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IDENTIFICATION OF GENERAL RISK-MANAGEMENT COUNTERMEASURES FOR UNSAFE DRIVING ACTIONS

Volume III: A Definitional Study of Speeding, Following Too Closely, and Driving Left of Center

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16. Abstract

This report develops a set of operational definitions for three unsafe driving actions (UDAs): speeding, following too closely, and driving left of center. The definitions flow from a methodological development and from an analysis of the literature and accident files at HSRI. Risk statements for these UDAs also are developed, along with a description of the circumstances under which the UDAs occur. The matter of driver consciousness of committing each UDA is discussed. It is recommended that the speed UDA be the target for countermeasure development in this project.

This report is a part of a larger study to identify promising countermeasures for high-priority UDAs. Other results of the study are reported in Volume I: Description and Analysis of Promising Countermeasures, and Volume II: A Review of Selected Literature.

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METRIC CONVERSION FACTORS

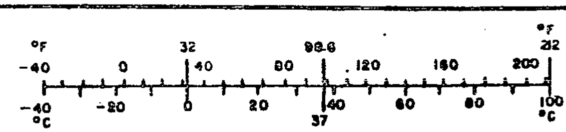
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER ONE
INTRODUCTION

This volume presents a definitional study of three unsafe driving actions (UDAs). The document was prepared under National Highway Traffic Safety Administration (NHTSA) contract number DOT-HS-7-01797, entitled "Identification of General Deterrence Countermeasures for Unsafe Driving Actions." The definitional study is one of a three-volume final report of work conducted under this contract. The other two volumes are "Volume I: Description and Analysis of Promising Countermeasures for Speed-Related UDAs" and "Volume II: A Review of Selected Literature." The project was conducted by the staff of the Policy Analysis Division of The University of Michigan Highway Safety Research Institute (HSRI). The UDAs treated in the study are:

- speeding,
- following too closely, and
- driving left of center.

The work reported in this document also supports two other NHTSA-sponsored projects being conducted by HSRI. The first project, "Police Enforcement Procedures for Unsafe Driving Actions" (contract number DOT-HS-8-01827), describes and assesses police enforcement practices designed to reduce the incidence of these UDAs. The second project, "National Analysis of Unsafe Driving Actions and Behavioral Errors in Accidents" (contract number DOT-HS-8-02023), will use methods developed here to analyze the traffic crash risk associated with a wider range of UDAs, and to further refine the definitions in this report.

OBJECTIVES

The general objective of this document is to present a set of operational definitions of the three UDAs listed above. The definitions are in sufficient detail to support the identification and assessment of general strategies and countermeasure concepts for reducing the crash risk associated with the UDAs. The information used in arriving at these definitions was drawn from existing highway safety literature and data bases.

Specific objectives of the definitional study were to:

- develop a rigorous, broad definition of UDAs in general;
- develop a more specific but preliminary definition of each of the three subject UDAs;
- determine the feasibility of using the preliminary definitions as a basis for developing more detailed definitions and descriptions from accident investigation data bases;
- to the extent possible, use these data bases to obtain a better estimate of the incidence of the subject UDAs in crashes and to identify important characteristics associated with UDA-caused crashes; and
- refine the preliminary definitions for use in the general-deterrence project.

BACKGROUND

Problem definition is the first step in the solution of any problem. Unfortunately, this step has not always been taken in dealing with the problems caused by our nation's highway transportation system. Often, highway safety countermeasures have been instituted with little or no understanding of the nature or causes of the problem. It is therefore not surprising that many countermeasures have had a negligible effect on the problem.

Sometimes, a little knowledge of the problem has, by instilling a false sense of understanding, proved more harmful than no knowledge. The field of alcohol and highway safety provides some classic examples of the tendency to translate superficial understanding of gross causal effects into countermeasures aimed at the subtlest and most complex interactions between individuals and their environments. Often, countermeasures have been implemented with little thought of how their behavioral effects would be measured, and with the result that they could not be measured.

These same pitfalls await the designer of any driver-oriented countermeasure. The knowledge that human factors "cause" ninety percent or more of all traffic crashes (Treat et al. 1977) makes them an enticing target for countermeasures. Yet, such countermeasures will have little hope for success unless it is understood: first, how and under what conditions a specific driver action or omission affects crash risk; and second, how that driver action can be detected and measured.

Hiett et al. (1975) has stated these general requirements succinctly in defining target driving behaviors:

> Target driving behaviors are, in the broadest sense, those driver actions whose omission or commission are causally related to automobile accident occurrence. More specifically, they are actions which are presumed to be controllable by normal, trained, and licensed drivers and are detectable by observers outside of the vehicle. Target driving behaviors must be associated with relatively frequently occurring accidents so that their modification or elimination would result in a significant reduction in the frequency of accident occurrence.

This statement is the starting point of our inquiry here. We seek more specific definitions of three driving actions identified as "unsafe" in a previous NHTSA study by Lohman et al. (1976): speeding, following too closely (FTC), and driving left of center (DLOC). The definitions must be stated in operationally useful terms and in sufficient detail for the generation and assessment of countermeasure concepts.

SCOPE AND APPROACH

We begin by restating Hiett's definition of a UDA in a slightly different form:

> An unsafe driving action is an act or omission by a driver that increases the risk of a traffic crash above a level that is societally acceptable.

This definition focuses on the driver as the controller of a vehicle. Also, it implies that the act or omission is causally related to crashes, but in a probabilistic sense. This relationship establishes the meaning of the term "unsafe."

The ultimate objective of the research conducted under the general deterrence project was to develop and assess countermeasures that can, in the near-term future, reduce the incidence of UDAs. This means that a UDA must be detectable and measurable using methods and instruments that are neither intrusive nor highly sophisticated and costly. Actions that are very subtle or far back in the causal chain are, in effect, excluded from the inquiry. **We, therefore, restrict our examination to actions that can be readily observed or measured**, and define an **observable UDA** as follows:

> An observable UDA is a UDA that can be detected and measured by an external observer of traffic flow behavior.

The most obvious manifestation of traffic flow behavior is the motion of the vehicles that comprise the flow, that is, the trajectories of vehicles and the speed and acceleration histories of vehicles. A vehicle's motion must be measured in the context of the total driving situation of the driver/vehicle. This includes the presence and motion of other vehicles, and environmental characteristics such as road geometry, road conditions, and weather.

NHTSA's original concern in this project was driving actions that result from a conscious decision to engage in the action. Unfortunately, this interest conflicts with the requirement that UDAs be observable as defined above. It will be difficult, if not impossible, for an external observer to distinguish between conscious and unconscious UDAs. Thus, in **defining** a UDA, we will not be concerned with the decision-making process of the driver that led to the UDA. However, in **analyzing** UDAs, the reasons behind the UDAs will be considered. The issue of conscious versus unconscious UDAs will be included in the analysis.

Our approach to developing definitions for the three UDAs closely parallels the specific objectives listed in the preceding section. First, in Chapter Two, the elements of the general definition are extracted and rigorously described to provide a firm analytical foundation for the study. Next, relevant highway safety literature is examined to expand the general definition into preliminary specific definitions for each of the three UDAs. Available information from the literature is used to develop rough estimates of the risk associated with each UDA.

Following this, a procedure for analyzing HSRI's file of in-depth case reports is developed (Chapter Three). The purpose of the analysis is to examine the preliminary definitions in more detail. A refined estimate of the overall crash risk associated with the UDAs is then made after performing a clinical analysis of a sample of cases from the file. This activity is described in Chapters Four, Five, and Six, which deal with speeding, FTC, and DLOC, respectively. Also, these sections analyze the in-depth files further to identify significant driver, vehicle, and environmental characteristics that are associated with each UDA. The driver awareness issue is treated in the analysis. Chapter Seven examines the feasibility of using the definitions in clinical analyses of crash causation.

The final step in the definitional process is to use the results of the more detailed analysis to refine the preliminary definitions and to specify a set of operational definitions (Chapter Eight). The operational definitions and the findings on associated characteristics comprise the final definitional statements developed in this report. The major conclusions and recommendations of the study are reported in Chapter Nine.

The reader should note that this report is one of a series of reports in which UDA definitions are developed and refined. Subsequent refinements of the definitions will be presented in reports prepared under contract DOT-HS-8-02023 (see, Treat et al. 1980, for the latest refinement).

CHAPTER TWO

PRELIMINARY DEFINITIONS OF UDAs

In this section, pertinent literature is examined and preliminary definitions of speeding, following too closely (FTC), and driving left of center (DLOC) UDAs are developed. The starting point of the analysis is the general definition of a UDA set forth in Chapter One. According to this definition, a UDA is an act or omission by a driver that increases the risk of a traffic crash above a level that is societally acceptable. Also, it is assumed that more specific definitions must be stated in terms of driving actions that can be detected and measured by an external observer of traffic flow behavior.

The development in this section is in two parts. First, we examine in some detail the elements of the general definition in order to determine precisely what must be expanded to arrive at more specific definitions. These elements are:

- the meaning and significance of the terms "risk" and "exposure,"
- the general nature of the variables that are related to risk,
- the concept and meaning of maximum acceptable risk, and
- the concept of causation and ways of estimating the role of a driving action in causing a traffic crash.

The second part of this section applies the results of this examination and information gleaned from the literature to developing specific preliminary definitions of speeding, FTC, and DLOC.

ELEMENTS OF THE GENERAL DEFINITION

Risk and Exposure

In general, we define risk as the probability of an undesirable event. In the case of traffic crashes, the event can be the crash itself or the consequences of the crash, e.g., loss of life or property, injury, etc. The event can also be defined in terms of the individual who causes it to occur and in terms of the conditions under which it occurs. Thus, risk can be defined at any level of detail that suits a particular analysis.

Clearly, the longer the time period during which an event **can** occur, the greater the probability that it **will** occur. Time, in this case, is a measure of **exposure.** Traffic crash risk is thus a function of driving time, or of the time period during which a person **might** be exposed to crashes caused by himself or other drivers. Traffic crash risk can also be expressed as a function of the time period during which some specific driving activity is occurring, e.g., the time spent driving in excess of 70 mph. Since distance is a function of time for any given speed history, miles traveled can also be used to measure exposure except for the trivial case where a vehicle is not moving (e.g., stopped at a stop light).

Thus, risk cannot be completely defined until the risk event and exposure are defined. The definition of exposure must specify both the nature and amount of the exposure. The definition of the risk event must specify the type of crash loss and conditions under which the loss can occur. A complete statement of risk might read, then, as follows:

> The probability that any licensed driver will cause a fatal accident during a one-year period is .0004.

Here, the undesirable event is "a fatal accident caused by any licensed driver," and the exposure is one year. The statement implies that the risk is that of "any licensed driver," all of whom comprise the "population at risk." The population at risk could also be defined as the individuals who might be killed, injured, and/or suffer property damage in a fatal accident.

A more specific statement of risk must be made when defining the risk created by a given driving action. For example, such a statement might read:

> The probability of a fatal accident caused by a given driving action committed by any driver who commits that action continually for a period of one year is 0.10.

In this report we will call this a statement of **conditional risk** because it specifies the risk of a fatal crash, given the **condition** that the driving action is being performed. The population at risk is composed of drivers who commit the driving action. If the population at risk were redefined to consist of all licensed drivers, then the risk statement would read:

> The probability of any licensed driver being involved in a fatal crash caused by a given driving action in a one-year period is .004.

We will call this type of risk **unconditional risk** because it is not known beforehand whether a member of the population at risk is performing the specified driving act or even driving at all during the one-year period.

One more term must be introduced to complete our definition of risk and exposure. This term is called **hazard rate.** It is measured in units of number of risk events (i.e., "hazards") per unit time per member of the population at risk. When used in describing conditional risk, the hazard rate, $\lambda(t)$, is defined such that:

$\lambda(t)dt$ = the probability that a continuously-performed driving action will cause a crash event in the time period $t \rightarrow t + dt$.

It follows that

$$P(t) = 1 - e^{-\int_0^t \lambda(\tau)d\tau} \qquad (2\text{-}1)$$

$P(t)$ = the probability that a continuously-performed driving action will cause a crash event on or before time t.

= the conditional risk associated with the driving action.

If a hazard rate is not a function of time (i.e., is a constant), then:

$$\bar{\lambda} = \frac{1}{\bar{T}} \tag{2-2}$$

where $\bar{T}$ is the mean time before a continuously performed driving action will cause a crash event. Also, if hazard rate is computed as a function of time over a time period, T, then the average hazard rate is:

$$\bar{\lambda} = \frac{1}{T} \int_{0}^{T} \lambda(\tau)\, d\tau \tag{2-3}$$

When the product of the average hazard rate and the exposure time is very small, the following approximations hold:

$$P(t) \simeq \bar{\lambda} T \tag{2-4}$$

$$\dot{P}(t) \simeq \bar{\lambda} \tag{2-5}$$

where $\dot{P}(t)$ is the risk rate per unit time. As long as $\bar{\lambda} T$ is less than .02, the error of these approximations will be less than 1%.

Similar relationships can be developed for unconditional hazard rate, $\Lambda(t)$, which is defined such that

$\Lambda(t)dt$ = the probability that a member of a specified population-at-risk will be involved in a crash event caused by a given driving action in the time period $t \rightarrow t + dt$.

Clearly, then, if we know hazard rate and exposure, we will know risk. The close association between these terms has led some writers to refer to hazard rate as risk. In this report we will treat hazard rate as a surrogate of risk but will maintain the distinction between the two terms.

Hazard rate is used as a measure of risk in many fields. Reliability engineers and systems safety analysts use it in analyzing system failures, system availability, and system effectiveness. Epidemiologists and demographers often use hazard rates in estimating life expectancies of populations and in projecting population growth. Actuaries and insurance underwriters use it for determining insurance rate structures. Adopting the term for analyzing highway safety will provide a linkage to this "community" of risk analysts and to the tools, techniques, and data that they have generated.

Covariables of Risk

Hazard rate (and thus *risk*) is a function of many other variables as well as of time. It will be convenient here to separate these covariables of risk into two groups, observable-driving-action variables and other variables. The former group will be used to define such observable driving actions as speed and distance between vehicles. The latter group will be used to define all other factors that may affect hazard rate (e.g., driver age, time of day, type of roadway). Mathematically,

$$\lambda = \lambda(x_1, x_2, \ldots, x_n; y_1, y_2, \ldots; y_m; t) \qquad (2\text{-}6)$$

where

x_i = the <u>ith</u> observable driving action variable

y_i = the <u>ith</u> other variable

t = time of exposure

Note that the two groups of variables may be related. For example, it may be that

$$x_3 = f(y_6),$$
$$x_5 = g(y_1, y_3), \qquad (2\text{-}7)$$
etc.

When this is so, the y variables will be said to be **correlates** of the x variables. For example, if x_1 is the speed of a vehicle and y_2 is a variable measuring the degree of consciousness of the driver, accident and exposure data may show y_2 to be a correlate of x_1. If y_4 is the estimated coefficient of friction of the roadway, x_1 may be related to y_4 for some values of y_5 (the age of the driver) and unrelated for other values of y_5, etc.

The first task in defining a UDA is to determine how hazard rate varies with a given risk variable. Two ingredients are needed for calculating hazard rate functions:

1. Number of persons in the population at risk as a function of the risk variables and of time, and

2. Number of persons in the population at risk experiencing crash events caused by a given risk variable per unit time, as a function of the risk variable and of time.

Hazard rate is then calculated as the quotient of these two factors, that is, factor two divided by factor one.

For a given driving action, the conditional and unconditional hazard rates differ only in respect to their populations at risk. The population at risk in a conditional hazard rate is composed of drivers who are performing a given driving action. The population at risk in an unconditional hazard rate is composed of any specified group of individuals who could be involved in a crash caused by a given driving action. Here, the term "driving action" is used to indicate a particular value of a given observable variable of risk.

Maximum Acceptable Risk

Our general definition states that a given driving action becomes a UDA when the risk associated with that action becomes unacceptably high. The value of the observable variable of risk corresponding to this maximum acceptable risk defines the UDA threshhold for the driving action.

This concept applies to both unconditional and conditional **risk** and their respective **hazard rates.** That is, for each observable variable of risk, there is a maximum acceptable conditional hazard rate and a maximum acceptable unconditional hazard rate. Exceeding either of these rates results in a UDA. Since these two hazard rates are not independent, specifying one is equivalent to specifying the other.

If the maximum acceptable hazard rate associated with a given risk variable is known, then the UDA threshhold for that action can be determined graphically as indicated in Figure 2-1. A given variable may be constrained either by an upper or a lower boundary or both. The hazard rate curves and the limiting values of the covariables for UDAs will in general vary for different types of crash events (e.g., all crashes, fatalities due to crashes, etc.).

A major problem in defining UDAs is the lack of information about the level at which a given driving action becomes "societally unacceptable." We have found no literature that deals explicitly with this issue. However, several interesting avenues exist for developing such information.

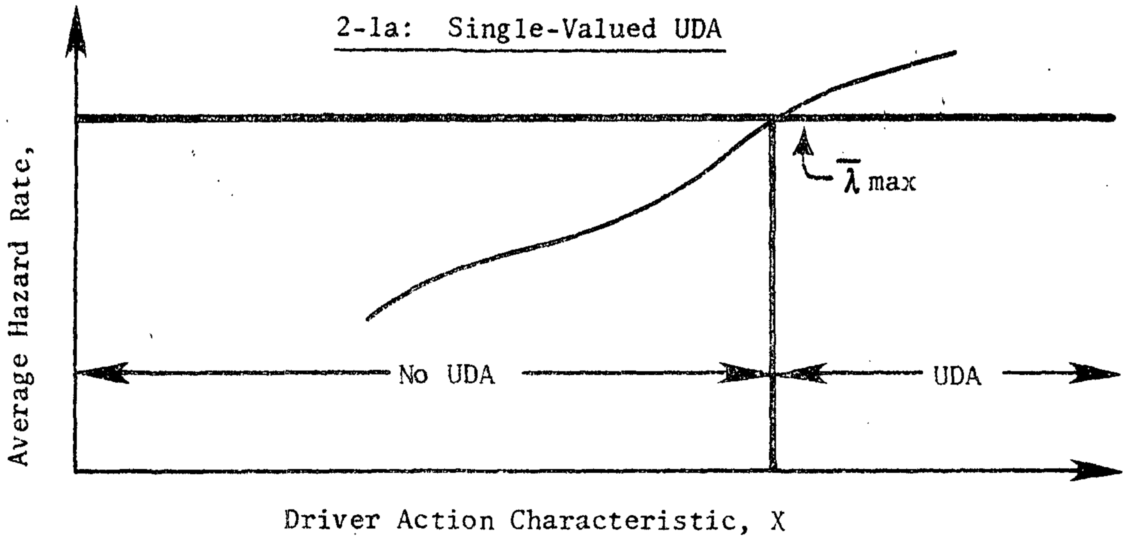
For example, for the past fifty years, the hazard rate (unconditional) of the general population in the United States has varied between 20 to 30 fatalities per year per 100,000 population due to traffic crashes of all causes (National Safety Council 1978). Clearly, this represents an overall level of risk that society as a whole is willing to accept. It might thus be argued that any driving act that created a hazard rate that was very much higher than this would be "societally unacceptable."

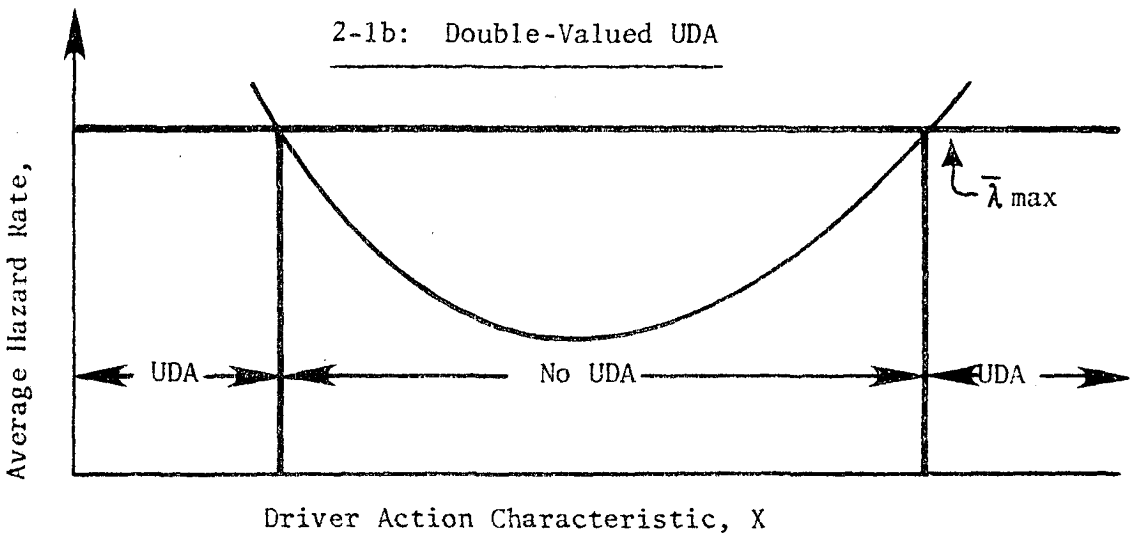
This definition has a serious flaw, in that it does not adequately account for the contribution of driving actions with hazard rates equal to or less than the overall hazard rate of **all** driving actions. It would be better to define a unique maximum acceptable hazard rate for each driving action. Thus, a driving action would become a UDA when its contribution to overall hazard rate exceeded a specified percentage. For example, car-following might become "unsafe" at a headway that would cause enough fatalities to account for more than five percent of the overall hazard rate.

The above approaches (and variations of them) are oriented toward

FIGURE 2-1

EXAMPLES OF GRAPHICAL DETERMINATION OF UDAs FROM HAZARD RATE CURVES





unconditional hazard rates. It would also be useful to have estimates of maximum acceptable levels of **conditional** risk or hazard rate. In this case, the risk limit would be stated in terms of crash events per year per driver performing a given driving action.

It might be possible to estimate maximum acceptable hazard rate (λ_{max}) by assuming that a driving action becomes a UDA whenever the percentage of on-the-road drivers who are performing that act is less than a given value. For example, car-following would become a UDA for drivers whose headways were less than the headway that 95% or less of all drivers were maintaining (see Figure 2-2). The crash rate caused by that unacceptably risky group of drivers would then be estimated from accident data, and λ_{max} would be calculated. Clearly, this approach assumes that all but a few drivers are driving "safely" at a given time.

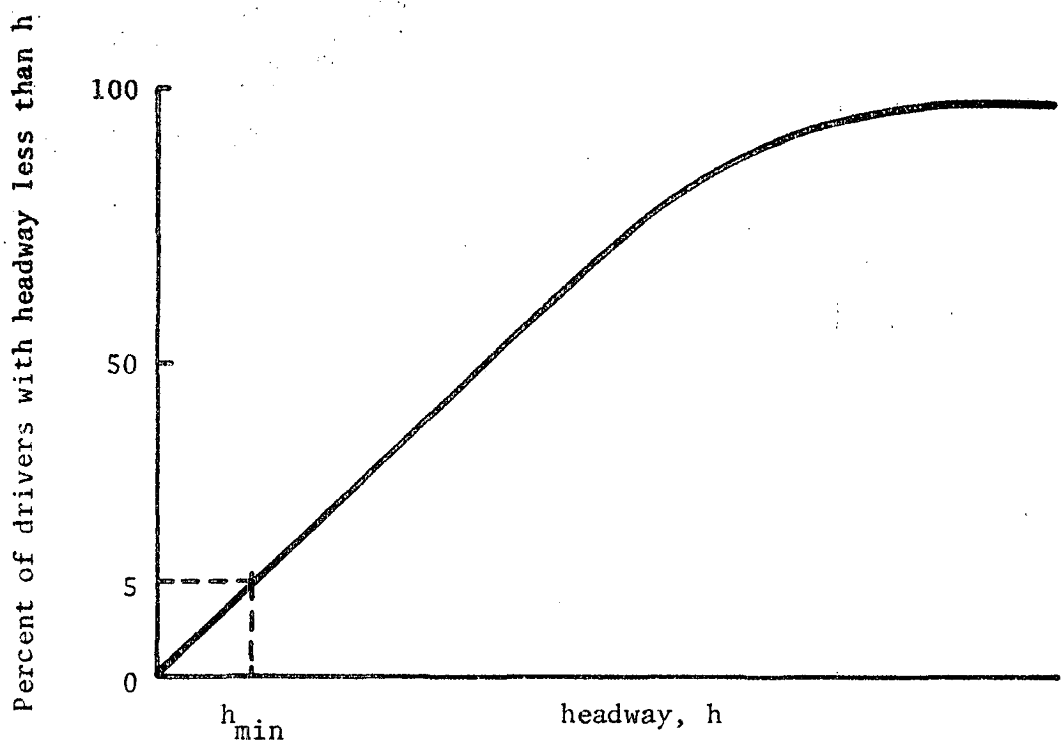
Legal Definitions

Many unsafe driving acts are prohibited by law. In our terms, the statement of law is an expression by society of the level of risk that will be tolerated. Traffic laws appear to be quite precise but unfortunately often are not. Some laws are stated in terms that require the actual risks associated with a particular event to be established. For example, many states have laws prohibiting driving at a speed too fast for existing environmental conditions. Such laws require that the relative risk be established before the unsafe act can be defined. The tolerable level of risk must be defined in terms of existing conditions.

When speed laws were first established it was common to state them in presumptive terms like the general unsafe speed law noted above. Difficulties in prosecution and a desire for more objective communication with the motoring public led to the use of maximum speed limits. An operator driving a motor vehicle in excess of a maximum speed limit commits an offense, per se; no evidence of relative safety is required. The establishment of a maximum speed limit for a particular highway flows from an analytic process that assesses the relative risk on the highway. In many cases, maximum speed limits are set at or near the eighty-fifth percentile travel speed of traffic under normal, free-flow

FIGURE 2-2

DETERMINING MINIMUM ACCEPTABLE
HEADWAY FROM TRAFFIC FLOW DATA



travel speeds (Joscelyn, Jones, and Elston 1971). Other traffic laws are implemented after similar relative risk studies. Stop signs are placed after an engineering analysis that determines that the highway configuration and traffic conditions warrant the installation of a stop sign as opposed to a yield sign, a traffic light, or no sign.

