behaviors can lead to crashes and their disutilities. Most past highway safety efforts have focused on ameliorating a loss after a crash has occurred, or on deterring unsafe behaviors by the threat of traffic law system action or some other threat.

The threat of traffic law system action is a general deterrent. It flows from the actions taken against individual drivers (special deterrent action) and the communication of those special deterrent actions to the public. This is illustrated below.



This general deterrence functions as a surrogate risk. The risk of a crash is perceived as too remote to deter most drivers from unsafe driving acts, so society creates a present "risk" to modify behavior. There are actually many such risks, but most are not as evident as the TLS sanction.

If we think about the process that a driver goes through in deciding to commit an unsafe driving act, we can describe it as a balancing of perceived utilities and disutilities.

The benefits of driving unsafely are compared with the potential negative consequences of the act. Most countermeasures seek to increase the magnitude of the potential negative consequences and thus deter unsafe acts.

Limited examples appear in the literature of techniques designed to reduce the benefits so that the value of engaging in the act decreases. Some cities provide free taxi service for individuals who are intoxicated on New Year's Eve to reduce the utility of driving while intoxicated.

Training programs for emergency vehicle operators use a variety of demonstrations to establish that extreme high-speed operation produces little benefit in the delivery of emergency services. This is intended to reduce the perceived utility of high-speed emergency driving.

An approach that considers reducing the utility as a strategy to reduce risk requires information about the utility associated with unsafe driving acts. Information is also needed about safe driving to understand how other drivers reached a decision not to engage in unsafe driving acts under the same circumstances.

The incorporation of the HTS and its outputs (utility <u>and</u> disutility) within the conceptual framework suggests new avenues for inquiry in the development of risk-management approaches.

8.2 How About Non-Traditional Risk-Management Systems?

We noted above the reliance on the traffic law system to increase the likelihood of negative consequences for drivers who engage in unsafe driving acts. Examination of TLS operations indicates that they are quite cumbersome. Moreover, because they use the criminal sanction, they are rigidly bound by the fundamental protections of the Constitution.

Examination of the range of existing risk-management systems suggests that it may be able to increase negative consequences use of other systems and thus reduce the probability that unsafe driving acts will occur.

For example, enforcement of laws prohibiting driving while intoxicated does not appear to occur at a rate commensurate with the rate of driving while intoxicated. Various explanations appear in the literature. One of the most frequent is that the police are discouraged from making arrests by subsequent actions of the prosecutors and courts. Also, the time that the police must spend on a DUI case is a disincentive to making arrests. When one talks with Motor Vehicle Administrators, they report that drivers who have been arrested are most concerned with preventing their insurance companies from learning of the arrest for fear their policy rates will increase or the policy will be cancelled.

This suggests some alternative risk-management approaches that use the flow of information among systems as suggested by the conceptual framework. First, a procedure might be tried whereby police tests for Blood Alcohol Concentrations (BAC) became a public record. This information could be made available to the media, insurance companies, or other interested parties. This basic information could form the basis for risk-management action by insurance carriers without the necessity of formal sanctioning by the traffic law system.

Another similar thought--many states have passed implied consent laws. These laws provide that when a person operates a vehicle on the highways of the state, he has given his consent to a BAC test when a police officer arrests him for a drinking-driving offense. Criminal and administrative penalties are provided for those who refuse to take the test. In many states enforcement of the laws has proved cumbersome and somewhat ineffective. Should an approach be considered whereby insurance policies would provide for a rate increase or policy revocation if an operator refused to take a test when requested?

The use of other technological advances suggest themselves. The ORBIS device is a camera system that automatically photographs a vehicle that is exceeding a specified speed. Use of these devices has been limited because most jurisdictions attach traffic violation liability to the driver, not the vehicle. In contrast, most insurance companies insure a vehicle and not an individual. ORBIS and other technological systems can easily identify vehicles via license plates. Should we consider simply transmitting photographs of public violations of the speed limit to insurance companies and vehicle owners, rather than worrying about tracking down the operator and proving beyond a reasonable doubt that he was illegally operating at an unsafe speed?

These suggestions are raised as illustration of potential new countermeasures. Another aspect of the conceptual framework dictates that before implementation is attempted, we must examine societal perceptions about the benefits of such countermeasures and the risks they address. Some risk-management approaches may be economically defensible but not acceptable to society. For example, when one considers the total societal cost that a chronic drinking driver can cause, a cheap countermeasure might be to provide him with a full-time chauffeur. Perhaps this would be cost effective, but it is doubtful it would be societally acceptable.

8.3 Summary and Conclusions

Several brief examples were presented to illustrate that the new conceptual framework directs inquiry to areas not previously examined in depth. Specifically, the concept of decreasing the utility associated with unsafe driving needs to be examined. Also the functions of risk-management systems and their linkages need to be studied. Society's reaction to new approaches needs to be examined before they are implemented.

Each of these three points: (1) examining utility; (2) broadening our perspective of risk-management systems; and (3) ascertaining societal response to new highway safety approaches before implementation, flow from an understanding of the conceptual framework. These specific points reflect only a few of the directions for inquiry suggested by the conceptual framework.

9.0 CONCLUSIONS AND RECOMMENDATIONS

This paper has examined existing theory in the field of highway safety and described a new conceptual framework for the highway safety process. The framework illustrates the importance of understanding how people make decisions about risk. It also emphasizes the importance of using sound management methods in the risk-management process. Application of basic management methods will improve the operations of risk-management systems.

When the conceptual framework is used to examine past and current problems in highway safety, it identifies some research questions that need to be pursued.

Each of the chapters raised and discussed highway safety issues, reached conclusions and made recommendations related to those issues. We now identify a limited set of top level conclusions and accompanying recommendations that we believe are most important for immediate consideration.

