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REVIEW OF METHODS FOR STUDYING
PRE-CRASH FACTORS

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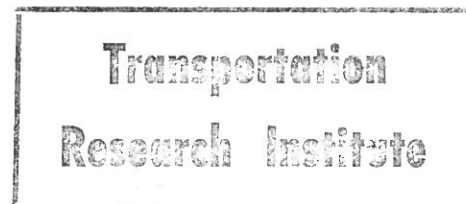


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16. Abstract Considerable effort has been expended particularly over the previous decade in the area of examining pre-crash factors in an attempt at developing appropriate highway safety countermeasures. This report summarizes the review of this field by a select panel of highway safety researchers and includes recommendations for NHTSA-sponsored research in accident causation over the next several years. After attempting to clarify the significance of the "cause" of an accident, the report outlines various approaches to accident causation research and indicates the relevant data needs. The extent and type of exposure information required is addressed. A detailed critique of the major research efforts in this field is provided. This critique centers mainly on the work done by Indiana University, Cornell Aeronautical Laboratory, Inc., Operations Research, Inc., and the University of Miami. Finally, short and long-range recommendations for NHTSA-sponsored research are presented. These include in general utilizing the NASS system to the fullest extent possible. Several specific studies recommended include: examination of data needs; survey of the possible existence of this required data; exploration of various alternative approaches to data collection (e.g. simulation); establishing appropriate quantifiers (e.g., what defines "following too closely"); determining exposure requirements; upgrading the statistical techniques utilized in this field; ascertaining the effectiveness of various countermeasures; and examining alternative information retrieval systems. In addition, several small open-ended research contracts for just plain "thinking about" accident causation methodology were recommended.				13. Type of Report and Period Covered Final report October 1, 1975-May 31, 1976	
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EXECUTIVE SUMMARY

Considerable effort has been expended, particularly over the previous decade, in the area of examining pre-crash factors in an attempt to develop appropriate highway safety countermeasures (CM's). This report summarizes a review of this field carried out by a select panel of highway safety researchers and includes recommendations for NHTSA-sponsored research in accident causation over the next several years.

The panel reviewed a number of studies dealing with accident causation or pre-crash factors. While recognizing the considerable difficulties that pioneering efforts such as these inevitably encounter, the panel nevertheless has serious reservations about the conclusions reported in these studies. Generally, it is felt that these conclusions should be considered instructive but by no means conclusive. The panel strongly feels that NHTSA should not accept the conclusions reported as being warranted necessarily by the research that was conducted. These studies constitute a foundation that is likely to shift in light of new information, and thus further program efforts based on them will be open to serious question. The panel does feel, however, that much can be learned from these prior efforts that should influence the course further research will take.

The following specific recommendations are made for an improved program of accident causation research:

1. Police level data collection should continue in much the same form as is presently the case. Any changes should be considered in light of the problems they may introduce in detecting changes over time. There is room for some enhancement of

current data such as more specific description of truck or motorcycle characteristics.

2. Level III (or in-depth) data should be expanded to include more information on trucks, motorcycles, and bicycles because of the serious nature of such crashes. In addition, at least some information on minor crashes should be included, since it is likely that the relative roles of human, vehicular, and environmental factors differ from the situation in more serious crashes. It is most difficult to summarize data from Level III investigations, and the panel feels that it may be more fruitful to consider such information primarily as a basis for leads as to the kind of information that should be collected in Level II-type (or intermediate level) investigations.
3. The panel supports the implementation of NASS, a national accident data collection system. NHTSA should pay special attention to the following important aspects of such a program:
 - (a) More than one research center should be involved in the design of the NASS system;
 - (b) Research workers should be considered among the potential users of NASS data, and there should be some mechanism by which researchers could have an interactive role in the development and modification of the program;
 - (c) The NASS design should not be considered complete at the time of its implementation but rather should be regarded as a flexible system that can be modified in light of subsequent information and questions;

- (d) Some procedure for regular feedback to the accident investigators should be adopted;
- (e) The system should include a few extraneous variables both to provide for the opportunity to develop new hypotheses and to determine whether the accident sample is actually representative of the whole population;
- (f) There should be some parallel effort to collect good exposure information to make the accident data more readily interpretable;
- (g) All levels of crashes should be included, from minor property damage to fatal injury, and all vehicle types should be investigated.

4. NHTSA should consider the possibility of sponsoring a major accident causation study directed at identifying as many factors, conditions, and events describing an accident as are justified on the basis of current knowledge and on the basis of their potential usefulness for the development of countermeasures. The study should be conducted as follows:

- (a) For the development of the sampling plan, the detailed information requirements, and the analysis plan, there should be two or three contracts awarded with NHTSA selecting the best plan for implementation;
- (b) The field investigation should be conducted according to the specifications developed in the first

phase but handled under a separate contract (and possibly by a different organization);

(c) The analyses of the data, interpretation of the results, and conclusions regarding possible countermeasures should be handled by the organization whose plan was selected after Phase 1.

5. A number of short-term studies should also be conducted to develop a basis for accident causation research. These include studies in the following areas:

(a) Data needs: What information must be collected to allow for the design, planning, and evaluation of specific CM's as well as for the full range of potential CM's?

(b) Existence of required data: Has the kind of information required already been collected and, if so, how extensive is the quantitative knowledge?

(c) Alternative approaches to data collection: In what cases would it be more efficacious to conduct controlled laboratory studies rather than attempt to investigate enough accidents fulfilling the conditions under consideration?

(d) Development of appropriate quantifiers: How does one quantify such factors as "following too closely" or "excessive speed" so as to avoid the possibility of circular reasoning, e.g., a crash occurred; therefore, the vehicle was following too closely?

- (e) Exposure requirements: What amount, type, and level of exposure data is needed and what are the trade-offs among the various types of exposure measures?
- (f) Statistical methodology: Which statistical techniques should be used to organize accident data in a meaningful manner, to identify independent factors, to identify the interaction of factors, and to estimate how the individual CM's or a combination of CM's might operate?
- (g) Determination of CM effectiveness: What percentage of all accidents will be affected by a particular CM and what is the national frequency of such accidents?
- (h) Information retrieval: Can existing techniques in information retrieval be utilized to study unstructured verbal and perhaps graphical information from accident reports?

6. Finally, it is recommended that NHTSA sponsor some less-structured research on accident causation, as part of a continuing effort to promote creative thinking and extend knowledge in this highly complex field.

Generally, it may be said that the panel feels research to date does *not* constitute an adequate basis for arriving at firm conclusions regarding pre-crash factors. There needs to be considerable input from a variety of sources to arrive at a better formulation of the problem and procedures for attacking it. Outcomes at any point should be considered tentative at best and susceptible to further modification.

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I. INTRODUCTION

A major area of research in highway safety in the coming years will be the identification of factors contributing to highway accidents and the recommendation of appropriate countermeasures (CM's). Since considerable research on the subject has already been carried out, it seemed appropriate to take the time and effort to review procedures and evaluate results obtained to date in order to better plan future research in the area.

Accordingly, NHTSA proposed that this review, evaluation and recommendations be performed under an existing contract with the Highway Safety Research Center (HSRC) of the University of North Carolina. In making this decision, time was a primary factor, since it was then mid-September of 1975 and feedback from the project was to be incorporated into NHTSA proposal requests the following spring and summer.

To carry out this effort, HSRC, working with NHTSA, secured the consulting services of several individuals who represented a broad base of experience in the highway safety field. The following persons were selected and agreed to participate on this "blue ribbon" panel:

Dr. Frank Haight, with The Pennsylvania Transportation Institute at Pennsylvania State University.

Dr. Hans Joksch, with The Center for the Environment and Man, Inc., in Hartford, Connecticut.

Mr. James O'Day, with the Highway Safety Research Institute at the University of Michigan in Ann Arbor.

Dr. Patricia Waller, with the University of North Carolina Highway Safety Research Center in Chapel Hill.

HSRC assumed responsibility for organizing the panel's efforts and compiling the final report for this project.

The objectives of the panel were 1) to review and evaluate some 25-30 studies on accident causation, and 2) on the basis of these reviews

along with their own experience in the field, to make recommendations to NHTSA for future research in the area. These panel recommendations were to include general recommendations for the field of accident causation research (data needs, exposure considerations, etc.) as well as specific recommendations for NHTSA-sponsored research in this field over the next several years.

To accomplish these goals, panel members worked both independently and jointly over a period of approximately four months. A total of three sessions (each of one to two days duration) were held at the end of October, the first of December and in mid-January. Between sessions, panel members reviewed materials and formulated their ideas and suggestions. They also prepared written contributions which were forwarded to other panel members and to HSRC. Each panel member devoted up to fifteen man-days to the project.

Following is the final report of this panel. Section II presents a general orientation to causation research along with the panel's views on the meaning of "cause" in accident studies, the derivation of effective countermeasures, and the role of exposure data in accident causation research. The guidelines set forth in this section serve as a basis for the reviews which follow in Section III. Finally, in Section IV, the panel's recommendations are outlined.

As would be expected, sometimes there were differences of opinion. No attempt was made by the editors to compromise these distinctive differences. Instead, where differences exist, or where individual ideas are advocated, these are attributed to their author by having his last initial follow the statement. For example, a particular recommendation suggested by Dr. Joksich would be succeeded by (J).

II. BACKGROUND

Defining the "Cause" of an Accident

Webster defines cause as "that which occasions or effects a result", and lists such synonyms as determinant, antecedent, and reason (all of which mean "that which in whole or in part produces an effect"). But each of the synonyms seems to have a slightly different connotation -- antecedent, for example, being a sort of progenitor or precursor. (O'D)

In the highway accident literature, these and several more specialized terms are used. Some authors talk about causes being preceded by conditions, and proximate causes being more important (at least in a legal sense) than ordinary causes. A whole chain of modifiers for cause has been invented to describe the causal concept as thought most appropriate by a particular author -- direct cause, indirect cause, critical cause, certain cause, probable cause, possible cause, pseudo-cause, causal sequence, causative factors, etc. (O'D)

A distinction frequently made in the past is between "narrowly" and "broadly" defined causes. Generally, a "narrowly" defined cause is one that satisfies the "but for" test--i.e., "but for" this factor the accident would not have occurred. Some examples might be a chuckhole in the road, a broken wheel, a driver who had gone to sleep, an icy road, etc. In some cases, several factors might be necessary for an accident to occur, and in these instances, this set of factors would be the narrowly-defined cause. The implication here is that, if one of the factors in the set had not been present, the accident would not have happened (or at least would have been greatly modified). (O'D)

In contrast, a "broadly" defined cause is anything subject to change wherein the change will reduce the probability of that accident occurring. This is the approach taken by Shaw and Sichel in their book on accident proneness (1971). One possible example of a "broadly" defined cause is "being a high school dropout." Certainly, if being a high school dropout had the effect that the driver did not acquire certain knowledge, skills or attitudes which those completing high school did acquire, then it would be a "cause" in the meaning of the broad definition, since by completing high school, the dropout would also have acquired these attributes. On the other hand, if being a dropout is just an indicator of certain other factors "causing accidents" (or, if being a dropout is "caused" by the same unobserved factors as being involved in an accident), then it may be argued that "being a high school dropout" is not a cause in the meaning of the definition. (O'D, J)

As a final example of the confusion resulting from the lack of preciseness in defining the "cause" of an accident, consider the following: Suppose one finds that drivers under age 21 are overrepresented in the accident population. This may be viewed as a simple correlation. One cannot conclude that being under 21 "causes" accidents -- or can one? Certainly, if all drivers under 21 are removed from the roads, there should be a disproportionate decrease in accidents. While this may not be the most effective countermeasure, one can still argue that young drivers "cause" accidents, and that by removing them from the population (e.g., by raising the age of first licensing) one can disproportionately reduce the incidence of accidents. (O'D)

In conclusion, accident causation might be considered from a narrow or a broad point of view -- or anywhere between such limits. Indeed, the

entire range of definition is evidenced in the causation studies reviewed by this panel.

Clearly, this lack of agreement as to what constitutes the "cause" of an accident creates problems for accident causation researchers. Rather than trying to identify specific causes of accidents, a more appropriate approach to accident causation research might be the identification of pre-crash factors (PF) -- factors which may or may not have "caused" an accident in any traditional sense, but which reflect aspects of the vehicle, driver or environment which were present at the time of the accident. The task then becomes one of determining what pre-crash factors are associated with what types and frequencies of accidents. A given pre-crash factor would only be a candidate for a "cause" of an accident if the probability (Pr) of an accident in the presence of that factor was greater than in its absence; that is, if

$$\text{Pr}(\text{accident}|\text{PF}) > \text{Pr}(\text{accident}|\overline{\text{PF}}).$$

The effect of introducing a countermeasure (CM) would be that of reducing the "level" of the PF, or frequency of its occurrence, among certain populations, resulting in fewer accidents.

Using this definition, no PF could be designated the absolute cause of an accident. Rather, the greater the ratio, $\frac{\text{Pr}(\text{accident}|\text{PF})}{\text{Pr}(\text{accident}|\overline{\text{PF}})}$, the more highly is the factor associated with the accident (and the more likely it is its "cause"). As an example, icy roads might be shown to be more highly associated with accidents than chuckholes and chuckholes more than loose steering systems in automobiles.

This approach to studying accident causation can also be extended to account for various interactive effects. Consider for example the case

where excessive freeplay in the steering system results in a greater probability of an accident only for beginning drivers. Letting E represent the conditional factor "beginning driver", the model then becomes

$$\text{Pr}(\text{accident}|\text{PF},\text{E}) > \text{Pr}(\text{accident}|\overline{\text{PF}},\text{E}).$$

Obviously, if this relationship holds, then the greater the probability of E, the greater the chance that a given PF will result in an accident.

This view of causation was first introduced by Greenberg (1969) in a discussion of problems of statistical inference in health, with special reference to the cigarette smoking and lung cancer controversy. However, it seems equally applicable to the field of accident causation research. Obviously, the model would be of little value to the police investigator at the scene of an accident, trying to record its "cause" so that a local "fix" could be introduced. Neither would it be of great value to the in-depth investigator, working with a comparatively small sample of accidents. However, it would be of particular use to analysts working with intermediate-level files (Level II).

In the remainder of this report, the terms "pre-crash factor" and "cause" will be used more or less interchangeably. In either case, however, the view of this panel is that there is virtually never an absolute cause of an accident, only greater or lesser associations between accidents and certain driver, vehicle, and environmental factors.

Approaches to Accident Causation Research

There are two major components to highway accident causation research. One is the identification of "causes" of highway accidents. The second is the designing of cost-effective countermeasures to reduce the likelihood and/or consequences of these accidents. While not all accident

causation research encompasses both aspects, the assumption of this panel is that the only reasonable justification for finding "causes" to accidents is that these findings can be used to determine "fixes" which will lessen the chance of such accidents in the future. (O'D)

In the past, accident causation research has most often taken the form of analysis of accident data. However, it is possible to introduce countermeasures to reduce the probability of the occurrence of an accident without reference to any accident data at all. Indeed, this is the approach usually taken in such fields as aviation and engineering. For example, although there has never been a commercial midair collision on the transatlantic routes, there have been many "countermeasures" introduced and modified over the years to keep the probability of such a collision low. Industrial plants have safety engineers who seek out situations which might be dangerous (grease on the floor, paint stored in non-fireproof containers, etc.) and have them corrected without ever having an accident to analyze. Such countermeasures, introduced prior to an accident's occurrence, might be more appropriately termed "safeguards". (O'D)

Likewise in the highway field, it is possible to study accident causation and to design effective countermeasures or safeguards without relying on "real life" accident data. For example, simulators allow one to study the reactions of many drivers in identical situations, to obtain frequency distributions of different reactions and to relate the reactions to driver characteristics and background. Similar detailed observations and measurements are possible in controlled experiments where real drivers in real cars perform maneuvers on test ranges. (J)

Some other methods of studying accident causation which do not rely on actual accident data include stochastic and physical modeling, and

observation of conflict situations. The latter involves observing situations which are necessary (but not sufficient) for certain types of accidents to occur. One example is (legally) turning left at an intersection, another (illegally) being in the intersection when the light has turned red. (J)

Thus, one need not rely on analysis of accident data to design valid countermeasures and reduce accident frequency. But in the highway field there are accidents aplenty, and it seems most appropriate to study these to learn more about how they happen, so that means can be devised to reduce their occurrence. And, as mentioned earlier, this is indeed the approach most often taken by highway safety researchers. (O'D)

Data Sources for Accident Causation Studies

In studying accidents to determine causes and possible "fixes", the kind of data recorded is of foremost importance. This, in turn, is largely determined by the data source. Basically, there are three distinct accident data sources that have been utilized by highway safety researchers. These three sources, which represent three levels of detail in data collection, are reviewed in Kahane, Lee, and Smith (1975), and will be briefly summarized here.