Thus, in theory, the implementation of traffic law follows a process that analyzes the relative risk and establishes safe and unsafe definitions for a particular roadway. In practice, however, there is significant local variance. Often traffic engineering resources are not available. The judgments that are made in establishing speed limits, signing intersections, or installing signals often deviate from recognized engineering practices. Signing decisions may result in safe behaviors being labeled as legally unsafe. Thus, while the law may be regarded as providing an indicator of unsafe driving actions, legal definitions cannot be generally accepted as operational definitions for the study of unsafe driving acts.

An important distinction can be made for one class of legal definitions--those that establish "absolute" laws, such as these that establish the 55 mph national maximum speed limit. Society, after weighing a variety of risks that include energy risks as well as safety risks, established a maximum speed limit. Such laws define **absolute UDAs** and constitute formal societal statements of the level of maximum tolerable risk. Such absolute laws can be distinguished for those based on traffic engineering studies of the relative risk of different travel speeds on a particular road.

Causation

Our definitions of risk and hazard rate require that the crash events of concern be "caused" by a given driving action, but we need to specify what is meant by the term "cause" as used in this context. In general, we are using the term to define an event that results in the occurrence of another event. As was observed by Hall and O'Day (1971), such events can be interconnected in a causal chain that culminates ultimately in the crash event. Thus, it is pointless to speak of **the** cause of a crash. A given event (e.g., an observable driving action) can only be **a** cause of a crash.

Two fundamental types of approaches have been used for determining whether an event is a cause of a crash: the clinical approach and the statistical approach. In the clinical approach, individual traffic crashes are examined by trained analysts who make informed judgments about causation (Joscelyn and Treat 1971; Treat et al. 1977). In the statistical approach, quantitative studies are performed to determine whether the presence of a factor is associated with increased crash risk.

The research literature provides guidance in applying the clinical approach. The construction of causal-chains is described by Fell (1976), and this method was used by Joksch and Reidy (1977) in developing an extensive network of accident causes. Specific assessment procedures are described in Joscelyn and Treat (1971), and these are further refined and tested in Treat et al. (1977). The latter provide the following definition of a causal factor:

> A factor necessary or sufficient for the occurrence of the accident; (such that) had the factor not been present in the accident sequence, the accident would not have occurred (p. 16).

This definition describes a "but for" test, which asks whether "but for the occurrence of (a factor), this accident would not have occurred." In other words, if the factor had been absent, the causal chain would have been broken, and more recent events leading to the crash event could not have occurred. Other language appears in the Treat and Joscelyn references to add time and distance constraints to the range of factors that may be considered. Like the UDA concept, their work focussed on behaviors and other factors that immediately preceded the occurrence of an accident; these amount to the final links in a causal chain or set of chains.

The clinical approach alone is insufficient for determining conditional risk or hazard rate, because it does not deal with the relevant populations at risk. However, it can be used without exposure data for determining both relative and absolute values of unconditional hazard rates due to various driving actions (and to other factors as well). This is done as follows. First, we define relative hazard rate (unconditional) as:

$$R_{\Lambda_i} = \frac{\Lambda(x_i)}{\Lambda_o} \tag{2-8}$$

where

R_{Λ_i} = relative unconditional hazard rate due to the ith observable variable

$\Lambda(x_i)$ = unconditional hazard rate due to the ith observable variable

Λ_o = unconditional hazard rate due to all possible causes

Both hazard rates in equation 2-8 are based on the same population at risk. Thus,

$$R_{\Lambda_i} = \frac{\dot{N}_c(x_i)}{\dot{N}_{c_o}} \tag{2-9}$$

where

$\dot{N}_c(x_i)$ = number of persons from population at risk experiencing crash events caused by x_i per unit time

$\dot{N}_{c_o}(x_i)$ = number of persons from population at risk experiencing crash events due to all possible causes per unit time

Note that

$$\sum_i \Lambda(x_i) > \Lambda_o \text{ and} \tag{2-10}$$

$$\sum_i \dot{N}_c(x_i) > \dot{N}_{c_o} \tag{2-11}$$

since there is in general more than one cause per crash event.

Clinical assessments of samples of accident populations can also be used to estimate absolute values of unconditional hazard rates of specified populations thought to be at risk of losses growing out of given driving actions. Thus,

$$\Lambda(x_i) = \left(\frac{1}{N_P}\right)\left(\frac{\mathring{N}_{c_o}}{\mathring{n}_{c_o}}\right)\left(\mathring{n}_c(x_i)\right) \qquad (2\text{-}12)$$

where

N_P = number of persons in the population at risk

$\dot{N}_{c_o}$ = number of crash events per year due to all causes that could occur among the population at risk

$\mathring{n}_{c_o}$ = number of crash events per year due to all causes that could occur among a representative sample of crash events involving the population at risk

$\mathring{n}_c(x_i)$ = number of crash events per year due to x_i that could occur among a representative sample of crash events involving the population at risk

The clinical approach can yield erroneous assessments of causes and hazard rates. First, it relies on the intuition and judgment of the investigators, in much the same way that a physician's diagnosis of a patient depends on his or her experience and reasoning as well as on the evidence (symptoms) available. Some judgments may be straightforward and reliable. Others may be vague and uncertain. Some causal chains may go unrecognized if the mechanisms they represent are not known to the investigators.

The second weakness of the approach is that it examines only accidents, and consequently may identify a behavior as a cause that often leads to accident avoidance. If a behavior is involved in the occurrence of some accidents, but also suppresses or results in the avoidance of other accidents, its overall effect on the rate or severity of accidents may be nonexistent or even beneficial. Surpressing such a behavior could be nonproductive or even detrimental.

The statistical approach can be used to provide additional information to support or refute the judgments made in the clinical approach. The statistical approach uses a conditional hazard rate based on crash involvement rather than crash causation. This hazard rate is defined as:

$$\lambda'(x_i) = \frac{\dot{N}'_c(x_i)}{N_p(x_i)} \qquad (2.13)$$

where

$\dot{N}'_c(x_i)$ = number of persons who experience crash events after having been exposed to the ith observable driving action, per unit time

$n_p(x_i)$ = number of persons who are exposed to the ith observable driving action

The procedure used is to compare λ' at some given value of x_i to λ' at some reference value of x_i. If all other covariables of risk are controlled for, then the change in λ_i can be considered to be caused by the change in x_i. For example, if we have two groups of drivers that are exactly alike in every respect (including their vehicles and their driving environment) except the speed at which they drive, then any difference in the hazard rates of the two groups can be attributed to speed.

The problem in using the statistical approach alone for determining causes of traffic crashes is that all other covariables of risk **cannot** be controlled for in any real-world experiment. There will always be some chance that some other variable caused the observed change in hazard rate. The better the experiment, the more confidence one has in the results. Carefully designed, controlled experiments have provided useful information for assessing the role of alcohol and other factors in causing traffic crashes (Borkenstein et al. 1964; Perrine, Waller, and Harris 1971). Such experiments could also be useful in defining other UDAs.

In sum, both the clinical and the statistical approaches have shortcomings. The most confidence about the role of a factor in causing crashes can be gained by applying both approaches.

SPECIFIC DEFINITIONS

In this subsection, the concepts and terminology outlined above are used to develop preliminary definitions of three specific UDAs: speeding, following too closely (FTC), and driving left of center (DLOC). The definitions are preliminary because they are drawn from information contained in the highway safety literature. At this stage in the definitional process, such information is restricted to that which has already been placed in a form that is directly related to risk or hazard rate. The search and analysis of existing data bases (for example, the multidisciplinary accident investigation files) is specifically excluded.

Another reason that the definitions are preliminary is that they deal with broadly stated driver actions. In general, risk is a complex function of many observable and nonobservable variables. The analysis here aggregates these variables into a single observable variable for each driving action. The value of that variable that results in "maximum acceptable risk" defines the UDA. The analysis of Chapters Four, Five, and Six will provide additional information for sharper definitions of the UDAs.

Speeding

Both conditional and unconditional risk have been studied as a function of vehicle speed. Many of these studies have been discussed in past reviews (see, for example, Cleveland 1970; Joscelyn, Jones, and Elston 1970) and will not be reviewed in detail again here.

The most significant finding of these studies that address **conditional** risk was stated succinctly by Solomon:

> . . . The greater the differential in speed of a driver and his vehicle from the average speed of all traffic, the greater the chance of that driver being involved in an accident. (1964, preface.)

Solomon's own study was the most comprehensive of all the speed and accident studies. It was conducted in the late 1950s and involved 600 miles of main rural highways at thirty-five sites in eleven states. His measure of risk was number of crash involvements per 100 million miles of travel at a given speed and is thus a form of the conditional hazard rate used in the statistical approach to determining causation.

Solomon's study did not use a clinical approach for determining causation; thus, all of the crashes that were counted were not necessarily caused by speed. The speeds of the accident-involved vehicles were determined by examining police accident reports, and the speeds of the nonaccident-involved vehicles were determined from spot-speed measurements on sections of road where the accidents occurred.

Figure 2-3 summarizes Solomon's findings on involvement rate as a function of a vehicle's speed deviation from the mean speed of all vehicles observed in the study. As Solomon (1964) observed,

> The lowest involvement rate occurred at the average speed or slightly above it. As speeds departed from the average speed in either direction, the involvement rate increased in a nearly symmetrical fashion. (p. 17.)

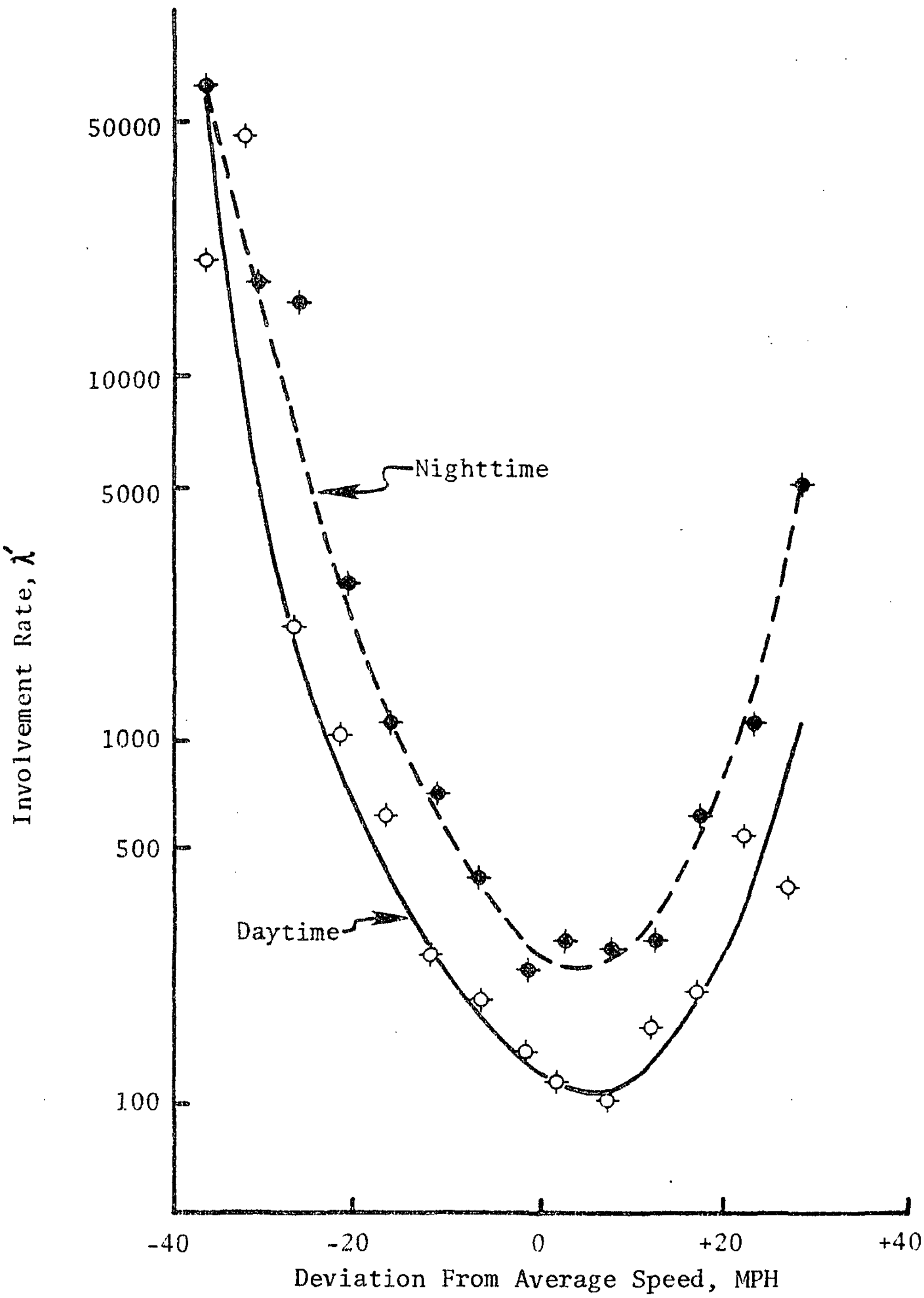
The increases in involvement rate became very large at large deviations from the mean speed. For example, the involvement rate in the daytime at 37 mph below the mean speed was about 500 times the rate that occurred at the mean speed. Combining the daytime and nighttime data yields similar but slightly smaller increases in involvement rate at given deviations from the mean speed (Figure 2-4).

Note that involvement rate curves are U-shaped and appear to be nearly symmetrical about a point displaced some +5 to +10 mph from the average speed of traffic. The reason for this displacement is not known, but it indicates that a given negative deviation from the average speed was considerably more "dangerous" than an equal positive deviation.

Figure 2-4 also shows that 95th percentile speed deviation occurred when involvement rate was a minimum, indicating that nearly all drivers were keeping their speed below that which would result in an absolute minimal crash risk. In fact, many drivers were driving too slowly and as a result were exposed to a higher crash risk. The data suggest that more drivers were willing to tolerate the risk associated with a given negative speed deviation than a lesser risk associated with the same positive speed deviation. Fifty percent of all drivers drove at a speed that resulted in

FIGURE 2-3

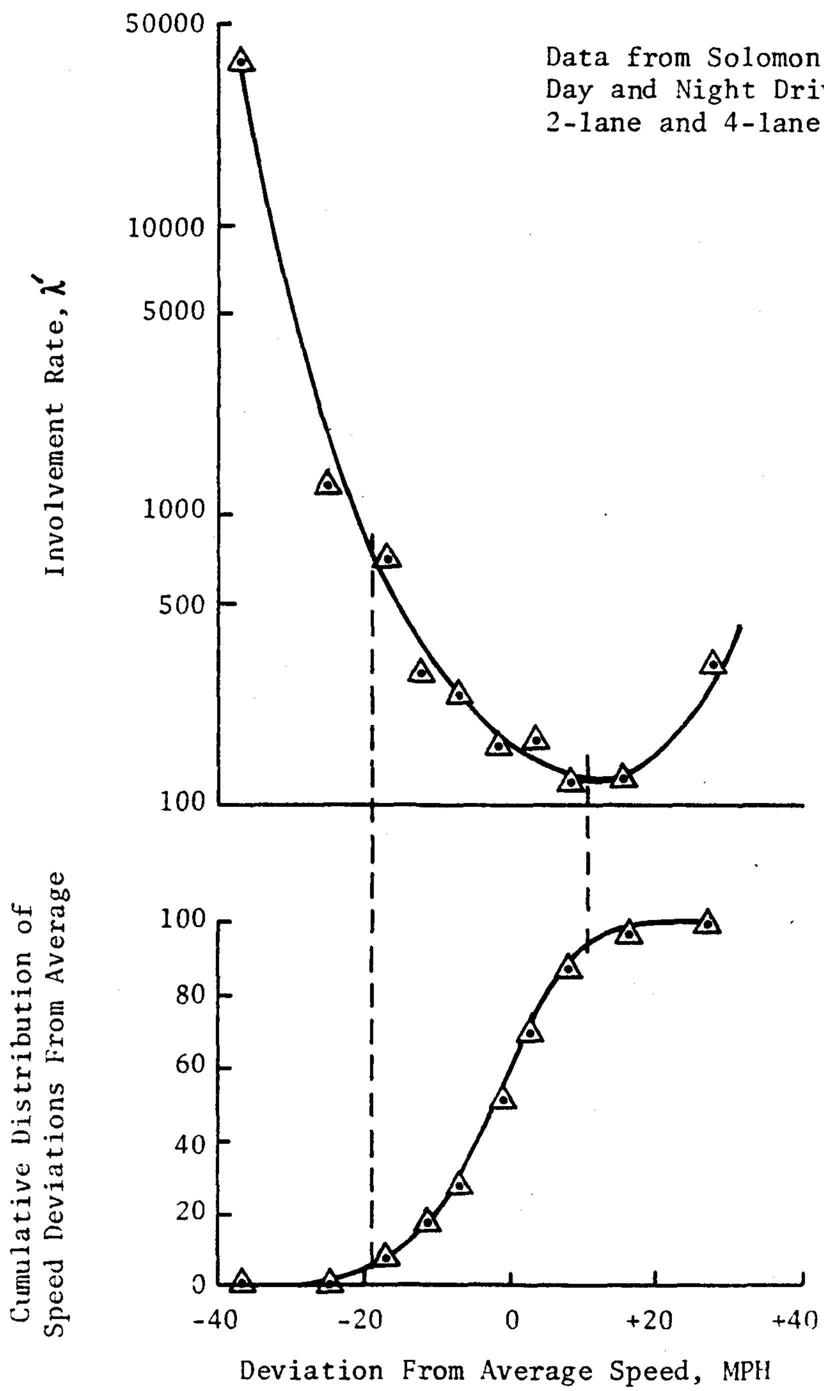
INVOLVEMENT RATE VERSUS DEVIATION
FROM AVERAGE SPEED, DAY AND NIGHT



Source: Solomon 1964

FIGURE 2-4

INVOLVEMENT RATE AND CUMULATIVE DISTRIBUTION OF SPEED FROM AVERAGE SPEED VS. DEVIATION FROM AVERAGE SPEED, DAY AND NIGHT DATA COMBINED



a crash risk of at least forty-six percent higher than minimum. Five percent of all drivers drove so **slowly** as to have a crash risk of at least 5.7 times the minimum risk. By contrast, only a negligably low number of drivers drove fast enough to have such a high risk.

The involvement rates in Figures 2-3 and 2-4 were for crashes of all kinds. When crashes of different severity are examined separately, a different picture emerges. Figure 2-5 indicates that as the crashes become more severe, the U-shaped curves start shifting to the left, until for fatal crashes, the point of symmetry is very close to, or possibly even to the left, of the average speed of traffic. For fatal crashes, the risk at the 5th percentile is equal to the risk at the 95th percentile, in both cases about twice the minimum risk of a fatal involvement. Thus, the vast majority of Solomon's drivers made a more correct assessment of the comparative risk associated with slow and fast driving and drove accordingly.

The fact that risk (or hazard rate) of involvement in a fatal incident begins to increase so drastically at the 5th and 95th percentile speed provides support for speed being a causal factor in serious crashes that occur outside those two regions. If a speeding UDA were defined at speed deviations of less than those of the 5th percentile drivers and more than those of the 95th percentile drivers, then about thirty-two percent of all of Solomon's fatalities would have involved such a UDA (see Figure 2-6). Figure 2-6 also shows that about 33% of all involvements and 38% of all injuries occurred at speeds outside the boundaries imposed by 5th and 95th percentile speeds.

It is also of interest to consider the conditional hazard rates associated with driving greater than the 95th percentile speed and less than the 5th percentile speed. These rates can be computed from the cumulative distributions of crash events from Figure 2-6 and the cumulative distribution of vehicle miles traveled from Figure 2-7. Performing the calculations using Solomon's data yields the results shown in Table 2-1 for involvements and fatalities.

The table shows that it was about eighteen times more risky (in terms of involvement) to drive slower than the 5th percentile speed than to