Conclusion I	Immediate emphasis should be placed on development of an organized body of theory of highway safety.
Discussion	The lack of order, conflicting demands for resources, and absence of an organizing framework for decision-making are evidence of the need for a general theory and model. We offer a conceptual framework as a starting point, but much more must be done.
Recommendation	Formal programs designed to develop theory should 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 take a leadership role in encouraging the start of a research program and critically reviewing its progress.

Conclusion II Priority should be given to improving the use of existing knowledge about the traffic crash risk and methods for managing that risk.

Discussion Available evidence indicates that societal perceptions 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.

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

Conclusion III 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.

Discussion 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.

Recommendation The responsible federal agencies should 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.

Conclusion IV The general concept of highway safety should be broadened and more disciplines encouraged to study problems of crashes and crash losses.

Discussion The conceptual framework identifies 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 (e.g., decision theorists).

Recommendation Public and private institutions should establish and fund programs designed to apply the best minds from a wide range of disciplines to an examination of crash risk and crash risk reduction.

In turn, the research and academic community should formally recognize, to a greater extent, the importance of managing the traffic crash risk. An understanding of 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.

We close this paper by emphasizing our opening statement. The paper has been written in the context of discovery to raise issues and stimulate discussion, and not necessarily to resolve questions or prescribe solutions.

We hope that it will contribute to some short-term solutions. But, more important, we hope that it 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.

Appendix A

INFORMATION ABOUT TRAFFIC CRASH RISK

Chapter 6 discussed the importance of risk identification for the management of risk. The risk identification process must take place in at least two contexts. First, the magnitude of the risk of concern--in this case the traffic crash risk--must be examined in light of other societal risks. This examination leads to a ranking of societal risks to guide allocation of resources by society to deal with such risks. This is a societal decision process that determines relative importance among conflicting concerns.

Second, the nature of the specific risk must be examined in detail to ascertain factors that create the risk and associated disutilities. This examination allows priorities to be established for risk management actions, suggests targets for countermeasures, provides information on the dynamics of cause and subsequent loss that shape the nature of the risk management response, and provides a baseline measurement of risk that can be used in the evaluation of risk management actions that are implemented.

Our knowledge of the nature and extent of the traffic crash risk is limited, as is our knowledge of other similar societal risks. Present data provide insights and perspectives for further inquiry. They suggest directions that should be taken for the future and raise issues for discussion about the wisdom of directions followed in the past. The following sections present general information comparing the traffic crash risk to other societal risks as well as information on traffic crash causation. These data are not definitive and are provided to illustrate the problem and to foster discussion.

A.1 Societal Risk of Traffic Crashes

One of the most complex problems in societal science is developing valid operational definitions of concepts. In most cases the major validity problem relates to measurement. How we choose to measure a problem may well influence the outcome. For some time it has been fashionable to discuss traffic safety and other areas of safety in terms of deaths. To a lesser extent safety discussions examine injuries and property losses. Quantification of the number of deaths has proved simpler than assignment of a value to an injury or determination of costs associated with traffic crash risks. Cost data and injury data do exist and are regularly (or irregularly) reported. Yet deaths appear more persuasive and pervasive in safety discussions.

While we do not believe that deaths alone are an adequate measure of disutility, it is interesting to compare the number of deaths from traffic crashes with other "accidental" deaths. Table A-1 lists causes of death by type of accident and the number of deaths in recent years associated with each type of accident. This information was obtained from the 1976 edition of Accident Facts, a publication of the National Safety Council (4).

Traffic crashes are the largest single category of accidental deaths. It would be logical to expect that the societal response would be to allocate more resources to deal with this problem than other risks that produce accidental death. Yet, this has not been done in the United States.

Examples of this discontinuity come quickly to mind. Seven traffic deaths occur for every fire death. Yet, most communities have fire departments funded and staffed at a level nearly equal to their law enforcement agencies that have the primary responsibility for traffic control. The law enforcement agencies must also deal with general crime, maintenance of order and community service demands.

In recent years public perceptions of the crime problem have frequently resulted in diversion of police resources from traffic duty to more general law enforcement functions. This trend started

TABLE A-1

Accidental Deaths According to the International List of Causes of Death

Deaths are classified on the basis of the Eighth Revision of "The International List of Diseases and Causes of Death", which became effective in 1968. This revision provides for a class of deaths due to injury when it cannot be determined whether the death was an accident, suicide, or homicide. There were 5,149 deaths classified in this category in 1974.