In the past, researchers have relied primarily on police accident reports, automated onto traffic records files. These Level I-type data have the advantages of being readily accessible and plentiful. In addition, some of the better files may contain information on a variety of potentially relevant variables, including road defect, road condition, speed of vehicle prior to impact, vehicle defect, vehicle damage, etc.

However, there are several weaknesses in the Level I-type files which create problems for accident researchers. This is at least partly

understandable, since police have many more important duties to perform beyond filling out detailed and lengthy accident report forms. As a result, data on the police-level files are frequently inaccurately recorded or missing altogether (e.g., information on travel speed before the accident or seat belt usage). Also, the abbreviated police reports are not able to cover the full range of potentially useful data items. The items that are included may not be recorded at a sufficient level of refinement to be useful to accident researchers (e.g., defining injury in terms of K,A,B,C,O). And finally, the police files are usually not representative (other than of a given state or city), and there are seldom well-defined criteria for what data are collected or, in turn, automated. Thus, one municipality may capture only injury accidents on tape, while another will capture property damage cases as well.

At the other extreme are the in-depth or Level III data files, which are collected and for the most part automated entirely by accident research professionals. These files have the advantage of accuracy and completeness, and contain data on a great number of potentially relevant variables. However, since the various in-depth investigation teams operate with different case selection rules, the compilation of these cases is clearly not representative of the national accident population. The fact that the investigations can only be conducted in cases where the data is completely available creates further biases in the file. Thus, although the files may be sufficiently large, they are of limited value for statistical analysis. (O'D)

Between the police report and in-depth files are a number of data collection efforts which comprise Level II files. According to Kahane et al., (1975), these files "have mated the accuracy and controllability of professional investigators with the efficiency of a short protocol that

contains only the data items needed for analysis." While Level II files clearly have the greatest potential for statistical analysis, in the past they have often suffered from lack of a large sampling based on clearly defined specifications. The current NHTSA-sponsored Restraint Systems Evaluation Program has overcome most of these sampling problems.

Examples of each of these three levels of accident investigations can be found in the literature reviewed by the panel. Thus, the CALSPAN studies (1972) are based on police-level data, while the Indiana studies (1971, 1973a, 1973b, 1975a, 1975b) combine all three levels of accident investigations.

Whatever the level of accident investigation, the process or scheme used in recording information is of great consequence to later development of effective countermeasures. This, in turn, is largely determined by the underlying taxonomy employed by the researchers.

One of the difficulties in developing a taxonomy is that it will likely reflect the particular interests of the developer. If he is primarily concerned with human factors, the taxonomy may go into great detail in that field to the neglect of the highway and the vehicle. But if the developer is a highway designer, he may begin by assuming that people (drivers) have a wide range of acceptable characteristics (some sleepy, some with poor vision, some with short legs, etc.), but that any highway characteristics which enhance the probability of an accident (a too narrow shoulder, a change in the coloring of the pavement, worn paint lines, a less than optimal friction coefficient, etc.) should be cited as causes. Similarly, a vehicle designer might find that accidents could be prevented by making major changes in vehicle design (e.g., dual rear wheels, all cars with steel-belted radials, all cars with power brakes or steering, etc.), and the lack of one of these factors might be cited as a cause. (O'D)

Most of us are nominally experts in the human factors, and it is easy to lay out an accident causation taxonomy in some detail in that area. The method may vary (e.g., the CALSPAN model developed by Perchonok et al. is different from the Indiana model), but it can be considered useful if one can devise effective countermeasures on the basis of the recorded data. It seems clear, though, that a taxonomy oriented primarily toward human factors will be of value only in devising countermeasures in that area. (O'D)

If the purpose of recording accident causation information is to decide how best to allocate resources among competing countermeasure areas (e.g., redesign of highways, redesign of vehicles, or retraining of drivers), it would be important to design the recording scheme to provide proper weight for each area. It is not immediately clear what "proper weighting" should be, for in the end it depends on how clever the countermeasure thinker-uppers can be, and how much their designs cost. (O'D)

Finally, before reviewing the literature on accident causation, there are at least two questions which must be addressed. These are:

- 1) How can countermeasures be derived from knowledge of accident causes? and
- 2) What role does exposure data play in studies of accident causation?

The panel's views on these critical issues are presented in the remainder of this section.

Deriving Countermeasures

Determining the "cause" of an accident, or a set of pre-crash factors highly associated with accident involvement, is the first step in accident causation research. The second step is the design of cost-effective countermeasures that will reduce the frequency and/or consequences

of accidents attributable to these "causes" or factors. Unfortunately, the existence of a set deserving to be considered a "cause" usually says little about how to design such CM's. (H)

For a given cause or pre-crash factor, there may be a number of possible CM's which will vary in terms of cost-effectiveness, ease of implementation, social acceptability, etc. For example, CM's for bald tires may range from legislating tougher tire standards to requiring steel-belted radials on all vehicles or to conducting a "Check-Your-Tires" campaign using the media. And, while it is usually easier to design and implement a CM for a more narrowly defined cause, this is not always the case, as shown by the scattergram in Figure 1. The arrows in the figure connect possible causal sequences, and illustrate that a CM may be effectively implemented at different stages of the causal chain. As an example, consider the chain of events where an unrestrained child distracts the driver, causing the driver to lose attention and run a stop sign, resulting in an accident. In this case, "running a stop sign" may have been the immediate cause of the accident, but an effective CM would probably be to require child restraints. (O'D, J)

The process of using information derived from accidents to develop and implement countermeasures is illustrated in Figure 2. Two loops are shown -- the first being a simple loop in which the accident investigator studies one accident, draws a conclusion about the cause or causes and what might be done to eliminate them, and then makes a recommendation for change, with the change then being implemented by some operational agency. For example, a police officer might investigate a single accident, determine by interview with the driver that the driver did not see a stop sign, observe at the scene that the stop sign was hidden from view by new growth on a tree, and make a recommendation to the local traffic engineer

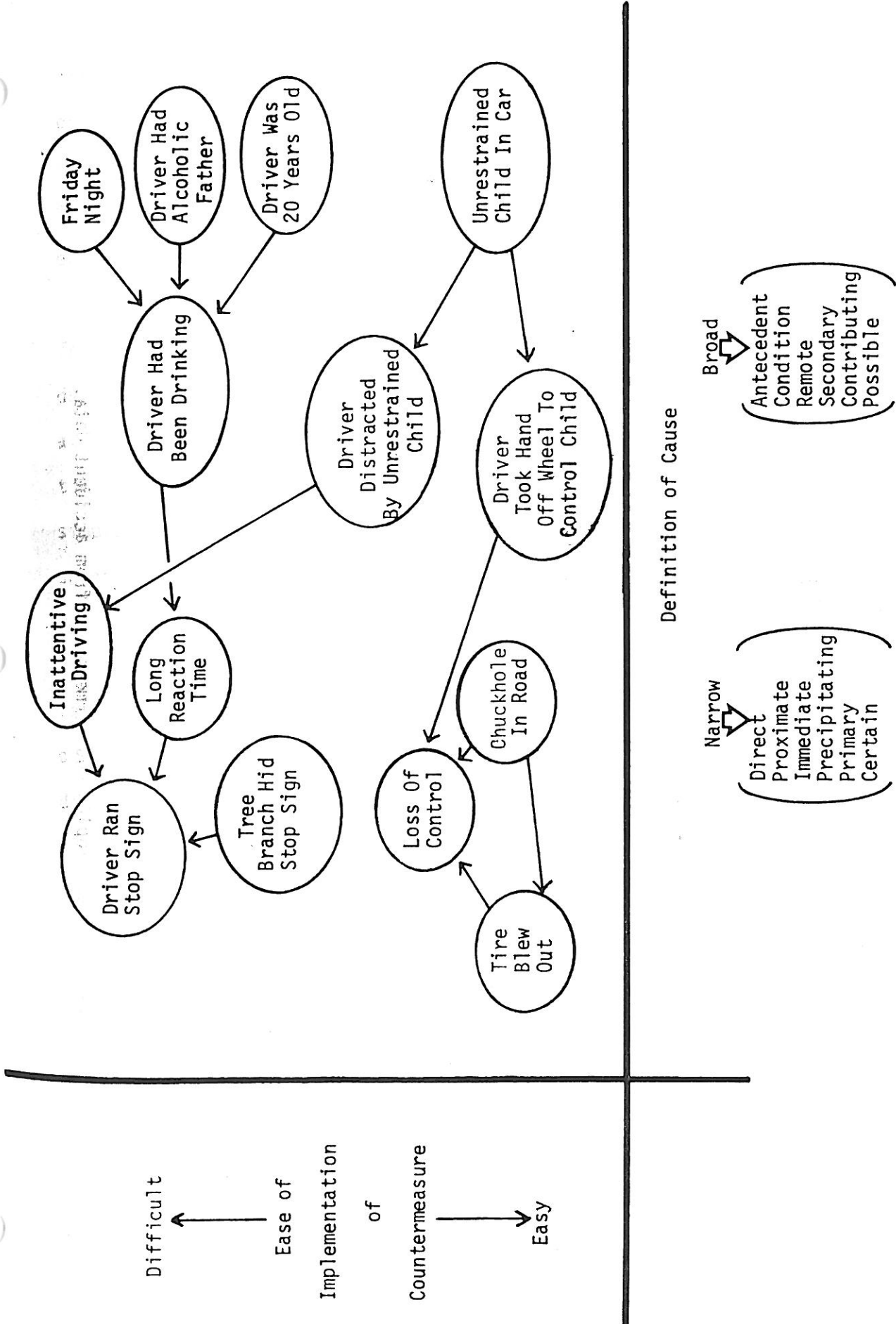


Figure 1. Scattergram -- ease of implementation of countermeasure versus breadth of definition of cause.

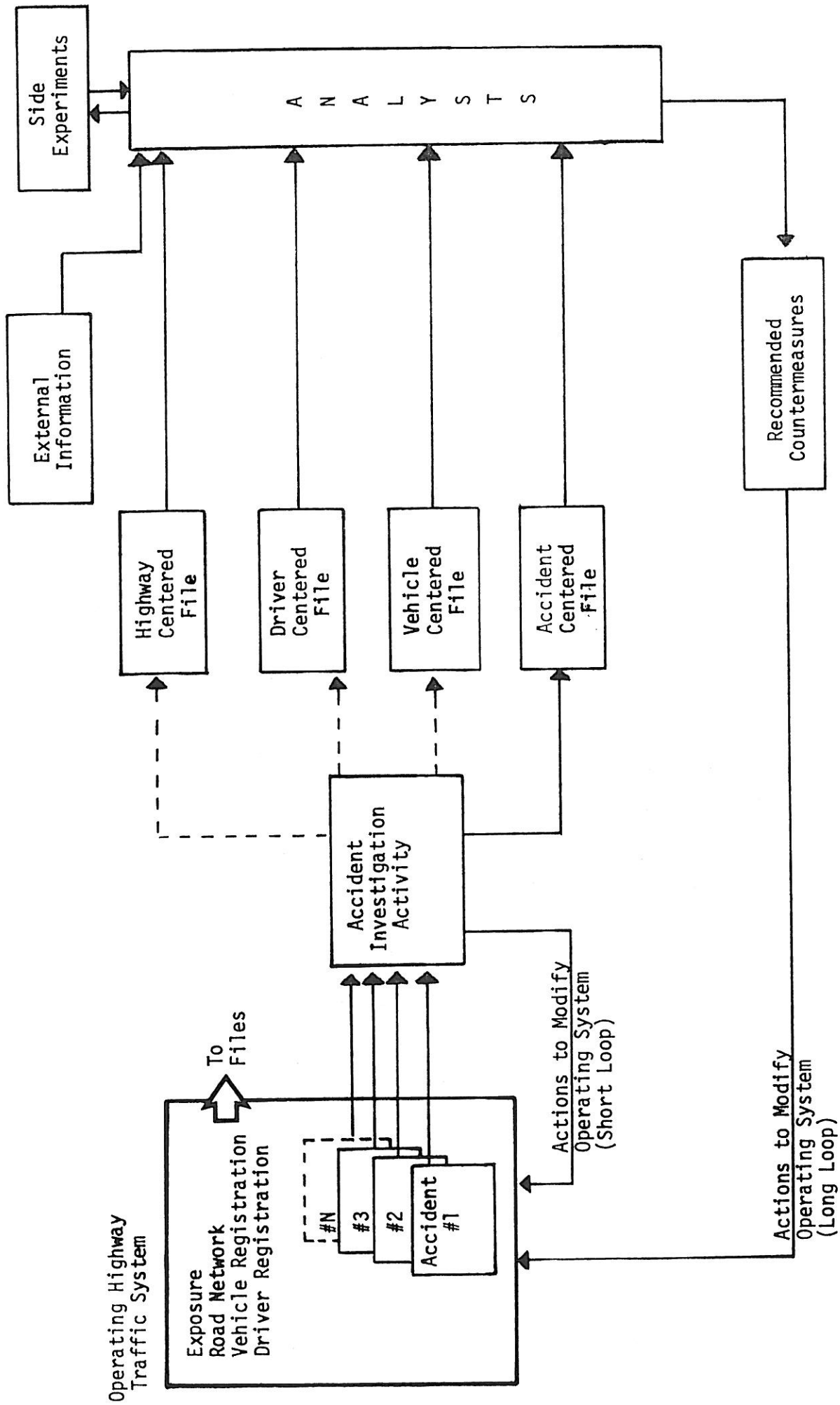


Figure 2. Developing countermeasures from accident data.

that he either move the stop sign or cut a branch off the tree. This process indeed takes place rather continuously in the highway traffic system, and there is little reason to question it. It depends on the investigator's capabilities (training, insight, cleverness, initiative, etc.), but it is likely a very successful process. (O'D)

The larger loop is somewhat more complex. Accident data are collected from a number of accidents and by a number of people, compiled (in these days in a computer), and then analyzed by persons who were not present at the scene of the accident but who have an interest in the various potential countermeasure fields which may be applied. The process may be as simple as placing the accident information on a pin map, having the traffic engineer inspect it from time to time looking for dark spots, and then devising some countermeasure for the indentified location. Alternatively, the process might be as complex as the study of road curvature and grade reported by Dunlap, Fancher, Scott, MacAdam and Segal (1974) in which an overrepresentation of accidents was discovered (by computer analysis) on downgrades of modest curvature in wet weather, and further analysis and experience showed that these particular road segments were not sufficiently superelevated to provide proper drainage -- an observation not easily made in a single accident, and requiring a sophistication of analysis not provided by the pin map process. (O'D)

For simplicity, one might dichotomize these two loops into one in which the accident investigator does everything -- investigates the accident, considers and defines the "causes", devises countermeasures, and makes a recommendation for action -- and one in which the investigator's principal function is to record information about the accident in such a way that someone else (a traffic engineer or an entire analysis team) may study potential problems. (O'D)

In the literature reviewed by the panel, there were examples of both ends of this spectrum. Thus, Wilson and Moore (1971) have suggested that, for each accident, the accident investigator consider all possible countermeasures, evaluate their relative merits on a cost/benefit basis, and make recommendations for change directly. The ORI Pedestrian Study (1971), by contrast, used data which came from police investigations, and the analysis procedures were set up to study that data in the context of some contemplated pedestrian accident countermeasures. For the most part, the analysts did not know the policemen, or in fact have more than a cursory knowledge of their reporting procedures. (O'D)

In the context of the three levels of accident investigation discussed previously, Level III (or in-depth) investigations tend to identify with the former (short loop); Level II investigations tend to identify with the latter. Level I, or police-reported information, has some elements of both -- direct feedback at the local level, and the provision of larger data sets for subsequent analysis at higher levels. (O'D)

Clearly, there are pros and cons for both systems. In the majority of cases, it is more likely that an experienced investigator can delineate "causes" than be able to consider the total range of possible CM's. And yet, this is what is required in the simple loop system. In addition, one might suspect that the investigator would have some biases regarding causation which derive from his own experience or training, and that the set of causes defined by him would be less than complete. (O'D)

Perhaps the greatest advantage of the simple loop system is that the investigator-CM designer has a close tie to the real world of accidents and a first-hand knowledge of the data. The analysts working with the more complex system lack this advantage. However, they are more likely to be

highly trained specialists in, say, human factors and traffic engineering, and they can apply that expertise to whatever problem areas they discover. (O'D)

While it is difficult to achieve the best of both worlds, it would seem useful to devise a system in which the analysts had an opportunity to make their needs known to the data collectors, and conversely in which the data collectors have some concept of what is going to be done with the information. (O'D)

Exposure Requirements

Exposure, as it is applied to highway accident problems, is a little like Mark Twain's weather. Almost everybody talks a lot about it, but nobody does much about it. (O'D)

Exposure information allows one to separate the quantitative (volume) aspect of traffic accidents from the qualitative (risk) aspect. It can be used for the design of countermeasures in the following ways (J):

- (1) Eliminating differences in accident frequencies resulting merely from differences in "exposure" or volume, and highlighting differences in risk; e.g., differences between driver age groups in the types of accidents (which may be subject to countermeasures, whereas differences in exposure usually are not).
- (2) Measuring the risk in highly specific exposure situations in which, and only in which, a certain countermeasure may have an effect (e.g., side marker lights).
- (3) Evaluating the effects of countermeasures (e.g., old cars with no CM's are differently exposed than new cars with CM's).