FIGURE 2-5

CONDITIONAL HAZARD RATES VERSUS SPEED DEVIATION FROM AVERAGE SPEED

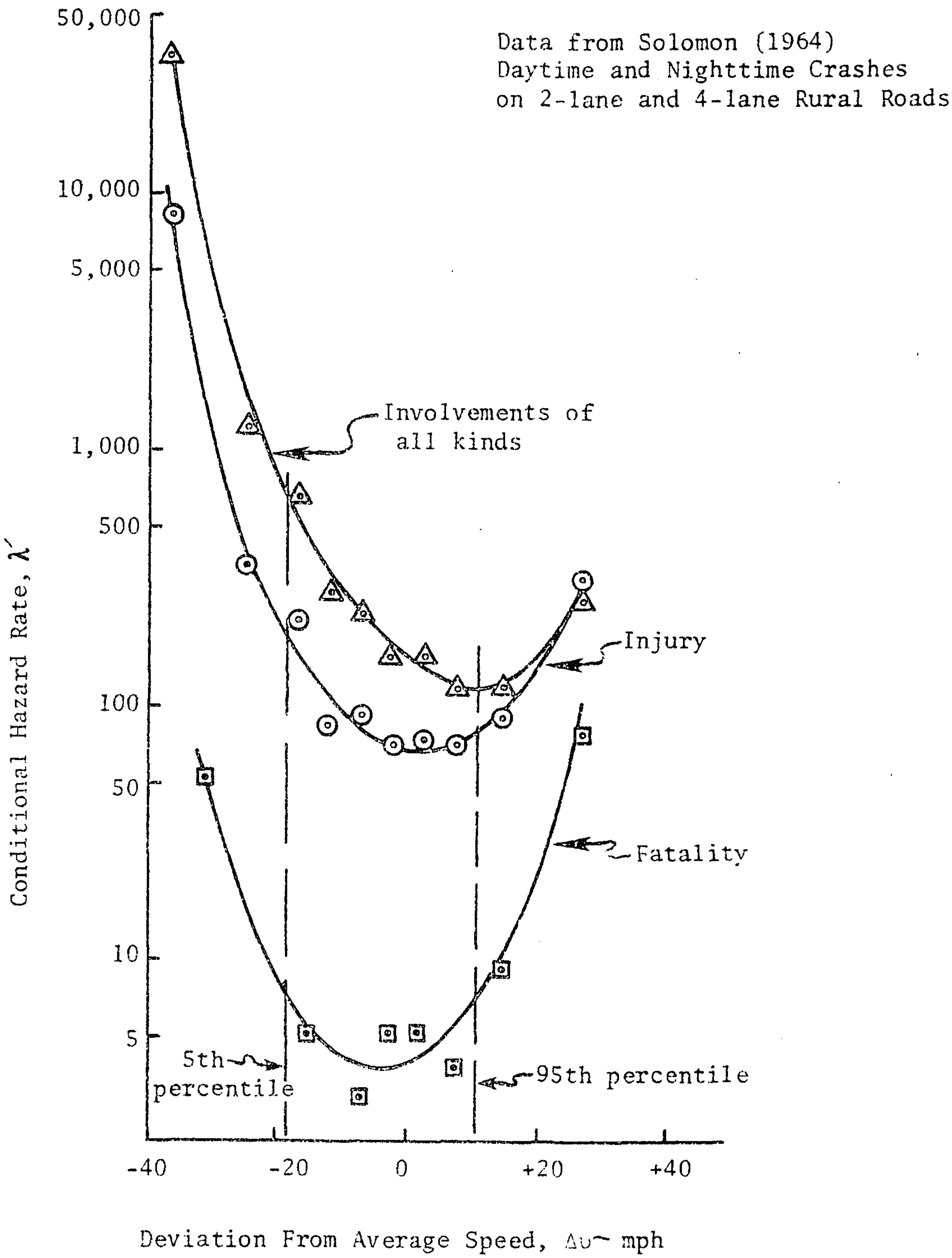


FIGURE 2-6

CUMULATIVE PERCENTAGE OF FATALITIES, INJURIES, OR INVOLVEMENTS VERSUS DEVIATION FROM AVERAGE SPEED

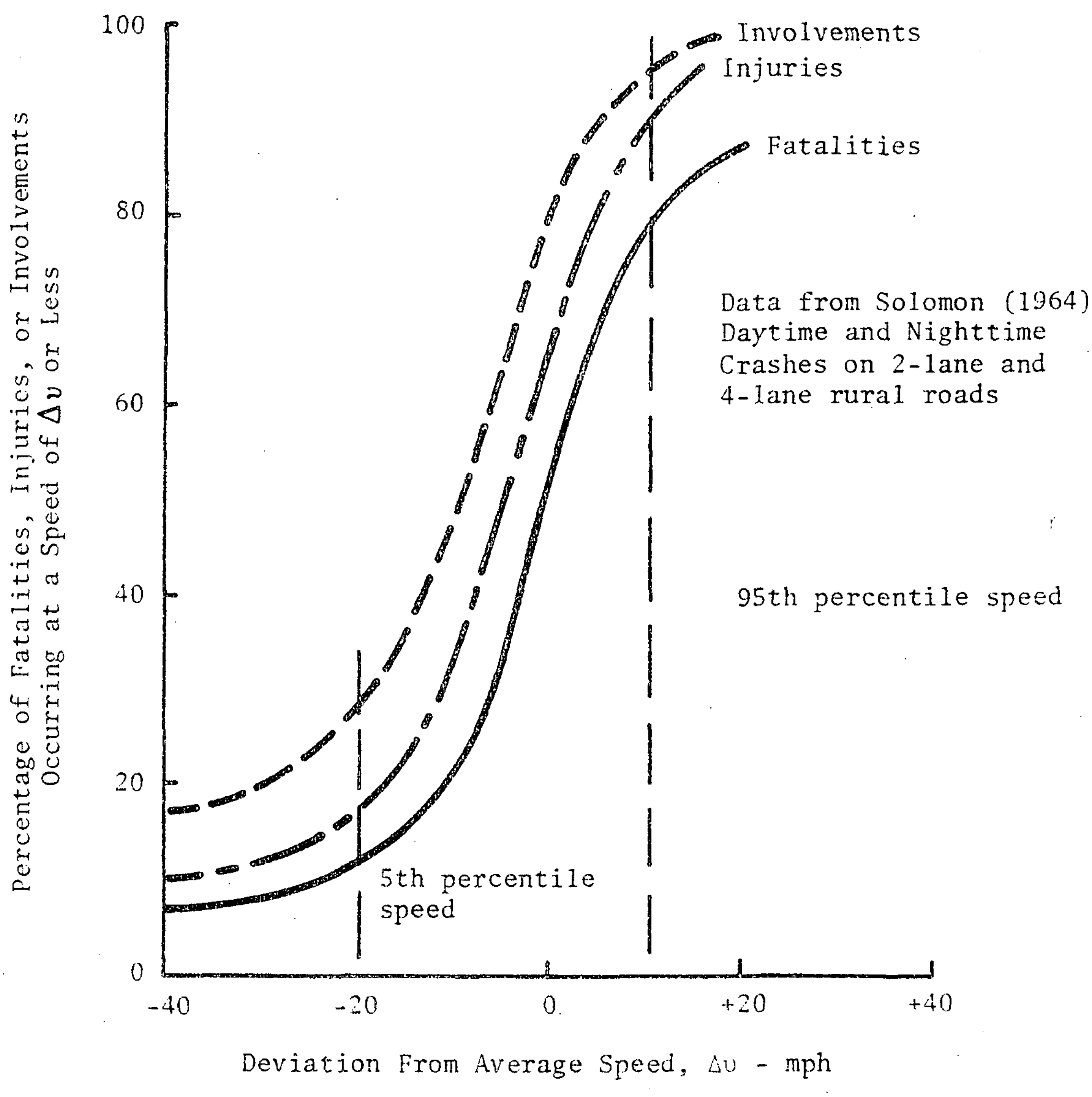


FIGURE 2-7

CUMULATIVE PERCENTAGE OF VEHICLE MILES TRAVELED VS. DEVIATION FROM AVERAGE SPEED

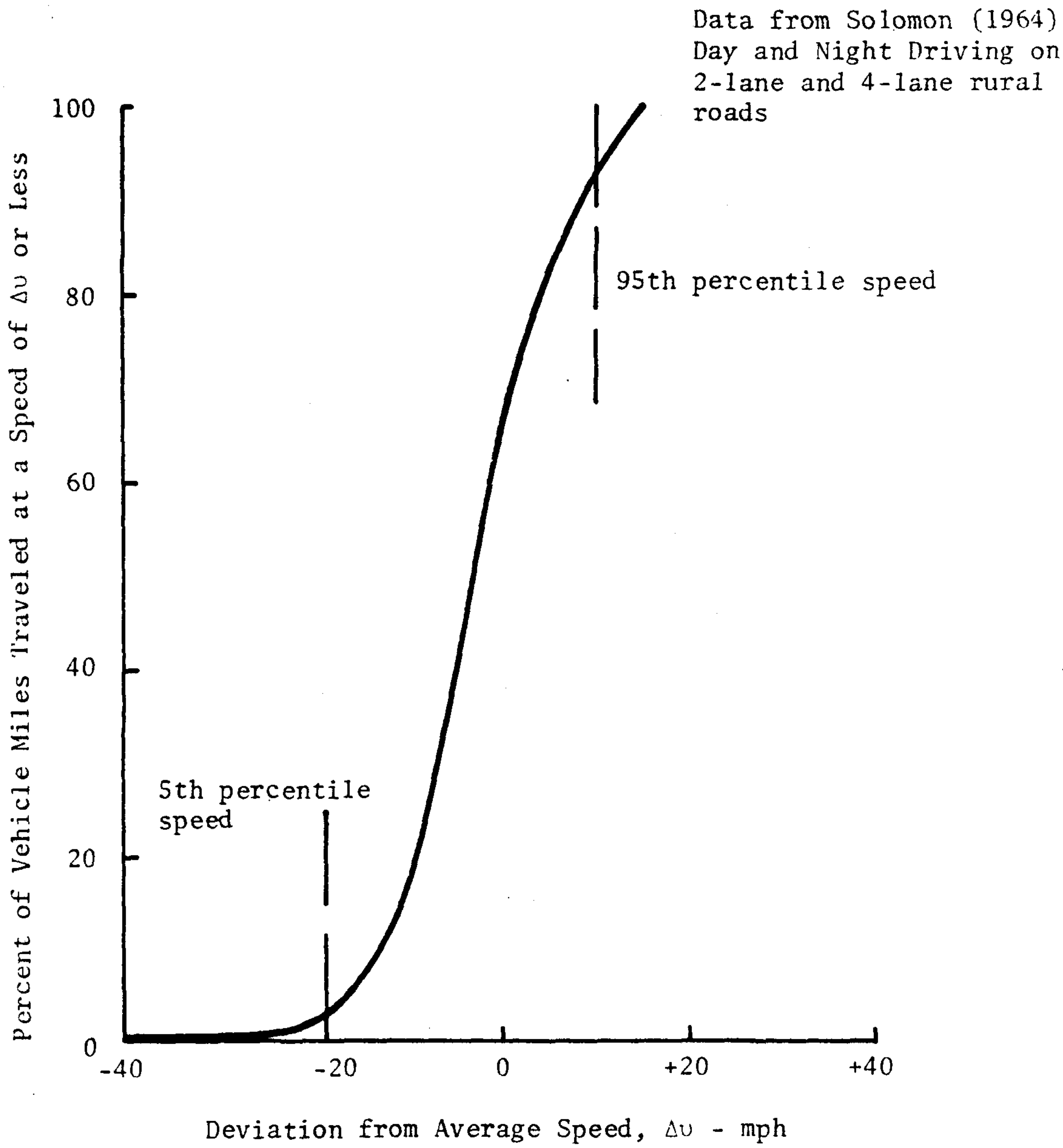


TABLE 2-1

CONDITIONAL HAZARD RATES
FOR INVOLVEMENTS AND FATALITIES WHEN
DRIVING AT SPEEDS GREATER THAN OR LESS THAN GIVEN SPEEDS

Type of Crash Event	Conditional Hazard Rate, λ'		
	$\geq$ 95th Percentile Speed	$\leq$ 5th Percentile Speed	< 95th Percentile Speed
Involvements	165	2915	254
Fatalities	17.9	32.2	5.8

Notes: 1. Data from Solomon 1964, Day and Night Driving on 2-lane and 4-lane Rural Roads.

2. Hazard rates are number of indicated crash events per 100 million miles driven at indicated speeds.

drive faster than the 95th percentile speed. More surprising, it was about 1.5 times more risky from an involvement standpoint to drive slower than the 95th percentile speed than to drive faster than the 95th percentile. Clearly, this is because of the very high involvement risk associated with slow-speed driving. By contrast, the conditional hazard rate of a fatality at speeds less than the 5th percentile speed was less than twice that at speeds greater than the 95th percentile speed. Also, the conditional hazard rate of a fatality at speeds greater than the 95th percentile speed is about three times the rate at speeds less than the 95th percentile speed. Thus, Solomon's data suggest that, from a fatality standpoint, it is much safer to drive below the 95th percentile speed than above that speed.

A more recent study by the Research Triangle Institute (1970) confirmed the general trends observed by Solomon. This later study did not show the same rightward shift of the U-shaped curve as Solomon found. Also, the RTI study did not present speed distribution data, so the risk associated with 5th and 95th percentile speeds cannot be determined. Figure 2-8 compares the Solomon data with the RTI data.

Treat et al. (1977) estimated the role of "excessive speed" in all types of crashes. A clinical approach was used, and each assessment was accompanied by a statement of its degree of certainty, that is the extent to which the assessment team believed that a given factor was a causal factor. The data used in the assessments were taken from reports prepared by teams of accident investigators. The reports were at two levels of detail, level B and level C. The level B data were from on-site investigations of accidents by technicians immediately after their occurrence. Level C data were from independent, in-depth investigations of a subset of the Level B accidents by highly trained professionals. The data collection occurred in Monroe County, Indiana, during late 1971 through early 1975. There were 2,258 level B reports and 420 level C reports generated (Treat et al. 1977).

The results of the study's findings on excessive speed are summarized in Table 2-2. About seven to sixteen percent of the level B accidents were classified as involving excessive speed as a causal factor. A slightly

FIGURE 2-8

COMPARISON OF RELATIVE RISK OF CRASH INVOLVEMENT CALCULATED IN STUDIES BY SOLOMON AND THE RESEARCH TRIANGLE INSTITUTE

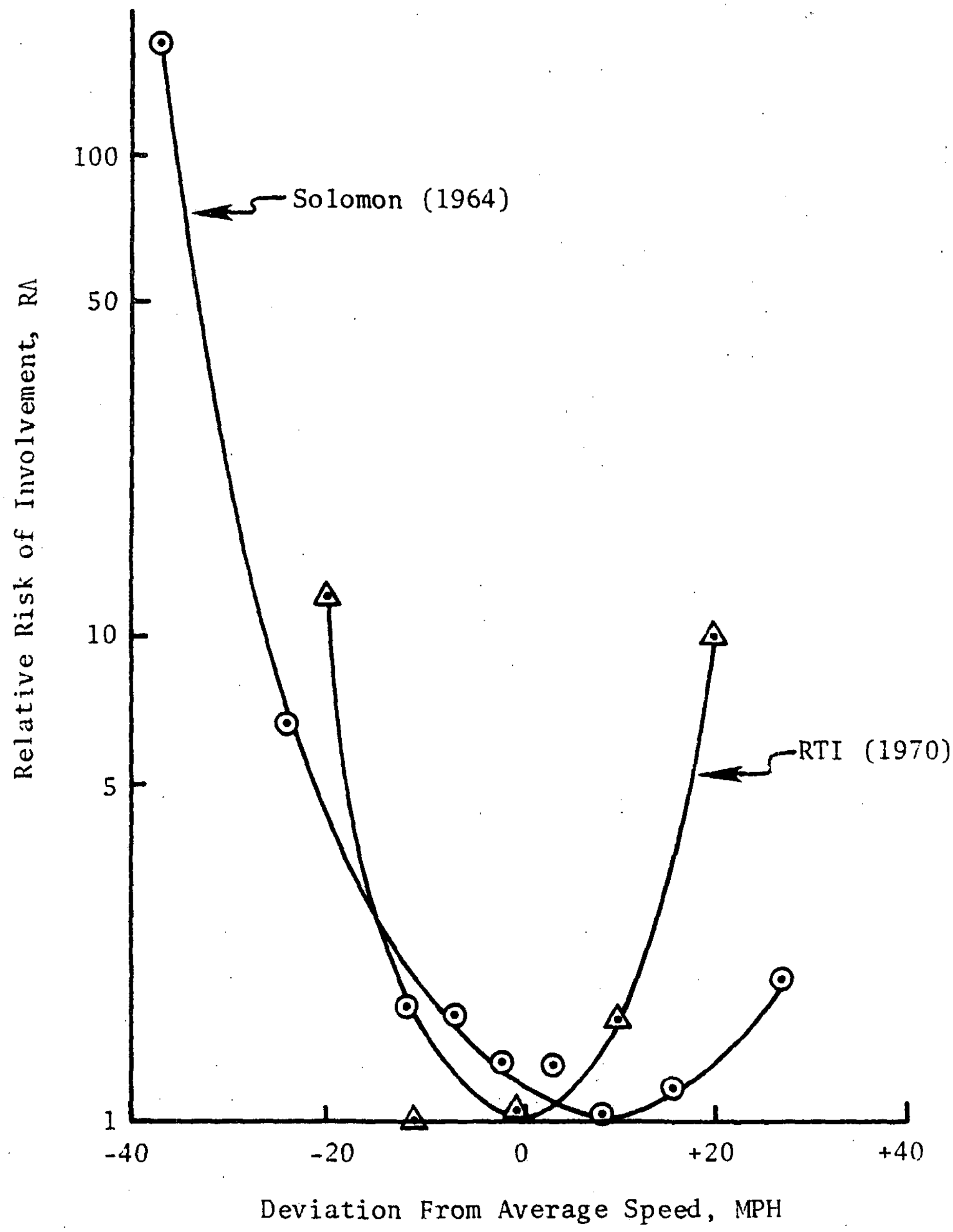


TABLE 2-2

THE ROLE OF "EXCESSIVE SPEED"
AS A CAUSAL FACTOR IN CRASHES

DEGREE OF CERTAINTY	LEVEL OF STUDY	%ACCIDENTS WITH EXCESSIVE SPEED AS A CAUSE
CERTAIN	C	7.9
	B	7.1
CERTAIN OR PROBABLE	C	16.0
	B	13.8
CERTAIN OR PROBABLE OR POSSIBLE	C	19.0
	B	16.4

Source: Treat et al. 1977, p. A-18.

higher percentage of the level C accidents (8 to 19%) were said to have been caused (at least in part) by excessive speed.

The term "excessive speed" was defined in qualitative rather than quantitative terms in the study. Specifically, the report defined excessive speed as:

> . . . one greater than a person driving to a high, but reasonable standard of good defensive driving practice, would choose to travel under existing conditions. (p 207.)

The report noted that:

> . . . prevailing speed limits are to be considered, but primarily in the context of determining the reasonable expectations of other drivers as to the speed of traffic likely to be encountered.
>
> Excessive speed in this context may be excessive for the road design, regardless of condition or prevailing traffic conditions; in light of traffic, pedestrian, or number of accesses; in light of weather conditions; or in light of a combination of these factors. (p. 207.)

This definition is not incompatible with a definition that would establish a maximum "safe" speed at the 95th percentile speed of all traffic. In Solomon's study (see Figure 2-6), such a limit resulted in about five to twenty percent of involvements, injuries, or fatalities occurring at "excessive speeds." This range is in the same "ball park" as the percentage range of crashes of all types attributed to excessive speed by Treat et al. (i.e., 7 to 19%).

Lohman et al. (1976) developed data related to both the conditional and unconditional risk of a type of speed-related driving action in a three-county region of North Carolina. By studying a sample of police reports of accidents in those counties, the researchers estimated that speeding above the speed limit was a cause of four percent of accidents of all types and that speed too fast for the weather conditions or location (below the speed limit) was a cause of another four percent. Combining the two figures yields a total of eight percent of crashes of all types having this type of a speeding UDA as a cause. This is almost exactly the same percentage of crashes found by Treat et al. (1977) to "certainly" have been caused by "excessive speed." It is also close to the approximately five percent of all crashes in the Solomon study that involved drivers who were exceeding the 95th percentile speed of traffic. The North Carolina study also found speeding to be a cause of twenty-eight percent of all fatal crashes in the three-county area, a slightly higher percentage than for Solomon's fatalities involving drivers who were exceeding the 95th percentile speed.

In analyzing the relative conditional risk of speed-related driving actions, the North Carolina researchers collected data on the number of vehicles in the traffic stream that were traveling at various speeds. In this case the driving action was defined as **speeding above the speed limit** only. The number of vehicles that were speeding too fast for the weather conditions or location (below the speed limit) were **not** tallied. "Point" data were taken at forty-one randomly selected accident sites in the three counties. In addition, a sample of vehicles in the traffic stream were followed by observers to determine whether the speed limit was being exceeded.

Combining these exposure data with companion data on accidents in the three-county area yields an interesting result: the conditional risk associated with **not** exceeding the speed limit was about 2.6 times the conditional risk associated with exceeding the speed limit. Lohman et al. (1976) noted that a sampling error may have been "partially responsible for the very low relative risk associated with speeding" (p. 55). The sampling error could have occurred because driver behavior was not observed 24-hours a day, 7 days a week at all sites, and an "adjustment factor" was used to aggregate data from the different sites.

However, Solomon's data also show that the risk associated with driving below a similar speed limit (95th percentile) was greater than the risk of driving above that limit, although by a factor of only 1.5 rather than 2.6. Thus, the North Carolina finding about the risk due to exceeding the speed limit is in general consistent with Solomon's data, but the magnitude of the effect observed by the North Carolina researchers appears high in comparison with that computed from the Solomon's data.

Of the possible definitions of a speeding UDA discussed above, only the definition based on deviations from traffic speed is clearly risk-related and can be quantified by direct observation. Further, such speed deviations could also be estimated for accident-involved vehicles if the roadway were instrumented properly (see, for example, Research Triangle Institute 1970). We, therefore, adopt this approach here for developing a preliminary definition of a risk-related speeding UDA. Because of the dependence of hazard rate on the speed of a vehicle **relative** to that of other vehicles, we define this UDA as a relative-speed UDA, viz.:

> A relative-speed UDA is the act of driving a vehicle at a speed that is so different from the speeds of vehicles around it that the risk of a crash exceeds that which is societally acceptable.

A societally acceptable risk is defined as that associated with the speeds of the 5th through the 95th percentiles of vehicles in the traffic stream. Thus, a relative-speed UDA occurs when the speed of the subject vehicle is greater than a speed not being exceeded by 95% of vehicles in the traffic stream. A relative-speed UDA also occurs when the speed of the subject vehicle is greater than zero but less than a speed not being exceeded by 5% of vehicles in the traffic stream. It appears that a reasonable first estimate of the percentage of crashes of all types caused by the relative-speed UDA would be of the order of 30%. The unconditional hazard rate associated with this type of UDA is about 2,400 crashes per year per 100,000 population.

An **absolute-speed** UDA can also be defined, but in terms of law rather than relative risk. A formal definition of this type of UDA is:

> An absolute-speed UDA is the act of driving a vehicle at a speed in excess of a maximum legal limit, or in a normal driving environment, at a speed below a minimum limit.

Speed in this case is measured relative to the roadway. The limit is assumed to have been **properly established** by a legally recognized authority. A "normal" driving environment is that associated with roadway usage under baseline or design conditions, for example, dry pavement, no construction, "average traffic density," etc.

Following Too Closely

We define the following too closely (FTC) UDA in the usual context of car following (see Figure 2-9). Both vehicles of a car-following pair are assumed to be traveling at about the same speed in the same lane of traffic. The observable risk variable is the time separation between the two vehicles. An FTC UDA would occur at a time separation that created an unacceptably high hazard rate.

Both predictive models and epidemiological methods have been used in past studies of the risk associated with car following. The paper by Harris (1964) typifies the former approach. Harris used a simple physical model to determine the conditional probability of a rear-end crash in a vehicle-following situation, given that the lead vehicle stops as quickly as possible. Theoretically Harris's model could be used to calculate the conditional hazard rates associated with such a crash. The following expression would be used in the calculation:

$$\lambda = \lambda_s \, p_{c|s} \qquad (2\text{-}14)$$

where

λ = conditional hazard rate of a rear-end crash in a car-following situation

λ_s = number of maximum deceleration stops per unit time per lead vehicle of a car-following pair

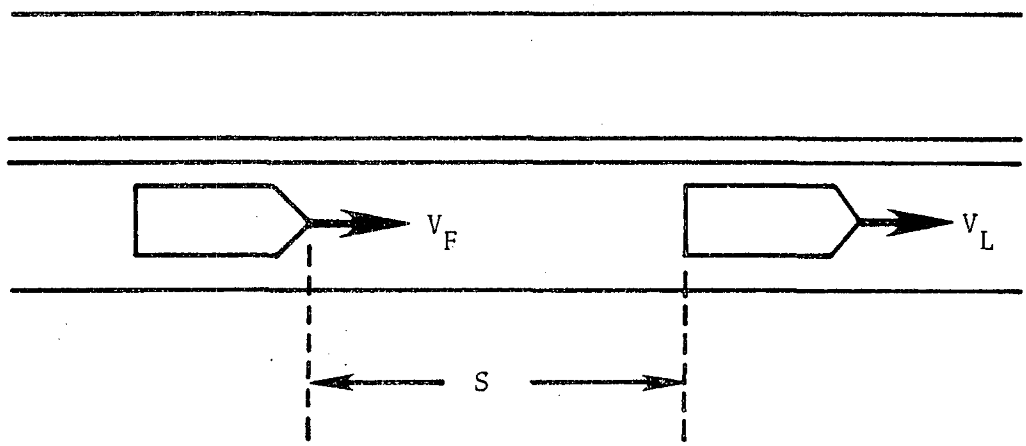
$p_{c|s}$ = probability of a rear-end crash, given a maximum deceleration stop by a lead vehicle of a car-following pair

Harris's model calculates $p_{c|s}$ as a function of:

- the speed of the two vehicles,
- the reaction time of the following driver,

FIGURE 2-9

CAR FOLLOWING RELATIONSHIPS



$V_F = V_L$

$$\text{Time Separation} = \tau = \frac{S}{V_L} = \frac{S}{V_F}$$

- the spacing between the two vehicles,
- the braking capability of the two vehicles, and
- the distribution of braking capability in the vehicle population.

Following too closely (FTC) crash risk is determined by Harris as being too great whenever $p_{c|s}$ (called the "probability of collision danger") exceeds some given value. His model thus ignores the frequency of the precipitating event, a maximum deceleration stop by a lead vehicle. It is nevertheless useful for estimating the upper bound to safe following distance. Clearly, such an upper bound would occur when $p_{c|s} = 0$; that is when the combination of vehicle speed, braking capability, reaction time, and spacing was such as to eliminate any possibility of a rear-end crash.

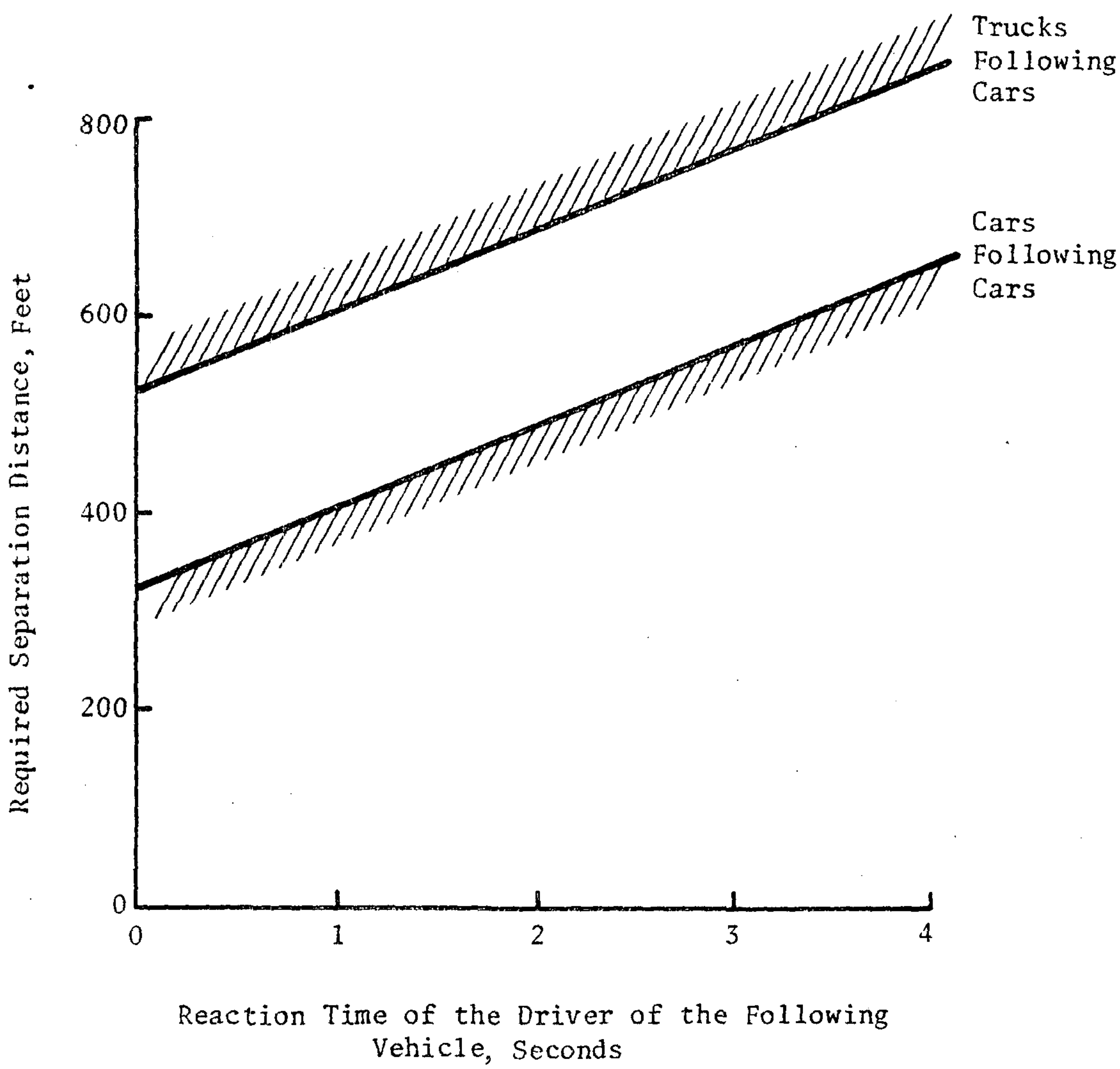
Figure 2-10 shows what the spacing between two vehicles would have to be for a zero crash probability at a speed of 55 mph. The curves are based on Harris's data for cars and trucks in England circa 1956. The top curve is for trucks following cars, and the bottom curve is for cars following cars.

For a reaction time of one second, the required separation distance would be somewhere between 400 and 600 feet. This amounts to about four to five 20-foot lengths for each 10 mph of speed. Traditionally, highway safety organizations have advised drivers to maintain a separation of only one 20-foot length per 10 mph of speed (American Automobile Association 1957). Such a separation would be associated with a $p_{c|s}$ of about .43 for cars following cars and about .83 for trucks following cars. The fact that such large values of **conditional** crash probability have, in effect, been recommended indicates that safety organizations have perceived sudden stops by leading vehicles in following situations to be very rare on U.S. highways.