Type of Accident or Manner of Injury	1974†	1973	1972	1971
All Accidental Deaths	**104,622**	**115,821**	**115,448**	**113,439**
Transport accidents	**50,659**	**59,986**	**60,480**	**58,529**
Railway accidents	716	789	692	750
Motor vehicle	46,402	55,511	56,278	54,381
Traffic	*45,314*	*54,347*	*55,214*	*53,366*
Nontraffic	*1,088*	*1,164*	*1,064*	*1,015*
Other road vehicle	275	293	306	263
Water transport	1,579	1,725	1,568	1,531
Drowning (excluded from drownings below)	*1,413*	*1,573*	*1,390*	*1,375*
Other water transport	*156*	*152*	*178*	*156*
Air and space transport	1,687	1,668	1,636	1,604
Poisoning by solids and liquids (See also page 82)	**4,016**	**3,683**	**3,728**	**3,710**
Poisoning by drugs and medicaments	2,742	2,444	2,516	2,528
Poisoning by other solid and liquid substances	1,274	1,239	1,212	1,182
Poisoning by gases and vapors (See also page 82)	**1,518**	**1,652**	**1,690**	**1,646**
Falls	**16,339**	**16,506**	**16,744**	**16,755**
Fires and flames	**6,236**	**6,503**	**6,714**	**6,776**
Conflagration in private dwellings	4,369	4,362	4,654	4,401
Conflagration in other buildings or structures	224	230	268	265
Conflagration not in buildings or structures	75	37	92	123
Ignition of clothing	445	517	542	655
Ignition of highly inflammable materials	185	254	224	223
Other and unspecified fires and flames	938	1,003	934	1,109
Natural and environmental factors	**1,427**	**1,348**	**1,800**	**1,366**
Excessive heat	140	131	234	112
Excessive cold	348	381	490	361
Hunger, thirst, exposure and neglect	201	240	268	283
Bites and stings of venomous animals and insects	53	49	42	48
Other accidents caused by animals	139	164	146	163
Lightning	112	124	94	122
Cataclysm	384	193	500	248
Other natural and environmental factors	50	16	26	29
Other accidents	**20,711**	**21,936**	**20,320**	**20,241**
Drowning, submersion (excl. water trans. drownings above)	6,463	7,152	6,196	6,021
Inhalation and ingestion of food	2,161	2,210	2,088	2,227
Inhalation and ingestion of other object	810	803	742	650
Mechanical suffocation	1,083	1,109	1,104	1,176
In bed or cradle	*234*	*287*	*322*	*435*
Other and unspecified mechanical suffocation	*849*	*822*	*782*	*741*
Struck accidentally by falling object	1,143	1,196	1,218	1,168
Striking against or struck accidentally by objects	927	882	846	836
Caught accidentally in or between objects	521	598	536	548
Cutting or piercing instruments	112	133	125	147
Explosion of pressure vessel	57	73	60	72
Firearms	2,513	2,618	2,442	2,360
Self-inflicted	*512*	*516*	*538*	*524*
Other and unspecified firearms	*2,001*	*2,102*	*1,904*	*1,836*
Explosive material	459	512	518	544
Fireworks	*3*	*5*	*10*	*3*
Blasting materials	*24*	*21*	*24*	*24*
Explosive gases	*230*	*234*	*242*	*228*
Other and unspecified explosive material	*202*	*252*	*242*	*289*
Hot substance, corrosive liquid, and steam	216	279	282	248
Electric current	1,157	1,149	1,088	1,065
Home wiring and appliances	*203*	*232*	*206*	*216*
Industrial wiring and appliances	*163*	*181*	*142*	*155*
Other electric current	*636*	*564*	*604*	*534*
Unspecified electric current	*155*	*172*	*136*	*160*
Radiation	1	0	0	0
Machinery accidents not elsewhere classified	793	884	896	874
Other and unspecified	2,285	2,338	2,176	2,305
Surgical and medical complications and misadventures	**3,021**	**3,525**	**3,324**	**3,740**
Operative therapeutic procedures	2,151	2,612	2,504	2,736
Other and unspecified therapeutic procedures	638	646	628	787
Other and unspecified nontherapeutic procedures	232	267	192	217
Late effects (death more than a year after accident)	**695**	**682**	**648**	**676**
Motor vehicle	166	152	132	137
Falls	172	190	156	181
Other and unspecified late effects	357	340	360	358

Source: National Center for Health Statistics. See page 22 for comparability. †Latest official figures.

in the late 1960s and continues today. The underlying philosophy is reflected in a 1969 statement by Chief Robert Igleburger of the Dayton, Ohio, Police Department.

> "While traffic moves freely and efficiently in many sections of our urban centers, crime continues to rise, severe social problems prevail and disorders frequently break out. It seems to signify that new concerns and priorities have arisen in metropolises."
>
> With this in mind, the Dayton Police Department recently undertook a program of massive review of its goals, priorities, mission and methods of operation. We reviewed expectations of the community by analyzing our service requests, citizen complaints, and community attitudes and desires...had we done this five years ago, our major priority would have been traffic law enforcement; our present analysis showed it to be repression of criminal activity and general public service. Traffic control and traffic law enforcement we determined could not continue to receive the manpower allocation--over 20 percent--they had previously received". Traffic Safety 69 (June 1969): pgs 14-16.

This comment reflects the reactions of a risk manager, in this case a police chief, responding to societal perceptions of the importance of various societal risks. Crime, in this case, was deemed more important than traffic crashes. That societal perceptions reflect this value probably cannot be disputed. The accuracy of the perception and its acceptance by risk managers is more debatable.

This can be illustrated by a rather interesting outcome of a study conducted in St. Louis, Missouri. The study, designed to improve allocation of police resources, started with the premise that not all crimes were the same. For example, not all events described as robberies present the same risk to the public. Some involve violence and injury, while others, although serious, do not have the same level of risk. The study examined a series of crimes and rated their seriousness, based on the characteristics of the event (i.e., was there injury, was a weapon used, what was the value of the property stolen, etc.). To quantify seriousness the authors, Nelson Heller and Thomas McEwen, used the Sellin-Wolfgang scale to assign a numerical value to the characteristics associated with each event. The same scale was also applied to traffic crashes occurring during the study period. One would have expected a significantly lower score for traffic crashes, as one component of the scale--intimidation--does not apply in the case of nondeliberate crashes. The results were surprising: "The injury and property loss occurring in the average traffic accident is over fifty percent more serious than that occurring in the average Part I offense." (Journal of Criminal Justice, Vol. 1, No. 3 pg 242). (Part I offenses refer to the crimes of homicide, rape, robbery, aggravated assault, burglary, larceny over $50, and auto theft that are reported in Part I of the Uniform Crime Reports).

While this study cannot be viewed as definitive, it strongly suggests the inaccuracy of the societal perception that crime is a greater personal risk than traffic crashes.

In the first part of this discussion, data that contrasted traffic crash deaths with other accidental deaths were presented. Next, the risk of traffic crashes was contrasted with that of crime. Other comparisons can be drawn. Table A-2, reproduced from reference (1), shows that motor vehicle crashes rank as the leading cause of death in the age group 5-24 years, and are a major cause of death through middle age.