In concept, exposure information must be available in the same detail as the accident information. For example, if one knows that 70 percent of the accident drivers are males and 30 percent females, and similarly that males account for 70 percent of the mileage, then it is clear that there is no "over-involvement" of either sex in the exposure-adjusted data. However, if one should discover that female drivers have a young child as a passenger several times more often than do male drivers, and if it has been shown that children distracting drivers "cause" accidents, then a difference between male and female drivers in "exposure" to a higher risk situation has been found. Consequently the CM of publicizing the risk resulting from having a small child in the car should utilize a woman's magazine rather than Playboy. In this case, the observation that women more often have small children in their cars than men was needed, not to define a problem, but to point out the most effective avenue for countermeasures implementation. (O'D, J)

Following are three additional examples of the value of good exposure data in designing effective countermeasures (O'D):

- (1) Consider the following sequence: It has been determined that three quarters of all fatal bicycle accidents (in some jurisdiction) occur during hours of darkness. It has been separately determined (by an exposure survey) that three quarters of all bicycle mileage occurs during hours of daylight. One is led to a countermeasure effective primarily during darkness, such as better lights on bikes, more use of reflector tape, reflectorized tire sidewalls, etc. If one had found the over-representation of fatalities to be in the daytime, one would have had to search for CM's affecting certain hazardous daytime conditions, e.g., painting

lines on the street to make bikeways to counteract the effect of denser automobile traffic. In this case, knowledge of bicycle exposure helped to recognize a problem. However, it was not important for the design of the CM's mentioned.

- (2) The study of road grade and curvature referred to earlier (Dunlap et al, 1974) is less obvious than the first example, and illustrates the essential role that exposure information can play in some accident causation studies. Data were available on accident counts by milepost on turnpikes (recorded to a precision of 0.1 miles), and traffic count data were available by time of day and by road segment (i.e., derived from the toll booth records). The latter served as an exposure data set, and allowed the analyst to compute accidents per vehicle mile traveled as a function of curvature and grade combinations. A typical result is shown in Figure 3, which is taken from the referenced report. Note the peak in the crash rate in the curvature range $0^{\circ}44'$ to $1^{\circ}5'$. This finding ultimately resulted in a recommendation to change the superelevation of such curves to improve the drainage patterns.
- (3) In San Diego, California, a certain traffic engineer had been concerned with the number of pedestrian accidents at intersections in that city. He tabulated the number of accidents by location, noting whether or not there was a painted crosswalk. Subsequently he stationed observers at a sample of intersections with and without painted crosswalks to count the number of pedestrians crossing under the various circumstances and then computed the number of accidents per crossing with and without painted crosswalks, discovering that the accident

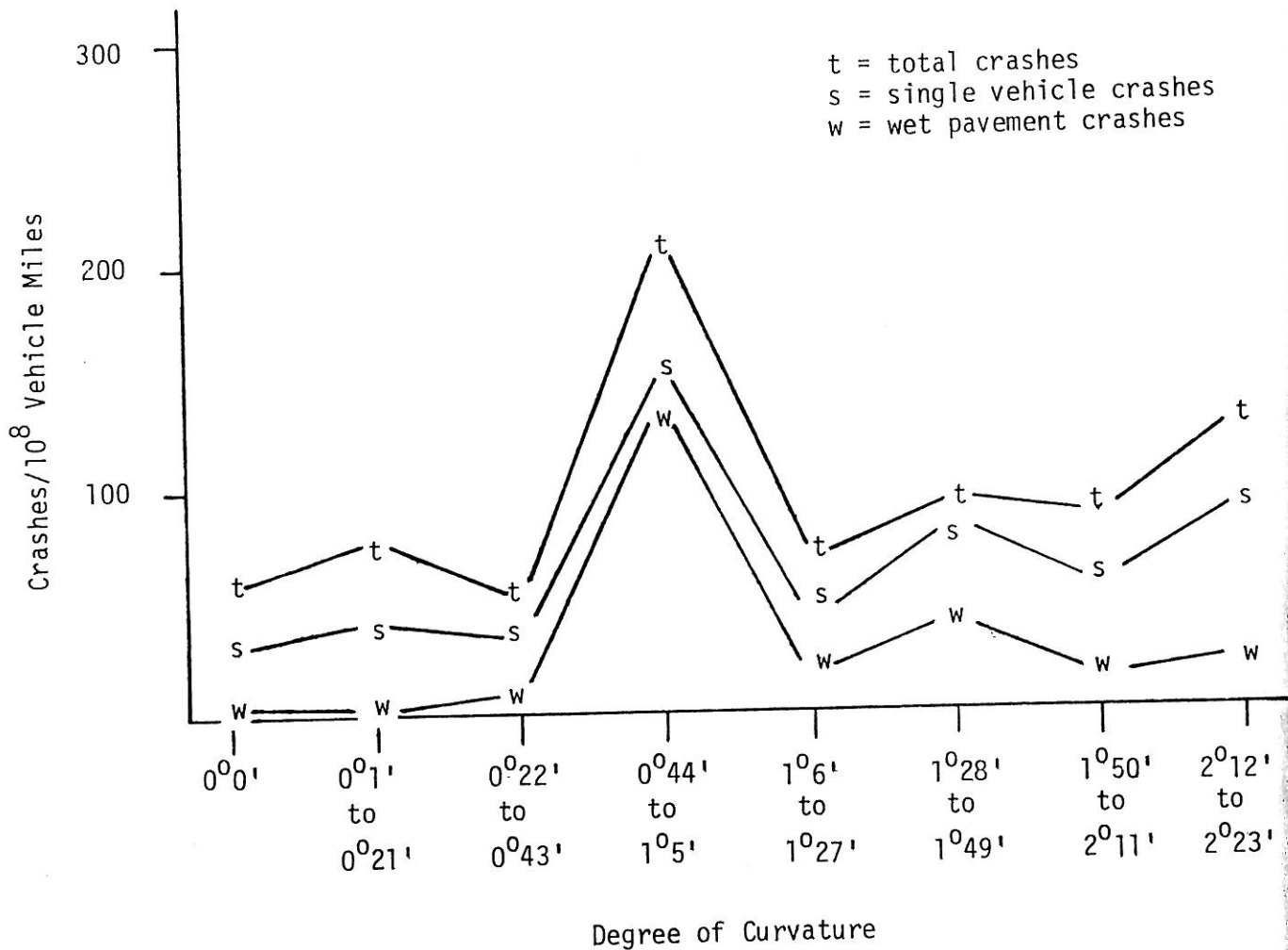


Figure 3. Curvature model showing expected relationship between curvature and crash rate using Ohio Turnpike data.

rate was greater when there were painted crosswalks. Finally, the quality of the exposure was examined in this case. Detailed observation suggested that pedestrians were less careful when crossing at designated intersections. If the traffic engineer had looked only at the number of pedestrian accidents and assumed that there would be many more crossings at painted crosswalks and thus a lower accident rate, then more and more crosswalks would have been painted. However, the actual exposure information and the quality thereof (namely carelessness on the part of the pedestrians in the crosswalks) dictated modifying the designation of crosswalks in that region.

In the past, a variety of exposure measures have been proposed. These include traffic volume, number of trips, number of registered vehicles, number of licensed drivers, driving time, passenger miles, occurrence of traffic conflicts, and fuel consumption. However, the measure that has been used most often is "vehicle miles of travel (VMT)."

VMT can be viewed as a measure of the "product" of transportation, and accidents/VMT as a measure of the "cost" -- in terms of accident risk -- of making this "product." The expected number of accidents in an area, for a car or group of cars, a driver or a group of drivers, should then increase proportionately with the VMT for this population. Such an increase leads to the concept of the "accident rate." Differences between the accident rate of different populations are then studied in relation to characteristics of these populations. As an example, it has been shown that more experienced drivers (i.e., those who drive more) have a lower "accident rate" than less experienced drivers. (J, W)

For a given population of drivers, it appears indeed plausible that, under otherwise identical conditions, one with more VMT has proportionately

more accidents than another one. However, "under otherwise identical conditions" implies identical traffic density. This means that comparing the same area in different time periods is possible only if the highway system is expanded proportional to VMT. If that is not the case, traffic density and consequently speed and the relative frequencies of accident types change. The adjustments necessary to account for this makes the value of the concept of an "accident rate" in this context questionable. It also throws doubt on the use of the "before-after, experiment-control group" type of evaluation of countermeasures (J).

Consider the following: Certain types of accidents can occur only (or most frequently) in very specific situations, e.g., head-on collisions on two-way, undivided highways (and traffic has to be dense enough that there will be oncoming traffic), right angle collisions only at intersections or driveways. Such situations represent "exposure to a certain accident" in the narrowest sense. With enough patience one could develop a catalogue of situations representing exposure to the risk of specific accidents, for most types of accidents. A complete count of the frequency with which these exposure situations occur would be the conceptually rigorous measure of exposure. VMT would be an adequate measure of exposure if the relative frequencies of these exposure situations were the same for the populations compared and if their actual numbers were proportional to VMT. (J)

Since this is unlikely to be the case and since it is also unlikely that such a detailed exposure measure as described can be developed for most situations, it is necessary to compromise. To do this, one may define "exposure classes," so that differences in exposure situations are as large as possible between groups and as small as possible within these groups. Crude examples are "urban" vs "rural" driving, or "driving on Interstate

highways" vs "driving on secondary rural roads," etc. Finer classifications might add a day/night distinction, even finer an hour of day distinction, etc. If such classifications are made on the basis of detailed studies, one can expect that within each classification the relative frequencies of exposure situations per any one VMT vary less than within broader exposure classes. This way of defining "exposure classes" is intended to separate situations of unequal accident risk. (J)

The recent final report by RTI (1975) for NHTSA is a step in this direction. In this report, a cost-effective procedure is presented for estimating VMT categorized by certain driver, vehicle, and environmental characteristics. For this particular study, the pertinent factors were driver age, driver sex, vehicle make and model year, time of day, (day vs. night) and location (rural vs urban).

Rather than measuring exposure in terms of VMT, a somewhat different approach is to use the method of induced exposure. Basically, this indirect procedure determines relative exposure for certain classes of drivers, vehicles, driving environments, etc., by obtaining the corresponding distributions for "non-responsible" driver-vehicle combinations in collision accidents.

Unfortunately, current models of induced exposure generally compare the frequencies of single-car crashes and two-car crashes between population groups. This is conceptually deficient because single car accidents and two-car accidents tend to occur under different conditions: e.g., the one more in rural, the other in urban environments. Most factors leading to or contributing to a single-car crash can also do this for a two-car crash, but not every factor leading or contributing to a two-car crash will do so for a single-car crash. Thus, measures of induced

exposure must be conceptually refined before they can be used with any confidence. (J)

Finally, it is interesting to note that for the pre-crash factor approach to accident causation outlined earlier, where the goal is to determine if the frequency of accidents is greater in the presence of a factor than in its absence, appropriate exposure data are implicitly assumed. For this situation, the exposure measure is simply defined as the population proportion having the pre-crash factor under study. (For example, the proportion of vehicles having slick tires, driving on icy roads, etc.)

It seems clear (at least to this panel) that adequate exposure information will lead to a more precise identification of effective countermeasures, and that there should be some provision for obtaining measures of exposure in a nationally representative sample to be able to compare with any nationally representative accident data set (W). While the nature of the exposure collection methodology will not be further addressed in this report, the panel nevertheless expresses a need for such information.

With this background material in mind, the panel's review of the accident causation literature follows in Section III.

III. REVIEW OF ACCIDENT CAUSATION METHODOLOGY

A major task of the panel was to review critically the more consequential and recent efforts in the area of accident causation methodology. To be sure, in order to make meaningful recommendations about needed research in this most difficult area, one must be aware of the extensive efforts that have been carried out primarily under NHTSA funding. Thus, the panel was provided with nearly 30 reports representing the major recent work in this area. Of these, ten reports emanating from four organizations represent the most significant efforts, namely, those done by the University of Indiana Institute for Research in Public Safety (IRPS), Cornell Aeronautical Laboratory, Inc. (now Calspan Corporation), Operations Research, Inc., and the University of Miami.

Initially, each member was to review each of the ten major reports and provide a critical review, with the review of the remaining reports being divided among the panel members. However, because of other pressures on the panel members along with fairly tight time constraints, few reports were examined by all four panel members. Nevertheless, each of the major reports was addressed by at least two reviewers.

To the extent possible, each major critique covered the following areas: purpose of the study, data base utilized (i.e., population studied, type of data collected, methods of data collection), aspects of analysis (i.e., statistical methods used, how the information was aggregated, interactions examined, what factors were omitted), and conclusions (re validity, usefulness with respect to countermeasures).

The review of each major work presented in this section will contain a brief summary largely extracted from the referenced report followed by the observations made by the panel members. To preserve the intent of the panelist and likewise to acknowledge the contributor, editing has been

kept to a reasonable minimum and the author of a particular observation or section indicated by one of the following: (H), (J), (O'D), (W) for Haight, Joksch, O'Day, and Waller, respectively.

With these details taken care of, a brief discussion of some of the work in the area of accident causation and avoidance prior to the late 1960's would seem to be in order. Fell (1975) provides this background. As early as 1920, the city of Detroit formed the first Accident Investigation Bureau which later became known as the Accident Prevention Bureau. "Accident proneness" studies in the 1930's by Weiss and Laver (1930), Forbes (1939), and Cobb (1939) indicated that, even at this early date, the accident problem was believed to be mainly a human one.

Baker and Marsh (then at the National Safety Council) initiated perhaps the first accident causation research study. However, after expending all of \$2000, it was abandoned.

Gordon (1949) introduced the epidemiological approach to the motor vehicle accident problem. McFarland's work in this area dominated the 1950's and early 1960's. It emphasized human factors, studying driver age, personality, medical conditions and alcohol and drugs, with lesser emphasis on highway and vehicle design (McFarland, Moore, and Warren, 1955; McFarland, 1966; McFarland, 1968).

Tharp and Garrett (1968) reported on a three-year study at Cornell Aeronautical Laboratory aimed at developing techniques for studying the causes of accidents using a multidisciplinary approach to establish a causal model for automobile accidents, which would account for driver, vehicle and environmental factors. This work served as a basis for the subsequent IRPS studies which began in mid-1969.

As indicated by Fell (1975), the intensified efforts which followed attempted to gather nationally representative data; involved limited-scope

(Level II) and full-scope (Level III) investigative approaches; developed causal models from different viewpoints; and attempted to tie together accident causation and accident avoidance research. The extent to which these goals were reached is discussed in the following sections.

As the most extensive effort has been carried out by Indiana University, and as their studies are perhaps the most frequently quoted and referenced in the field, Indiana's four major contract efforts will be reviewed initially followed by those at Calspan, Operations Research, Inc., and the University of Miami, respectively. Finally, a number of other related studies will be addressed briefly.