Harris's model has several built-in features and assumptions that should be noted. First, the model assumes that both the lead vehicle and the following vehicle are traveling at the same speed. Second, it makes no

FIGURE 2-10

REQUIRED SEPARATION DISTANCE FOR ZERO RISK OF A REAR-END CRASH AT 55 MPH
British Data From Harris (1964)



explicit allowance for the effects of environmental factors (e.g, road surface) on stopping performance. Third, the model treats the reaction time of the following driver as a parameter rather than a distribution. Fourth, the model does not incorporate impact speed as a variable, assuming that a crash occurs whenever the impact speed is greater than zero. Fifth, the model is a special case of car following, since it deals only with pairs of vehicles. The more general case is treated in the literature on traffic flow theory, but the mathematics are more cumbersome (see, for example, Gerlough and Huber [1975]). Finally, only rear-end crashes are treated in the model; other types of crashes caused, for example, by trying to steer around a stopping vehicle are not considered.

Many of these limitations were pointed out by Harris in his paper and could be taken into account in a revised model. However, such a "complete" FTC model has not been described in the available literature. For the present, we must regard the Harris model as, at best, a first approximation to FTC crash risk.

The Indiana study of crash causation reported by Treat et al. (1977) used a definition of FTC that was close to that implied by the Harris model, viz.:

> . . . when a vehicle follows another vehicle so closely that, even if [the driver] is attentive to the actions of the vehicle being followed (to the extent which can ordinarily be expected from a driver over an extended period of time), should the vehicle engage in maximum braking, collision could not be avoided. (p. 207.)

The study did not attempt to specify quantitatively the separation between vehicles that would be considered too short to avoid a collision, but did subjectively estimate the number of crashes in which close following was believed to be a cause. It estimated that from 0.2 to 2.0% of all crashes investigated by indepth and/or on-site teams were caused by FTC. Applying these figures to national data (National Safety Council 1978) would lead to an unconditional hazard rate of from 16 to 160 crashes per year per 100,000 population.

The North Carolina study by Lohman et al. (1976) also considered the risk due to FTC. It found that 17.9% of all crashes studied involved FTC as a causal factor, but that only 1.5% of vehicles at selected accident locations were committing this FTC UDA. The latter figure was based on a time separation between vehicles of .7 seconds or less. The data indicate that the crash risk associated with FTC was about 14.7 times that associated with not FTC. The validity of this relative risk figure is not known, because of possible sampling errors in the exposure data (see discussion in Speeding).

It is not clear why the incidence of FTC found in the North Carolina study was at least ten times that found in the Indiana study. Possibly, the North Carolina researchers used a broader definition of FTC in their clinical analyses. The FTC description and example provided in Appendix A to their report suggest that this could be the case.

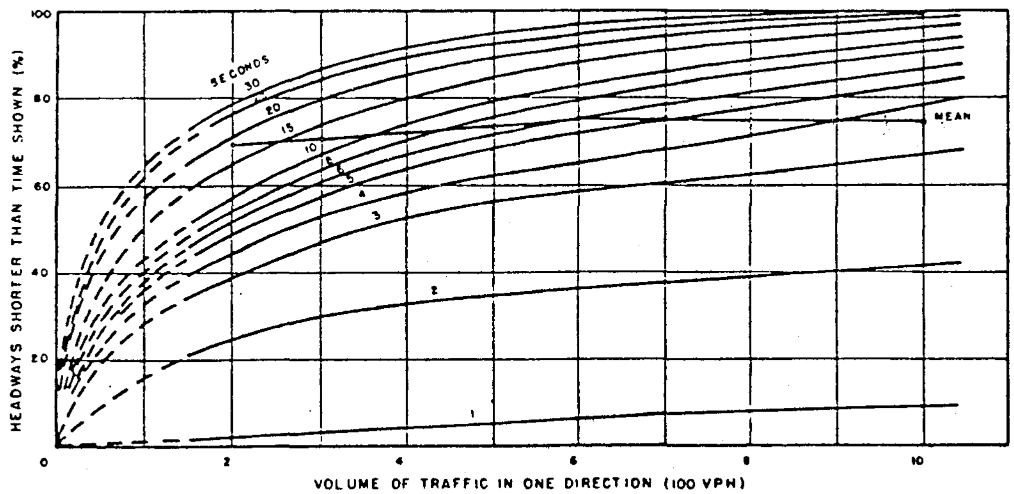
As noted previously in the section on maximum acceptable risk, a traffic flow approach could be used to determine when the spacing between two vehicles becomes too risky. Empirical studies of traffic flow would provide the data for such an analysis. Past studies have shown that the headway distribution is a function of traffic volume and type of road, among other things.

For example, data from the Highway Research Board (1965) show that 40% of the vehicles on selected rural, two-lane roads had headways of two seconds or less at a traffic volume of 900 vehicles per hour per lane (Figure 2-11). However, only 25% of the vehicles had such short headways at a traffic volume of 300 vehicles per hour. The data show that the shorter headways become increasingly rare as traffic volume decreases further. Similar trends are noted for four-lane rural highways, but headways tend to be slightly shorter at a given volume than those on two-lane roads.

If maximum tolerable risk were to be set at the 95th percentile level, it would be found that the corresponding "unsafe" headways would be very short, i.e., about a second or so at moderate traffic volumes and still shorter at higher volumes (Highway Research Board 1965). More recent data in this country (Tolle 1976) and abroad (Sumner and Baguley 1978)

FIGURE 2-11

FREQUENCY DISTRIBUTION OF HEADWAYS BETWEEN SUCCESSIVE VEHICLES TRAVELING IN THE SAME DIRECTION AT VARIOUS TRAFFIC VOLUMES ON TYPICAL TWO-LANE RURAL HIGHWAY



Source: Highway Research Board (1965)

indicate that 95th percentile headways are still in this same range.

The relatively common occurrence of short headways again suggests that a maximum deceleration stop by a leading vehicle is assigned a low probability by many following drivers. Otherwise, "safe" headways would be several times longer, as calculated by Harris.

Brake reaction time (BRT) of drivers could provide another means for defining an FTC UDA. Johansson and Rumar (1965) found that 95% of all subjects in a dynamic driving test had a BRT to an expected signal of 1.75 seconds or less. Other investigators have found lower BRTs at the 95th percentile level (Fink 1968). It would thus appear that a headway much less than 1.5 seconds would be "unsafe" for a significant percentage of drivers. Since the reaction time of a driver in a traffic stream could not accurately be determined by an outside observer, it would not be unreasonable to set the headway limit at the 95th percentile level BRT, i.e., about 1.5 seconds. However, the crash risk corresponding to such a headway is not known.

The lack of satisfactory data on hazard rates as a function of following distance makes it difficult to derive an operationally useful definition of FTC in terms of risk. The best that can be done at this juncture is to define FTC from a synthesis of information on intermediate variables that appear related to unsafe car following. We thus state our preliminary definition of FTC as follows:

> The FTC UDA is the act of driving a vehicle following another vehicle such that the time separation between the two vehicles is so short as to create a societally unacceptable level of crash risk.

"Following" is defined as driving about the same speed as a lead vehicle when both vehicles are in the same lane of traffic. "Time separation" is defined as the distance between the two vehicles divided by their speed. Time separation consists of two major components, a component due to the reaction time of the following driver and a component due to the difference in braking capacity between the two vehicles. It appears that time separations should be greater than one to two seconds to avoid an unacceptably high risk of an FTC-caused crash. The level of risk associated with this separation time cannot be reliably determined from the literature; however, data from Treat et al. (1977) suggest a range of absolute hazard rate of from 16 to 160 crashes per year per 100,000 population.

Driving Left of Center

The absolute risk variable for this driving action is less clear cut than for speed or car following. The North Carolina study (Lohman et al. 1976) used a definition that appears consistent with the intent of the work statement for this project, i.e.:

> . . . vehicles driving left of the center line or too near the center line to avoid an accident. Also considered were vehicles driving left of the center line in curves, e.g., cutting across the curve in a road.
>
> This category does not include drivers passing other vehicles. (p. A-2.)

This definition suggests a risk variable based on lateral lane placement of a vehicle that is neither passing nor turning. One possible such measure is the distance, d, from the center line of the road to the left-hand extremity of the vehicle traveling in a given lane. According to the North Carolina definition, a driving left of center (DLOC) UDA would occur when $d \leq 0$. If the criterion of maximum acceptable risk were used to define the DLOC UDA, the unconditional hazard rate function $\Lambda(d)$ could be plotted and the value of d corresponding to Λ_{max} would set the UDA.

Unfortunately, data needed to apply an approach based on risk do not exist at present. We have found no studies that would allow one to estimate $\Lambda(d)$. Data on the frequency distribution of d are also unavailable, so that it is not feasible to apply a traffic flow approach in estimating the value of d that is associated with Λ_{max}.

Lohman and associates have estimated that about 3% of their sample of North Carolina crashes involved DLOC as defined above as a causal factor. About 0.6% of all vehicles observed at high accident locations were said to be driving left of center. According to the data, DLOC was about 5.7 times as risky as not DLOC. The Indiana study did not have a specific DLOC category, but listed several subcauses that could be collapsed into such a category (see Table 2-3). The level B data are in close agreement with the North Carolina findings: approximately two to three percent of the crashes involved DLOC as a cause (Treat et al. 1977).

Our own experience with the Indiana files indicates that the categories listed in Table 2-3 may underestimate the number of crashes caused by DLOC. We found that many of the crashes that were caused by a vehicle that did not crash occurred because the "noncontact vehicle" committed the DLOC UDA. Approximately two to five percent of the level B crashes were caused by a noncontact vehicle problem. Thus, DLOC could have been a cause of four to eight percent of the Indiana level B crashes. Other unintentional UDAs classified in the Indiana files as "overcompensation" (e.g., vehicle skids across the road centerline) could increase this figure to as high as six to twelve percent.

Given the above descriptions and related data, the following preliminary definition will be adopted here for DLOC:

> The DLOC UDA is the act of driving a vehicle over or on the center line of a two-way, two-lane road when not passing or turning.

The unconditional hazard rate associated with this UDA appears to be of the order of 160 to 960 crashes per year per 100,000 population.

SUMMARY AND CONCLUSIONS

It is most meaningful to define a UDA in terms of the risk of a traffic crash event (e.g., crashes, fatalities). Risk, in turn, is best measured by hazard rate, defined as the number of crash events caused by a given driving action per year per unit of the exposed population.

Two kinds of hazard rate are useful in analyzing UDAs, unconditional and conditional hazard rate. The two rates differ only in respect to their exposed populations. The unconditional hazard rate is based on a population at risk that may or may not be performing a given driving action, for example, all persons residing in the United States. The

TABLE 2-3

ACCIDENT CAUSES RELATED TO DRIVING LEFT OF CENTER IN THE INDIANA TRI-LEVEL STUDY[1]

CAUSAL FACTOR	DEGREE OF CERTAINTY[2]					
	Certain		Certain or Probable		Certain, Probable or Possible	
	Level B	Level C	Level B	Level C	Level B	Level C
Drove in wrong lane, wrong direction	.7	.2	.7	.5	.7	.7
Cresting hill, driving in center of road	.5	.7	.6	1.4	.7	1.7
Driving too close to center line or edge	.1	0	.3	.7	.4	1.0
Inadequate directional control in curve or straightway, enter opposing lane of travel	.9	.9	1.4	1.6	1.5	2.9
TOTAL	2.2	1.8	3.0	4.2	3.3	6.3

1. Source: Treat et al. (1977), Appendix A, Phases II-V.
2. Numbers shown are percent of all accidents investigated at indicated level.

population at risk in a conditional hazard rate is made up of the individuals who are performing the subject driving action. The unconditional rate is most useful for analyzing the overall magnitude of the highway safety problem caused by a driving action, while the conditional rate is useful in designing and targeting countermeasures.

Hazard rates are, in general, functions of a large number of variables, some of which can be measured unobtrusively by observing the vehicles in a traffic stream. Other risk variables require more indirect measurement techniques. In this section, our preliminary definition of each UDA is stated in terms of a single observable risk variable. Other risk variables and their relationships to the three UDAs are discussed in Chapters Four, Five, and Six.

In a sense, any driving action could be defined as "unsafe," since there will always be some possibility that it could cause a crash event. Thus, total traffic safety could only be achieved by eliminating all traffic. Since we are concerned here with less drastic "countermeasures," a more restricted definition of "unsafe" is required. We define "unsafe" in terms of the maximum amount of risk (or hazard rate) that society will accept as a consequence of a given driving action. In our preliminary definition, a driving action becomes a UDA at the value of its observable risk variable that creates the maximum amount of risk that is societally acceptable.

Two general methods have been used in the literature to determine whether the given value of the risk variable actually creates (i.e., is a causal factor) the risk or is merely associated with it. In the **clinical approach,** trained analysts or teams of analysts examine individual crashes and form subjective judgments about the causative role of various factors. The **statistical approach** uses information about the relative incidence of a factor in crashes and noncrashes in determining causation. Both approaches are useful but have their shortcomings. A combined clinical-statistical approach will provide the most confidence about the role of a factor in causing crashes.

As might be expected, the available highway safety literature contains no evidence of a comprehensive application of the above principles in defining UDAs. A study by researchers from the University of North Carolina (Lohman et al. 1976) examined police accident reports and observed vehicles at accident locations in North Carolina to develop data that are relateable to unconditional and conditional hazard rate. However, hazard rates were not stated as continuous functions of specified risk variables, and the UDAs were not explicitly defined in terms of maximum acceptable risk. Other studies have developed useful information for analyzing various parts of the UDA problem (e.g., Solomon 1964; Treat et al. 1977), but have not attempted to define UDAs in a comprehensive or rigorous way.

Thus, it is necessary to piece together data from a variety of separate sources to arrive at a "first cut" definition of the three risk-related UDAs that are of interest here. (Policy-related speed UDAs are discussed in Chapter Four.) The results of this synthesis are summarized in Table 2-4. The reader is cautioned that the UDA frequencies and hazard rates are very rough estimates and are provided only to give an approximation of the magnitudes involved. Existing data reported in the literature do not permit accurate estimates of these variables to be made. Data on the frequency of the three UDAs among drivers who have not crashed are insufficient to estimate conditional hazard rates for FTC and DLOC.

Clearly, considerable work needs to be done before operationally useful definitions of the three UDAs can be specified. At this point, the definitional statements for FTC and DLOC must remain mostly qualitative and constitute no more than a point of departure toward more rigorous, quantitative definitions. The definition of the speeding UDA is more specific, and better information on its conditional risk is available. However, even the speeding UDA is insufficiently defined for determining the risk (both conditional and unconditional) of specific groups of drivers under specific driving conditions encountered on today's highways. Data on the conditional risk of the relative speed UDA are also needed.

As a first step toward developing better definitions of the three UDAs, accident files at HSRI were analyzed by the project staff. The results of this analysis are presented in the following chapters of this report.

TABLE 2-4

SUMMARY OF CHARACTERISTISTICS OF THREE UDAs DEFINED FROM INFORMATION IN THE HIGHWAY SAFETY LITERATURE

UDA	SUMMARY DESCRIPTION	OBSERVABLE RISK VARIABLE	ESTIMATED NO. OF UDA-CAUSED CRASHES AS A % OF ALL CRASHES	ESTIMATED HAZARD RATE	
				UNCONDITIONAL[1]	CONDITIONAL
RELATIVE SPEED	• Driving a vehicle at a speed so different from other vehicles as to create unacceptably high risk. • UDA occurs at speeds: ≥ 95th % speed and ≤ 5th % speed.	Speed deviation from average speed of traffic	30	2400	1800[2]
FOLLOWING TOO CLOSELY	• Driving a vehicle following another vehicle such that time separation between the vehicles creates unacceptably high risk. • UDA occurs at time separations ≤ 1 to 2 seconds	Time separation between following pair of vehicles	0.2-2.	16-160	Not Available
DRIVING LEFT OF CENTER	• Driving a vehicle over or on the center line of a two-way *two-lane road when not* passing or turning.	Lateral distance from road center line to left hand side of vehicle	2-3	160-960	Not Available

1 Crashes of all severities per year per 100,000 population.

2 Crashes of all severitities per 100 million miles of driving while performing the UDA. Data are for rural 2-lane and 4-lane roads (Solomon 1964).

CHAPTER THREE

PROCEDURES FOR DETAILED UDA ASSESSMENT

This section describes the procedures used in the more detailed assessments of the speed, FTC, and DLOC UDAs. These assessments and the sections describing them were organized around an examination of the following:

- frequency of UDA involvement as an accident cause,
- circumstances of UDA occurrence,
- driver awareness and reason for commission of UDA, and
- feasibility of UDA assessment.

Each assessment was made with reference to the preliminary definitions developed in Chapter Two. With respect to **frequency of occurrence**, interest focused not only on determining reported involvement in accidents, but also in verifying the causal role of such involvements. For this reason, a review of in-depth case reports was undertaken. Frequency of occurrence is used later in the report to estimate the unconditioned risk posed by the UDAs.

Finally, the **circumstances of UDA occurrence** were examined to characterize the driver, environment, and accident characteristics associated with involvement of each of the UDAs in accidents. This was accomplished through exercising various files at HSRI and examining relevant literature. As a result, possible correlates of the observable driving action variables were identified.

With respect to the **driver awareness** issues, knowledge of **why** drivers committed the UDA was believed important both in making an assessment of how amenable the behavior might be to countermeasures based on general risk-management strategies, and to better understand the circumstances under which it is likely to occur. Information on this issue is not provided by available computerized files and required a manual review of in-depth cases.

PRIMARY DATA AND INFORMATION SOURCES

The primary files and sources used, and their rationale for selection are as follows:

- **Collision Performance and Injury Report (CPIR) Files:** comprised of 9,222 vehicles from approximately 7,685 accidents. These crash reports are the result of in-depth investigations by multidisciplinary accident investigation teams sponsored by NHTSA, MVMA, and the Canadian Ministry of Transport. Motor vehicle crash data reported in the "Annotated Collision Performance and Injury Report, Revision Three," including various accident descriptors and data relevant to the precrash phase, have been edited and computerized by HSRI. Thus, both computer summary data and hard-copy case reports are available. Samples of the individual case reports involving the UDAs of interest were obtained and reviewed. This file was selected because it is the largest available file of hard-copy reports of in-depth investigations by professional, multidisciplinary teams. In addition, these cases have been summarized in a consistent format and automated, providing ease of access.

- **Texas Five Percent Sample for 1976:** consists of 40,712 vehicles from 23,257 accidents. This represents a 5% random sample of all reported accidents occurring in Texas during calendar year 1976. These data sets were constructed by HSRI from the Census data through a computer-generated random sampling technique. The file provides computer summary data, but no case reports are available. This is one of several large, mass-data files available at HSRI. It was selected because it is based on a large total sample and provides file descriptors that facilitate access to UDA cases.

- **Indiana In-depth Case File:** HSRI's archives contain 384 in-depth hard-copy case reports, drawn from both of its trilevel studies ("Vehicle Defects" and "Traffic Accident Causation"). Case reports involving the FTC and DLOC UDAs were sampled for review. The Indiana cases are an obvious choice for examination since they are unique in providing detailed examination of the precrash phase by a multidisciplinary team.

- **Tri-Level Study of the Causes of Traffic Accidents:**

Final Report (Treat et al. 1977): provides UDA frequency estimates and results of related analyses, based on 420 in-depth accidents investigations and 2,258 accidents investigated by technicians. This report is useful in tabulating the frequency and circumstances of involvement for various precrash factors similar to the UDAs, being examined. The report provides data from the large sample of technician-investigated (level 2) accidents, and adds other information beyond that available from review of the in-depth case reports alone.

The review of accidents reports used hard-copy case reports obtained from the CPIR and Indiana in-depth files located at HSRI. Information on circumstances of UDA occurrence was obtained primarily through exercise of the automated CPIR and Texas five percent (1976) files. Support data on frequency and circumstances of involvement were obtained from the Indiana Tri-Level Study final report and from other sources, as appropriate.

CASE REVIEW AND ASSESSMENT PROCEDURES

The "clinical assessment" of individual in-depth case reports (CPIR and Indiana Tri-Level) was undertaken to document the causal involvement of each UDA in a substantial number of accidents; to assess the reasons for commission of the UDAs (with particular emphasis on driver **consciousness** or awareness of UDA commission); and to assess the applicability of the preliminary UDA definitions to the accident population. Insight was also obtained as to the nature and circumstances of UDA involvement.

Cases involving all three UDAs were obtained from the CPIR file for review, but only cases involving FTC and DLOC were obtained from the Indiana file. Access to both files was judged necessary for the latter due to their relative infrequency and uncertainties as to their designation and coding within each file. Because of their great number and unambiguous coding in the CPIR file, access to additional speeding cases was not judged necessary.

For each file and each UDA, the initial step in the review process was to select variables and variable values that approximated the preliminary definition of the UDA. These variables were then used to filter out cases potentially involving the UDA. These case reports, or random samples of them, were then reviewed.

For example, in the CPIR file, variables 541 and 542 designate the "most responsible driver's primary errors." Value 09, "speeding, too fast for conditions," best approximates the speeding UDA definition. It is likely to obtain a high proportion of the cases that involve a "speed too fast" UDA, either in the sense of being over a limit or too fast for prevailing conditions. A total of 1,091 speeding accidents were identified in this manner. (Note, however, that there is no comparable code that adequately identifies cases involving a "too slow relative to traffic flow" UDA.)

Since remedial review of cases is a time-consuming process involving several professionals, it was necessary to reduce the number of cases to be reviewed. An additional consideration in determining the number of cases to be reviewed was the subjective nature in which judgments about causation were made. Thus, large sample sizes that would imply more precision than actually existed were not justified. In the end, the selection of sample sizes was judgmental, the objective being to select a number of cases that would provide a reasonable substantiation of a high, low, or moderate incidence of conscious behavior. In the case of "speeding" UDAs, forty-eight reports were randomly selected and reviewed. In similar fashion, additional cases were obtained and reviewed for the FTC and DLOC UDAs.

A human-factors-oriented review team was formed, consisting of two psychologists and one sociologist, to provide expertise in assessing the role of driver behaviors and the reasons or motivations for them. Each case was individually reviewed by each team member. The team members then met to discuss each case as a group and to reach a consensus on the issues considered.

A procedure was developed to guide the team in reviewing each case. This was believed particularly important since the cases reviewed were prepared by a number of different accident investigation teams, and varied in format and content. The main elements of the procedure involved recording specified descriptive information from each case; constructing an "events sequence" describing the precrash actions that led to the crash; and applying a "but for" test (i.e., a test of necessity) in validating the causal involvement of the UDA.

The information specified to be extracted from the individual reports included the following:

- **environmental descriptors:** weather conditions, road surface conditions, visibility, time, day, month, and type of roadway;
- **vehicle factors:** year, make, model, mileage, defects, and number of passengers; and
- **driver descriptors:** sex, age, blood alcohol concentration or other indication of alcohol impairment, other impairment, annual mileage, history of prior violations and accidents, occupation, and restraint usage.

This list is by no means inclusive of all information relevant to case assessment. However, it was felt that the structured identification of information in each of these areas would be adequate to promote consistency and thoroughness in the review process.

The team member's consideration of the actions and behaviors that immediately preceded the crash, and the reasons for them, were structured around construction of an "events sequence." For each driver and vehicle unit, events of potential relevance to an accident's occurrence were identified and put in chronological order. Emphasis was placed on the period beginning fifteen minutes prior to the crash, and extending through the first five minutes postcrash.

In considering relevant events, the traditional 9-cell matrix (human, environmental, and vehicle rows by precrash, at-crash, and postcrash columns) served as a mental checklist, with emphasis on the precrash phase. While there was no precise definition as to what constituted an "event," these included any actions or changes in physical or mental status of relevance to the accident's occurrence. Particular attention was paid to vehicle control inputs, maneuvers, and response immediately preceding the crash, and to driver attention and impairment status.

The events sequence was useful in assessing the role of the UDA in causing the accident and the reasons for the driver's commission of the UDA. To the extent that a "cause and effect" relationship between events can be established, the events sequence represents a causal chain. The focus of the present study is on that point in the sequence of events at which the driver engages in a behavior that results in a vehicle control input (or lack of input), which is relevant in terms of whether or not an accident occurs. The assessment of causation thus focuses on the sequence of events immediately following the behavior studied.

The issue of the driver's awareness or consciousness of his unsafe behavior, on the other hand, can be examined in the event sequence immediately preceding the behavior. Presumably, each behavior is a function of the driver's information processing activities. As he drives it is necessary to continually receive information, interpret it, make decisions as to necessary or desirable control actions based on it, and then execute and monitor the results of such actions. Failures in any of these functions (perception, comprehension, decision, execution) may be viewed as reasons for the commission of a particular behavior. Backing up one additional step in the causal chain, many factors may influence a driver's ability to function as an information processor, and may thus be reasons for particular information processing breakdowns. For example, alcohol impairment may be viewed as a physiological condition that may explain failures of perception or decision-making. Backing up further in the sequence, there are obviously many factors--knowledge, attitudes, anxieties, aggression, concerns or distractions, etc.—that are relevant in explaining a driver's behavior at a particular point in time. However, as one goes further back in the events sequence, it becomes less and less likely that the involvement or relevancy of such factors in a particular case can be accurately assessed.

CAUSAL ASSESSMENT

One objective of the review of in-depth case reports was to confirm the causal involvement of the UDA in a substantial number of accidents, and to better understand the nature and circumstances of such involvement. It was suspected that, in some files, the mere presence of a factor might be reported as an "involvement," with little or no assessment as to its actual role in the collision generation process. In the CPIR file, for example, while the case reports permit an assessment of the most responsible driver's primary error, there was no formal procedure guiding the individual teams in designating the most responsible driver or in assessing primary error. The meaning of **primary error** in terms of accident causation was not defined.

Thus, while it is likely that all cases actually resulting from "speed to fast" would be included under this heading, there is a possiblilty that additional cases in which excessive speed was merely present but not causally involved might also be included. Based on the review, it was ultimately concluded that nearly all of the CPIR speeding cases involved excessive speed in a causal role. However, it was found that the vast majority of the cases coded FTC in the CPIR file did not involve FTC in a causal role, in terms of the preliminary definition of the FTC UDA developed in Chapter Two. The review procedure thus appears to have been worthwhile in reaching a better understanding of each UDA's actual involvement as an accident cause. The procedure also enabled the assessment of driver awareness of UDA commission to be based only on those cases where the UDA, as defined for this study, actually played a causal role.