The data presented in this section are illustrative of the relative importance of traffic crashes as a societal risk. They are not definitive and, given present public perceptions, 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. As long as the risk of traffic crashes is perceived as less important than other risks, risk management efforts focused on traffic crashes will be inadequate.

FIGURE A-2

Leading causes of all deaths

	No. of Deaths	Death Rate*
All Ages	1,934,388	915
Heart disease	738,171	349
Cancer	360,472	171
Stroke**	207,424	98
Accidents	104,622	50
Motor-vehicle	46,402	22
Falls	16,339	8
Drowning	7,876	4
Fires, burns	6,236	3
Other	27,769	13
Under 1 Year	52,776	1,754
Anoxia	13,724	456
Congenital anomalies	8,607	286
Complications of pregnancy and childbirth	7,054	234
Immaturity	4,719	157
Pneumonia	2,577	86
Accidents	1,453	48
Ingestion of food, object	442	15
Mech. suffocation	285	9
Motor-vehicle	224	7
Fires, burns	136	5
Falls	87	3
Other	279	9
1 to 4 Years	9,831	74
Accidents	3,882	29
Motor-vehicle	1,322	10
Drowning	850†	6
Fires, burns	654	5
Ingestion of food, object	163	1
Falls	159	1
Other	734	6
Congenital anomalies	1,191	9
Cancer	785	6
5 to 14 Years	14,636	38
Accidents	7,037	18
Motor-vehicle	3,332	9
Drowning	1,020†	3
Fires, burns	569	1
Other	1,816	5
Cancer	2,001	5
Congenital anomalies	818	2
15 to 24 Years	47,303	122
Accidents	24,200	62
Motor-vehicle	15,905	41
Drowning	2,390†	6
Poison (solid, liquid)	1,088	3
Firearms	802	2
Other	3,985	10
Homicide	5,577	14
Suicide	4,285	11

	No. of Deaths	Death Rate*
25 to 44 Years	106,867	204
Accidents	22,547	43
Motor-vehicle	11,834	23
Drowning	1,650†	3
Poison (solid, liquid)	1,425	3
Falls	1,101	2
Other	6,537	12
Cancer	16,979	32
Heart disease	15,465	30
45 to 64 Years	462,930	1,069
Heart disease	166,558	385
Cancer	129,017	298
Stroke**	27,840	64
Accidents	20,334	47
Motor-vehicle	8,159	19
Falls	2,616	6
Fires, burns	1,585	4
Drowning	1,100†	2
Other	6,874	16
Cirrhosis of liver	19,131	44
Diabetes mellitus	8,897	21
65 to 74 Years	450,461	3,327
Heart disease	189,586	1,400
Cancer	104,846	774
Stroke**	45,273	334
Diabetes mellitus	11,040	82
Accidents	9,323	69
Motor-vehicle	3,071	23
Falls	2,384	18
Fires, burns	893	7
Surg. complications	752	6
Other	2,223	16
Pneumonia	8,959	66
Emphysema	7,545	56
75 Years and Over	789,084	9,524
Heart disease	364,195	4,396
Stroke**	129,183	1,559
Cancer	104,022	1,256
Pneumonia	29,652	358
Arteriosclerosis	26,509	320
Accidents	15,346	191
Falls	9,316	112
Motor-vehicle	2,555*	31
Surg. complications	923	11
Fires, burns	915	11
Ingestion of food, object	462	6
Other	1,675	20
Diabetes mellitus	15,577	188
Emphysema	7,024	85

Source: Deaths are for 1974, latest official figures from National Center for Health Statistics, Health Services and Mental Health Administration, U.S. Department of Health, Education and Welfare.

*Deaths per 100,000 population in each age group. Rates are averages for age groups, not individual ages.

**Cerebrovascular disease.

†Partly estimated.

A.2 The Nature of the Traffic Crash Risk

Knowledge of the nature of risk is necessary for the risk management process. We need to know what causes traffic crashes and the associated losses in order to reduce the risk of crashes and crash loss.

The state-of-the-art of knowledge about injury-producing mechanisms and the dynamics of the crash phase is far advanced, compared to knowledge about traffic crash causation. In reality, we do not know enough about either area.

The development of risk-management strategies is highly influenced by perceptions of what causes traffic crashes. It will be useful as we continue our discussion of highway safety theory to have a common understanding of traffic crash causation.

The study of traffic crash causation is still in a developmental stage. Advances have been made in explanations of crash causation. General findings have been replicated. Yet, there is no general scientific agreement on methods of inquiry or the analysis. Findings of recent studies should be regarded as indicative rather than definitive descriptors of the causes of traffic crashes.

In this context, summary findings are presented here from a study on Traffic Crash Causation conducted by the Indiana University Institute for Research in Public Safety under the sponsorship of the National Highway Traffic Safety Administration. These data represent the most recent results of this multi-year study. Prior findings have been reported in a series of reports (See reference 26, our thanks to John R. Treat for providing these data, which will appear in a report to be published soon).

The study was conducted in Monroe County, Indiana, over a period of more than five years. The general objective of the project was to satisfy national needs for data regarding accident causation and crash avoidance. Data were collected on three levels of detail, as shown in Figure A-1. Only crashes that were investigated and reported by police agencies in Monroe County were considered in the study. At level A, police reports of accidents, driver license data, and vehicle registration data were collected. At level B, technicians were sent to the scene of crashes shortly after they occurred to conduct an independent on-scene investigation. The level-C investigations were conducted subsequently and involved a multidisciplinary team of professions, many of whom held doctorates or advanced degrees. Quantitative measurements of a number of variables were made. Vehicles were removed to a garage facility and examined by automotive engineers. Drivers participated in vision and driver knowledge testing. Accident reconstruction specialists made detailed scene drawings and assisted in the recognition, collection, and interpretation of physical evidence.