Indiana University IRPS

Multidisciplinary Highway Crash Investigation Team (NHTSA Contract No. FH-11-7244)

Accident investigation, analysis, and reporting activity in conjunction with a Multidisciplinary Highway Accident Investigation Team study is reported. On-scene and in-depth follow-up investigation of 25 vehicle-related accidents was conducted from 1 July 1969 to 30 June 1970. Medical, engineering, and experienced accident investigation personnel comprised the primary elements of the investigation team. IRPS (1970)

The analysis in this volume consists of brief, summary narratives for each accident, followed by essentially the same narratives arranged by topic rather than by crash. (H)

The conclusions of the study relate to crash factors and not to the limitations of this type of research. The two pages of conclusions could be abstracted as follows: In these accidents, driver error, usually in the context of some external special circumstance, was responsible for most of the crashes. A rather curious conclusion is "that no tested, standardized methodology exists which will permit the drawing of conclusions about the meaning of any personal or psychological factor

as it relates to accident causation." (H)

This study suffers first of all from the same problem as many other studies in the field issuing careful caveats in the beginning and then ignoring them in the end.* This tendency is illustrated in connection with the issue of whether or not Monroe County is typical. For example, some care is taken to explain that the small size of the sample would not permit statistical conclusions, and yet the end of the report is replete with exactly this type of result. (H)

Case 69-4 illustrates one of the difficulties with the cases -- spinning out hypotheses. Here the driver "...might have corrected these dangerous tendencies" if he had been in the habit of receiving traffic tickets. If he had been familiar with the vehicle, it "might have allowed him to take corrective action." It seems that in the cases where the speculative 'mights' are allowed into the reports, they always refer to the driver, rather than, for example, "Indiana might have had better geometrics for secondary roads." (H)

Cases 70-2 and 70-4 contain what appears to be psychological diagnoses of the drivers -- in one case an "immature personality" and in the other "a sense of alienation and isolation, a deep sense of anger and frustration, and possibly his hostility towards women." These are not well-defined psychological terms and thus it would seem difficult to employ them reliably and objectively. For the purpose of this report, it would perhaps have been better to have included summaries of the actual factual material

*Editorial note: This problem is common in many areas of research where the investigator is confronted with data that are inadequate for drawing valid inferences by rigorous logic. Frequently, the authors state that the data "suggest" rather than "prove", and that results or conclusions are tentative. A large element of judgment is involved in the decision on how far to proceed with analysis of known faulty data.

used to arrive at such conclusions. (H)

In the specific recommendations, some appear to have been hastily put forth -- for example, on page 120 that these cases should be "utilized in the education of the public..." It is neither clear to whom this recommendation is directed nor on what evidence it is based. Other recommendations appear to be only loosely based on the study itself. In fact, recommendation 12, p. 123, actually goes against the Case 70-5 evidence. (H)

In spite of these criticisms, this study was nevertheless a useful effort. It would have been better, however, if the qualitative principles promised in the introduction had been given. Even so, it was remarkable to have documented both a suicide and an epileptic in 25 cases.

Where the authors go astray is in orienting their summary, conclusions and recommendations towards countermeasures. It might be noted that in all likelihood the sponsoring agency expected firm conclusions about accident causation (which IRPS provided) rather than properly guarded conclusions. (O'D) However, it is obvious that countermeasures cannot be based on a sample of 25, but must depend on larger, more representative samples. It would therefore have been more helpful if the authors had given carefully reasoned proposals for further mass accident data studies, suggested by the present study results. It would also have been helpful to have given some guidelines, based on this experience, as to how additional data might have been gathered to more accurately test conjectures arising from the present study. It seems that the cases studied should yield vastly fewer generalizations about how to improve traffic safety, and vastly more about how to extract conclusions from accident analysis. (H)

A Study to Determine the Relationship between Vehicle Defects and Failures, and Vehicle Crashes (NHTSA Contract No. DOT-HS-034-2-263)

This study focused on the statistical determination of the relative roles played by human, environmental and vehicular deficiencies in causing automobile accidents. It was based in Monroe County, Indiana. Data were collected on three levels, baseline data on the study area were assembled to allow definition of the project universe (Level I); accidents were investigated on-site at the time of occurrence by technicians (Level II); and a sample of these accidents was independently examined by a multidisciplinary team (Level III). Causative factors were identified and ranked. Study results are based on 999 accidents investigated on the on-site level, and 219 accidents investigated on the multidisciplinary level.

Results presented include identification of the extent to which various human, vehicular, and environmental factors were found to have been implicated in automobile accident causation, a comparison of the extent to which findings of the on-site team agreed with those of the multidisciplinary team; a comparison of component outage rates in the accident-involved vehicle population as compared to the non-accident (general) population; and comparisons between investigated, study area, and national driver, vehicle, roadway, and accident populations, which indicate the representativeness of the universe studied. Pertinent conclusions and recommendations and a summary of analysis procedures utilized are also presented.

Specifically, the Interim Report presents the study methodology in detail. The final report is given in a five-volume series. Volume I presents findings regarding accident causes. Volume II covers various component outage rates, representativeness of the samples, and other study topics. Volumes III and IV give case summaries from in-depth investigations conducted during the first and second data collection phases, respectively. Volume V then summarizes the results for the entire study. IRPS (1971, 1973a, 1973b)

The Interim Report consists mainly of an exhaustive list of details about the study methodology. Unfortunately lacking from the report is a description of what went wrong or what could have been improved. (H)

The major findings of this project effort are found in Volumes I and II and then summarized in Volume V. The analysis reported in Volume I consisted of classifying accidents according to the items of a large

taxonomy on the basis of 'on-site' or 'in-depth' study of these accidents. The relevant percentages were than given in tabular form. The analysis reported in Volume II consisted mainly of calculations of a large variety of relevant percentages. (H)

Before addressing some of the details of Volumes I and II, two major points need to be made--one dealing with the driver role versus that of the vehicle and the environment and the other addressing the basic logic used by IRPS for setting up a practically useful structure to determine causal factors against the background of potential counter-measures.

IRPS found that human factors consistently decreased as investigation level increased. Vehicle and environmental factors increased as investigation level increased. However, once again the human was seen as far and away the largest factor. It is a serious error to consider the vehicle and environment as non-contributory simply because they meet the currently established standards. Most drivers also meet the currently established standards. After all, driver licensing programs exist precisely to see that this is the case. Critics may quickly point out that our licensing standards are not adequate, but cannot the same criticism be made with equal validity of the standards concerning vehicles and roadways? Why are these standards somehow sacrosanct while the standards used to license drivers are so readily the object of criticism? If the driver in a crash holds a valid license, then the argument can be made that he, too, has met existing standards and can be held no more culpable than the inadequate signing that is nonetheless legal. (W)

With respect to developing a logically sound and practically useful structure to determine causal factors against the background of potential

countermeasures, the following quote is an indication of careless thinking if it is not the result of poor editing:

"Prime cause: A factor which it is highly certain was necessary or sufficient for the accident's occurrence, so that, had the factor not been present in the accident sequence, the accident would not have occurred."

If the factor is "sufficient," this means that the presence of this factor alone, regardless of other factors present, was sufficient to cause the accident. It is very difficult to imagine such a factor except, perhaps, the desire to commit suicide. On the other hand, if a factor was "necessary" for the occurrence of an accident, this does not rule out that other factors were also necessary. Mathematicians and logicians know the condition "necessary and sufficient," meaning that if and only if the factor was present, an accident could occur, but necessary or sufficient does at best rule out factors whose presence had nothing to do with the occurrence of the accident.

Another illustration of this questionable logic is the use of the causal factor "excessive speed." First, it is obvious that, without other factors, speed cannot be a "sufficient" causal factor of an accident. Second, there is the question, "What is excessive" ? This is determined only by the presence of the other factors, such as a curve with little or no superelevation, dense traffic, or whatever. To be operationally useful, the definition of "excessive" speed has to be quantified, depending on the other factors "necessary" for the occurrence of an accident. Finally, there is the question "why" excessive speed is important for designing countermeasures. Was the driver consciously exceeding what he considered a reasonable speed, intentionally taking a risk? Did he have a wrong perception of the situation, be it the road surface con-

dition, traffic conditions, etc.? Was he misinformed on the braking and handling characteristics of his car? Did another driver behave in an unexpected, but still legal, way? Without such additional information, the causal factor "excessive speed" is operationally useless, and might even imply an illogical circle: the speed was judged excessive precisely because an accident occurred.

Another obvious case where the definition of "cause" has to be sharpened is that of tire failure, which might naively be judged to be a prime cause. But there are other causal factors which are also amenable to countermeasures and should, thereby, be considered: inability of a driver to cope with such a situation, or the handling characteristics of the car. Training in emergency measures might allow the driver to compensate for a failing tire, and conceivably the vehicle handling characteristics could be designed so as to make it easier to control a vehicle after a tire failure.

Thus, the approach used in this study and the results obtained might be appropriate for answering the very narrow question, "What is the accident avoidance potential of motor vehicle inspection?" which apparently was behind the study. However, the results are of limited use for the assessment of causal factors in a broader context, and even misleading for the design or evaluation of countermeasures. (J)

More specifically, the portion of the overall study described in Volume II suffers from a number of defects enumerated briefly as follows:

(1) There is a lack of obedience to IRPS's caveats, for example, about the Chi-square test requirement that no more than 20 percent of the table cells have expected frequencies of five or less (cf. p. 24);

(2) there are problems with the taxonomy -- unreliability, tendency toward subjectivity, and difficulty with logically assigning crashes to categories; and (3) the recommendations are unfocused (for example, "... that continued attention be directed..."), are often either unconnected with the evidence of the study, or else simply reverse an observed condition without consideration of whether such a reversal is deserved on balance, and, finally, are sometimes based on poorly defined factors such as "improper look-out". (H)

There are also a number of strong points about the study, above all the attempt at careful objective dissection of cases. (It would have been good to see the case material for this contract as well.) If the authors, or perhaps the sponsors, had clearly in mind that (both scientifically and politically) 999 cases in Monroe County could not conceivably justify any sort of institutionalized national countermeasure program, then the orientation towards suggesting more definitive and focused further studies might have been strengthened. In other words, one principal difficulty with such an in-depth study is the misconception from the beginning as to what this tool could and should be used for. In some of the report introduction, it seems to be acknowledged that for many reasons (of which small sample and atypical location are primary) no definitive word on countermeasures can be given. Yet these words of wisdom are lost in the welter of conclusions and recommendations which follow. (H)*

*Editorial note: The result points to yet another problem often encountered by researchers in controversial subject areas of social science: potential misuse of results that are carefully qualified by an author, but then used by some of the public to their own advantage.

In Volume II, a comparison of the percentages of accident vehicles studied by IRPS having specific defects with a sample of vehicles studied by Ultrasystems, Inc. (ULTRA) reveals a number of significant anomalies, evident in Figures 2-1 and 2-2. It would appear from Figure 2-1 that the sample sizes were in several categories inadequate for statistical significance, but that there was a distinct overall tendency for ULTRA vehicles to be in substantially better condition, as far as tire tread depth was concerned. Figure 2-2 seems to indicate that when the comparison is made between "most-at-fault" IRPS vehicles and all vehicles, the difference is (perhaps unexpectedly) greater in the latter case. However, the degree of difference is very small, and it would seem that "most-at-fault" segregates no significant class of vehicles as far as tire tread depth is concerned. (H)

One of the most troublesome aspects of this study is the difference between what is written in the text and what appears in the tables. For example, the licensed population of Monroe County is compared with the licensed population of the total U.S. While there are categories showing up to almost four-fold differences in proportions of certain age drivers, the text reports that the Monroe County driver population is highly representative of those in the nation as a whole. Furthermore, one of the most disproportionate categories includes the large student population in Monroe County, indicating that this group is not only vastly overrepresented but is also not even representative of the particular age group as a whole. Likewise the data on vehicle model year indicate that the Monroe County vehicles are newer. (For the nine most recent years, Monroe County has a higher proportion of vehicles in all

but two of the years, and, for those two years, the proportions are equal. For all eight of the older categories Monroe County has lower proportions than the country as a whole.) Yet the report says that the vehicle population is also "highly representative" of the nation as a whole. However, there are evidently no statistical analyses employed to arrive at these conclusions. Such gross discrepancies between what appears in the data and what is reported in the text detract from the usefulness of this work. (W)

A major flaw lies in the ULTRA study, which is supposed to represent Monroe County (and hence the United States?), but which it appears may do neither. According to Volume II, "vehicles were sampled in an uncontrolled manner; the vehicles inspected were those brought to the centrally-located Ultrasystems inspection facility in response to a mass advertising campaign." Apparently because it had been determined in an earlier study that "willingness to cooperate" was not related to frequency of total component outages, controls on this factor were not attempted.

Specifically, it is assumed in the study that the percentages observed by IRPS were typical of the accident population, while those observed by ULTRA were typical of the entire population. It seems equally logical, and far more persuasive, to believe that those observed by ULTRA represented a population receptive to mass advertising, having an interest in traffic safety, with time to spare to go to and remain for some time at the ULTRA facility, and reasonably confident either that no significant defects would be discovered or else that no official action would be taken in case of defects; in short, middle class socio-economic status. According to this series of conjectures, the interest

in this report lies not so much in discovering what vehicle defects "cause" crashes, as in showing once again the relationships existing between vehicle maintenance and socioeconomic status.

Read in this light, the comparisons are indeed interesting. Also, it should be noted that IRPS does deviate somewhat on its own causal approach on p. 49: "No implications in terms of the causative role of deficiencies based on this comparison of accident and general population vehicles is intended; problem vehicles may be symptoms of problem drivers." Nevertheless, in spite of the disclaimer, these are the kinds of "factors" specifically listed as "causes" in Volume I, and furthermore, the quoted passage tacitly accepts the ULTRA sample as "general population vehicles." (H)

From the point of view of countermeasures, it is irrelevant whether or not Monroe County is America-in-miniature. (H). Nevertheless, Volume II contains some further data and argumentation regarding the representativeness of Monroe County. The conclusion that the accident samples investigated are sufficiently representative of those in the nation is misleading not only because of the kinds of drivers and vehicles present in Monroe County, but also because of the types of accidents investigated. Of necessity minor crashes were omitted. In addition, special vehicle classes such as motorcycles and trucks were omitted. While the majority of crashes involve only passenger cars, a significant proportion involve other vehicle types as well. These crashes involving other types of vehicles are more likely to result in serious injury or death and cannot be ignored. (W)

Tri-Level Study of the Causes of Traffic Accidents
(NHTSA Contract No. DOT-HS-034-3-535)

This is essentially a three-year continuation and extension of the previous study examining the relationship between vehicle defects and failures, and vehicle crashes. Data were collected on three levels of detail. Police reports and other baseline data on the Monroe County, Indiana study area were collected on Level I. On Level II teams of technicians responded to accidents at the time of their occurrence to conduct on-scene investigations. On Level III, a sample of 22 percent of these accidents were independently examined by a multidisciplinary team. A general population survey was also conducted.

Volume I, an interim report on research findings, covers methodology, findings regarding accident causes, accident and control sample comparisons, cluster analysis, problem driver identification, analysis of study sample representativeness, conclusions and recommendations.

Volume II, an interim report on driver vision and knowledge testing and other special study topics, presents results of the reliability and validity assessments of a Dynamic Vision Tester (DVT), an examination of the relationship between driving knowledge test scores in terms of both accident involvement and type of error committed, results of cluster and Automatic Interaction Detector (AID) analyses, and the methodologies for measuring driver characteristics and determining their relationship to accident causation (cf. driver "profile scores").