The first step in the causal assessment of the UDA is to determine its **presence in the accident.** This requires a careful assessment of the behaviors identified in the events sequence to ascertain that they conform to the specific UDA definition. Given the presence of the UDA, the second step is to assess its **causal involvement** in the accident.

The causation assessment approach developed in the Indiana Tri-Level Causation studies (Joscelyn and Treat 1971; Treat et al. 1977), was adopted for this purpose. A causal factor was defined as:

> . . . a factor necessary or sufficient for the occurrence of the accident; (such that) had the factor not been present in the accident sequence, the accident would not have occurred (p.16).

This is a so-called "but for" test of causation, which involves a hypothetical reconstruction of the event sequence in the absence of the "causal factor" to assess whether "but for" the factors occurrence, the accident would not have occurred (i.e., whether the factor was **necessary** for the accident's occurrence). Whether or not explicitly stated as such, this type of logic appears to underly nearly all assessments of cause based on the investigation of individual accidents (see, also, discussion on causation in Chapter Two).

Thus, having determined that the UDA was present in an accident, the case reviewers then applied the "but for" test to assess whether or not it was an accident cause. They did this by visualizing a traffic-flow situation that was the same as that during the accident, except for the unsafe act that resulted in the crash. The case reviewers were aided in this assessment by their individual backgrounds as human factors specialists. Questions regarding vehicle dynamics and the influence of roadway design were resolved by consulting HSRI personnel with expertise in such areas. The conclusions of each reviewer were then discussed in a group meeting, leading to a consensus as to the causal role of the UDA in each accident.

DRIVER AWARENESS/REASONS FOR UDA COMMISSION

For those cases which the reviewers assessed to have been caused by a UDA, a subsequent assessment was made as to the driver's awareness of UDA commission and the reasons for such behavior. It was concluded to be difficult to establish with certainty that a driver had been aware and conscious of any particular unsafe behavior, although it could often be shown that a driver was **not** aware or conscious of a particular UDA commission. For example, this would be true it if was established that a driver had fallen asleep or blacked out prior to UDA commission. Therefore, each driver was evaluated to assess whether the following explained his commission of a UDA:

- perception or comprehension failure (i.e., not conscious of UDA commission);

- skill or performance failure (i.e., conscious, but commission not intended); or

- impairment or other altered state of consciousness (i.e., either not aware or not the result of a rational decision-making process).

Those cases that remain serve as a best estimate of those for which the driver was aware and conscious of his UDA commission. This in turn provides an indication of the general risk-management strategies for reducing the incidence of UDAs.

As a part of the review of in-depth cases, an assessment was also made as to the feasibility of applying the UDA definition to each accident. In the case of the "speed too fast" UDA, for example, this involved assessing the accuracy and availability of precrash travel speed estimates. Similarly, for following too closely, the availability of the needed information on travel speed and following distance was carefully examined. In assessing such issues, members of the case review team discussed individual accident reports with other accident reconstruction personnel at HSRI.

DATA FILE ASSESSMENTS

In addition to reviewing in-depth case reports, information on the frequency and circumstances of UDA involvement was obtained from several of HSRI's automated accident data files, as well as through reference to the Indiana Tri-Level study final report and other appropriate literature. The analysis of UDA frequency expanded the preliminary analysis of unconditional risk presented in Chapter Two.

Frequency data were obtained from the CPIR and Texas five percent files using **driving error** and **driver violation** variables, respectively, as surrogates for the UDAs of interest. Other frequency data are also reported.

The Texas and CPIR files also served as the primary source of information on characteristics associated with UDA involvement in accidents. Bivariate distributions were obtained from these files using the same UDA surrogate variables to define the rows, and the other descriptors of interest to define the columns. Column descriptors included measures of driver age and sex; accident configuration and number of involved vehicles; accident damage and injury severity; roadway type, alignment, and number of lanes; and precipitation at time of accident. Data were obtained in this manner for all three UDAs examined.

The following three chapters report the results of these detailed examinations for the speeding, following too closely (FTC), and driving-left-of-center (DLOC) UDAs respectively.

CHAPTER FOUR
DEFINING SPEED-RELATED UDAs

The clinical assessment procedure described in Chapter Three was applied to two different sets of in-depth case reports in order to develop better incidence data concerning the UDAs and to better assess the feasibility of applying the preliminary definitions to the accident population.

In this chapter the clinical assessment procedure is applied to the speeding UDA. The following two chapters examine the FTC and DLOC UDAs respectively.

DISCUSSION OF SPEED-RELATED UDA DEFINITIONS

Preliminary definitions for the speeding UDA were developed in Chapter Two. These were of two types, **absolute** and **relative**, and were defined as follows:

> The **absolute-speed** UDA is the act of driving a vehicle at a speed in excess of a maximum legal limit, or in a normal driving environment, at a speed below a minimum limit.
>
> The **relative-speed** UDA is the act of driving a vehicle at a speed that is so different from the speeds of the vehicles around it that the risk of a crash exceeds that which is societally acceptable.

As shown in Table 4-1, it is likely that the only way traveling too slowly can increase risk is to increase conflicts with other traffic. (A possible rare exception might be in traveling so slowly on an icy superelevation as to slide towards the inside of the curve.) While an absolute measure based on minimum speed limits could be defined, such limits are usually not provided and, even where present, are usually not based on any rigorous assessment of risk. They are also often rendered meaningless by adverse weather and traffic conditions. The relative-speed

TABLE 4-1

APPLICABILITY OF PRELIMINARY DEFINITIONS OF THE SPEEDING UDA

Risk Mechanism	Applicable Definition(s)	
	Too Slow	Too Fast
Conflicts with other traffic	Absolute or Relative - Absolute--minimum speed limit, where provided, defines expectations for speed of traffic flow - Relative--direct measurement of speed of traffic flow	Absolute or Relative - Absolute--limits define static expectations for speed of traffic flow - Relative--direct measurement of speed of traffic flow
Vehicle control problems and tractive limits	Not Applicable	Absolute or Relative - Absolute--limits provide estimate of maximum "safe" speed - Relative--traffic flow measurement defines maximum "safe" speed, e.g., for a particular curve

definition provides the needed dynamic measure of prevailing speeds and distributions.

In terms of speeds that are too fast, the increase in risk is realized through both interactions with other road system users, and through effects on vehicle control, for example, as where the maximum possible cornering speed for a curve is exceeded. The posted or advisory limit provides a static estimate of maximum acceptable risk in terms of both other road users and road design—although changing conditions can reduce the maximum speeds that are acceptable. The relative measure is superior in taking into account such changed conditions.

As defined, however, relative-speed is concerned primarily with risk effects from interactions with other road users (e.g., a speed so different from the speeds of vehicles around it) and could be difficult to measure in circumstances where the conditions are transitory and the traffic flow data may be difficult to acquire with any precision; if the traffic volume is low, conditions could change before an adequate sample is collected, and much time on the part of an exposure data collection team could be required. Were it obtained, it would be useful as a risk measure not because it describes a level of traffic conflict, but rather because it provides a measure of **safe** travel speed for the curve under prevailing conditions.

Thus, relative speed can provide a superior, dynamic measure of the "too fast" speeding behavior, where the speed of other traffic is relevant both in terms of interactions and conflicts within the traffic stream, and in defining safe vehicle control limits given, road design, vehicle performance, and prevailing road surface conditions.

Because of its dynamic nature, the relative-speed UDA can be expected to be a useful measure for almost all types of speed-related involvements in accidents. However, determination of the mean flow speed and speed distribution of other traffic poses a serious problem. The problem is particularly severe in the accident population--for a given accident, the definition requires knowledge of the traffic flow behavior immediately preceding its occurrence. Even in a prospective data collection effort, this type of information would be difficult to obtain, other than in gross qualitative terms (e.g., a driver statement that "I was passing quite a few people but some people were passing me"). Only a heavily instrumented road network in a special study area could provide detailed and accurate information on the accident population.

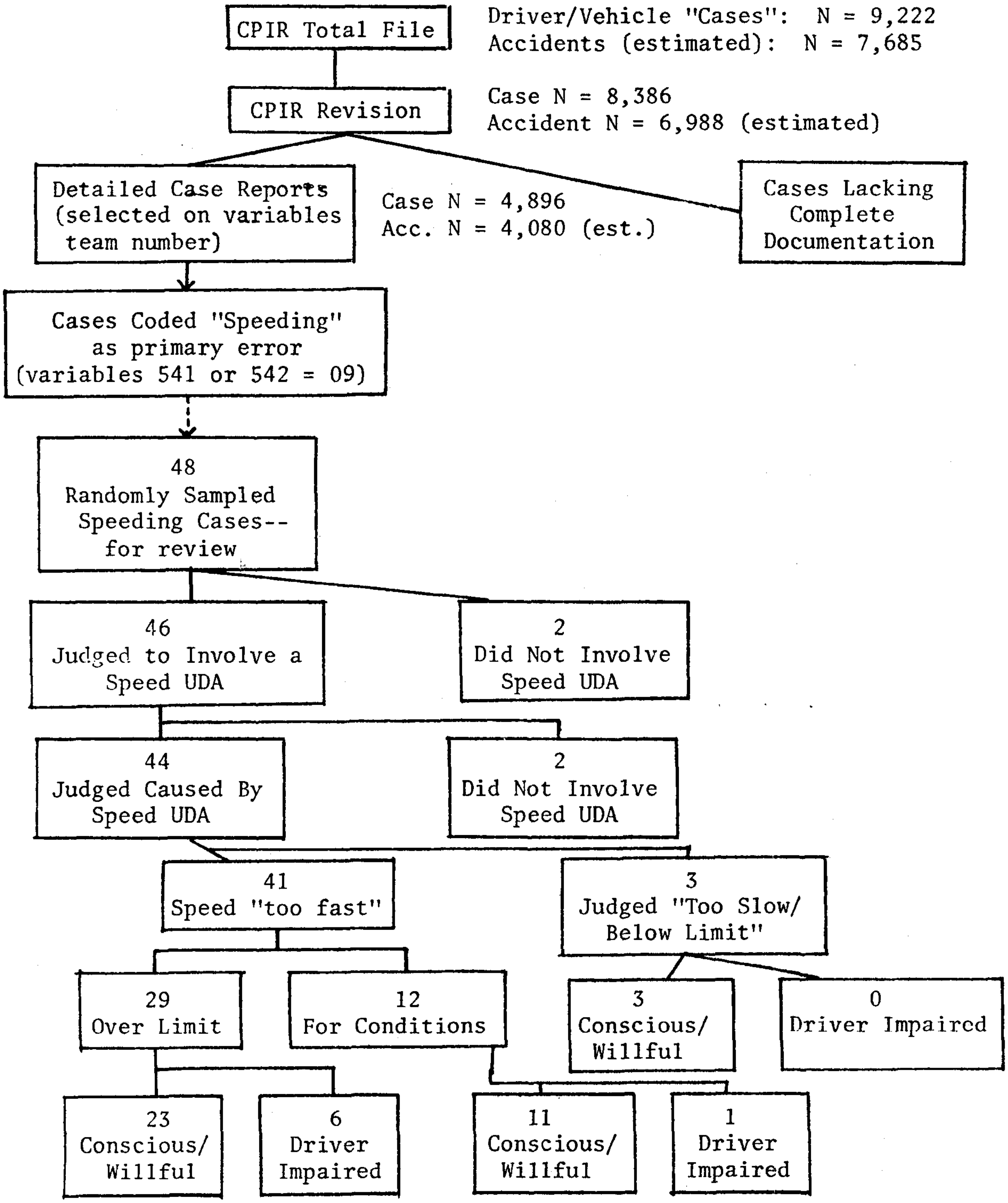
One solution is to estimate the prevailing traffic flow speed at the time of the accident by measuring the traffic flow speed at the same location, at the same time of day, and under similar circumstances, but on a following day (preferably within a day or two). Obviously, judgment is required in deciding which circumstances must be replicated, and the match cannot be perfect. Certainly traffic volume, road surface condition, and light condition are critical, so that the measurement should take place during the same part of the week, at the same time of day, and under essentially the same weather conditions. Given this traffic flow measurement, additional adjustments might be possible if the accident-involved driver drives this route routinely and can characterize anything unusual about the traffic flow for that particular day, time and location. Retrieving comparable information from existing in-depth files is obviously not possible; none were compiled with the relative speed measure and statistical comparisons of accident and nonaccident travel speeds in mind. Consequently, to acquire useful estimates of the relative speed UDA from existing accident files, some additional assumptions are necessary. Specifically, it must be assumed that whenever the investigators have concluded a driver's speed was too fast and that this excess was involved in the accident, that such a speed would in fact have exceeded, for example, the 95th-percentile flow speed of traffic at that place and under the same circumstances. This assumption has, of necessity, been made in the present review of existing files.

ACCIDENTS SELECTED FOR REVIEW

HSRI's Collision Performance and Injury Report (CPIR) file, as described in Chapter Three, was used for this assessment. As shown in Figure 4-1, only those cases designated Revision 3 were considered; these are the most recent and complete cases, and constitute more than 90 percent of the CPIR file (8,386 of 9,222 cases). The cases in this file

FIGURE 4-1

TAXONOMIC SUMMARY OF CPIR "SPEEDING" CASES EXAMINED



consist of 8,386 driver and vehicle units; since there are approximately 1.2 such units per accident within this file, they represent an estimated 6,988 accidents.

From these, those cases having written narratives and other precrash phase documentation suitable for manual review were identified and filtered out for further consideration on the basis of variable 5, team number. A total of 4,896 cases, comprising approximately 4,080 accidents, were obtained in this manner. These represent the total population of CPIR accident reports suitable for a case-by-case examination of precrash factors. Involvement rates for the speeding UDAs were calculated as a proportion of this total population.

INCIDENCE OF SPEEDING UDAs

Results of Review of Accident Reports

To filter out cases potentially involving "speeding too fast," CPIR variables 541 and 542 were used; these describe the **most responsible drivers'** primary errors. Cases coded 09, "speeding, too fast for conditions" totalled 1,091. Since there should be only one "most responsible" driver coded per accident, it may be assumed that these represent 1,091 accidents of the 4,080 considered (27%). Thus, as shown in Table 4-2, speeding was coded as a "primary error" in 27 percent of the CPIR accidents considered.

Reviews of individual case files were next undertaken. These reviews require considerable time and professional staff involvement. Consequently, random sample of 48 accidents was selected for reading (from the 1,091 that involved speeding).

It was concluded that only 46 of the 48 cases actually involved the speeding UDA, in terms of either the relative or absolute speed preliminary definitions. Of the 46 remaining, only 44 were judged to have actually been caused by the speeding UDA (i.e., such that "but for" its occurrence the accident would not have occurred). Thus, 44 of the 48 cases read involved, and were judged caused by, a speeding UDA. This corresponds to 1,000 of the 4,080 accidents considered (25%). Thus, based

TABLE 4-2

FREQUENCY OF INVOLVEMENT OF EXCESSIVE SPEED
AS A CAUSAL FACTOR IN TRAFFIC ACCIDENTS
(percent of accidents)

	Excessive/Over Design Speed or Limit	Excessive for Conditions	Total/Excessive Speed
Detailed CPIR Assessment[1] (N = 4080 accidents)	16%	7%	23%
Full CPIR File[2] (N = 7685 accidents)	Not Available	Not Available	25% (Fatals only: 35%)
Indiana Tri-Level Study[3] In-Depth Team—Level 3 (N = 420 accidents)	6%/9%/11%	2%/7%/8%	8%/16%/19%
	(Certain/Certain + Probable/Certain + Probable + Possible)		
Indiana Tri-Level Study[3] Technician Teams-Level 2 (N = 2258 accidents)	5%/8%/9%	3%/6%/8%	7%/14%/16%
	(Certain/Certain + Probable/Certain + Probable + Possible)		
Texas 5% File 1976[4] (N = 23,257 accidents)	4% (Fatals only: 24%)	15% (Fatals only: 8%)	19% (Fatals only: 32%)
Accident Facts 1978[5] (police data for 1977 from 41 cities and 11 states)	Not Available	Not Available	All Accidents: 18% (Fatals only: 30%
Fatal Accident Reporting System 1976[5]	Not Available	Not Available	(Fatals only: 37% of vehicles)

Sources:

1. Based on manual review of cases from HSRI's Collision Performance and Injury Report (CPIR) file of MDAI reports; review conducted as a part of this project.

2. Entire CPIR file, per CPIR Revision 3 Codebook, dated November 1978. HSRI file.

3. Based on Tri-Level Study of the Causes of Traffic Accidents, Final Report, Volume I, Appendix A, page A-18, March, 1977

4. 5% Random Sample of police-reported accidents in Texas for 1976. Based on reports of violations of accident-involved drivers. HSRI file. Fatal data based on total Texas 1976 File.

5. Reported in Accident Facts 1978, National Safety Council, Chicago, 1978, pg. 48.

on the review, 25 percent of the CPIR accidents are estimated to have been caused by a speeding UDA.

On examination of the forty-four "speeding UDA" caused accidents, it was judged that the vast majority (forty-one), involved speeding too fast, while three involved "speed too slow." Since the speeding too fast code was used to select these cases, it is not surprising nor indicative of any general result that "speed too fast" cases predominated.

Among the 41 "speed too fast" cases, the majority (29) were in excess of a posted limit, while the other 12 were "too fast for conditions." Thus, the "speed too fast" causation rates, as a proportion of CPIR cases considered, are as follows:

- Speed too fast--over posted limit; 29 of 48 cases read, corresponds to 659 of 4,080 accidents (16%).
- Speed too fast--for conditions; 12 of 48 cases read, corresponds to 273 of 4,080 accidents (7%).
- Speed too fast--either type; 41 of 48 cases read, corresponds to 932 of 4,080 accidents (23%).

Thus, the speed-too-fast UDA is indicated to be a cause of about twenty-three percent of this group of accidents. Since the CPIR file is biased towards more serious accidents, it may be expected to report a higher incidence of speeding too fast than would a file respresentative of all severities (e.g., the Indiana Tri-Level file).

SUMMARY OF INCIDENCE DATA FOR THE SPEED-TOO-FAST UDA

Table 4-2 summarizes data reflecting the frequency of involvement of excessive speed as reported by various accident data files. While the specific meaning of "involvement" and level of detail with which it is defined varies from file to file, there is believed to be a substantial degree of conceptual similarity in meaning. In general, these data reflect judgments as to frequency of causal involvement rather than mere presence.

For the excessive-speed category, overall estimates of involvement range from seven percent to twenty-five percent of all reported accidents, with the data believed to provide the best indication being in the range of sixteen to twenty-three percent.

The low figure of seven percent represents a conservative "causal-certain" estimate from the Indiana technician teams. Considering both the technician and in-depth team data, the "probable" and "probable or possible" results in the Indiana file are in the relatively narrow range of fourteen to nineteen percent. These data provide a good estimate of causal involvement based on a documented causal assessment procedure, and are based on a sample of more than two thousand traffic accidents that are generally representative of all police-reported accidents in the study area. As such, the majority (approximately 73%) are property damage only, although personal injury and fatal accidents are represented in approximately the same proportion as in police-reported accidents generally.

The high value of twenty-five percent, on the other hand, is for the full CPIR file. This file is oriented towards serious accidents (which may be expected to more frequently involve excessive speed), and was also indicated by the manual review to include some cases for which speeding, although coded as a driver error, was judged not to be causally involved. Based on the manual review, an actual involvement in twenty-three percent of these accidents was estimated.

Where only **fatal accidents** are considered, the involvement of excessive speed is considerably higher. Data reported by the National Safety Council (1978) indicate "speed too fast" to have been cited as a driver error in thirty percent of fatal accidents--a figure only slightly exceeded in the Texas Fatal Accident File. The NSC statistic is based on police-reported data for 1977 from forty-one cities and eleven states. The same document reports that, based on data from NHTSA's Fatal Accident Reporting System for 1976, "speed too fast" was indicated for thirty-seven percent of vehicles involved in fatal accidents. Considering the possibility that more than one vehicle per accident could be cited, a per-accident statistic of slightly less than thirty-seven percent may be indicated. In the Texas Fatal Accident File for 1976, a speeding "over limit" violation was coded in twenty-four percent of fatal accidents, and speeding "too fast for conditions" in eight percent. Thus, one speeding violation or the other was recorded in thirty-two percent of the fatal accidents. Of 891 fatal accidents in the CPIR file, speeding errors were coded for 312 (35%).

For some files, data were available segregating "speed too fast for conditions" (although possibly within posted or advisory limits) from speed that exceeded the constraints of road design or posted and advisory limits (Table 4-2). These data are unfortunately not very consistent; the CPIR and Indiana files indicate "over design speed or limit" to be the greater problem, whereas the Texas file indicates the reverse. Differences in both accident populations and coding definitions and procedures are probably involved.

In any case, it is clear that both types of errors are involved and merit serious attention. The "relative speed" UDA concept is applicable to both types of error. In the case of "road design/limit," the speed distribution of the traffic flow serves to define the safe limits of the road design and to establish a revised estimate of the appropriate limit. Under adverse traffic or weather conditions, the traffic flow data serves to provide the only useful means of objectively determining safe travel speed at each location for such conditions.

In summary, excessive speed is indicated to be causally involved in about sixteen to twenty-three percent of all reported accidents, and in some thirty to thirty-five percent of fatal accidents. Both the "over design speed/limit" and "too fast for conditiions" aspects are involved, and these merit equally serious attention.

Incidence of "Speed Too Slow" UDA

Consideration of risk data in Chapter Two led to the identification of traveling too slowly (e.g., below the mean speed of other traffic) as a serious problem and important aspect of the "speed UDA." Indeed, in terms of risk of reportable accident, the "too slow" aspect was shown to be at least as important as excessive speed.

Unfortunately, it appears that existing files and case reports were not compiled with this possibility in mind, so that comparable incidence data are not readily available. Indeed, HSRI's extensive bibliography of safety literature reveals no study that has specifically examined the possibility or tested the contention that "driving too slowly" (in relation to other traffic) is in fact the safety problem that the "speed versus risk" curves indicate it to be.

Confirmation of the "too slow" problem and identification of the "who, when, and where" of its occurrence can be an important product of the current study. It remains to be seen if the increase in risk reflected in the "speed versus risk" curves is primarily a consequence of situations where the driver has little discretion (e.g., slowing to turn or on account of other traffic or pedestrians), or of discretionary and inadvisable choice in electing to travel too slowly. The latter problem would obviously be the more amenable to driver conformance countermeasures.

Quite possibly, even if focused on the "too slow" problem, clinical studies would have difficulty in assessing it. This is because the primary effect may be in simply increasing the conflict rate, and hence the opportunity for an accident (e.g., causing more vehicles to attempt passing), rather than any specific "problem" in the interaction of an accident-involved vehicle with those around it. Only gross cases would likely be identified, and clinical studies would therefore probably tend to understate the influence.

A clue as to the involvement discernible in clinical studies is provided by Indiana's Tri-Level Study, which reported "inadequately defensive driving technique--should have adjusted speed" as a probable cause in about 4 percent of accidents and as at least a possible cause in up to 7 percent. Traveling too slowly can be a factor in many rear-end collisions (a substantial portion of all reported accidents are of this type), and in accidents involving passing (National Safety Council statistics for 1977 report "improper overtaking" as being involved in 2.7% of all accidents, based on police reports from eleven states and forty-one cities). Delays in recognition of vehicles "stopped or slowing ahead" were probable causes in about 9 percent of accidents investigated in the Indiana study, and many of these could have involved "traveling too slowly."

Based on these limited data, it is clearly possible that discretionary decisions to travel too slowly play a causal role in

five to ten percent or more of accidents.

CIRCUMSTANCES OF SPEEDING UDA OCCURRENCE

In this subsection, the circumstances of occurrence of the speeding UDA are examined; that is, selected driver, environment, and accident variables are examined to determine their association with the speeding UDA in cases where the UDA was identified as a cause. Primary sources of data for this review are HSRI's CPIR and Texas Five Percent Sample (1976) files, as described in Chapter Three. Results are summarized in Table 4-3.

Results are reported here for the "speed too fast" aspect of the speeding UDA. For data obtained from the Texas file, the "over-limit" and "too fast for conditions" violations are also examined separately. The UDA surrogate (filter) variable used for the CPIR file, however, classifies all types of "speed too fast" behaviors together, and does not permit this type of separate examination. In addition, available files do not provide for identification of the "too slow" UDA, so that the circumstances of its occurrence have not been documented.