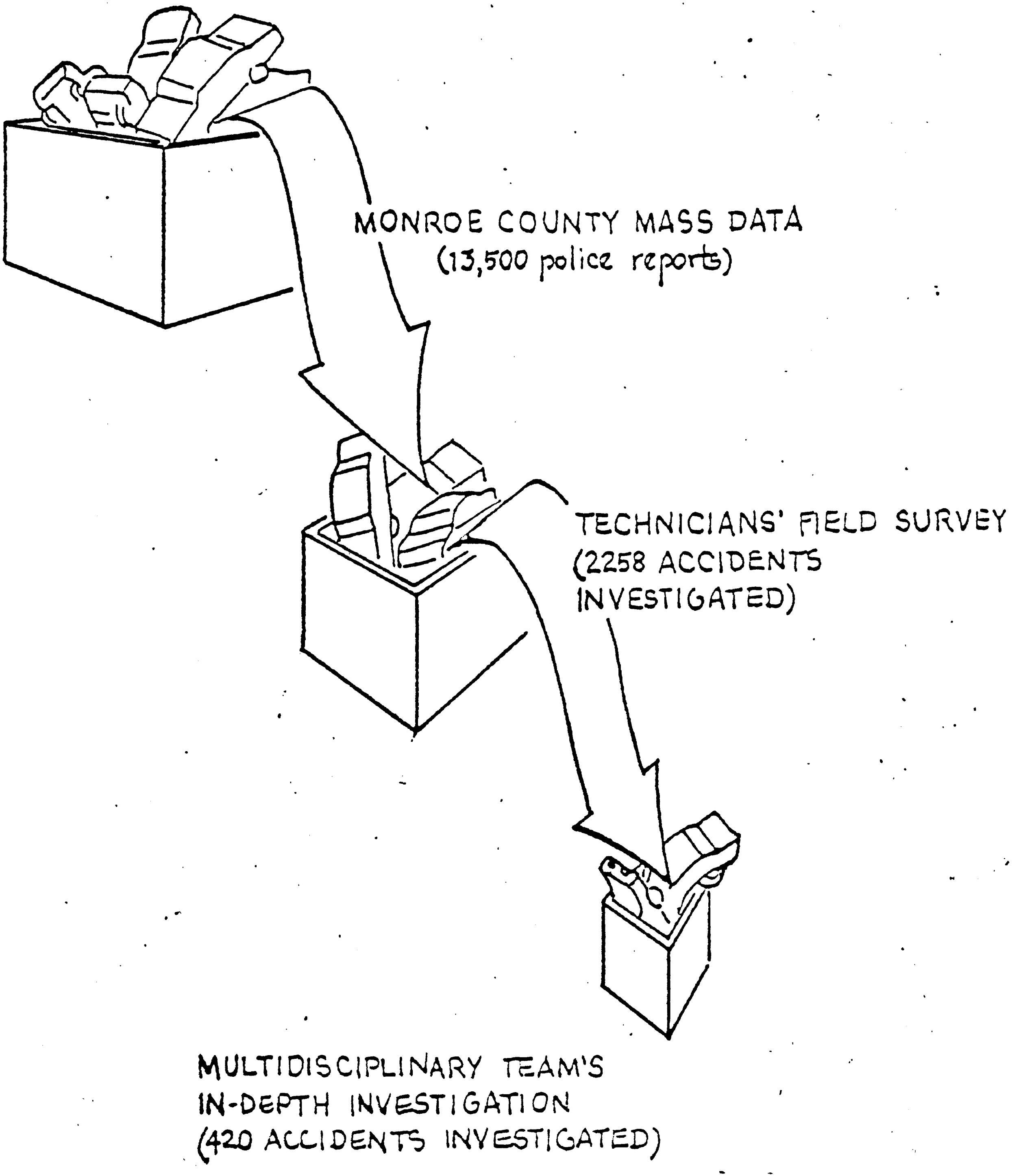
Following the data collection process, the multidisciplinary team convened as a group to develop a clincial assessment of accident causes associated with the crash. Causative factors are listed in three primary categories: human factors, environmental factors, and vehicular factors. A detailed definitional hierarchy of factors or causal factor trees was developed within each of the primary categories listed above. (Details of the definitional approach are provided in reference 26).

In a single accident it was possible for more than one factor to play a causative role. Thus, a single crash might have a human factor, a vehicle factor, and an environmental factor cited as causal factors.

A causal factor rating system was used to express the degree of confidence of the investigators in their conclusions. Conclusions were expressed as <u>certain</u> when there was no doubt as to the factor's role. Factors were assessed as <u>probable</u> when they were considered highly likely although not definite. A <u>possible</u> rating was used to

Figure A-1

Data were collected on three levels of detail.



designate factors of potential relevance, although the evidence did not substantially support their existence and/or involvement. Failure to assign a factor at the possible level reflected a judgment that its involvement was highly unlikely.

The findings of the study are presented in overview form in Figure A-2. Figures A-3, A-4, and A-5 detail the major causal factors within each primary category. Note that the human factors listed are defined as the direct causes of crashes. The study also considered indirect causes, such as human conditions or states which adversely affect the ability of the driver as an information processor and vehicle controller. These factors, which include categories such as fatigue, driver experience, and alcohol impairment, are sufficiently remote in their causal relationship that it becomes difficult to assess their involvement with certainty. (Summary discussion of this complex concept in this limited presentation is likely to introduce misunderstanding. A reader desiring more detailed information is referred to pages 41-48 in reference 26).

Caution should be taken in interpreting the data presented in the figures. Human factors were found to be the predominant causative factor. It is not correct to assume from this finding that the only risk management response to a human failing should be directed at the driver. Some underlying conditions that lead to human failure may be most effectively addressed by modification of either the vehicle or the roadway environment or both. It is also important to note that most of the vehicular factors noted were maintenance-related defects, not manufacturing defects. Thus, it well may be that the best way to address some vehicle defects will be through risk management actions targeted at the vehicle owner or operator.