IRPS (1975a, 1975b)

The analysis in Volume II consists mainly of cluster analyses along with the calculation of a variety of percentages. Cluster analysis is a series of ad hoc manipulations thought in some circles to be effective in bringing out "clusters" of variables of special significance. The application is handicapped by the particular set of variables used. However, some tidbits of interesting information are produced (see the Discussion, Section 5.4). Possibly with better categories to begin with, better results might be obtained. (H)

In this Tri-Level effort, there is a greater depth and detail than in previous efforts. This is evidenced by the cluster analysis approach,

a reference list including a reference to a book on principles of taxonomy, some degree of sophistication in accounting for the relationship between variables, an awareness of other studies, the inclusion of certain socioeconomic factors, and so forth. (H)

The conclusions and recommendations generally recapitulate previous findings, with 'improper lookout' reigning supreme. Some special new results include the following: Accidents associated with alcohol impairment differ in severity from expected values; older vehicles are associated with accidents involving component outages; and cluster analysis shows little in the way of useful results except for isolating alcohol-involved crashes for further investigation. (H)

The analyses utilized in Volume II (namely cluster and AID analyses), although innovative, suggest how difficult it is to obtain conclusive results from a limited data set. However, they also suggest that continued development of such methodology as an independent effort would be in order when better data sets become available. (O'D)

The conclusions and discussions for this effort are given separately and in some detail in Volume II for the following categories: Driver Vision Test, Driver Knowledge Test, Cluster Analysis, Characteristics of Drivers Committing Errors, and New Driver Measures. Most of these are detailed, and often technical, and thus not suitable for capsule reproduction. In these respects they are far superior to the conclusions produced in all previously reviewed IRPS studies. In fact, this report again represents a significant improvement on Volume I and is far superior to the previous contract efforts. Now there is a systematic, meaningful list of references and some well-qualified consultants. In

virtually every portion of this report, the studies are co-ordinated with and cognizant of other similar studies. (H)

Some section-by-section comments follow:

Driver Vision Test: This study is workmanlike and useful. (An expert in the field confirms this view.) (H)

Driver Knowledge Test: There are some definite weaknesses in this particular test. Several questions appear rather trivial since nearly all respondents answered them correctly (see Table 3-2). (They remind one of the hypothetical true-false question proposed by a celebrated mathematician as typical of drivers' tests: "It is illegal to drive while dead.") Others, such as the first one, are senseless in that they fail to test 'knowledge' of anything in particular. Thus, the schedule of responses is more an evaluation of the items than it is an evaluation of subjects. (H)

Cluster Analysis: Here, more than anywhere, the increasing capabilities of IRPS are evident. Contrast the psychological terms of this study -- 'decision errors', 'recognition errors', 'performance errors' -- with those of earlier studies -- 'sloppy life style', 'immature personality'. It is not clear how the author has formed his clusters, but, even with the relatively poor taxonomy, he has come up with interesting and possibly (a full-scale experiment would be needed) significant clusters. (H)

Characteristics of Drivers Committing Errors: This study has some good points and some bad points. Among its virtues is the fact that a well-defined technique, AID, was applied honestly and objectively. Just to give this example of the possible uses of AID in accident analysis is worthwhile in itself. On the other hand, the characteristic difficulties

of IRPS studies once again surface. Aside from the definition of 'error' which could be anything from something illegal to something impolite, the author goes overboard in claiming that such a study, if successful, could be useful in designing countermeasures -- specifically by lecturing drivers. A study of this sort, if based on a more rigorous definition of 'error' and conducted successfully, could at best only suggest how to design a focused, definitive experiment. (H)

New Driver Measures: This final study appears to have been intelligently and conscientiously executed. The author has creatively digested the relevant literature in the field, and has designed a neat, albeit simple, study. Furthermore, he has correctly and modestly reported that, although the results are somewhat interesting, they are not especially significant. (H)

An Analysis of Emergency Situations, Maneuvers, and Driver Behaviors in Accident Avoidance (NHTSA Contract No. DOT-HS-4-00960)

This project effort involved the development of taxonomies of both accident situations and vehicle maneuvers that might be taken to avoid accidents. Attention was focused particularly on the "emergency traffic conflict" situations involving more than one roadway user and requiring rapid and unplanned actions to avoid collisions. Subjective estimates of the probabilities of accident avoidance "success" were developed for all feasible combinations of emergency situations and maneuvers. (Project was performed as a subcontract to the URS/Matrix Company as part of a larger effort entitled "Accident Avoidance Skill Training and Performance Testing".)

IRPS (1975c)

This study has two main objectives:

1. To develop a taxonomy of emergency traffic conflict situations, and to estimate the probabilities for these situations, and
2. To develop a taxonomy of evasive maneuvers, and to assess the chances of success for each maneuver in each situation.

To accomplish these objectives, 372 accident case histories from Monroe County, Indiana, were classified according to whether there was "no conflict (30.9 percent of the cases), "conflict but no time" (14.2 percent), "conflict and time, but no evasion possible" (16.1 percent), "evasion possible" (6.5 percent), "conflict and time, evasion probable (21.0 percent), or "conflict and time, evasion certain" (11.3 percent). (H)

All results of the study rest on subjective assignments of probabilities of success for a maneuver in a given situation, on a six-value scale, ranging from "certain cause or increased severity accident" to "certain evade an accident." It is obvious that certain maneuvers could not have influenced the occurrence of an accident at all. Also, in some situations a certain maneuver might prevent an accident with practical certainty. In most cases, however, it will be difficult to assign, by purely subjective judgment, an operationally meaningful probability to the success of the maneuver (which might well be to substitute a less severe for a more severe accident). The authors recognize this problem implicitly in Recommendation 4, where they point out that they could study only drivers whose maneuvers had failed. Their recommendation for a "near-miss" analysis (to compare what drivers actually attempt and the maneuvers assessed as being most likely to succeed) misses the critical point: A comparison of near misses with accidents would provide empirical evidence of the success probability of various maneuvers and allow the elimination of the use of subjective assessments. (J)

Considering this, it is surprising how much effort is spent on analyzing the agreements and discrepancies of the various assessors' judgments. Even if perfect agreement were found, this might be due to

common misperceptions or prejudgments and would not imply agreement with the real world effect. (J)

A basic distinction the authors make is whether the driver was not aware of a conflict situation until after the accident, whether he was aware of it but did not have the time for avoidance maneuvers, or whether he was aware of a conflict in time for an evasive maneuver. Again, this is based on either the drivers' statements or the subjective evaluation of the assessors. More important is the question of why drivers were not aware, or not aware in time, of a conflict situation. Though this was not the subject of this study, a thorough analysis of the problem would have to ask the question: To what extent can evasive maneuvers which require quick judgment and reactions be traded-off against obtaining information earlier. The authors also recognize this point, to some extent, in their Recommendation 6 to increase drivers' attention and awareness. (J)

Also important for the success of evasive maneuvers are environmental conditions, as recognized in Recommendation 5. It is the case that environmental factors may critically influence the success of a maneuver (e.g., slamming on the brakes might work on a dry pavement but would be disastrous on ice). (J)

In summary, the authors have spent much effort on the irrelevant point of agreement between assessors, and neglected certain important points which they themselves acknowledged. This is definitely not an accident causation study. However, despite its subjective quality, the results might have some merit for designing emergency driving courses. Whether this is the case depends on how well the results can be

concentrated into a few simple rules which can be "learned" by a driver by practicing them often enough. (J)

General Comments on the Indiana Approach

Considerable emphasis is placed in the reports on the logic of attributing "prime cause", "contributing cause", "causal factor" or "severity-increasing factor" to aspects of the crashes examined. It would probably be true to say that the basis of the classification schemes lies in the ability to correctly make such attributions. However, this classification process would undoubtedly be hampered by the absence of rigorous definitions. As previously noted, the IRPS definition of "prime cause" is logically inconsistent; the expression "necessary or sufficient" has only a trivial meaning. One would suspect that what the authors intended was for a factor (F) to be considered a "prime cause" only in the case that it is necessary for the accident (A). Clearly this is implied in the text where the original definition is further explained by stating that "not F implies not A."

With these (conflicting) definitions in mind, consider the various factors in Appendix II of IRPS (1973a) given as feasible. It would not seem to be possible to find any single factor which would be necessary for a given accident (i.e., which would always be present irrespective of other factors) except possibly, depending on one's interpretation, such vague formulas as "critical non-performance" which are virtually equivalent to an accident. Looking for factors which would be sufficient, the following kind of possibilities are noted: "false assumption", "improper maneuver", "improper technique", "excessive speed", and so forth. It would be logical to suppose that these always lead to an

accident (and are thus sufficient) only by defining 'false', 'improper', and 'excessive' as that kind of assumption, maneuver, technique, or speed which leads to an accident. In other words, these factors do not appear to be objectively capable of definition, except in terms of the accident for which they are then found sufficient.

On the other hand, it would have been perfectly feasible to define objectively other concepts:

illegal maneuver	in place of	improper maneuver
illegal speed	in place of	excessive speed

Where law does not apply, as in assumptions and techniques, it might even be possible to substitute something based on sampling. For example, if a car runs through a stop sign and hits you, it is clear that your 'assumption' that it would stop is 'false!'. However, the point is rather whether you were justified, in terms of usual driving practices, in making such an assumption. If such an assumption is made by 95 percent of drivers, then one might say that it is a reasonable (95 percent level) assumption. That it subsequently turned out to be 'false' is quite irrelevant.

These two types of criticism -- the logic of 'prime cause', etc., on one hand, and the lack of a rigorous definition of supposed factors on the other hand -- tend to erode substantially the intellectual basis for the entire series of IRPS studies. (H)

A second major problem deals with the IRPS's analysis of the assessment practices. They purport to have examined how qualitative estimates of the existence and involvement of factors in an accident (in the three categories "certain," "probable" and "possible") relate to quantitative estimates in terms of probabilities. This is essentially a question of

psychological interest. It is not clear what this analysis contributes to an understanding of accident causation. The authors' conclusion that the IRPS procedure is an appropriate method for assessing accident causes is completely unwarranted and may be seriously misleading. NHTSA should refuse to accept this conclusion. The only conclusion one can draw is that people are reasonably consistent in expressing their opinions either in three categories or on a 0 to 1 scale. To prove anything about validity, a completely different approach has to be used, be it a comparison with statistical properties of accidents, simulated reconstructions of accidents or, perhaps, a step-by-step reconstruction of accidents and near misses in comparable situations. To design any validation study requires a high degree of sophistication. The authors appear to have completely missed the point. (J)

Cornell Aeronautical Laboratory, Inc. (Calspan)

Accident Cause Analysis (NHTSA
Contract No. DOT-HS-053-1-109)

A system had been developed to describe the process of accident generation. It was modified and applied to accident reports from a variety of sources ranging from routine police reports to intensive, on-scene investigations.

Comparisons were made among the samples in terms of their value in providing causation information. Frequently occurring accident causal structures were determined. The influence upon modes of involvement and culpability were measured by drinking, lighting conditions, driver education, and selected driver characteristics.

This study aims to develop a technique which could be used to extract "causation" information in a way amenable to quantitative analysis. The data used resulted from the Cornell Aeronautical Laboratory Tri-Level Accident Investigation Program which provided police data

(Level I), augmented police data (Level II) and in-depth investigations (Level III), all in an eight-county region in western New York State. (O'D)

This would appear to be a rather useful system for classifying accidents. The cornerstone for the causal structure was thought of as the last cause (in perhaps a series of causes) and was referred to as the "critical event" -- that behavior which transforms a situation into one in which, short of highly skilled driving, an accident is imminent. Another element in the causal chain is the "critical reason", which describes why the critical event occurred. "Culpability" is introduced as a behavior which creates an abnormal situation -- abnormal in the sense that it would not be what normal drivers would expect. Finally, the concept of "contributory" is introduced for the behavior of a driver who could have avoided an accident in an abnormal situation but did not do so. These "structures" are then compared in various tabulations. (J,H)

Although the conclusions may well be valid in a formal sense, they are not necessarily a good basis for countermeasures, since many events besides the critical event might be more easily controllable. Likewise, although the study introduces various concepts which can describe a considerable part of the causal chain leading to an accident, it does not make -- or perhaps recognize -- the logical next step to provide for a larger number of critical events and conditions, which would allow the study of interrelations between such events and conditions, and exploration of alternative countermeasures. However, to some extent the study does explore interactions, e.g., critical reason by culpability, or culpability versus drinking status. (J)

As is so characteristic of these causation studies, there is perhaps undue emphasis on the driver, unless one is concentrating solely on developing driver countermeasures. The vehicle or the environment is faulted only in the most blatant cases. If, for example, a driver rear-ends a parked car, it is virtually taken for granted that the fault must be found in the driver -- not, for example, in the parking regulations. (H)

The fact that the human error involved in accidents is frequently related to information failure (including recognition errors) strongly suggests that the demands of the driving situation are more than the driver can handle. There is considerable need to recognize that the human being varies in his performance and that on the whole it can be assumed that he probably does about as well as he can be expected to, given the circumstances. Accident investigations should be conducted in which the human element is taken as a given and the vehicle and environment are analyzed to determine the extent to which they need to be modified so that the human can function satisfactorily. Thus, simply because a vehicle is performing up to the manufacturer's standards does not mean that the vehicle performance is satisfactory. Perhaps the manufacturer's standards need to be modified and the vehicle performance enhanced. Simply because the roadway signing meets the criteria set down in a highway design handbook does not mean that the signing is adequate. The criteria often used call for signs that can be readily viewed by drivers with 20/30 vision. Furthermore, the standards must be met only by the signs when they are new. Most highway signs remain in place for years, and many legally

licensed drivers cannot meet a vision criterion of 20/30. Under such circumstances, when the driver fails to read the sign in time to make a decision, is it a driver failure? Most human factors experts would not agree, yet accident causation studies persist in perpetuating the myth that drivers are somehow supposed to be able to compensate under any conditions for the shortcomings (legalized failures?) of the vehicles and driving environment. (W)

In addition to this undue emphasis on accident causation factors related to the driver, there was inadequate care in controlling for certain important variables. For example, drivers who "had been drinking" but not so much as to be classified as intoxicated showed more control failures and more high risk behaviors, while drivers who had been drinking more heavily and were classified as intoxicated showed a lower incidence of high risk behaviors. It is concluded that the driver who has had a few drinks might consider himself sober and not exercise proper precaution, while the heavier drinker is aware of his condition and consequently avoids high risk maneuvers. It is further concluded that an appropriate countermeasure may be to direct a campaign toward the mild drinker rather than the heavy drinker. However, there was no attempt reported to control for driver age or socioeconomic status. A person familiar with driver research could immediately recognize that the high risk behavior described is characteristic of young male drivers, while low risk behavior is more characteristic of middle age drivers. Likewise, exceedingly heavy drinking is more characteristic of middle age drivers, while young drivers get into difficulty at much lower levels of alcohol. Once age is controlled for, the apparent effect may disappear, making the

interpretation and recommendation totally inapplicable. Perhaps the major point is that there should be researchers representing expertise in each aspect of the driver-vehicle-environment system if appropriate conclusions are to be drawn.

A major question about this study is that all the coding was done by one coder. It is stated that this probably was not a problem because the results showed valid relationships between the terms used and other variables. Nevertheless, if the coder had any systematic biases in his coding of causal data, then relationships would very likely be found. Since the coding of causal relationships is absolutely basic to the rest of this report, it would seem most important to determine that the coding procedures were reliable and valid. And yet, there is really no attention given to this problem. (W)

In summary, this study is conceptually a second step, going far beyond the conceptual level of the Indiana studies. On the other hand, it lacks the specificity of the "causes" given in the Indiana studies which do allow the design of specific countermeasures (though not necessarily the most efficient ones). (J)

Analysis of Vehicle Injury Sources
(NHTSA Contract No. DOT-HS-053-1-109)

This study examines the influence of a variety of interior vehicle component design modifications introduced by the automotive industry on the propensity for injury.

Two vehicle age classifications were selected (vehicles not equipped with a majority of the safety oriented modifications of interest, 1960-1965; vehicles equipped with these design modifications, 1968-1971) and compared on the basis of similar accident circumstances -- impact speed, seated position, restraint utilization, site of impact, vehicle make and vehicle size.

The analysis consists primarily of a classification of a variety of data from previous studies by year-model, especially pre-1965 vs. post-1968, with the overall conclusion that "...the difference in occupant injury risk between the two vehicle age classifications was found to be minimal."

This is in many ways one of the best studies in the entire group, and would need only a few improvements to be a model of its kind. It begins with categories which are very substantially objective. It is directed at a particular question. The question is of importance. The tone and analysis are objective. The other relevant literature is taken into account. The design of the study is ingenious. The only difficulty may be with the data which is a composite of accident information from two different studies: Cornell ACIR data from injury accidents occurring between 1953 and 1969; Tri-Level Accident Investigation Program data commencing with 1969 accidents. No post-1968 models would be found in the ACIR data set whereas the majority of information about the pre-1965 models would come from the ACIR data set. To the extent that there are major differences between the two data sets, differences found between model years might only be reflecting differences between the accidents analyzed! (H, J)

Operations Research, Inc.

Pedestrian Safety: The Identification of
Precipitating Factors and Possible
Countermeasures (NHTSA Contract No. FH-11-7312)

The study objective was to identify causes and countermeasures relevant to pedestrian accidents. Behavioral and descriptive data were collected by interviews and on-scene observations for over 2,000 pedestrian accidents in 13 major cities.

Subsequent analyses emphasized individual case causation and accident type classification relevant to countermeasure implementation. Cases were divided into accident types on the basis of causal factors and target groups, to provide a basis for countermeasure identification. The five most frequent types accounted for over 50% of the sample cases. Countermeasures relevant to each accident type are discussed.