As would be expected, accidents involving a "too fast" speeding UDA are more serious than accidents generally (i.e., fatal and serious accidents are overrepresented among accidents involving the speeding "too fast" UDA), although as for accidents generally, the majority of speeding accidents involve little or no injury and only minor to moderate damage (Tables 4-4 to 4-6). In both the Texas and CPIR files, accidents involving speeding were fatal approximately twice as often as would have been expected based on the appearance of fatal accidents in the total files. In the Texas data it is apparent that the speed "over limit" category is associated with a higher level of accident severity, in terms of both injury and vehicle damage, than speed "too fast for conditions," although even the latter is associated with increased levels of damage and injury. For example, in the Texas data, speeding accidents involved very severe vehicle damage about nine times as often as would have been expected, whereas very severe damage was overrepresented among too-fast-for-condition accidents by a factor of 1.7. Fatal accidents were

TABLE 4-3

SUMMARY OF LARGEST AND MOST OVERREPRESENTED CATEGORIES OF DESCRIPTIONS FOR ACCIDENTS INVOLVING "SPEEDING TOO FAST"

TABLE	DESCRIPTION	LARGEST CATEGORY(S) (involving UDA)	MOST OVERREPRESENTED CATEGORY(S)
4-4	Severity-Damage (Texas 5%)	Minor-Moderate Damage (levels 1-3)	Very Severe Damage (levels 3 and up are O.R.)
4-5	Severity-Injury (Texas 5%)	No Injury (72%)	Fatal (all injury categories O.R.)
4-6	Severity-Injury (CPIR)	Minor Injury (43%)	Severe Thru Fatal
4-7	Single v. Multiple Vehicle (CPIR & Texas 5%)	CPIR: evenly divided Texas: over limit= Single (61%) Texas: for cond. = Multiple (61%)	Single Vehicle Single Vehicle Single Vehicle
4-8	Configuration (CPIR)	Non-moving vehicle Intersecting (44%) (right angle and oblique)	Non-moving vehicle Sideswipe, rear-end
4-9	Driver Age (Texas 5%)	20-24 yrs. (25%)	10-14, 15-19, 20-24 yrs.
4-10	Driver Sex (Texas 5%)	Males (75%)	Males
4-11	Roadway Class (Texas 5%)	City Streets (44%) U.S./State trunkline	County Roads, State, Secondary, & Interstate/ Turnpikes
4-12	Roadway Lane Configuration (CPIR)	2-lane (53%)	
4-13	Road Alignment (Texas 5%)	Straight & Level (89%)	Curves, Hill, or Both
4-14	Road Alignment-Horiz. (CPIR)	Straight (61%)	Curve

TABLE 4-3

(continued)

TABLE	DESCRIPTION	LARGEST CATEGORY(S) (involving UDA)	MOST OVERREPRESENTED CATEGORY(S)
4-15	Road Alignment-Vert. (CPIR)	Level (63%)	Hill-related
4-16	Precipitation	None (74%)	Snow, Rain

"Speeding too fast" accidents were filtered from the files as follows:

- CPIR - variables 541 or 542, describing "most responsible vehicles" primary errors 1 and 2, coded 09, "speeding, too fast for conditions"
- Texas 5% - variable 117, "driver violation No. 1," coded 01, "speeding over the limit" or 02, "speeding during unsafe conditions."

TABLE 4-4

VEHICLE DAMAGE FOR ACCIDENTS INVOLVING SPEEDING VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE FOR 1976

	No Damage 0	Minor Damage 1	2	3	4	5	6	Very Severe Damage 7
Speeding over the limit N = 802	.4%	15.5%	20.4%	25.2%	16.3%	9.5%	4.6%	8.1%
Speeding too fast for conditions N = 2,792	2.6%	32.8%	26.6%	24.7%	9.4%	3.2%	2.8%	1.5%
Either speeding violation N = 3,698	2.1%	28.1%	24.5%	24.1%	10.7%	4.5%	3.1%	2.9%
Total Texas 1976 5% Sample N = 33,096	2.6%	40.1%	28.9%	18.5%	5.7%	2.2%	1.2%	.9%

TABLE 4-5

MAXIMUM INJURY SEVERITY IN ACCIDENTS
INVOLVING SPEEDING VIOLATIONS AND FOR
ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE FOR 1976

	No Injury	"C" Injury	"B" Injury	"A" Injury	Fatal Injury
Speeding over the limit N = 906	56.4%	8.1%	21.1%	10.7%	3.8%
Speeding, too fast for conditions N = 3,506	76.4%	7.8%	11.8%	3.5%	.5%
Either speeding violation N = 4,412	72.3%	7.9%	13.7%	5.0%	1.1%
Total Texas 1976 5% sample N = 23,257	79.3%	7.5%	9.6%	3.1%	.5%

TABLE 4-6

INJURY SEVERITY OF CPIR SPEEDING ACCIDENTS
COMPARED WITH TOTAL CPIR SAMPLE

	None	Minor	Moderate	Severe	Serious	Critical	Fatal
Speeding N = 1,298	8.1%	42.8%	18.7%	11.7%	4.7%	6.8%	7.2%
Total CPIR N = 8,940	12.9%	49.7%	17.1%	8.9%	3.1%	4.0%	4.2%

overrepresented among speeding "over limit" accidents by a factor of more than 7, but appeared among too-fast-for-conditions accidents in the same proportion as for all reported accidents. However, the "A and B" injury categories were overrepresented for both the "over limit" and "for conditions" categories.

These results are consistent with findings of the Indiana Tri-Level study, which recorded a significantly greater proportion of personal-injury or fatal accidents among accidents for which "excessive speed" was cited as a causal factor.

In both the Texas and CPIR data, single vehicle accidents are overrepresented among those caused by speeding, and this holds true for both the "over limit" and "for conditions" subtypes within the Texas data (Table 4-7). However, in terms of frequency, speeding accidents were about evenly divided between the multiple and single-vehicle categories in the CPIR file. In the Texas file the majority of "over limit" accidents were single-vehicle, while most "too fast for conditions" accidents were multiple-vehicle. Thus, while accidents involving speed are more frequently single-vehicle than accidents generally, a substantial portion are of the multiple-type.

In terms of collision trajectory, there is no clear pattern (Table 4-8). Sideswipe accidents are the most overrepresented, but constitute only a small proportion of accidents (8.8% of the speeding group and 5.7% of total CPIR file). Rear-end accidents are overrepresented to a slightly lesser extent, but constitute 27.6% and 22.3% of the speeding and total file, respectively. Suprisingly, the head-on configuration is only slightly overrepresented among speeding accidents (20.1% versus 18.6% of file). It is clear that intersection accidents, which constitute the majority (53%) of accidents in the CPIR file, are underrepresented among the speeding accidents.

As was expected, speeding accidents were also found to overrepresent young drivers and males (Tables 4-9 and 4-10, respectively). In the Texas data, although they constituted only a very small portion of the accident population, drivers ten to fourteen years of age were overrepresented to the greatest degree, and this was true in both the "over limit" and "for

TABLE 4-7

SINGLE V. MULTIPLE VEHICLE ACCIDENT TYPES FOR SPEED-RELATED ACCIDENTS AND FOR ALL ACCIDENTS IN THE CPIR FILE AND THE TEXAS FIVE-PERCENT FILE 1976

	Single	Multiple
Speeding N = 1,091	49.3	50.7
Total CPIR N = 9,219	28.0	72.0
Speeding over the limit N = 959	60.7	39.3
Speeding too fast for conditions N = 4,331	39.3	60.7
Either speeding violation N = 5,290	43.1	56.9
Total Texas 5% File, 1976 N = 23,256	26.0	74.0

TABLE 4-8

COLLISION CONFIGURATIONS OF SPEEDING ACCIDENTS COMPARED WITH TOTAL CPIR FILE

	Head-On	Intersection L-type	Sideswipe	Rear-End	Intersection T-type
Speeding N = 536	20.1%	20.7%	8.8%	27.6%	22.8%
Total CPIR N = 6,630	18.6%	30.6%	5.7%	22.3%	22.6%

TABLE 4-9

AGE DISTRIBUTION OF DRIVERS CITED FOR SPEEDING VIOLATIONS AND FOR ALL DRIVERS IN TEXAS FIVE PERCENT FILE FOR 1976

	ACCIDENT DRIVER AGE (YEARS)								
	10-14	15-19	20-24	25-34	35-44	45-54	55-64	65-74	75+
Speeding over the limit N = 896	1.6	27.7	28.3	22.4	8.8	5.0	4.0	1.3	0.8
Speeding too fast for conditions N = 3,789	0.6	23.5	24.5	23.1	10.7	8.8	5.1	2.9	0.8
Either violation N = 4,685	0.8	24.3	25.3	23.0	10.3	8.0	4.9	2.6	0.8
Total Texas 1976 5% Sample N = 37,469	0.4	16.8	20.5	24.8	12.8	10.8	7.4	4.7	2.0

TABLE 4-10

SEX OF DRIVERS CITED FOR SPEEDING VIOLATIONS AND FOR ALL DRIVERS IN TEXAS FIVE PERCENT FILE FOR 1976

	Male	Female
Speeding over limit N = 912	83.2%	16.8%
Speeding too fast for conditions N = 3,964	72.6%	27.4%
Total-- All Speeding N = 4,876	74.5%	25.5%
Total File-- All Accidents N = 38,344	66.8%	33.2%

conditions" subcategories. Ranking second and third in terms of degree of overrepresentation were the fifteen to nineteen and twenty to twenty-four years of age categories. Drivers falling within these two categories comprised more than half (56.0%) of all speeding "over limit" drivers in the Texas file, compared to 48.0% of the "for conditions" drivers and only 37.3% of drivers in the total file. The overinvolvement of young drivers in accidents resulting from excessive speed has been reported in numerous studies. In the Indiana Tri-Level study, drivers under twenty years of age were judged to have committed an excessive speed error more than twice as often as accident involved drivers older than twenty.

Males were found to be overrepresented among "over limit" speeding accidents by a factor of 1.2 in the Texas data, and to a lesser extent among "too fast for condition" accidents as well (Table 4-10). While only mildly overrepresented in involvement in accidents by reason of speeding, more than two-thirds of all accident-involved drivers in the Texas file are male, and they consequently constitute a high proportion of all drivers in speed-related accidents. A total of 83.2% of all accident-involved drivers cited for "speeding over limit" in the Texas file were male.

In terms of roadway class (Table 4-11), it was found that while slightly over half the accidents in the Texas file occurred on city streets, speeding accidents were most seriously overrepresented in accidents occurring on county roads (although these constituted only about six percent of all speed-related accidents). Accidents on interstate and turnpike and state secondary roads were also overrepresented. While speeding accidents are not overrepresented among those occurring on city streets in the Texas data, accidents involving speeding occur more frequently on city streets (44.1%) than on any other road system reported in the Texas file. Over half (51.6%) of the speeding "over limit" accidents occurred on city streets.

Next to city streets, the largest proportion of accidents in the Texas file (28.8%) occurred on U.S. and state trunk lines. Among accidents occurring on such roads the "over limit" violation was slightly underrepresented and the "for conditions" violation slightly overrepresented.

In summary, the Texas data indicate most "speed too fast"

TABLE 4-11

TYPE OF ROAD FOR ACCIDENTS
INVOLVING SPEEDING VIOLATIONS
AND FOR ALL ACCIDENTS IN THE
TEXAS FIVE PERCENT FILE FOR 1976

	Alley	City Street	County Road	State Secondary	U.S. and State Trunkline	Interstate Turnpike
Speeding over the limit N = 933	0	52.3%	7.1%	10.0%	20.6%	10.1%
Speeding too fast for conditions N = 4,318	0	42.2%	5.4%	8.1%	31.4%	12.8%
Either speeding violation N = 5,271	0	44.1%	5.7%	8.4%	29.4%	12.3%
Total Texas 1976 5% Sample N = 23,257	0	51.6%	3.3%	6.5%	28.8%	9.6%

UDA-caused accidents occur on either city streets or U.S. and state trunk lines, and are most overrepresented as an accident cause in accidents occurring on county, interstate, and state secondary roads.

Somewhat different insight is provided by the CPIR data on roadway lane configuration (Table 4-12). The largest share of accidents in the CPIR file (47.2%) and an even greater proportion of accidents caused by speeding (53.2%) are reported as occurring on two-lane roads. Note that speeding accidents are reported as overrepresented among accidents occurring on divided highways but underrepresented among accidents on "four and over lane" nondivided highways. The reason for this reversal is not known, but could be due to the confounding influence of traffic density associated with urban or rural place of occurrence. That is, nondivided four-plus-lane roads may be primarily densely traveled urban streets affording less opportunity for speeding.

The Texas and CPIR files are unambiguous in indicating that accidents occurring on curves, hills, or both are overrepresented among speeding-caused accidents as compared to accidents generally (Table 4-13 to 4-15). That is, among accidents that occur on curves, hills, or both, speeding is more frequently cited as an accident cause than among accidents occurring on "straight-level" roads or among accidents generally. However, the vast majority (89.1%) of all speed-related accidents in the Texas file occurred on "straight-level" roads. Thus, while speed is relatively more important as a cause among accidents occurring on hills and curves, most of the "speeding too fast" UDA problem appears to be one that manifests itself under straight and level conditions. In the Texas data, this was true for both the "over-limit" and "too fast for conditions" aspects.

The occurrence of speeding accidents is also related to precipitation. While most speeding accidents (73.7%) in the CPIR file occurred under conditions of no precipitation, speeding was overrepresented among accidents occurring during conditions of rain and snow (Table 4-16). This is also reflected in the precipitation rate variable, where speeding accidents are overrepresented among accidents occurring during light, moderate, and heavy precipitation; and in the road slipperiness variable,

TABLE 4-12

ROADWAY LANE CONFIGURATION
FOR SPEED-RELATED ACCIDENTS AND
FOR ALL ACCIDENTS IN THE CPIR FILE

	1-Lane	2-Lane	3-Lane	≥ 4 Lanes	≥ 4 Lanes & Divided	Other
Speeding N = 1,091	0.6	53.2	1.8	16.1	25.6	2.7
Total CPIR N = 9,184	0.6	47.2	3.2	25.3	21.7	1.9

TABLE 4-13

ROAD ALIGNMENT FOR ACCIDENTS
INVOLVING SPEEDING VIOLATIONS AND
FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE, 1976

	Straight-Level	Curves, Hill, or Both
Speeding over the limit N = 953	78.5%	21.5%
Speeding too fast for conditions N = 4,318	91.5%	8.4%
Either speeding violation N = 5,271	89.1%	10.9%
Total 1976 Texas 5% Sample N = 23,257	95.0%	5.0%

TABLE 4-14

HORIZONTAL ROAD ALIGNMENT
OF SPEEDING ACCIDENTS
COMPARED WITH TOTAL CPIR FILE

	Straight	Curve
Speeding N = 1,090	61.1	38.9
Total CPIR N = 9,184	80.6	19.4

TABLE 4-15

VERTICAL ROAD ALIGNMENT OF SPEEDING ACCIDENTS COMPARED WITH TOTAL CPIR FILE

	Level	Hill-Related
Speeding N = 1,091	63.1	36.9
Total CPIR N = 8,892	73.6	26.4

TABLE 4-16

PRECIPITATION STATUS FOR SPEEDING ACCIDENTS COMPARED WITH TOTAL CPIR FILE

	Rain	Snow	None
Speeding N = 1,371	16.7%	9.6%	73.7%
Total CPIR File N = 8,979	13.4%	5.6%	81.0%

where most speeding accidents occur under "not slippery" conditions but are overrepresented substantially among those occurring on "surface slippery" conditions. While the CPIR file does not distinguish between "too fast for conditions" and "over-limit" behaviors, it is likely that precipitation is particularly relevant to the former.

In summary, accidents involving a "speeding too fast" UDA generally involve low levels of damage and injury but, on average, are more serious in terms of both than are accidents generally. Although the speeding UDA is a causal factor in substantial portions of both single- and multiple-vehicle accidents, single-vehicle accidents are considerably overrepresented among the speed-caused accidents. Although right-angle and oblique-type (intersection) collisions comprised the largest share of speeding-caused accidents in the CPIR file, speeding is most overrepresented among sideswipe and rear-end collisions. Young drivers (ages twenty-four and under) and males are the most overrepresented in accidents, and also constitute the largest group of "speed-involved" drivers.

In the files examined, while the largest proportion of accidents occurred on city streets and two-lane roads, accidents occurring on county and state secondary roads were the most overrepresented among those caused by speeding. Accidents occurring on interstates were also somewhat overrepresented.

And, while most of the speed-caused accidents occurred on straight, level, and dry roads, accidents occurring on curves, hills, and during rain or snow were overrepresented among those caused by speeding.

DRIVER CONSCIOUSNESS OF UDA COMMISSION

Reasons for commission of the speed-related UDA were investigated through the review of CPIR cases (Figure 4-1). Forty-four cases judged as being "caused by" a speeding UDA were evaluated.

It was found that in the vast majority of cases, speeding too fast was a conscious, intentionally undertaken behavior. In a minority of cases, "impairment," principally by alcohol, was judged responsible. This held true for both the "over limit" and "too fast for condition" cases.

Of twenty-nine cases where the "speed over limit" UDA was judged causally involved, twenty-three (79%) were judged conscious and intentional, while the remaining six cases involved "impairment." Of twelve "too fast for conditions" caused cases, eleven were judged conscious and intentional, while the remaining one involved "impairment." **Altogether, in eighty-three percent (thirty-four of forty-one) of the "speed too fast" caused accidents, UDA commission was judged to have been conscious and intentional.** The drivers were impaired in each of the remaining cases.

Lack of an adequate number of "speed too slow" cases precludes any comparable assessment of them. However, in all three of the CPIR cases examined in which speed too slow was judged a cause, it appeared to have been consciously undertaken.

SUMMARY

Speed-related UDAs were defined as being either **absolute** or **relative**--the former being defined relative to properly established maximum or minimum limits and the latter relative to the actual speed of the traffic flow. Both "too fast" and "too slow" conditions were considered.

A speed-too-fast UDA was indicated to be causally involved in about sixteen to twenty-three percent of reported accidents, and some thirty to thirty-five percent of fatal accidents. Both over-design-speed/limit and too-fast-for-conditions aspects are involved, and merit equally serious attention. Although existing accident files do not provide comparable incidence data, other data indicate the speed-too-slow UDA to be a causal factor in ten percent or more of all accidents.

Accidents involving the speed-too-fast UDAs usually involved low levels of damage and injury but, on the average, were more serious in terms of both than are accidents generally. Involvement is similar in both single- and multiple-vehicle accidents, but single-vehicle accidents are considerably overrepresented. Although intersection-type configurations predominated in the CPIR file, speeding is most overrepresented among sideswipe and rear-end collisions. Most drivers committing speed-related UDAs were under twenty-four-years old and most were male; these groups were also substantially overrepresented.

These accidents most often occurred on city streets and on roads having two lanes, but were most overrepresented on county and state secondary roads. Accidents occurring on interstates were somewhat overrepresented. While most speed-caused accidents occurred on straight, level, and dry roads accidents occurring on curves, hills, and during rain or snow were overrepresented.

In the majority (83%) of in-depth accident reports reviewed, the speed-too-fast UDA was concluded to be a conscious, intentionally undertaken behavior. In a minority of cases, impairment, principally by alcohol, was judged responsible. This held true for both over-limit and too-fast-for-conditions situations.

CHAPTER FIVE
DEFINING FOLLOWING TOO CLOSELY

This chapter examines the following-too-closely (FTC) UDA, as defined broadly in Chapter Two. Results of a review of in-depth case reports drawn from the CPIR and Indiana Tri-Level Study files are integrated with information drawn from other files and relevant literature.

DISCUSSION OF FTC DEFINITION

A preliminary definition of the FTC UDA was developed in Chapter Two:

> The FTC UDA is the act of driving a vehicle following another vehicle such that the time separation between the two vehicles is so short as to create a societally unacceptable level of crash risk.

"Following" was defined as driving about the same speed as a lead vehicle when both vehicles are in the same traffic lane. "Time separation" was defined to include a component due to the reaction time of the following driver, and another due to the difference in braking capacity between the two vehicles.

Time separation can potentially influence societal risk within the highway transportation system in a number of ways. For example, maintenance of completely adequate separations during rush hour traffic on major metropolitan freeways might promote excessive lane changing and unsafe "cut-in" behavior; and, on a national scale, as a consequence of reduced roadway volume, could cause a diversion of traffic from freeways to other more dangerous kinds of roads.

However, information is not available to document or quantify such potential effects or their relation to following distance at this juncture. Accordingly, the definition assumes "time separation" to have relevance primarily in terms of vehicle braking distance; that is, that a vehicle is following another too closely if, given a sudden maximum braking effort by the lead vehicle, the separation is not adequate to provide for the driver of the following vehicle to react to the lead vehicle's braking action and come to a stop *without striking the lead vehicle.* Components of the definition are shown in Table 5-1.

It is proposed that a standard reaction time be assumed based on the appropriate literature. While a conservative value is suggested (e.g., a ninety-fifth percentile BRT of one and a half seconds), no allowance is made for gross inattention that might delay perception of the lead vehicle's braking and thereby extend actual reaction time--even though a substantial level of such inattention can be expected (Zaidel, Paalberg, and Shinar 1978). The preliminary definition of FTC thus describes the minimum definition that could be "safe," but not necessarily one that, on the average, actually is. This definition leads to a separate identification of inattention-caused accidents, where stopping is physically possible but does not occur due to the driver's excessive delay in perception or response to lead vehicle braking. A similar concept of FTC was used in the Indiana Tri-Level Study, as mentioned in Chapter Two.

Other data files (e.g., Texas Five Percent File), on the other hand, may either implicitly or explicitly include a number of the latter types of FTC cases--that is, those involving an excessive delay in response—under the FTC heading (see Table 5-1). In effect, this interpretation assumes that a safe following distance is one that allows for a reasonably high level of driver inattention (i.e., a considerably extended reaction time). Such files can be expected to report a higher proportion of FTC. Thus, the Texas File reports a greater frequency of FTC involvement than did Indiana.

Since drivers are not continuously attentive with respect to vehicles they are following, it is likely that following distance does influence risk well beyond the range defined by brake reaction time, plus stopping distance. However, there are not adequate data to support other than an arbitrary extension of reaction time to account for such inattention, and this is not consistent with the need for an objective measure. Accordingly, the BRT-based reaction time assumption is maintained. In

TABLE 5-1

ALTERNATE CONNOTATIONS OF "FOLLOWING TOO CLOSELY" DEFINITION

Preliminary FTC/UDA Definition	Narrow FTC Interpretation	Broad FTC Interpretation
	• Indiana Tri-Level Study • Manual CPIR & Indiana Case Review • Proposed UDA	• Texas 5% File • CPIR Case File • National Safety Council Data
Driving a Vehicle Following Another Vehicle	• Same Lane, and • About Same Speed	(Probably about same as narrow definition)
Such that the time separation between the two vehicles is so short as to create a societally unacceptable level of crash risk	Too Short to Allow for: • Reaction (e.g., 95th percentile BRT) • Stopping (e.g., assuming standard rate for vehicle classes and road surface conditions) Short of collision with lead vehicle	Too Short to Allow for: • Recognition that lead vehicle is stopped or slowing (e.g., by an inattentive or distracted driver); • Reaction Time; • Stopping
Implications:	Places "vehicle following" collisions that involve delays in response, e.g., as a consequence of inattention or distraction, under other UDA or error categories. Results in more conservative estimates of FTC involvement	Includes "delayed response" collisions under FTC heading. Most "car following" collisions will tend to be included. Results in greater reported involvement of FTC in accidents.

another study being conducted to assess the risks of UDAs (contract no. DOT-HS-8-02023), an attempt will be made to define the actual relationship of time separation to risk under varying circumstances. Note that the reaction time parameter is not a part of the basic definition, but is only a preliminary decision rule for deciding if the following distance is unsafe. This is needed, for example, before cases involving FTC behavior can be identified in existing data files for manual review.

The braking distance component is assumed to be standard within vehicle classes (e.g., dry, wet, snow, ice). Thus, for a given speed and road surface condition, the minimum "safe" following distance is defined as a function of lead and following vehicle class (reflecting differences in average braking performance). This assumption is necessary because actual vehicle stopping capacity in each accident would be difficult and expensive to determine. It is potentially affected by prior brake usage (influencing friction surface temperature), and manner and force of brake application. Postcrash testing to determine such precrash conditions is often precluded by accident damage.

The differences in interpretation indicated in Table 5-1 are both accommodated by the preliminary FTC definition. Thus, while the interpretation chosen for purposes of case review does influence the cases selected and the frequency of involvement reported, the criteria can be altered in the future without any change in the basic definition. The analysis of accidents, exposure, and other evaluative information will permit a better understanding of the relationship between following distance and risk under different circumstances and will thereby provide a basis for future revisions.

ACCIDENTS SELECTED FOR REVIEW

Both the CPIR file and HSRI's Indiana Tri-Level study case report files were used for the FTC and review assessment (Figures 5-1 and 5-2).