While these findings come from a relatively large study and reflect perhaps the best available information on traffic crash causation, they are not definitive. They should not be extrapolated

Figure A-2

CAUSATIVE FACTORS IDENTIFIED BY INDIANA TRI-LEVEL STUDY

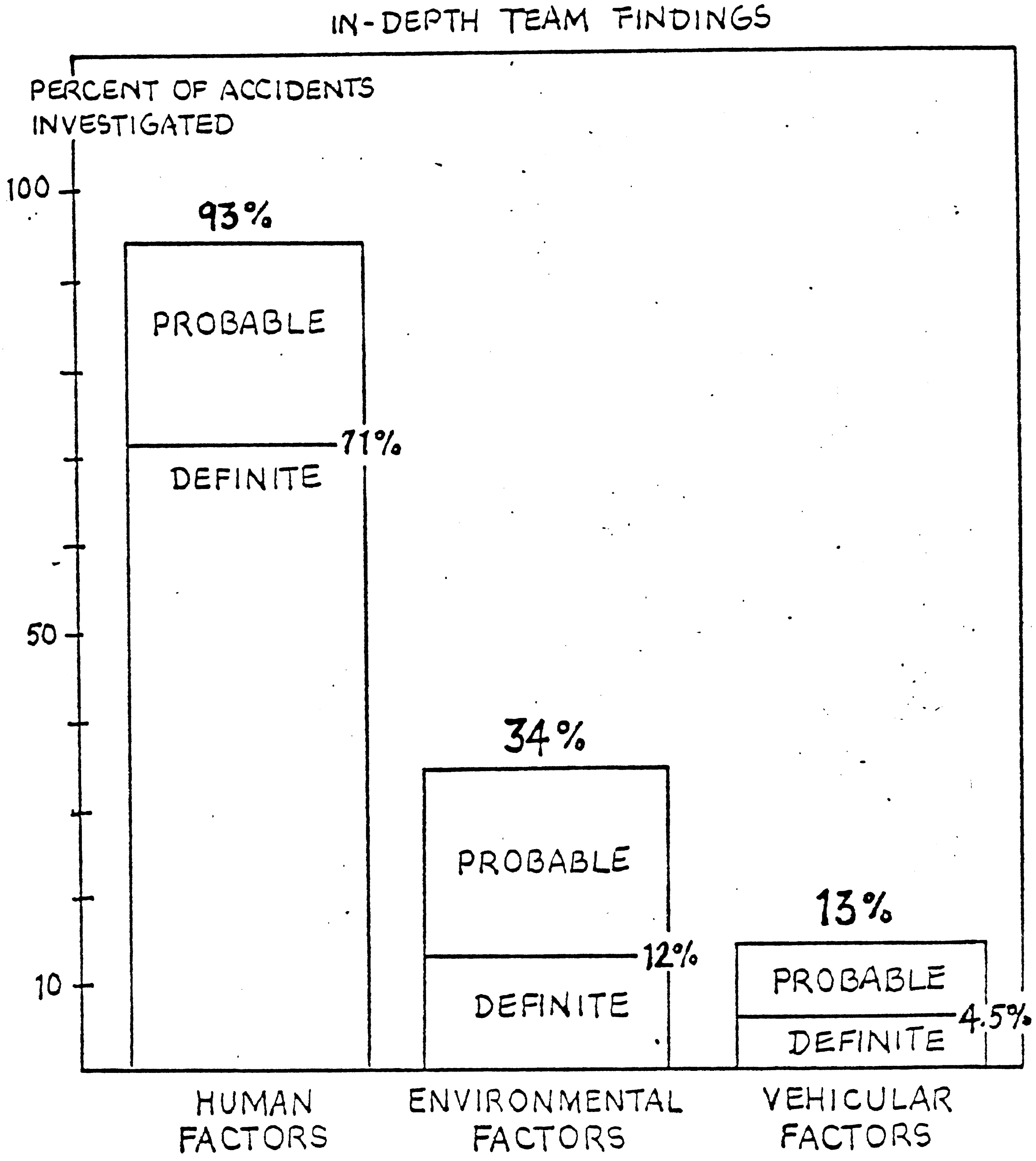


Figure A-3

The four major human direct causes were:

1. Improper lookout
2. Excessive speed
3. Inattention
4. Improper evasive action

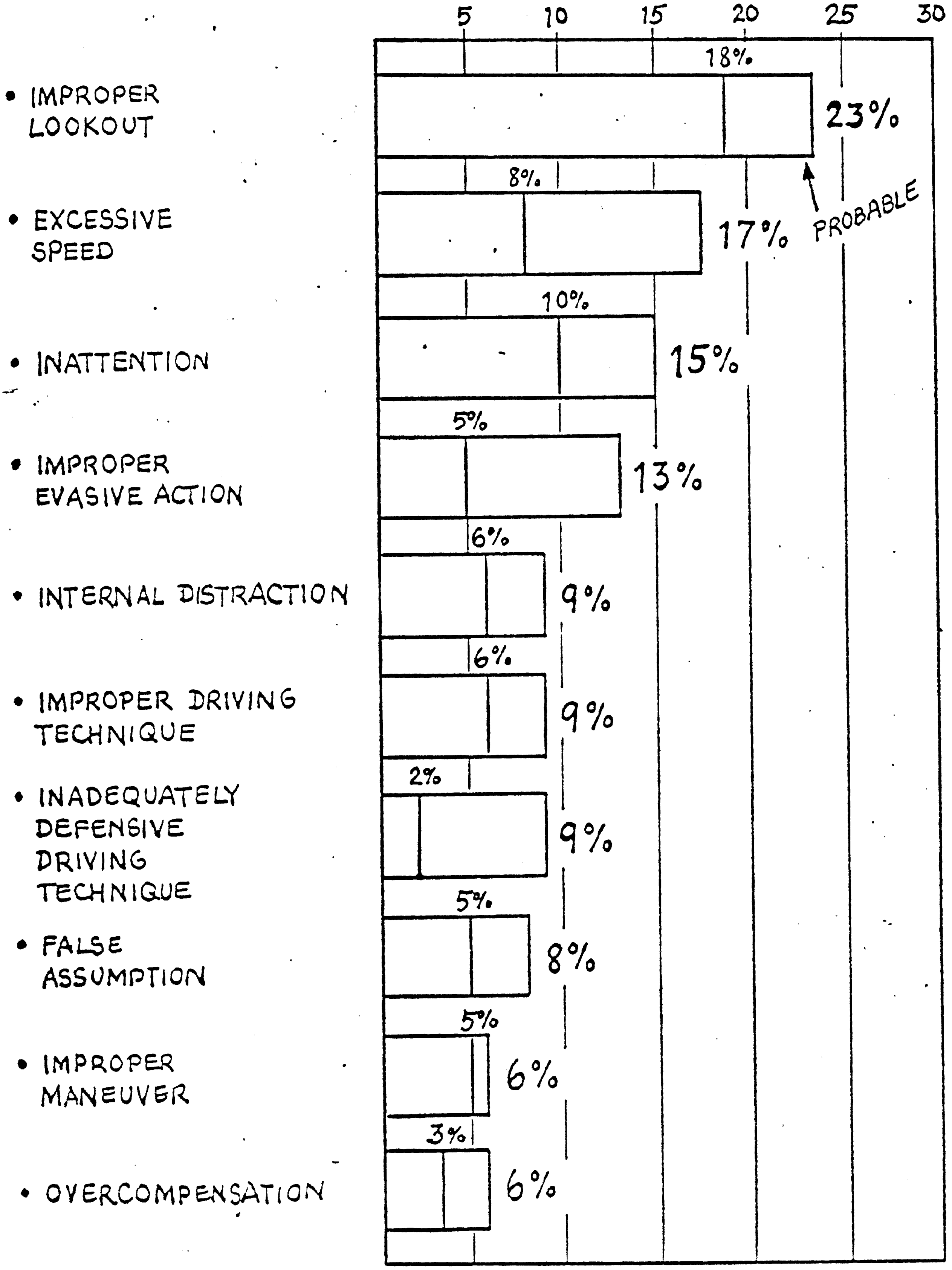


Figure A-4

View obstructions and slick roads were the environmental factors which most frequently caused accidents.