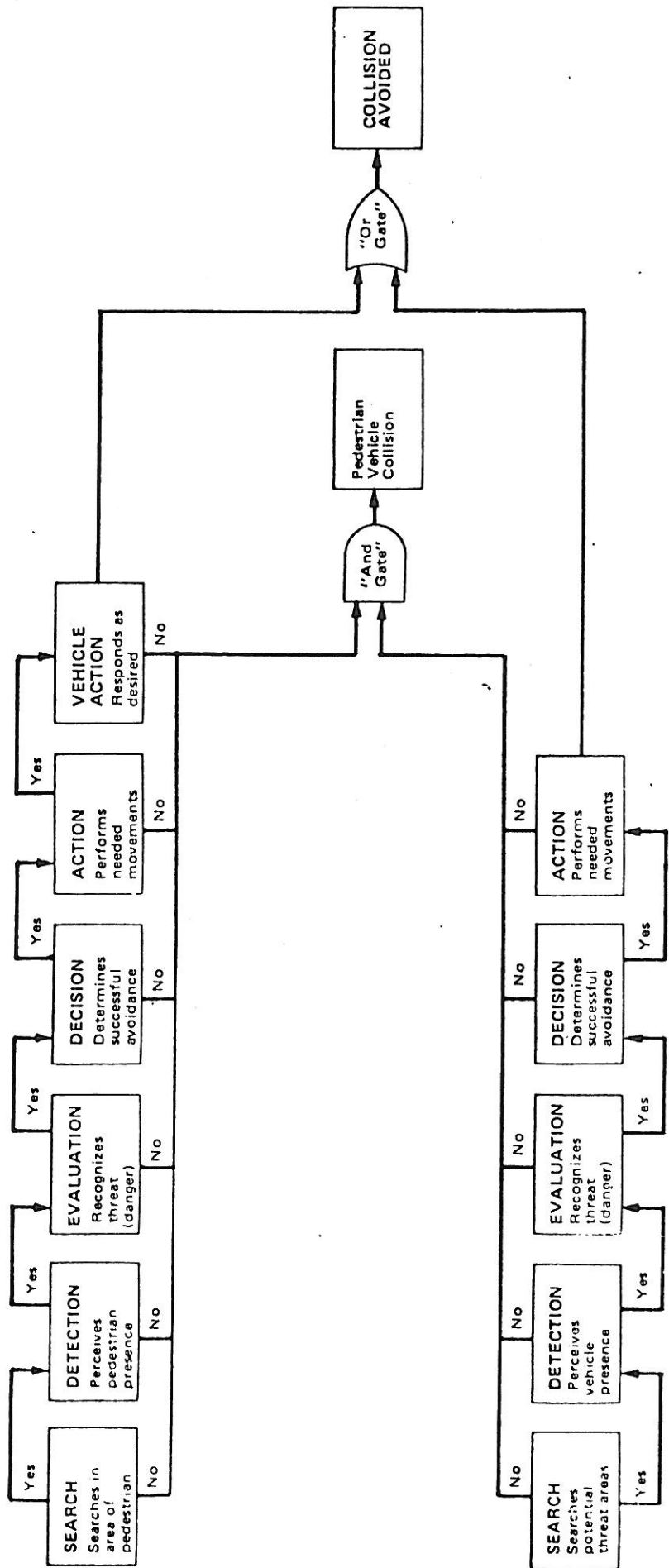
Beginning with 'cause', the authors almost immediately relax to 'factors', then 'predisposing', then an elaborate structure (see, e.g., Figure 3.2 in the referenced report) which seems unnecessarily complicated.

There must be some rules governing the use of block diagrams. The arrows leading from block to block must make some kind of sense. Something must be moving along these arrows: a substance, a chain of logic, etc. The intellectual failure of Section III is best shown by considering the diagrams. In Figure 4 (taken from the report), not only is the chain arbitrary (any number of other imaginary links could be put in, such as 'perception', 'reflection', 'acquisition', etc.) but also appears to be wrong. Following the arrows, it appears that, if the answer to SEARCH is NO, one is led invariably to PEDESTRIAN VEHICLE COLLISION. The sequence of tautologies supposedly explaining this situation is equally wrong. Thus, the vehicle action is defined as response 'to the motor behavior of the driver' --not to the environment or internal vehicular factors.

Rather than going further into the complicated forms of this "Conceptual Framework," it is best to examine it in a simple form. In Figure 3.3 in the report, there are but four boxes, connected by one dotted and three solid arrows. A close examination of this diagram, in connection with the 'explanation' (see Section 3.22 of the report) yields no enlightenment. What are the arrows, whether solid or broken, supposed to indicate?

icated.

DRIVER AND VEHICLE



PEDESTRIAN

Figure 4. The "generalized function/event sequence" (taken from Operations Research, Inc., 1971).

Thus, it would appear that the conceptual model is (1) illogical, (2) based on introspection rather than on evidence, and (3) unrelated to the study.

Proceeding now to the study itself, rather than to its packaging, one finds useful information, somewhat biased by the authors' tendency to make assumptions. The sample design is weak, however, containing reasons for the choice of accidents studied like "because of the late start"(!). Also, accidents were "those reported to the city police". However, for example, only the conveniently accessible portion of Los Angeles was used.

The data collection methods (i.e., interview, police records, and on-scene observations) also seem rather informal and unstructured. The data presentation suffers in two respects: (1) it consists mainly of lists of percentages, and (2) the lists of percentages are so expanded that it is difficult to make sense of them. Furthermore, although the evidence on types of collisions, and indeed the types of percentages and subsequent conclusions, are evidently reliably based on evidence, the similar conclusions about countermeasures seem to be guesswork. The countermeasure discussions and the corresponding summaries do not appear to be based on any evidence or on any systematic investigation including cost considerations. (H)

Univeristy of Miami

A Causal Model for Single Vehicle Accidents
(On-going project with NHTSA)

A causal model is developed for single vehicle accidents which, with slight modification, will accommodate multiple vehicle and other accident situations. The model consists of the following: (1) description of the activities and

events in an accident sequence; (2) specification of appropriate categories of causation (e.g., accident causation vs. direct injury production), and (3) causal factor taxonomy defined within the framework of the accident sequence.

It does not appear from the review of the Interim Report that many novel insights to accident causation will come from this on-going project effort. Many of the criticisms made regarding previous efforts in the field apply here as well, e.g., lack of an objectively determined taxonomy, lack of rigorous definitions, etc. In addition, certain sections of the report are inconsistent and difficult to follow (see for example the block diagram preceding Figure 5.3 in the referenced report). Further conclusive comments on this project should await availability of the Final Report.

Review of Papers Presented at the 1975 Calspan Symposium

The Motor Vehicle Collision Investigation Symposium held October 6-10, 1975, at Calspan Corporation in Buffalo, New York, devoted nearly one entire day to methodological approaches in the area of accident causation and accident avoidance. It provided an excellent opportunity for many of the more prominent accident investigators and researchers to be briefed on the variety of approaches that have been taken and then to discuss and to recommend purposes, uses and directions for future accident causation research.

Fell (in "Accident Causation and Accident Avoidance: Methodological Approaches. Introduction and Systems Overview") briefly reviewed four approaches to determining accident causation, namely (1) Calspan's descriptive model; (2) Indiana's accident causal taxonomy; (3) a human factors causal system; and (4) Miami's model for single vehicle accidents.

Treat and Shinar (in "A Methodology for Assessing and Classifying Traffic Accident Causes") presented an intelligent, coherent justification of the IRPS studies, framed in historical perspective. Treat, Tumbas and Drahos (in "Accident Prevention and Avoidance Assessment Methodologies") dealt with countermeasure choice from the IRPS point of view.

Perchonak (in "The Accident Generation Process") described the rationale for the descriptive model approach (Calspan) using Level I accident data while Kurucz and Morrow (in "A Causal Model for Single Vehicle Accidents") described Miami's causation model for single vehicle accidents.

Other Studies Dealing with Accident Causation

In addition to the studies addressed in detail in previous sections, a variety of other references in the general and broad area of accident causation were also examined. These efforts fall into the following categories: (1) general causal studies; (2) the role of the driver and/or vehicle in accident causation; and (3) improved methods of investigating accidents, structuring the data elements, and collecting and processing the data. A brief summary and critique of each report (in the appropriate subsection) concludes the panel's review of previous efforts in the accident causation field.

General Causal Studies

"Cause Factors in Highway Accidents: A New Methodology" (Surveys and Research Corporation, 1958) produces a taxonomic scheme for accident classification (using police reports from Richmond, Virginia). While this may have been a rather novel study in its time, it does not appear to offer much in light of present day standards.

"Causes of Highway Accidents: United States Experience" (Surveys and Research Corporation, 1958) surveys the magnitude of the accident problem, rural-urban accidents and their economic costs, the driver-vehicle-roadway components, and the need for accident cause classifications. Finally, a program for accident cause research is outlined. Again, it would appear that this report mainly presents a number of tabulations which are not particularly useful in furthering the case of causal research. (H)

The Role of the Driver and/or
Vehicle in Accident Causation

"Pre-Driving Identification of Young Drivers With a High Risk of Accidents" (Kraus, Steele, Ghent, and Thompson, 1970) compares 205 drivers under age 21 recently in accidents vs. matched (on age, sex and size of community of residence) controls to determine unique characteristics of young accident-involved drivers. Drivers who had terminated their education early, had failed one or more grades, had begun regular smoking before age 16, or who had been charged with a (non-driving) criminal offense, were overrepresented in the accident involved group.

From an accident causation point of view, this study concentrates on human factors, primarily drawing conclusions by seeking overrepresentation of factors speculated to be of interest (in the accident vs. the control group). Knowledge of single or multiple vehicle involvement is essentially the only "accident" data. The analysis procedure exemplifies what might be done combining an accident and an exposure sample. (O'D)

On the vehicle side, "Vehicle-in-Use System Safety Analysis" (Booz, Allen Applied Research, Inc., 1970) performs a detailed vehicle

safety analysis to identify and rank vehicle failure modes according to their "criticality", which is defined as the product of the probability of occurrence of a fault times its potential effect in accident causation. A number of detailed conclusions and recommendations are given on pages I-40 through I-47, relating to standards development, standards implementation and recommended research.

This is an interesting and valuable study. While the concept of "criticality" may not be entirely clear, it is obvious that a serious attempt is being made to rationalize vehicle defect analysis. It seems probable that one fundamental mistake was in attempting the concept definition and its application in the same study. Since the data were hardly more than just some that happened to be convenient, it would perhaps be better to disregard the conclusions, and concentrate on formulation of the concepts, regarding the data treatment as exemplary rather than conclusive. It is particularly praiseworthy that the study goes all the way from calculation of criticality to consideration of countermeasure areas. (H)

If it may be justified to regard this as a pilot study, then some recommendations for additional such studies may be in order. These include:

- (1) Formulation of plans for an experimental design to sample the vehicle features required, rather than using existing data;
- (2) Explicit consideration of injury causation in the definition of criticality, as well as "...potential effect in accident causation."
- (3) Empirical investigation of the consequences of various calibrations of the "effect" variable. (H)

"The Role of Vehicle Handling in Accident Causation" (Jones, 1975) seeks to establish whether there is a relation between the handling characteristics of cars and their accident frequency. This is done using a synthesized single vehicle accident rate by car model as the dependent variable in a simple linear regression on driver age, sex, and several parameters related to vehicle handling.

Three points should be made regarding this study. First, as some of the independent variables are clearly correlated, the inclusion of interaction terms in the model would have provided a means for identifying the interactions between the various parameters, which might be more important than their individual contributions. Second, as the accident data is based on driver reports, there is reason to question the data. Third, there are a number of point-blank assumptions about relationships among variables, such as: "Deficiencies in handling are likely to be associated with accidents involving loss of control," "It is necessary to determine which type of accident most commonly involves loss of control," "It is assumed that the proportion of mileage traveled in urban and rural areas is the same for each model car," "If the dependence on age and sex of driver can be established for each model of car, any further difference in accident rates between models of car should be explained in car characteristics." It is also assumed that vehicle weight is a "handling characteristic".

As the conclusions are based on the results from a questionable analysis of questionable data and requiring a chain of perhaps questionable assumptions, they cannot be considered conclusive. (H, J)

Improved Methods of Investigating
Accidents, Structuring the Data Elements
and Collecting and Processing the Data

To obtain improved accident data for examining causal factors,

the upgrading of several ingredients in the process is essential. These include the following components: (1) investigation and reporting procedures; (2) content and structure of the data elements; and (3) coordination of the data processing and analysis efforts. Over the last two decades, considerable innovation and improvement have been realized in all three areas.

In the area of investigation and reporting procedures, there has been considerable activity on all levels of investigation--Level I (police level) with improved report forms and additional training, Level II (police level augmented by special teams) as seen, for example, in the Indiana studies and the current Restraint Systems Evaluation Program, and Level III (in-depth) with the various MDAI efforts. The following studies represent some of the major work in this area.

"Bi-Level Reporting of Accidents" (Recht, 1970) argues for a bi-level (i.e., a general plus a detailed supplementary form) accident reporting scheme for acquiring data in sufficient detail so that countermeasures can be defined. Axioms for the supplemental report include keeping the report form brief; reporting observations--not opinions; using only a single form for a limited time period; and applying on a random (or stratified random) sample of accident types or subjects. The basic principle appears sound: First obtain a broad picture, and then make special investigations to the extent that particular features require further illumination. (O'D, H)

"Transportation Resource Allocation Based on New Methods of Accident Reporting" (Wilson and Moore, 1971) contains one very important basic idea: that accident data should be collected for the purpose of selecting countermeasures. The key issue is the requirement that the ac-

accident investigators should assign to various crash factors and potential countermeasures "estimated reductions in cost of accidents," had the factors been different or the countermeasures applied. Considering the low accuracy with which the effects of crash-phase countermeasures are known and considering the conceptual controversy about what constitutes "accident cost" along with the numerical uncertainty of the various cost elements, the accident investigators would have to have superhuman minds to accomplish this task. (J)

There is no discussion of the use of accident data for the evaluation of countermeasures, or quantification of the impact of environmental factors, design features, driver characteristics, etc., which are basic to the quantitative estimates that the accident investigators are required to make. (J)

The statistical aspects are not discussed either. Any detailed analysis of accidents from a limited population or area--even as large as one state--runs into the problem of low "cell frequencies" once several factors are used for stratifying. With the consequently large variance of the resulting estimates, any attempt to "optimally" allocate funds to countermeasures is likely to be illusory. Thus, beyond a few basic ideas, this paper contains little of practical value. (J)

"Accident Investigations: Multilinear Events Sequencing Methods" (Benner, 1975) concerns a proposed methodology for reporting accidents which have been investigated in some detail. The intent is to provide a method which can be applied consistently, and which will yield information in a form appropriate to the definition of countermeasures. The questions to be answered in the investigation are (1) what happened? and (2) why did it happen as it did? The generalized recording technique

proposed is to start with the action preceding the untoward event, and proceed by identifying the actors (people or things) and the actions of each until the accident sequence is completed.

However, the report does not go far enough in treating multiple (parallel) causes to be immediately useful. In addition, it would seem that the schedule of questions, which form the basis of the methodology, cannot be devised simply by someone sitting in an office thinking as is proposed in this report. (O'D, H)

Finally, the report, "Utah Multidisciplinary Highway Crash Investigation" (Weston, 1974), describes the results of 25 in-depth investigations of serious crashes involving late model vehicles. The purpose of the study was to: (1) identify accident causation; (2) identify injury causation; (3) evaluate effectiveness of safety features; (4) assist in early detection of design and functional problems; and (5) determine aging effect of vehicles and value of periodic motor vehicle inspection.

Other than the special psychological evaluation developed by the team's consulting psychiatrist, the accident "causation" reporting is fairly conventional--low guard rail height noted in one case permitted vehicle to vault the rail; a front tire blowout initiated a collision; a hidden exit gore had inadequate signing; etc. (O'D)

The content and structure of the data elements is most consequential in any subsequent analysis of the data. "Data Coding System for Highway Accident Reports" (Surveys and Research Corporation, 1969) suggests a system for codification of all the information contained in accident reports along with recommending a coding structure. It is implied that the system would be suitable for adoption.