For the CPIR file, variable five, team number was used to select a subset of cases that provide full documentation of the precrash phase and are thus suitable for review. A total of 4,896 driver and vehicle cases representing approximately 4,080 accidents were selected in this manner

FIGURE 5-1

TAXONOMIC SUMMARY OF
CPIR FTC CASES EXAMINED

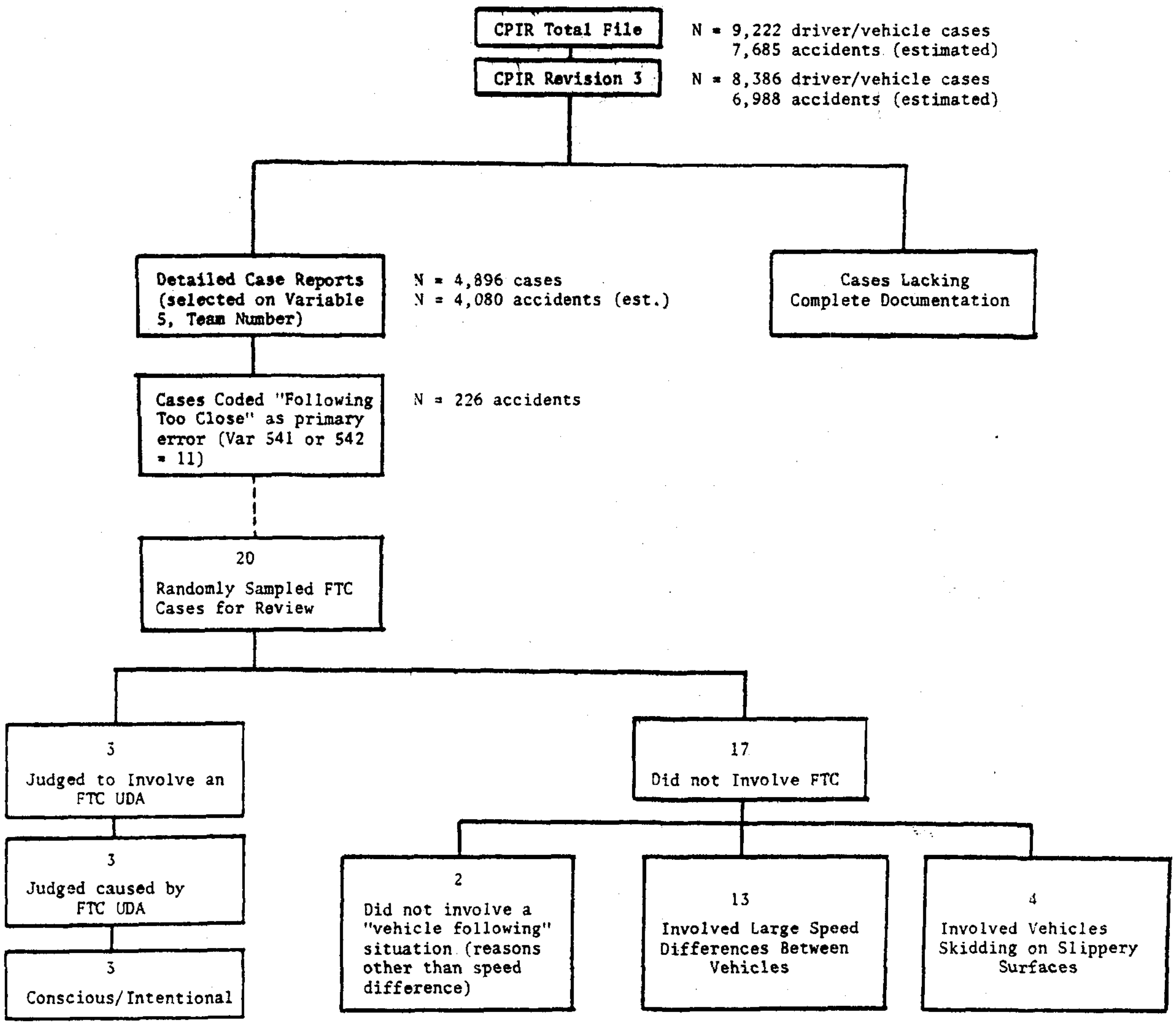
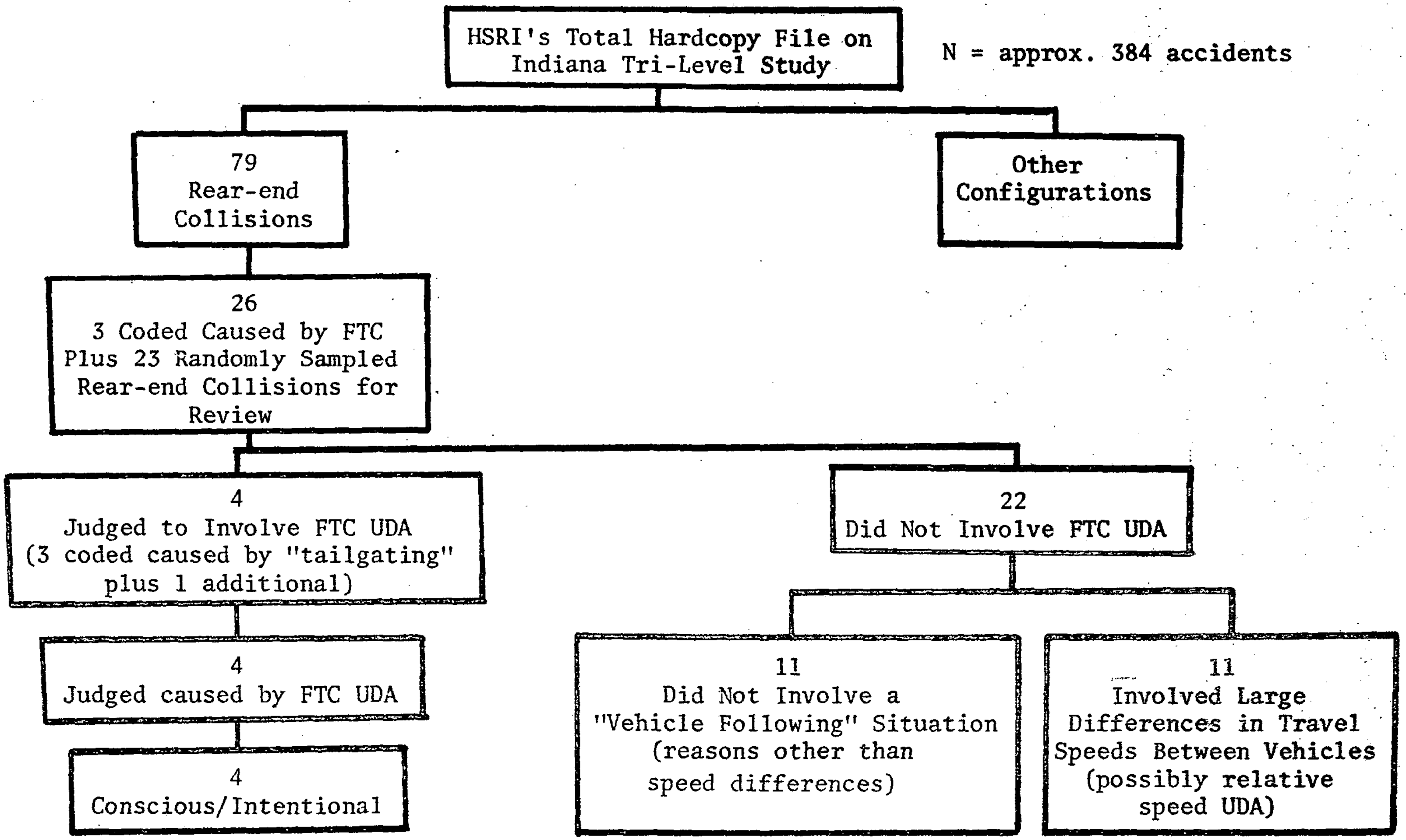


FIGURE 5-2

TAXONOMIC SUMMARY OF INDIANA FTC CASES EXAMINED



from the total CPIR file. From these, cases for which the most responsible drivers primary errors were coded "following too closely" (i.e., variable 541 and 542 equalled 11) were filtered out for possible review; a total of 226 accidents were identified. From these, a random sample of twenty reports was selected and reviewed by the team of human factors specialists.

Another group of cases was drawn from HSRI's hard copy file of approximately 384 Indiana Tri-Level accident reports. From these, the rear-end collision configuration descriptor was used to filter out 79 potential FTC cases. Because the Indiana FTC definition was narrow in scope, it was thought that examination of these rear-end collision cases would provide an opportunity to evaluate the feasibility of discriminating FTC from nonincluded rear-end accidents occurring under otherwise similar circumstances. From these 79 rear-end collisions, 26 cases were selected for review; these included 3 cases coded as caused by FTC, plus an additional 23 randomly sampled cases. Thus, a total of 46 CPIR and Indiana cases were reviewed.

INCIDENCE OF FTC UDAs

Results of Review of Accident Reports

As shown in Figure 5-1, under the narrow interpretation of the FTC definition used for this review, it was concluded that most of the twenty CPIR cases actually did not involve the FTC UDA. Only three of the twenty were judged to involve the UDA, as defined. All three were concluded to involve the UDA in a causal relationship, and to be the result of a conscious, intentional behavior.

Of the remaining seventeen cases concluded not to involve the FTC UDA as defined, the largest group (eleven accidents) involved large speed differences between vehicles (e.g., as where one vehicle is stopped waiting to make a left turn and is struck from the rear by another vehicle). Another four cases involved vehicles that skidded on slippery surfaces (but had not been following too closely within the definition provided), while the remaining two did not involve a vehicle-following situation.

The review thus served primarily to point up the magnitude and nature of the disparity between the narrow and broad connotations of FTC in various files.

For the most part, the review team concurred in the judgment of the Indiana team as to the occurrence or nonoccurrence of FTC (narrowly defined) among these twenty-six rear-end collisions. All three cases coded as caused by FTC under the Indiana definition were agreed to also be FTC under the proposed UDA definition. One additional case among the twenty-three randomly sampled was judged by the reviewers to involve the FTC UDA, for a total of four accidents (Figure 5-2). All four of these accidents were also evaluated to be caused by the FTC, and to have been the result of a conscious, intentional behavior on the part of the driver.

The remaining twenty-two accidents judged not to involve the FTC UDA were evenly divided between those where there were large precrash differences in travel speeds between vehicles (eleven accidents), and those that did not involve a vehicle-following situation for reasons other than a speed difference (eleven accidents).

In general, the Indiana interpretation of FTC was concluded to be similar to that employed by the review team under the proposed FTC UDA definition, with the review team possibly applying FTC slightly more broadly than did Indiana. Results for FTC incidents were as follows:

- CPIR cases reviewed: FTC caused 3 accidents out of 20 read and was judged the result of conscious choice in all three; **this corresponds to 34 out of 4,080 total accidents (0.8%).**

- Indiana cases reviewed: FTC caused all 3 FTC-coded cases, plus one additional case out of 23 cases read (all 4 judged consciously committed); **this corresponds to about 6 or 7 out of 384 total accidents (1.7%).**

Thus, narrowly defined, it appears that the FTC UDA may be a cause in perhaps one to two percent of reported accidents in the files examined.

Summary of Incidence Data for the FTC UDA

Table 5-2 summarizes data reflecting the frequency of involvement of FTC as reported by various accident data files. While no specific definition of "involvement" is provided for some of these files, and the intended meaning may vary somewhat from file to file, there is believed to be a substantial degree of similarity in meaning. In general, these data are intended to reflect frequency of causal involvement rather than mere presence.

Under the narrow FTC definition, estimates of involvement among accidents of all severities range from 0.8% (CPIR manual review) to 2.1% (Indiana Tri-Level Study final report, possible cause level). The CPIR manual review and Indiana probable-cause data are in the narrow range of 0.8 to 1.2%.

Under the broader FTC definition surmised to be used in coding many accident reports, estimates of FTC involvement ranged from 5.8% (total CPIR file as coded) to 12.3% (Texas Five Percent Sample for 1975).

Note that within the Texas Five Percent Sample files, the incidence of FTC violation has steadily decreased from 12.3% in 1975, to 10.1% in 1976 and 8.5% in 1977. The samples are sufficiently large here (over 20,000 accidents within each year) to assure that this represents a real change in either the nature of accidents or their coding by Texas authorities. Note that the Texas data for 1977 report an incidence about the same as that reported by the National Safety Council for the same year, based on data from forty-one cities and eleven states.

Where only fatal accidents are concerned, the proportion attributable to FTC is considerably less—in the range of one percent—even under the broader definition. Consequently, while data on fatal accidents for the narrow FTC UDA definition are not available, it is likely to be considerably less than one percent of accidents. It appears that compared to the other UDAs examined, FTC is associated with a lower level of accident severity. FTC tends to result in involvement in the rear-end collision configuration, where both vehicles are moving in the same direction. Damage and injury sustained therefore tends to be somewhat less than in other configurations.

TABLE 5-2

FREQUENCY OF INVOLVEMENT OF FOLLOWING TOO CLOSELY (FTC)
AS A CAUSAL FACTOR IN TRAFFIC ACCIDENTS

Accident Severity	Narrow FTC Definition (similar to proposed UDA definition)	Surmised Broader FTC Definition (common to mass data files)
All Severities	• CPIR Manual Review[1]: .8% • Indiana Tri-Level Study[2] Final Report, cert./prob./poss. cause - In-depth Team (N = 420 acc.): .2/1.2/2.1% - Technican Teams (N = 2,258 acc.): .5/1.1/1.6% • Manual Review of Indiana[3] Tri-Level (In-depth) cases (N = 384 acc.): 1.7%	• Total CPIR File[4] (N = 7,685 acc.); FTC coded as a "primary error": 5.8% • Texas 5% Sample Files[5] - 1975 (N = 22,676 acc.): 12.3% - 1976 (N = 23,257 acc.): 10.1% - 1977 (N = 24,448 acc.): 8.5% • Accident Facts, 1977[6] Data (41 cities, 11 states): 8.6%
Fatal Accidents Only	(Data not available)	• Total CPIR File (N = 891 Fatal acc.): .6% FTC coded as a "primary error": • Texas 5% Sample Files - 1975 (186 acc.): .7% - 1976 (158 acc.): .5% - 1977 (177 acc.): .5% • Accident Facts, 1977 (41 cities, 11 states): .8% o Fatal Accident Reporting System[7] (FARS; 1976 data: 1.3% (vehicles)

Sources: 1 - Based on manual review of cases from HSRI's Collision Performance and Injury Report (CPIR) File of MDAI reports.
2 - Tri-Level Study of the Causes of Traffic Accidents, Final Report. Volume I, Appendix A, pg. A-20, March 1977.
3 - Based on manual review of HSRI's file of Indiana Tri-Level Study reports.
4 - Entire CPIR file based on CPIR Revision 3 Codebook dated November 1978.
5 - HSRI's random sample files of police-reported accidents in Texas for 1975, 1976, and 1977.
6 and 7 - Reported in Accident Facts 1978, National Safety Council, Chicago, 1978, pg. 48.

In summary, under the proposed (narrow) definition of the FTC UDA, the behavior described appears to be involved in only about one percent of all accidents, and is probably involved in a considerably smaller proportion of serious and fatal accidents.

CIRCUMSTANCES OF FTC OCCURRENCE

The present subsection identifies various accident, driver, and environmental characteristics associated with the involvement of FTC as an accident cause. These results, which are summarized in Table 5-3, are based primarily on automated analyses of the full CPIR file and the Texas Five Percent Sample file for 1976. Distributions of accidents involving FTC in each file were compared with distributions for all accidents in each file, across the various categories of descriptors. In the CPIR file, the most-responsible-driver's-primary-errors variable and following-too-closely response were used for this purpose. For the Texas file, the driver violation of following too closely reponse was used. Note that earlier in this section we concluded that most of the FTC accidents identified in this manner actually do not involve FTC as we have defined it. However, the files were not set up to access FTC as we have defined it, nor would the numbers of FTC accidents obtained be adequate for this purpose. Accordingly, the FTC descriptors used are only rough surrogates for the FTC UDA behavior we have defined. However, we have no reason to suspect that the circumstances of the near-FTC's involvement would be radically different from that of the FTC UDA.

As shown in Table 5-4, accidents in the Texas file involving FTC are generally minor (damage categories one and two total eighty-nine percent of all FTC accidents), and both no-damage and minor-damage categories are considerably overrepresented. Thus, on the average, accidents involving FTC tend to be less severe in terms of vehicle damage, than are reported accidents generally.

As shown in Table 5-5, the vast majority (86.3%) of FTC accidents in the Texas file involve no injury, and this category is also somewhat overrepresented with respect to all reported accidents. Fatal and A and B injury categories are correspondingly underrepresented.

TABLE 5-3

SUMMARY OF LARGEST AND MOST OVERREPRESENTED CATEGORIES OF DESCRIPTIONS FOR ACCIDENTS INVOLVING THE FOLLOWING-TOO-CLOSELY (FTC) UDA

Table No.	Description	Largest Category(s) (involving FTC)	Most Overrepresented FTC Category(s)
5-4	Severity-Damage (Texas 5%)	Minor Damage (levels 1 and 2 total 89%)	No Damage and Minor Damage (levels 1 and 2)
5-5	Severity-Injury (Texas 5%)	No Injury (86%)	No Injury
5-6	Severity-Injury (CPIR)	Minor Injury (62%)	No Injury, Minor Injury
5-7	Single versus Multiple Vehicle (CPIR and Texas 5%)	Multiple (Texas, 100%; CPIR, 95%)	Multiple
5-8	Configuration (CPIR)	Rear-end (92%)	Rear-end
5-9	Driver age (Texas 5%)	Ages 15 to 34 total (69%)	15 to 19, 20 to 24 years
5-10	Driver Sex (Texas 5%)	Male (68%)	(None)
5-11	Roadway Class (Texas 5%)	City Streets (43%) U.S. and State Turnpike (34%)	Interstate and Turnpike, U.S. and State Turnpike
5-12	Roadway Lane Configuration (CPIR)	4 + Lanes (35%) 4 + Divided (31%)	4 + Lanes and 4 + Divided
5-13	Road Alignment (Texas 5%)	Straight-Level (98%)	Straight-Level (slight overrepresented)
5-14	Road Alignment (CPIR)	Straight (90%)	Straight
5-15	Road Alignment (CPIR)	Level (75%)	(None)
5-16	Precipitation	No Precipitation (75%)	Rain

Source: See Table 4-4

TABLE 5-4

PROPERTY DAMAGE LEVELS IN TEXAS FTC AND TOTAL FIVE PERCENT SAMPLE CASES

	No Damage	Minor Damage						Very Severe Damage
	0	1	2	3	4	5	6	7
FTC N = 2,273	4.0%	46.7%	42.9%	16.2%	2.8%	.4%	.1%	.04%
Total Texas 1976 5% Sample N = 33,096	2.6%	40.1%	28.9%	18.5%	5.7%	2.2%	1.2%	.9%

TABLE 5-5

INJURY SEVERITY IN TAXES FTC AND ALL FIVE PERCENT SAMPLE ACCIDENTS

	No Injury	"C" Injury	"B" Injury	"A" Injury	Fatal
FTC N = 2,728	86.3%	8.9%	4.2%	.6%	0%
Texas 1976 5% Sample N = 23,257	79.3%	7.5%	9.6%	3.1%	.5%

Table 5-6 reflects a similar trend in the CPIR data, where 62.3% of all FTC accidents involve minor injury, and both the no-injury and minor-injury categories are substantially overrepresented.

As would be expected, nearly all FTC accidents involve multiple vehicles, and the multiple vehicle category is overrepresented (Table 5-7). This is true for both the CPIR and Texas files.

As shown in Table 5-8, most FTC accidents in the CPIR file are of the rear-end configuration (92%), and this category is seriously overrepresented. However, as noted previously, it is believed that the CPIR and some other files often categorize rear-end accidents as being caused by FTC, which might instead be attributed to other causes (e.g., relative speed UDA, delays in perception or comprehension). In testing this possibility, the proportion of rear-end (RE) collision coded as involving FTC was examined in several files. Results were as follows:

- Texas Five Percent File, 1976; 51% of REs coded FTC
- CPIR; 26% of REs coded FTC
- Indiana Tri-Level Files; 5.1% of REs coded FTC (certain, probable, or possible).

The Indiana FTC definition, similar to the proposed FTC UDA definition, can be seen to have applied to a much smaller proportion of rear-end collisions than did the (apparently much broader) Texas FTC violation.

However, even if assessed properly in terms of our proposed definition, it is expected that the majority of FTC accidents would be of the rear-end configuration.

In terms of driver age, Table 5-9 indicates that most FTC drivers are in the fifteen to thirty-four year age range, with the fifteen to nineteen, twenty to twenty-four, and twenty-five to thirty-four increments about equally populated. However, this UDA is most overrepresented within the fifteen to nineteen years of age category, and is also somewhat overrepresented for drivers twenty to twenty-four. It is underrepresented among remaining age categories. FTC is thus indicated to be primarily a

TABLE 5-6

MAXIMUM CASE VEHICLE INJURY SEVERITY FOR FTC CASES AND TOTAL CPIR FILE

	None	Minor	Moderate	Severe	Serious	Critical	Fatal
FTC N = 228	20.6%	62.3%	13.6%	2.6%	.4%	0%	.4%
Total CPIR N = 8,940	12.99%	49.7%	17.1%	8.9%	3.1%	4.0%	4.2%

TABLE 5-7

SINGLE- VS. MULTIPLE-VEHICLE ACCIDENT TYPES FOR FTC ACCIDENTS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT, 1976 AND CPIR FILES

	Single	Multiple
Texas FTC N = 2,728	0%	100%
All Texas 5% Accidents N = 23,256	26.0%	74.0%
CPIR FTC Accidents N = 231	4.8%	95.2%
Total CPIR N = 9,219	28.0%	72.0%

TABLE 5-8

COLLISION CONFIGURATIONS OF FTC ACCIDENTS
COMPARED WITH TOTAL CPIR FILE

	Head-on	Intersection L-type	Side-swipe	Rear-end	Intersection T-type
FTC N = 220	2.3%	1.8%	3.2%	91.8%	.9%
Total CPIR N = 6,630	18.6%	30.6%	5.7%	22.3%	22.6%

TABLE 5-9

AGE DISTRIBUTION OF DRIVERS CITED FOR FTC VIOLATIONS AND FOR ALL DRIVERS IN THE TEXAS FIVE PERCENT FILE FOR 1976

Driver Age Category	Texas FTC Sample N = 2,442	Total Texas 5% Sample N = 37,469
10-14	0%	.4%
15-19	21.1%	16.8%
20-24	23.8%	20.5%
25-34	23.9%	24.8%
35-44	12.1%	12.8%
45-54	8.9%	10.8%
55-64	6.4%	7.4%
65-74	2.7%	4.7%
75 +	1.0%	2.0%

problem among young drivers (nearly seventy percent being thirty-four years or younger), and to be a relatively greater problem within this age group than for older drivers. FTC thus joins speeding as a UDA for which the young driver is an appropriate target.

As for accidents generally, Table 5-10 indicates the majority of FTC drivers to be male, although neither sex is overrepresented among accidents involving the FTC behavior. Thus, although males are a possible target due to their greater overall involvement in accidents, they are indicated to be neither more nor less likely than females to be involved in an accident by reason for FTC.

As shown in Table 5-11, accidents involving FTC in the Texas file, like all accidents in the file, occur most frequently on city streets and on U.S. and state trunk lines, but are most overrepresented on interstates and turnpikes and on U.S. and state trunk lines. Thus, city streets are an attractive target for UDA owing to frequency of involvement even though an accident occurring on such streets is less likely to be FTC-caused than an accident generally, according to the Texas data. In relative terms the FTC UDA would appear to be a particular problem in the interstate highway setting, inasmuch as this type of roadway is overrepresented by a factor of 1.8 among accidents coded FTC in the Texas file.

In terms of roadway lane configuration (Table 5-12), the largest proportion of FTC accidents occurred on four-lane nondivided (34.6%) and divided (31.1%) roads, and these roads were also overrepresented among FTC accidents in the CPIR file. In comparison with all accidents in the CPIR file the most noticeable difference is the underrepresentation of FTC in accidents occurring on two-lane roads.

As shown in Table 5-13, in the Texas data nearly all FTC accidents (98%) occurred on straight and level roads as opposed to curves or hills or both. This represents a slight overrepresentation as compared to the total file.

In terms of horizontal alignment only, in the CPIR data nearly all FTC accidents (90.4%) occurred on straight rather than curved roads, and this represented a slight overrepresentation as compared to the total file (Table 5-14).

TABLE 5-10

SEX OF DRIVERS CITED FOR FTC VIOLATIONS FOR ALL DRIVERS IN TEXAS FIVE PERCENT FILE IN 1976

	Male	Female
FTC N = 2,561	68.2%	31.8%
All Texas 5% Sample N = 38,344	66.8%	33.2%

TABLE 5-12

ROADWAY LANE CONFIGURATION FOR FTC ACCIDENTS
AND FOR TOTAL CPIR FILE

	1-lane	2-lane	3-lane	4+lane	Divided	Other Nonroad
FTC N = 231	1.7%	28.1%	3.0%	34.6%	31.1%	1.3%
Total CPIR N = 9,184	.6%	47.2%	3.2%	25.3%	21.7%	1.9%

TABLE 5-13

ROAD ALIGNMENT FOR ACCIDENTS INVOLVING FTC VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE, 1976

	Straight-Level	Curves, Hill, or Both
FTC N = 2,728	98.0%	2.0%
Total Texas 5% Sample N = 23,257	95.0%	5.0%

TABLE 5-14

HORIZONTAL ROAD ALIGNMENT OF FTC ACCIDENTS
COMPARED WITH TOTAL CPIR FILE

	Straight	Curve
FTC N = 230	90.4%	9.6%
Total CPIR N = 9,184	80.6%	19.4%

For vertical alignment, however, although most FTC-caused accidents occurred on level as opposed to hilly roads (75.2%), this was little different than for CPIR accidents generally (Table 5-15).

While most FTC accidents (75%) occurred under conditions of no precipitation, the proportion occurring under conditions of rainfall is substantially greater than expected based on the total CPIR file (Table 5-16).

The above data suggest that the FTC UDA tends to involve rear-end collisions on straight, level, multilane (four lanes and over), divided, and nondivided highways. These accidents are generally minor; multivehicle; involve drivers fifteen to thirty-four (and particularly overrepresent drivers fifteen to twenty-four); and involve more males than females, but no more so than accidents generally. Although the largest roadway category in the Texas data was city streets (43%), interstate highways and U.S. and state trunkline highways were overrepresented among FTC-caused accidents. In the CPIR file, most FTC accidents occurred on roads having four lanes and over.

DRIVER CONSCIOUSNESS OF UDA COMMISSION AND IMPLICATIONS FOR ITS DEVELOPMENT

Reasons for commission of the FTC UDA were investigated through the review of CPIR and Indiana cases (Figures 5-1 and 5-2).

Since only seven FTC UDA-caused accidents were ultimately identified among the forty-six total CPIR and Indiana cases reviewed, statistically reliable conclusions are not possible. However, each of the seven FTC cases was judged to result from conscious driver actions.

SUMMARY

FTC was defined in terms of the time separation between vehicles. Under the proposed definition FTC appears to be involved in only about one percent of all accidents and is probably involved in a considerably smaller proportion of serious and fatal accidents.

FTC tends to be involved in rear-end-type collisions that occur on

TABLE 5-15

VERTICAL ROAD ALIGNMENT OF FTC ACCIDENTS COMPARED WITH TOTAL CPIR FILE

	Level	Hill-related
FTC N = 226	75.2%	24.8%
Total CPIR N = 8,892	73.6%	26.4%

TABLE 5-16

PRECIPITATION STATUS FOR FTC ACCIDENTS
COMPARED WITH TOTAL CPIR FILE

	Rain	Snow	None
FTC N = 220	19.1%	5.7%	75.2%
Total CPIR N = 8,979	13.4%	5.6%	81.0%

straight, level, multilane (four lanes and over) highways, both divided and nondivided. These accidents are generally minor; multivehicle; involve drivers fifteen to thirty-four years old (and particularly overrepresent drivers fifteen to twenty-four); and involve more males than females, but to no greater degree than do accidents generally. Although the largest roadway category in the Texas data was city streets (43%), interstate highways and U.S. and state trunkline highways were overrepresented among FTC-caused accidents. In the CPIR file, most FTC accidents occurred on roads having four lanes and over.