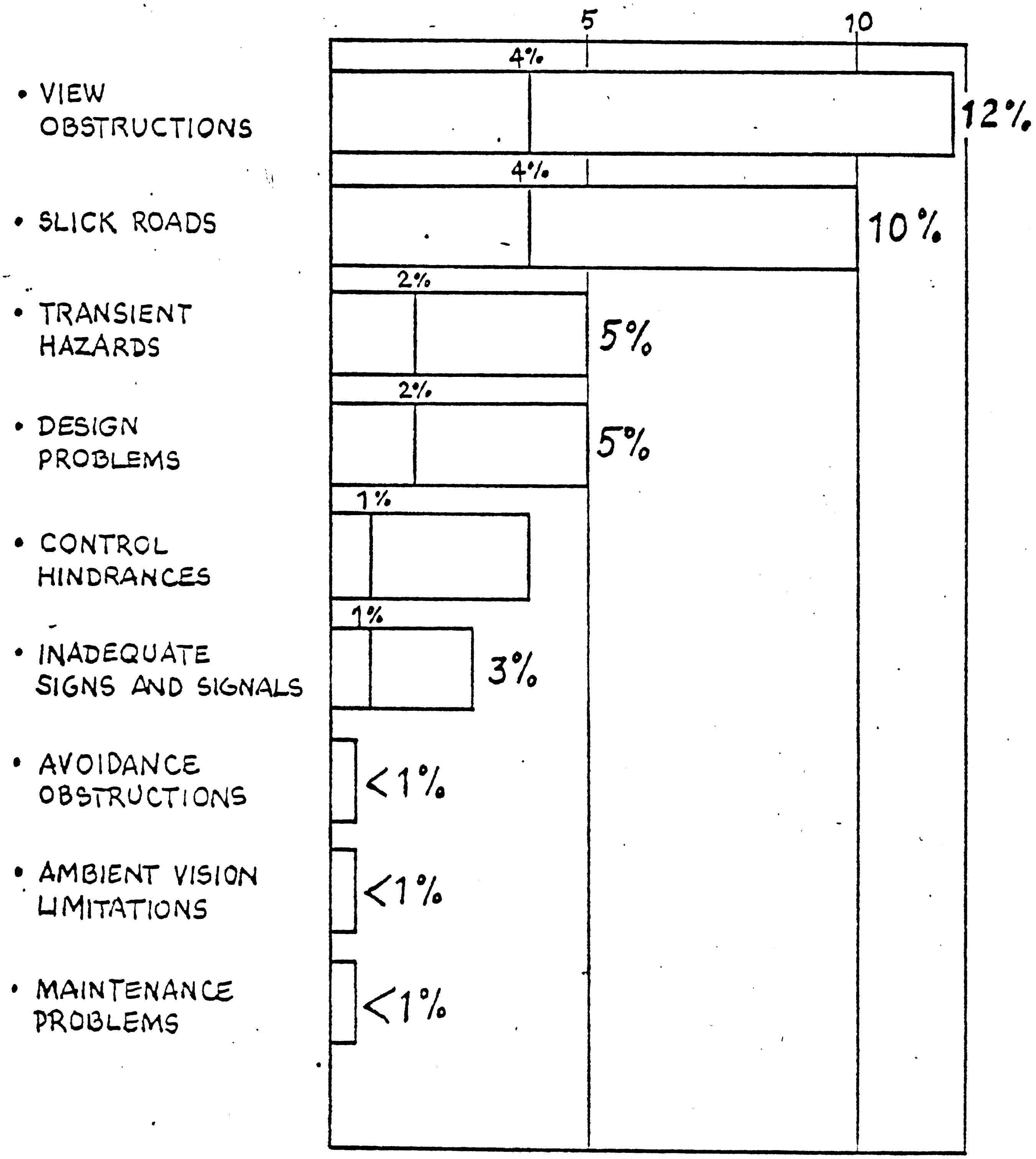
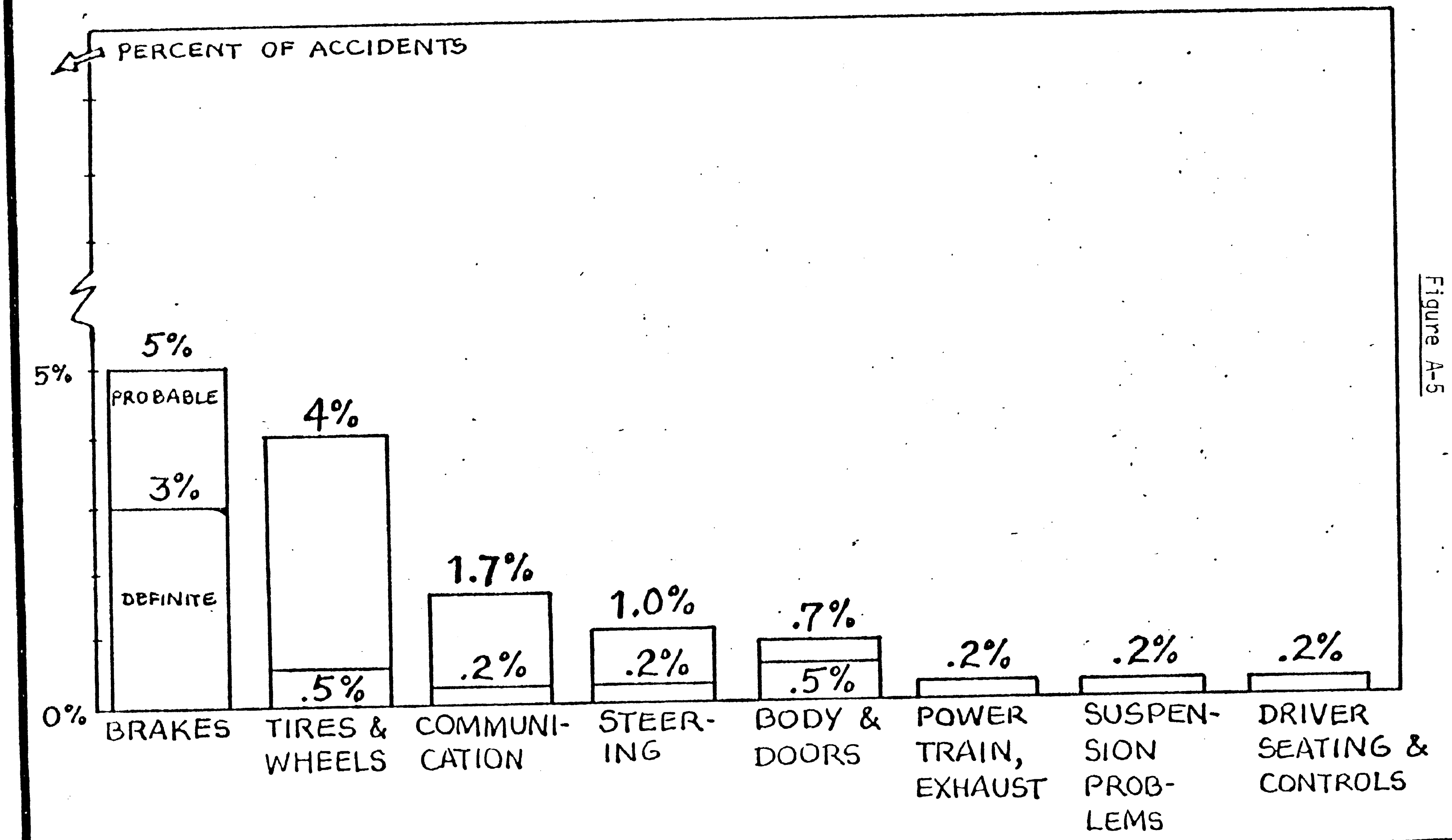


Figure A-5

Brake systems and tires were the vehicular factors most frequently involved in accidents.



to the entire United States or used to generalize in precise terms (i.e., 93% of traffic crashes are caused by human failures). The data, however, are remarkably consistent with other more limited studies in the United States and in other countries as well. The data have also shown a consistency from year to year within the study even though both the observers and the observed conditions have varied.

Perhaps the most significant point, for purposes of this discussion, is the relative involvement rates of the human, vehicle, and environmental factors. In assessing risk management approaches, establishing priorities, and developing strategies and tactics, it will be desirable to keep in mind the general trends as shown by the data from this study.

A.3 Summary and Conclusions

Risk management requires an understanding of the nature and extent of the traffic crash risk. First, the magnitude of the risk must be known to assess its importance relative to other societal risks. Second, characteristics of the risk must be known to select and establish priorities among risk management strategies and tactics and to evaluate the effectiveness of selected approaches.

Current data demonstrate that traffic crashes are a major source of death and injury when compared with other types of accidents. Crashes appear to present a greater risk than crime in some settings. Even when compared with all causes of death in the United States, traffic crashes are a major societal risk.

Examination of data that describe traffic crash causation reveals that human factors are far more frequently involved in a causative role in traffic crashes than either environmental or vehicle factors. The relative role of human, environmental, and vehicular factors must be considered in developing risk management strategies and establishing priorities among approaches.

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