It appears that this system might be faulted on two possible grounds: (1) the implicit assumption that a good source of data would be existing accident reports, and (2) the details of the system itself. On the first point, there is a persuasive argument often made--namely, that existing reporting systems do not produce information which is very useful either for designing countermeasures or for suggesting further research.

On the second point, the details of the system appear sound except perhaps that the system was "developed" ad hoc for the express purpose of dealing with existing reports rather than ab initio with the view to understanding the accident process. It further seems that the value of this or any similar system could only gradually be revealed as it was being used, with appropriate provision for pruning, enlarging and modifying. (H)

A final matter concerns the coordination of data processing and analysis efforts. Currently, there are major national efforts involved in designing and setting up the National Accident Sampling System (NASS), which promises to provide an excellent vehicle for providing causation information. A decade ago, "A National Highway Accident Records Center" (Surveys & Research Corporation, 1966) recommended that the U.S. Bureau of Public Roads develop a national highway accident records center (HARC) which would compile a combination of data from all of the states, encourage the states to prepare their data in a common format, and perform certain analytical operations leading to national statistics and (presumably) to the development of countermeasure programs.

There is little data included in the report except for some tabulation of data elements maintained by the several states. Further, there is little analysis. There is some philosophy on the utility of such a data base as has been proposed--particularly on pages 22 and following under the heading: "How would detailed data and analysis assist in programming safety research?"

Emphasis in accident causation is primarily on the road, although this conclusion has to be inferred simply from listings of accident data elements which are likely to be recorded. For example, one of the questions in the list is "Was the road to blame?" (O'D)

Conspicuously absent is an indication that HARC would have any responsibility in the field of data collection. The impression gleaned is that the HARC proposal would institutionalize existing practices, i.e., amass police-record type material. This would be most regrettable. (H)

Summary

The past is prologue. The panel has been rather critical of the work in accident causation which has gone on before, mainly because this work has certainly not solved the problem in a universal fashion. One of the reasons for this is that gaining this solution is a difficult job, but it has often been approached as if it were not. Perhaps the majority of the findings of the studies reviewed can be faulted on the basis of poor methodology in sampling, analysis, or simple logic.

But, on the other side of the ledger, much has been learned from the past. For example, the Indiana group (IRPS) has learned (or others have learned from them) that it is exceedingly difficult to attain a representative sample of accidents even in an isolated district, and that it is even more difficult to convince others that such a sample

then truly represents a national population. Indiana has also demonstrated some interesting analytical techniques (albeit with suspect data), and has shown how hard it is to draw a statistically supportable conclusion with small samples.

Calspan has presented a possible structure for considering the sequence of events in an accident from a human factors point of view using police-level accident report information. While it did not lead to many countermeasures, it may have value methodologically. (O'D)

These efforts, along with the others reviewed in this chapter, provide considerable important information about "what not to do" as well as a foundation for "what to do" in this complex area of examining pre-crash factors. The following chapter summarizes the panel's recommendations for NHTSA-sponsored work in this area over the next several years.

IV. RECOMMENDATIONS

Based on its review of the literature and experience in the field, the panel recommends that Level II-type studies be the backbone of NHTSA sponsored programs in accident causation research, with Levels I and III serving primarily as auxiliary systems. While the Level II approach is relatively undeveloped in comparison with the other approaches, it clearly has the greatest potential for producing sufficient quantities of well-controlled data.

Thus, the panel supports NHTSA's plans for implementation of NASS, the "National Accident Sampling System" (see O'Day, Wolfe, and Kaplan, 1975), which will be characterized primarily by Level II-type accident investigations. Many of the recommendations that follow are directed at the ongoing development of this program. Parallel recommendations are aimed at the development of a more general NHTSA-sponsored program of causation research.

Before specifying these recommendations, some comments on Level I and Level III data collection efforts will be presented, along with some suggestions for making these data more useful in their own right as well as more supportive of an expanded Level II system.

Recommendations for Level I and Level III Data Collection Efforts.

Level I or police level investigations should be continued in much the same way as is now the case, with perhaps some minor modifications to make them more useful in deriving hypotheses for further

investigation. Any major changes in their format should be viewed in light of the problems these changes would introduce should it be necessary to have longitudinal data concerning some particular aspect of crashes. For such purposes, one would want data collected in a similar fashion over a long period of time. In addition, police officers should be encouraged to improve their skills in accident data collection. (W)

Reports from both Level I and Level III accident investigation suffer from inadequate information on certain vehicle categories such as motorcycles, large trucks and bicycles. While the omission of such vehicles is understandable in light of the problems they pose for investigation (e.g., the high probability that a motorcyclist will have been seriously injured or killed, the difficulty in removing a large truck to a location suitable for careful vehicle examination), nevertheless, the fact that such vehicles are so heavily involved in serious and fatal injury crashes appears to constitute sufficient justification for their inclusion in any study purporting to deal with a representative sampling of accidents. In addition, while it is recognized that serious and fatal injury crashes constitute a small proportion of all accidents, they nevertheless represent by far the most costly portion of the accident picture and should not be overlooked simply because of expediency. (W)

One specific data problem involves the recording of VIN's on large trucks. While police report forms provide for the recording of this information, the investigating officers are usually unable to determine which of several numbers on the truck is the VIN. This

confusion stems from a lack of standardization on the part of the manufacturers as to where the information is to be located. It is a problem that probably cannot be solved by more careful training of investigating officers but rather must be handled at the level of the manufacturer. Even so, the solution will not be immediate, since the trucks presently in use will remain on the roads for many years to come so that it will only be in the distant future that any present change will result in significant payoff. (W)

It should be noted that once the VIN has been correctly recorded, some problems still persist. A complicated computer process is needed to decode the VIN's and obtain information on the manufacturing specifications of the truck. But even this information may not be entirely correct, since quite frequently modifications are made on trucks after they are first manufactured -- putting on a special body, adding another axle, etc. So the problem is not just a lack of standardization about where the VIN information is to be located on the truck, but also what information is in the VIN and just what it would mean if there were modifications. To overcome these latter problems, more careful questioning of the driver and more detailed reporting by the investigating officer would seem in order. (O'D,W)

In summary, although cars account for the vast majority of crashes, nevertheless there should be provision at every level of accident investigation for adequate information on trucks, motorcycles, and bicycles because of their prominence in serious crashes. (W)

At the other end of the spectrum (at the MDAI or Level III accident investigations), there is a need for more complete information on minor crashes. Although the mechanics of collecting such information

are formidable, it is essential that at least basic information be collected from an adequate sample so as to be able to determine the role of human, vehicular, and environmental factors in such crashes and the extent to which such roles differ from the situation in more serious crashes. (W)

It is likely to be the case that the relative importance of various factors changes dramatically as crash severity changes. A case in point is the role of alcohol in fatal crashes. The best information available suggests that alcohol is a factor in only a small percentage of property damage crashes (though this small percentage represents a much larger actual number of crashes than the roughly half of all fatal crashes that are associated with alcohol). The relative importance of other contributing factors is also likely to vary. Thus, while it may not seem worthy of the effort, in order to gain an overall better understanding of accident-related factors, it would appear important to conduct Level III investigations of some limited number of minor crashes. (W)

Finally, an even greater problem with MDAI studies (and one that perhaps cannot be overcome) is the difficulty in summarizing information from a variety of crashes. Thus, the panel concludes that perhaps one of the more fruitful ways to use information from MDAI studies is to examine them for leads as to the kind of information that should be collected more systematically in Level II investigations.

Recommendations for the Development of
a Level II Accident Investigation System

Review of NASS design.

In turning towards the development of a "National Accident

Sampling System" primarily for collection of Level II accident data, a systems design was provided by the University of Michigan Highway Safety Research Institute for NHTSA. The recommended system consists of 35 primary sampling units (PSU's) distributed throughout the 48 contiguous states, and has the following three major facets: 1) a program for continuous acquisition of data from a random sample of all towaway and/or pedestrian-bicycle-motorcycle accidents occurring in the U.S.; 2) a program for occasional acquisition of additional data on selected topics quickly and on call; and 3) a program for conducting in-depth or multidisciplinary accident investigations for accidents of particular interest. With the submission of this design, the system was deemed complete and ready for pilot implementation over a period of three years.

On reviewing this report, there was general agreement with the overall concept, and a feeling that the task of sorting out the objectives, the difficulties and subsequent solutions had been well thought out. In addition, the recommendation that the system be introduced piecewise and operated interactively with strong central policy control seemed most desirable. (H)

However, the following specific points were made regarding the NASS design:

1. With a project of this magnitude, it would be necessary to be overly careful with "Statistical Nuts and Bolts (SNAB)". Even if the details had been worked out by the best design center in the country, these should be evaluated by perhaps five other design centers. Best of all, a NASS/SNAB Symposium should be convened to hammer out inevitable

problems. This is too significant a project to rely on one team, however well-qualified, for SNAB.

Along this line, while the arguments in favor of 35 PSU's are certainly persuasive, they are not ipso facto conclusive. A difference of even one PSU would represent an annual cost of several hundred thousand dollars, or a capital investment of millions. Similarly, although the arguments in favor of different sampling of different types of accidents seem persuasive, there may be some pitfalls. The arguments often seem to contain rather 'soft' phrasing; for example, on p. 29 of the text "some sort" of population survey. (Could the technique of Foldvary in connection with the Queensland survey be appropriate? At what cost?)

The arguments in favor of continuing MDAI teams seem to refer mainly to the fact that these teams are already in existence rather than to any concrete evidence that they will be needed. Also, the principal concept of overrepresenting severe accidents seems by no means obviously valid, and some discussion of whether severe cases are indeed of overwhelming importance in designing CM's seems in order. Referring to the hypothetical questions given on p. 11 of the text, it would seem that accurate information on the most minor events would be helpful in obtaining certain answers, and essential for others. (H)

2. There appears to be a deliberate lack of research orientation for NASS users. From the first statement concerning NASS

users on p. 11 through the subsystems and SNAB details, there is a specific exclusion of research workers as recipients. It would seem desirable to add to the Continuing Sampling System (CSS), Quick Response System (QRS), and the MDAI System a fourth Research Oriented System (ROS). This would provide for the integration into QRS of suggestions received from professional research groups, and, if meritorious, modification of CSS. It may be reasonable to suppose that NASS usefulness in suggesting countermeasures, and their translation into standards, can be fully absorbed by NHTSA, but one would think that interaction between NASS via NHTSA and other research groups (and perhaps on a limited scale even public interest groups) would have payoff not only in terms of information derived but also goodwill gained. Even if ROS were to be confined exclusively to NHTSA service, it would be worthy of consideration.

As an interesting aspect of the ROS question, consider the two 'conditions' placed on the system: representativeness and completeness. The first of these is an important SNAB question and has already been discussed. By completeness, the authors were referring to the "condition" of having all required information accurately recorded on the investigation forms. This is certainly an admirable objective; however, an even more important subject for detailed study relates to the completeness of the NASS taxonomy itself.

There is simply no way to be sure that a NASS taxonomy will be 'complete', and of course the originators recognize

this by allowing for the evolution of the system with experience and other factors. But one of the most important other factors will be input, not from NASS itself, but from NHTSA and from research groups outside of the government. As information accumulates and is made public, it will be inevitable that some worthwhile ideas for NASS modification will arise both inside and outside NHTSA. These will tend to redefine 'completeness.' One simply cannot assume that the schedule of items currently of interest represent "all the facts" even if they eventually give a total vehicle-dynamic picture.

Perhaps an example will clarify this important point. Suppose that some years after NASS is fully operational, Smith, a professor of sociology at a reputable mid-western university, finds in his study of family position (first child, first of several, second, with brothers, with smaller sisters, etc.) that individuals placed last in a line of at least four boys tend to exhibit anti-social behavior. In Smith's study, he stumbles onto some of the old, discredited 'accident proneness' literature of the 'thirties, and is struck by how similar those arguments are to his own empirical data. He would therefore like to find out if this sibling-placement hypothesis has any basis in statistical fact, and appeals to NHTSA for assistance from NASS. In the present design, there is no place for Smith's request in the QRS, simply because it can hardly lead to any conceivable countermeasure, but it could be placed on the ROS agenda for study. If this item,

by chance turns out to have predictive value, then it will be clear that the taxonomy up to that time had not been complete because it lacked an item about sibling-placement.

The opposite side of the coin is that some items may well be dropped. A favorite candidate is sex. With only two values (M and F) which relate very closely to well-understood characteristics (size: different, intelligence: same, for example), this does not appear to be a useful taxonomy item. (However, there was not a consensus of opinion on this example.) While it may be possible to invent more realistic examples, the point remains that completeness of the NASS taxonomy must be recognized as an important aspect of that ~~ongoing~~ project effort. (H)

3. A third major point relates to evaluation. The authors correctly recognize that NASS should evolve with experience, but they do not provide any systematic channels for this evolution. Other than the external-to-NHTSA input already mentioned as important, it seems clear that there will be a welter of inputs: from the PSU commandants, from NHTSA monitors, from DOT rivals, from encroached upon ('cooperating?') local agencies, from victims of the accident cases, and so forth. With all of these potential sources for feedback, it would seem desirable to have procedures for deliberate evaluation of system performance according to preassigned criteria. (H)

Also, in order to assure that the data collected from one region are comparable to those collected from another, there

needs to be some procedure for regular feedback to the investigators. For example, in North Carolina, the publication The Accident Reporter, a monthly newsletter to city and state police, as well as inservice workshops, has been used to accomplish this purpose. There would appear to be no substitute for regular systematic communication between data collectors and data users. (W)

4. Finally, taking into consideration the above points, it is suggested that the process described on p. 88 of the report -- namely, "The proposal test of CSS questions was continually reviewed and updated to ensure comprehensiveness and relevancy" -- may not be as simple as it sounds. Furthermore, if performed mechanically without some imaginative input, it may lead to increasingly sterile results. Hopefully NASS will find out new things, not confirm old ones. The discussion of which parameters to measure (p. 89) is all very well as far as it goes. Although they appear to be based very largely on traditional taxonomies, they do reveal much of interest and should represent a good starting point. (H)

In way of summary, it might be noted that an attempt to sample characteristics of accident production should not be compared to searching for a needle in a haystack -- there is no needle, only the haystack. This means, the sampling should be designed with the end in view, not to 'solve' or 'cure' but to 'monitor'. Therefore the design should permit endless continuation and, as experience is gained, endless modification of plans. Hopefully, the NASS design will reflect this viewpoint. (H)

Developing a Level II taxonomy.

Regarding the development of a Level II-type taxonomy for NASS, the scheme developed by Indiana University for identifying causes associated with the vehicle, the driver and the environment seems a reasonable starting point. A first step would be to adapt from the Indiana scheme a specific NASS data collection form convenient for the investigator. This should be done by an in-house NHTSA team. Consultants could be used if necessary, but this should be considered a short-term effort to get something working quickly. (O'D)

Before employing this form in actual data collection, there are two questions which might well be asked: First, does the Indiana taxonomy adequately represent each of the areas of interest -- human, vehicle, and environment? And second, can it be applied consistently by reporters working more or less independently? (O'D)

The answer to the first questions is not easy to come by. Presumably the Indiana University staff constructed their taxonomy from a relatively exhaustive search of the literature and the suggestions of the participants, and they believe it to be as complete in each field as they can make it. However, there does remain the question as to whether or not this taxonomy adequately represents all of the areas of importance. (O'D)

The omission of sobriety information in an existing Level II data collection form concerning restraint system effectiveness is a case in point. Recent data suggest that sobriety may be closely associated with severity of injury, even when seat belt usage and other known relevant factors are controlled for. While Level II investigations are usually aimed at a fairly specific question such as the effects of restraint systems, it is essential that care be given not to omit

certain variables simply because they may not appear at first glance to be relevant. Presumably as our understanding of crashes and injuries increases, we will be in a better position to determine which variables are relevant. (W)

Therefore, research directed at reviewing the Indiana taxonomy (along with any NHTSA revision) appears in order. The project should investigate the adequacy of the scheme in providing for the data users -- including analysts and CM developers in various fields (driver behavior, vehicle design, etc.). The goal of the project would be a modified taxonomy which may or may not differ from the present one. (O'D)

As part of this same research study (or as an independent effort), a controlled experiment should be conducted to test the potential for consistency of the modified NASS recording scheme. This study would be aimed at developing a concise set of instructions for use of the method and such modification of the method as is necessary to assure consistent reporting. (O'D)

Along this line, as part of the MDAI editing and coding effort at HSRI, an attempt was made to apply the Indiana taxonomy to a small number of in-depth accident cases. Three experienced editors were given a copy of the taxonomy and asked to record the causative factors. There were certainly some problems with inadequate data -- i.e., things which were not recorded on the accident report but which would have been available to an investigator at or near the time of the accident. But, in addition, it was exceedingly difficult to get consistent causation reporting by the three editors -- particularly in the human

factors area. It was judged that this consistency might be improved with a more complete set of instructions, but no test was made of this possibility. (O'D)

In summary, if the Indiana scheme is employed initially in the NASS effort, it seems important to (1) make sure that the taxonomy is adequate in defining the broad range of "causes" and potential countermeasures and (2) make sure that it can be applied consistently by field investigators. It is recommended that NHTSA sponsor research efforts in each of these areas.

Alternatively, the Indiana scheme could be disregarded, and a new taxonomy developed entirely from scratch. This would hopefully result in a scheme that was not only complete and reliable, but also more objective than the Indiana-based schemes. (H) Of course, these qualities would again need to be investigated by carefully controlled research.

When the "final" taxonomy for NASS is formed, it might be beneficial for it to contain some "null categories" under each of the main headings (driver, environment and vehicle). These null categories would be items not now supposed to be related to the accident process, like sibling-placement or car color. The purpose of the null categories would be two-fold: on the one hand to discover ('by accident'!) something of interest (since so little is known about the process, and since so many preconceptions have proven faulty, why not provide for just a little frivolous variation?) and on the other hand to control (in the statistical sense) whether the sample is indeed representative of the whole population. If it turns out that sibling-placement mirrors demographic data or that car color corresponds to Level I

police data, then one would have no reason to doubt the system. But, if in any of the null categories, a perturbation of significance occurred, then one would have either found out something about accidents, or something about NASS. NHTSA should make a commitment to as many as ten null categories, to be established by inviting suggestions from the scientific community. These categories should be permuted gradually over the years. (H, O'D)

Usefulness of NASS.

Thus far, accident causation has been viewed in a fairly broad sense with the thought that a compilation of many data elements may lead an analyst to a better understanding of how or why accidents occur. Alternatively, it is sometimes useful to assume a causative factor, and to define a data collection operation aimed at proving or disproving an hypothesis. It is in that sense that the special studies in NASS may be most useful. (O'D)

As an example (O'D) of this process, suppose that someone (e.g., an NHTSA motor vehicle program person) has studied the European practice of carrying warning signs in the car for placement behind a disabled vehicle on the highway, and that he has suggested that such a practice would be useful in the U.S. There are a number of questions which might be asked: What is the frequency of disabled vehicles? How long have they been parked (e.g., long enough to have emplaced warning systems)? In short, how big a problem is this in the U.S. and would an additional warning system be likely to reduce the incidence of such crashes?

All of these questions may not be answerable from accident data alone. Indeed, it may be necessary to conduct laboratory tests, or highly controlled field tests, to determine the reaction of drivers

to particular warning devices. But, within the context of NASS, one could design a scheme for taking data about parked vehicle accidents -- determining the speed of the striking vehicles, the kinds of roads, the lighting conditions, the types of vehicles and their lighting systems, etc. -- and then to analyze that data to come to a stronger position with regard to a possible standard.

Further, if the data are taken in the context of a national sample, the results should be generalizable to a national standard. The research program for each identifiable program area should be done in the context of an existing national data collection system. Outputs of the research program would be first a definition of the specific data to be collected, and second the result of the analysis of that data.

With this point in mind, it is recommended that NHTSA sponsor at least one research design program in the context of an operating NASS. A specific topic has not been suggested here, but could be an item such as restraint system effectiveness, weather influence on accidents, collisions with parked vehicles, motorcycle accidents, etc. Some of these are currently being addressed in existing MDAI programs, but it would not be out of order to duplicate at least the design effort.

Other Recommendations for the Field of Accident Causation Research

Since full implementation of a National Accident Sampling System will take several years, it would seem desirable for NHTSA to sponsor at least one major accident causation study in the interim. This study should overcome many of the weaknesses of past efforts in the area, and provide useful input for the future NASS. Accordingly, it is recommended that the study be directed at identifying as many factors, conditions and

events describing an accident as justified on the basis of current knowledge and on the basis of their potential usefulness for the development of CM's. All factors which could be changed by potential CM's and whose modification could have influenced the occurrence or severity of the accident should be considered. However, as a practical matter, one has to consider that the investigators of an accident have a comprehensive perception of the accident and so are in a fairly good position to identify the most important factors. Therefore, they should be allowed to do so. Any disagreements among the investigators should also be indicated. In any case, the basic data and summaries should be presented in such a manner as to allow statistical or other analyses without having to rely on the subjective judgments of the investigators. (J)

The analysis should be directed at exploring the individual and joint potential of various countermeasures. If possible, this major accident causation study should be conducted as follows (J):

1. Develop the sampling plan, the detailed information requirements, and the plan for the analysis. It is suggested that two or three contracts be awarded for this phase, and that NHTSA select the best one for implementation. The rationale for this recommendation is that organizations which can efficiently perform the field work are not necessarily the strongest in terms of structuring the research and analyzing and interpreting the results.
2. Conduct the field investigation and collect data according to the specifications developed in the first phase. This includes the case-by-case identification of important factors, based on the overall knowledge of each accident, and the coding of the data.

3. Analyze the data, interpret the results and draw conclusions with regard to potential countermeasures. This phase is to be conducted by the organization whose plan was selected after the first phase.

In addition to this major effort, the following eight study areas are recommended for developing a basis for improved accident causation research. These studies would be on a comparatively smaller scale than that suggested above, about one to three man-months each. Parallel efforts by different organizations might be helpful.

1. Data Needs (J). In addition to developing a general accident causation taxonomy, one might also conduct a study aimed at developing various structures that would indicate what information must be collected in order to allow for the design, planning, and evaluation of specific CM groups or individual CM's, as well as for the full range of potential CM's. Special attention should be paid to the types of information which can be collected at various levels of accident investigations. When collecting "general purpose" data, the requirements should be such that interactions between factors and interactions between CM's can be studied. Also, when developing data requirements for specific CM's sufficient information should be required to consider the influence of other relevant factors.

As an example, highest priority might be given to studies to determine the kind of information needed to establish a quantitative basis for Federal Motor Vehicle Safety Standards. For instance, what information is needed to have a rational basis for requiring a certain tread depth on tires, such as the currently recommended 2/32 inch minimum? To have such a basis,

at least crude quantitative relationships between the requirements set by the standard and accident risk must be established. Also, other factors entering this relationship (e.g., road surface characteristics) should at least be categorized, if not quantified.

The purpose of this effort is not to actually develop such relationships, but to identify what data would be required. In order to accomplish this, one must have at least a listing of CM's which are currently conceivable and appear practical. It would be preferable to have a structure which indicates which CM's might be fully or partially interacting. For instance, limiting top speeds and improving brake performance are to some extent substitutable. In such cases, for each CM, the information required to study a complementary CM should also be specified.

2. Existence of Required Data (J). The second class of studies can be performed in close relation to the first ones. They would essentially determine whether the kind of information needed to design or evaluate certain countermeasures has been collected at all, and, if so, how extensive is the quantitative knowledge; e.g., has tread depth been recorded or just the information "worn" or "bald" tires? Also, how many cases have been studied and how well do they cover the range of tread depth, road surface conditions and other important factors?

More generally, one might study the potential for "re-viewing" existing accident studies. Considerable information related to accident causation has been collected by IRPS, CALSPAN, and

MDAI's. The analyses, however, have been performed from the point of view of specific causative factors and/or CM's. It should be determined whether the basic data collected in each of these studies could be used in these broader studies, and whether, perhaps, data from various studies could be pooled. If the results of this study indicate that it may be promising to review existing accident data, then one or several such studies should be conducted.

3. Alternative Approaches to Data Collection (J). If the data needed for CM evaluation is not already available in sufficient detail, then it should be determined to what extent the needed information can be obtained by direct measurement or collection of information, and to what extent it can be obtained by reconstructing a given accident situation. Certain aspects of accident causation can be determined only by investigating and analyzing actual accidents; e.g., interactions between driver behavior in traffic and vehicle failure. However, for establishing certain qualitative relationships (e.g., those needed to define performance standards), an impracticably large number of accidents may have to be studied. Otherwise, the effects of the many factors influencing an accident cannot be separated and the data will have limited accuracy. In such situations, studies conducted under controlled laboratory conditions might be more efficient.

As an example, test tracks can be used to obtain relatively accurate quantitative results on the effect of tire tread depth on stopping distance for various speeds and road surfaces.

Similarly, driver behavior during skidding or loss of control can be studied using simulators.

Thus, an important aspect of accident causation research is to determine what information has to be collected from real world accidents, and what information can be obtained more easily from "laboratory" experiments -- be they test track runs, simulations, or actual laboratory studies.

This, however, is not sufficient. Equally important is the question of "calibration." As an example, in laboratory experiments travel speed "before the accident" (e.g., before loss of control) might be a critical parameter. However, in real accidents one can usually quantify impact speed only from measures of vehicle deformation, and perhaps estimate a lower bound for travel speed from measures of tire marks. Thus, one must study whether laboratory experiments can be sufficiently calibrated to allow meaningful conclusions on the effects of certain countermeasures in real life accidents.

4. Developing Appropriate Quantifiers (J). Regardless of whether one relies on real life accidents or controlled experimental situations for accident data, there is a need for identifying appropriate quantifiers, e.g., what constitutes "following too closely," or "excessive speed"? The accident investigation should establish the actual following distances, the actual speeds, etc. Then, it should examine how the accident probability would have changed if the second car had followed at another distance, if the cars had been traveling at different speeds, etc. The ultimate question to be answered is: Can "following

too closely," or "excessive speed for conditions" be defined in operationally meaningful terms so that a sufficient majority of drivers can estimate on the basis of easily observable conditions (such as highway type, weather, and traffic density) what "too close" is and which speeds are "excessive for conditions"? To be able to answer this question, one must develop an information structure which allows the reconstruction of an accident in sufficient detail in order to "repeat" it under various assumptions about the application of CM's of varying specifications.

Other factors which should be considered are "systemic". To what extent do differences between the braking capabilities of cars contribute to the probability of an accident? To what extent is the distance to the car in front determined by the frequency of other drivers "cutting in"? Here, one should determine which relevant information must be obtained from accident investigations, and which information must be obtained from "exposure" studies -- exposure in the broadest sense as exposure to certain traffic and highway conditions.

Finally, one might suspect that under certain circumstances a large percentage of all cars "follow too closely," but that other factors are necessary to result in a rear-end collision. If the judgment of drivers about which distance to hold cannot practically be changed, then "following too closely" is useless information. From the point of view of CM's, "inadequate braking capability" might be the more appropriate "cause."

In either case, however, this information needs to be operationally defined so that appropriate CM's can be developed and tested.

5. Exposure Requirements (J). In addition to these studies directed at refining accident data collection efforts, an investigation into the requirements for exposure data is needed. The purpose of such an investigation would be to (1) determine what can be learned about accident causation and CM's without exposure data; (2) determine what exposure data are required or desirable for the design, planning and evaluation of potential CM's; (3) determine for which purposes and to what extent currently used exposure measures such as vehicle miles of travel, average daily traffic, hours driving, etc. are useful; (4) explore possibilities for collecting accident-related exposure data of various kinds; (5) consider at a detailed level exposure information implicitly contained in accident data, as reflected in the concept of "induced exposure"; and (6) study the trade-offs between collecting "second-best" or less accurate measures of exposure and performing analyses using alternative approaches.
6. Statistical Methodology (J). Since most factors influencing the occurrence of accidents interact, and because in most cases alternative countermeasures will affect the occurrence and severity of an accident, a complete description or tabulation of accidents would require many dimensions. There should be an investigation of which statistical techniques should be used to organize this information in a meaningful manner, to identify independent factors, to identify the common occurrences of factors as well as the interaction of factors, and, to estimate how individual CM's and the simultaneous use of several

CM's might affect an accident population. It should also be determined whether a biased -- or stratified -- sampling rather than a representative one would be more efficient, and to what extent results from a non-representative sample can be extrapolated.

Special attention should be paid to significance tests. Currently, significance levels of 90 percent, 95 percent or 99 percent are used like the magic numbers 7 and 13 in medieval times without regard to the relative losses resulting from committing an error of the first and of the second kind. Accident and CM costs should be considered in selecting significance levels or in proposing alternatives.

7. Determining CM Effectiveness (J). In order to evaluate the total benefits of an accident CM, one needs to know what percentage of all accidents it might affect. For example, one would want to know what percentage reduction in accidents nationwide would occur if tire tread standards were increased to a 3/32 inch minimum.

To accomplish this goal, accident studies in the past have examined to what extent the area where they were conducted was representative of the country, or how representative the studied accidents were of "all" accidents. However, a more efficient approach would be to determine what types of accidents are affected by the CM, and the national frequency of these accidents. Therefore, a study might be directed at developing for NASS the set of data requirements necessary for determining the national frequency of different accident types. (These accident types would be defined so as to be differentially

affected by the various CM's.) It would then be a much simpler task to estimate the total national benefits of a given CM.

Subsequent Level III investigations could provide the data requirements needed to quantify such CM effects.

8. Information Retrieval (J,W). Most accident investigations use mainly a structured format, listing the various data to be collected and allowing multiple-choice or numerical entries. In addition, often sketches and narrative descriptions are used. Sometimes, this graphical or narrative information is also later coded. However, this usually requires an information structure thought out beforehand. A practical, apparently little recognized problem is: How can one utilize unanticipated information for which no entries are provided, but which appears obviously relevant to most students of the accident report? It is conceivable that the study of such information in several accident records could reveal a pattern which would not be recognized if only the coded information were analyzed. Therefore, it would appear worthwhile to study whether existing techniques in information retrieval could be utilized to study unstructured verbal and perhaps also graphical information from accident reports.

One information retrieval system which appears particularly promising has been developed by the University of North Carolina Highway Safety Research Center. In North Carolina, all narratives from the accident report forms are placed on magnetic tape verbatim. This system, known as the "computer dictionary," makes it possible to retrieve these stored accident narratives

in quantity. To facilitate use of the system, a dictionary file has been compiled containing an alphabetical listing of every word found in the North Carolina accident narratives along with the frequency of such occurrences. To retrieve information pertaining to specific types of crashes, one consults the dictionary, selects appropriate search words or phrases, and inserts them into a computer program. The program then scans the narratives and prints out all those which contain the desired words or phrases, along with the associated accident case numbers. This specific subset of narratives can then be scanned to study a variety of accident-related topics, such as truck jackknifing and overturning, billboard distraction and accidents involving blind pedestrians.

Subsequent (FY-78 and beyond) efforts would stem from unanswered questions arising from this variety of small-scale studies. As the NASS system would be closer to full implementation, extensive utilization of this vehicle would be anticipated. The studies, in all likelihood, would involve data element requirements, reporting consistency, exposure collection techniques, and evaluation of subsequent CM's.

Concluding Comments

For a number of years the typical accident investigation program has been defined to address a specific subject such as "the involvement of vehicle defects in crashes," "the causes of single vehicle accidents," "the causes and effects of truck (or motorcycle, or recreational vehicle) accidents," etc. In general NHTSA contracts have been awarded to single agencies for the design of a study, the collection of data, and the

subsequent processing and analysis of this data. While each such contract usually specified the desirability of having the data represent the national population, the arrangement with specific contractors usually inhibited this. Thus, vehicle defects have been studied in Indiana, motorcycles in California, recreational vehicles in Kentucky, single vehicle accidents in Florida, etc. The generalizability of the results has been difficult. In addition, the typical contract awarded emphasized the need for data, and allowed only a short time for planning and for analysis. (O'D)

NASS has the potential for changing this situation. Sources could be solicited to perform the planning and analysis functions only, assuming that the data collection activity will be taken care of by an existing system. Even prior to the implementation of NASS, however, the panel strongly recommends that NHTSA issue separate RFP's for the different phases of a major research project -- particularly for the design and analysis phases as compared with the data collection phase. Not only would this allow proportionately more time for the planning and analysis phases, but it would also capitalize on the highly specialized capabilities which some research organizations have to offer.

As this panel has discovered, developing a theory of accident causation/countermeasure is no simple matter. And so, a final major recommendation is for NHTSA to sponsor a relatively open piece of research into accident causation, to be done in parallel by several independent contractors with only light monitoring. Hopefully, an open-ended project of this sort would bring out some creative thinking on this complex and challenging issue.

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