Although the number of FTC-caused accident reports reviewed was insufficient to support any firm conclusions as to reasons for commission, the fact that FTC was concluded to be a conscious action in each is encouraging for the notion that FTC may often be a conscious and intentionally undertaken behavior.

CHAPTER SIX
DEFINING DRIVING LEFT OF CENTER

This section examines in additional detail the driving-left-of-center (DLOC) UDA, as broadly defined in Chapter Two. Results of a manual review of in-depth case reports drawn from both the CPIR and Indiana Tri-Level Study files are integrated with information drawn from other files and relevant literature.

DISCUSSION OF DLOC DEFINITION

A preliminary definition of the DLOC UDA was developed in Chapter Two:

> The DLOC UDA is the act of driving a vehicle over or on the center line of a two-way road when not passing or turning.

The DLOC definition differs from those for the speed and FTC UDAs in being limited to a particular class of roads. Where possible, two subcategories of DLOC will be examined: DLOC on a straight segment and DLOC on a curve.

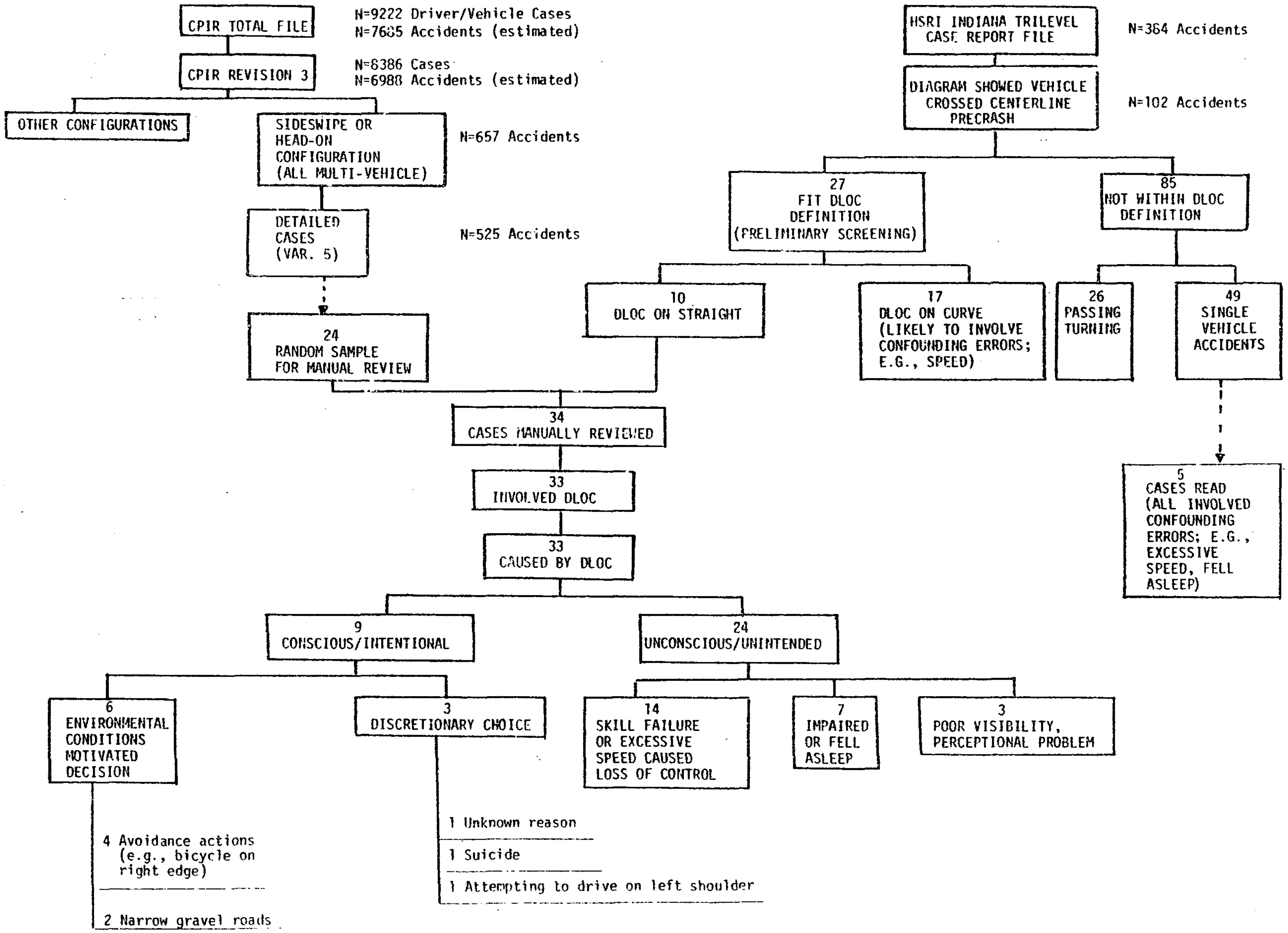
ACCIDENT SELECTION FOR REVIEW

As illustrated in Figure 6-1, HSRI's CPIR and Indiana Tri-Level Study files were accessed to obtain DLOC cases for review.

For the CPIR file, variable 59, vehicle to vehicle configuration, was used to filter out all head-on and sideswipe collisions (values 03 and 05). From these, variable 5, team number, was again used to filter out cases suitably documented for review purposes; a total of 525 head-on and sideswipe accidents were identified in this way. From these, 24 were randomly selected for review by the assessment team.

Added to these were cases from HSRI's file of 384 Indiana Tri-Level Study case reports, spanning Indiana's Vehicle Defects and Traffic

FIGURE 6-1: TAXONOMIC SUMMARY OF CPIR AND INDIANA DLOC CASES EXAMINED



Accident Causation studies. In order to identify DLOC cases, all 384 collision diagrams were examined. One hundred and two accidents were identified in which at least one vehicle crossed the center line prior to collision. These cases were screened to assess which appeared to involve DLOC as defined. Twenty-seven were within the definition and eighty-five were not. Of the eighty-five judged not to be within DLOC, twenty-six involved passing or turning, and thus were specifically excluded from DLOC. The remaining forty-nine were single-vehicle accidents, and it was judged that nearly all would involve errors other than conscious DLOC (e.g., vehicle defects, excessive speed, impairment, falling asleep, skill failures). Five such cases were randomly selected and read, and in each this assumption held true.

Of the twenty-seven Indiana cases that fit the DLOC definition, seventeen occurred on curved segments and the remaining ten on straight segments. On the assumption that the curved-segment-DLOC cases would overrepresent nonintentional DLOC (e.g., excessive speed or skill failures), only the ten DLOC-on-straight cases in the Indiana file were selected for detailed review. Ten Indiana and twenty-four CPIR cases were reviewed, or a total of thirty-four.

INCIDENCE OF THE DLOC UDA

Results of Review of Accident Reports

Of the thirty-four cases reviewed (Figure 6-1), all but one CPIR case was concluded to involve and be caused by DLOC as defined. Of these thirty-three, nine (27%) were concluded to be conscious and intentional, while the remaining twenty-four (73%) were judged not consciously or intentionally undertaken.

Of the nine cases (conscious DLOC), six involved drivers who drove left of center intentionally as a consequence of environmental conditions (e.g., to avoid a bicyclist on the right edge of the road or to stay near the center of a narrow gravel road). The remaining three cases might be termed conscious and "without good reason" or discretionary, and thus represent the cases for which countermeasures using persuasion or coersion might be effective. However, the circumstances of these cases offer little encouragement. One was a suicide, the reason for the second could not be determined, while the third involved a driver intent on reaching and driving on the left shoulder.

The twenty-four unconscious and unintended DLOC consisted of fourteen accidents in which excessive speed or directional control (skill) problems caused a loss of control; seven in which the driver was alcohol-impaired or fell asleep; and three in which poor visibility led to perceptual problems.

In summary, the incidence of DLOC (both conscious and unconscious) based on the review was as follows:

- Indiana cases:
  - DLOC on straight: 10 of 384 = 2.6% (excludes single-vehicle accidents)
  - DLOC on curve: 17 of 384 = 4.4% (excludes single-vehicle accidents)
  - ALL DLOC UDAs: 27 of 384 = 7.0% (excludes single-vehicle accidents)
- CPIR cases:
  - DLOC in 23 of 24 cases reviewed corresponds to an estimated 552 of 657 head-on and sideswipe accidents, or 552 of the total 6,988 accidents in file (7.9%).

Thus, in both files the incidence of DLOC was about seven to eight percent, excluding single-vehicle accidents. These results are further summarized in Figure 6-2, where it may be seen that **conscious DLOC was indicated to be a cause in only about two percent of these accidents.** Intentional DLOC not compelled by environmental circumstances occurred in **less than one percent of these accidents.**

Summary and Discussion of DLOC Incidence Data

Table 6-1 summarizes data on the frequency of involvement of DLOC as reported by various accident data sources. It can be seen that these estimates vary widely, ranging from 2.4% in the Texas file to 11.3% for

FIGURE 6-2

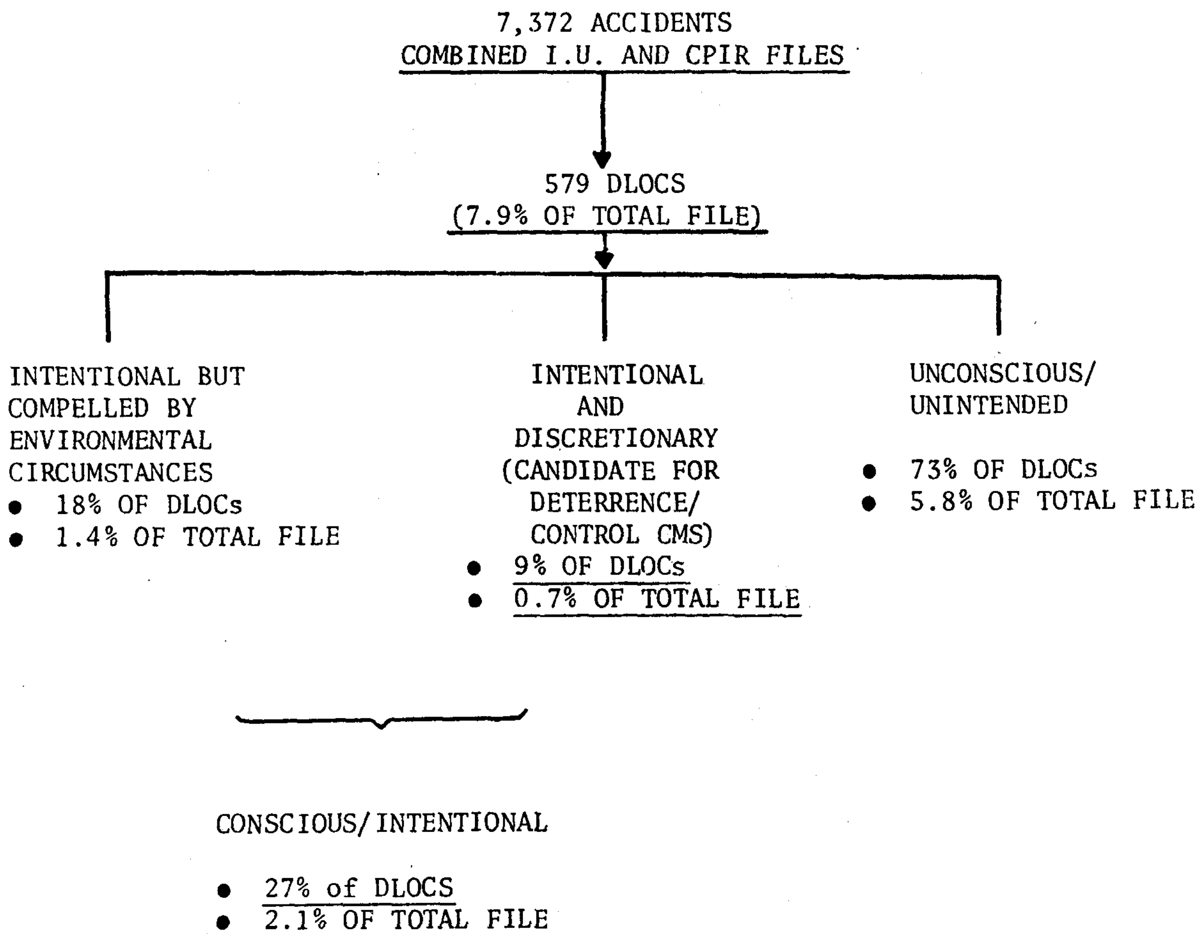

7,372 ACCIDENTS
COMBINED I.U. AND CPIR FILES
579 DLOCS
(7.9% OF TOTAL FILE)
INTENTIONAL BUT COMPELLED BY ENVIRONMENTAL CIRCUMSTANCES
• 18% OF DLOCs
• 1.4% OF TOTAL FILE
INTENTIONAL AND DISCRETIONARY (CANDIDATE FOR DETERRENCE/ CONTROL CMS)
• 9% OF DLOCs
• 0.7% OF TOTAL FILE
UNCONSCIOUS/ UNINTENDED
• 73% OF DLOCs
• 5.8% OF TOTAL FILE
CONSCIOUS/INTENTIONAL
• 27% of DLOCS
• 2.1% OF TOTAL FILE

TABLE 6-1

FREQUENCY OF INVOLVEMENT OF DLOC AS A CAUSAL FACTOR IN TRAFFIC ACCIDENTS

DATA SOURCE	PERCENT OF ACCIDENTS INVOLVING CLOD	COMMENTS
ALL SEVERITIES:		
CPIR MANUAL REVIEW[1] OF HEAD-ON & SIDESWIPE CASES	(552 of 6,988) 7.9%	HEAD-ON AND SIDESWIPES ONLY; EXCLUDES SINGLE VEHICLE ACCIDENTS. FILE BIAS TOWARDS MORE SEVERE ACCIDENTS MAY INCREASE DLOC. INCLUDES BOTH INTENTIONAL DLOC AND DLOC AS CONSEQUENCE OF OTHER ERRORS. EXCLUDES MOST NONCONTACT VEHICLE DLOC.
CPIR TOTAL FILE[2]: MOST RESPONSIBLE DRIVER's PRIMARY ERRORS 1 or 2 CODED "WRONG WAY INTO ONCOMING TRAFFIC"	(PRIMARY ERROR NO. 1 8.6%) (PRIMARY ERROR NO. 2 2.7%) TOTAL DLOC (868 of 7,685) 11.3%	INCLUDES ALL CONFIGURATIONS. FILE BIAS TOWARDS MORE SEVERE ACCIDENTS MAY INCREASE DLOC. INCLUDES INTENTIONAL DLOC AND AS CONSEQUENCE OF OTHER ERRORS. EXCLUDES MOST NONCONTACT VEHICLE DLOCS.
INDIANA TRI-LEVEL STUDY[3]: MANUAL REVIEW OF ALL IN-DEPTH CASES IN WHICH ANY VEHICLE CROSSED CENTER LINE PRECRASH	(DLOC ON CURVE 4.4%) (DLOC ON STRAIGHT 2.6%) TOTAL DLOC (27 of 384) 7.0%	SINGLE VEHICLE ACCIDENTS EXCLUDED; THIS ALSO EXCLUDES NONCONTACT DLOC VEHICLES. INCLUDES BOTH INTENTIONAL DLOC AND DLOC AS CONSEQUENCE OF OTHER ERRORS.
INDIANA TRI-LEVEL STUDY[4]: DLOC COMPOSITE FROM FINAL REPORT (PRESENT REPORT, CHAPTER TWO) IN-DEPTH LEVEL (N = 420)	IN-DEPTH LEVEL (CERTAIN OR PROBABLE) BASIC 4.2% NONCONTACT VEHICLE CAUSED 3.8% TOTAL ABOVE 8.0%	INCLUDES ALL CONFIGURATIONS. THE BASIC DLOC COMPOSITE, DEVELOPED IN SECTION 2, INCLUDES BOTH INTENTIONAL AND SKILL/PERFORMANCE ERRORS. MANY "NONCONTACT VEHICLE CAUSED" ACCIDENTS MAY INVOLVE DLOC, BUT SOME OF THESE MAY BE PASSING.
INDIANA TRI-LEVEL STUDY[4]: DLOC COMPOSITE FROM FINAL REPORT (PRESENT REPORT, CHAPTER TWO) TECHNICIAN LEVEL (N = 2,258)	TECHNICIAN LEVEL (CERTAIN OR PROBABLE) BASIC 3.0% NONCONTACT VEHICLE CAUSED 3.8% TOTAL ABOVE 6.8%	(SAME AS PREVIOUS FILE)
TEXAS FIVE PERCENT FILE 1976[5]: DRIVER VIOLATION CODED "WRONG SIDE, NOT PASSING" (VAR. 117 = 10)	(554 of 23,257) 2.4%	POLICE DATA, ALL CONFIGURATIONS. PROBABLY INCLUDES DLOC AS A CONSEQUENCE OF OTHER ERRORS WHERE DLOC VEHICLE STRIKES ONCOMING VEHICLE. PROBABLY EXCLUDES DLOC NONCONTACT VEHICLES. IT IS LIKELY THAT NOT ALL DLOC ERRORS ARE RECORDED AS VIOLATIONS.
ACCIDENT FACTS, 1978[6]: (POLICE DATA FOR 1977 FROM 41 CITIES AND 11 STATES) IMPROPER DRIVING: "DROVE LEFT OF CENTER"	(RURAL 7.1) (URBAN 2.2) TOTAL DLOC 3.6%	(SAME AS PREVIOUS FILE)

TABLE 6-1 (CON'T)

DATA SOURCE	PERCENT OF ACCIDENTS INVOLVING DLOC	COMMENTS
FATAL ACCIDENTS ONLY:		
CPIR TOTAL FILE[2]: MOST RESPONSIBLE DRIVERS PRIMARY ERRORS 1 OR 2 EACH "WRONG WAY INTO ONGOING TRAFFIC" (VAR. 591 or 542 = 13)	(PRIMARY ERROR NO. 1 17.3%) (PRIMARY ERROR NO. 2 17.7%) TOTAL DLOC (312 of 891) 35.0%	(SEE COMMENTS ABOVE)
TEXAS FATAL FILE 1976[5]: DRIVER VIOLATION CODED "WRONG SIDE, NOT PASSING" (VAR. 117 = 10)	(19 of 158) 12.9%	(SEE COMMENTS ABOVE)
ACCIDENT FACTS, 1978[6]: (POLICE DATA FOR 1977 FROM 41 CITIES AND 11 STATES) IMPROPER DRIVING: "DROVE LEFT OF CENTER"	(RURAL 14.2) (URBAN 3.7) TOTAL DLOC 10.5%	(SEE COMMENTS ABOVE)

SOURCES:

1. BASED ON MANUAL REVIEW OF CASES FROM HSRI'S COLLISION PERFORMANCE AND INJURY REPORT (CPIR) FILE OF MDAI REPORTS: REVIEW CONDUCTED AS A PART OF THIS PROJECT.

2. ENTIRE CPIR FILE, PER CPIR REVISION 3 CODEBOOK, DATED NOVEMBER. 1978.

3. BASED ON MANUAL REVIEW OF CASES FROM HSRI'S FILE OF REPORTS FROM THE TRI-LEVEL STUDIES (VEHICLE DEFECTS AND ACCIDENT CAUSATION) CONDUCTED BY INDIANA UNIVERSITY, 1971-1977.

4. TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS, FINAL REPORT, VOL. I, APPENDIX A, PGS. A-14, 15 16, 23, 24 AND 44, MARCH, 1977.

5. HSRI ACCIDENT DATA SYSTEM CODEBOOK, TEXAS FIVE PERCENT STATE SAMPLE, 1976, DATED OCTOBER 1978. SPECIAL RUNS TO PRODUCE DLOC CODEBOOK AND FATAL ACCIDENT SUMMARY.

6. REPORTED IN ACCIDENT FACTS 1978, NATIONAL SAFETY COUNCIL, CHICAGO, 1978. PG. 48.

the total CPIR file. Factors that may account for some of these differences are indicated in the "Comments" column of Table 6-1.

Incidences of DLOC in the two mass data sources in Table 6-1 (National Safety Council and Texas Five Percent) are in the range of two to four percent. These data are comprehensive in being based on accidents of all configurations and severities, but to the extent that police reports fail to cite all violations and contributing circumstances may understate the incidence of DLOC. They are also unlikely to tabulate instances where a vehicle causes an accident by running left of center, but is not itself involved in the collision; our experience is that such drivers seldom stop following an accident and would not be recorded under violations.

On the other hand, to the extent that the CPIR file is nonrepresentative and biased towards accidents of greater severity than police-reported accidents generally, it would be expected to overstate the involvement of DLOC relative to reported accidents; the 11.3% recorded for DLOC in the total CPIR file is in the same general range reported for fatal accidents by the mass data files.

In terms of the preliminary DLOC UDA definitions, the review of CPIR and Indiana University cases can be expected to provide the best indication of involvement, even though the necessity of developing decision rules to filter out appropriate cases produces opportunity for bias. Specifically, the CPIR review is constrained in being based entirely on head-on and sideswipe accidents, and the procedure for selecting Indiana cases eliminated single-vehicle accidents. While more than ninety percent of DLOC accidents in the Texas and CPIR files are multiple-vehicle, there are other configurations that may involve DLOC (e.g., where a noncontact vehicle causes another vehicle to run off the road, or where a left-of-center vehicle loses control in an effort to avoid an oncoming vehicle). Thus, the 7.9% and 7.0% involvements reported for the CPIR and Indiana case manual reviews, respectively, provide good—but probably conservative—estimates of DLOC involvement. Note also that 73% of the DLOC accidents reviewed involved unconscious and unintended travel of the vehicle into the opposing lane (e.g., as a consequence of losses of control, perceptual and visibility problems, and falling asleep). The inclusion or exclusion of these unintended DLOCs that result from other root causes could be a factor in the variance of reported DLOC involvement between files.

As discussed in Chapter Two, while there was no specific DLOC category in Indiana's Tri-Level study of accident causation, several other causal categories can be combined to provide a composite estimate. The first three Indiana categories (Table 2-3) describe primarily conscious DLOC actions; at the probable degree of certainty these total 1.6% and 2.6%, respectively, for the technician and in-depth teams. At the same degree of certainty, the inadequate directional control category (describing unintended DLOC) adds another 1.4% and 1.6%, respectively. The Indiana final report (Treat et al. 1977) thus suggests DLOC (conscious and unconscious) to be a probable cause in 3% to 4% of accidents.

The Indiana data also provide one of the few available assessments of the role of noncontact vehicles in causing accidents. A noncontact-vehicle-caused problem was cited by both technician and in-depth teams as a probable cause in 3.8% of accidents investigated, and possibly played a causal role in up to 5.0% and 6.9% of the accidents these teams investigated, respectively. While not all such accidents involve DLOC behavior, Indiana staff involved in the Tri-Level study indicate that this was usually the case. Consequently, there may be another three to four percent of accidents attributable to DLOC, that are not generally reflected in mass data or even CPIR files. Including these noncontact vehicle accidents, the Indiana data provide an estimate of probable DLOC involvement (conscious and unconscious) in seven to eight percent of accidents.

Another ambiguous class of accidents in terms of DLOC is that where control is lost well in advance of travel into the opposing lane--for example, where control is lost on an icy surface and the vehicle, out of control, skids across the center line; or, where a driver who runs his vehicle off the right edge of the road overcompensates, causing the vehicle to return to the road and cross into the opposing line of traffic. These types of problems, designated "overcompensation" errors in the

Indiana data, were recorded as probable causes in six percent of accidents investigated by the in-depth team. Adding the composite DLOC involvement figures, those caused by noncontact vehicles, and the overcompensation-caused accidents, the Indiana technician and in-depth team data establish an upper bounds of DLOC, broadly defined, of ten to fourteen percent. However, based on the Indiana definition, this would not include accidents where excessive speed, falling asleep, etc., were the primary reasons for the left-of-center travel.

It is apparent that extreme care is required in classifying left-of-center driving behavior. Some of the major influences on reported frequency of involvement appear to be as follows:

- **Severity**—Since left-of-center driving tends to result in head-on and sideswipe collisions of above-average severity, files biased towards accidents of increased severity (e.g., CPIR) will report a higher incidence of DLOC.

- **Inclusion or exclusion of unintended left-of-center driving that is a consequence of other errors**—Exclusion of DLOC resulting from excessive speed, control loss, falling asleep, impairment, perceptual and visibility, or other directional control problems, will reduce the reported incidence of DLOC.

- **Inclusion or exclusion of noncontact vehicle DLOC**—According to the Indiana in-depth data, noncontact vehicles were probable causes in about four percent of accidents and may possibly have caused up to seven percent. While not all noncontact vehicle accidents involve DLOC, Indiana personnel indicate this was usually the case. Data based on violations and errors of involved vehicles, or that exclude single-vehicle accidents, thus tend to understate the involvement of DLOC.

- **Inclusion or exclusion of various accident configurations**--While most DLOC can be expected to occur in multiple-vehicle accidents and to involve head-on or sideswipe configurations, in a smaller proportion of cases this will not be true. Accordingly, exclusion of single-vehicle accidents and other configurations will tend to understate DLOC.

Considering each of these influences and the various strengths and weaknesses of the information presented in Table 6-1, DLOC incidence is concluded to be as follows:

- Under the preliminary DLOC UDA definition which encompasses both concious and intentional left-of-center driving and unconscious and unintended left-of-center driving as a consequence of other errors or problems, DLOC is estimated to be causally involved in about ten percent of all accidents and fifteen to twenty percent of fatalities;

- Conscious and intentional DLOC is estimated to be causally involved in about three percent of reported accidents; and

- Conscious and intentional DLOC, which is not compelled by environmental circumstances, is estimated to be causally involved in less than one percent of reported accidents.

CIRCUMSTANCES OF DLOC UDA OCCURRENCE

In this section the CPIR and Texas Five Percent files are examined to characterize the circumstances of DLOC involvement in accidents in terms of selected accident, driver, and environmental discriptors.

Results of these analyses are summarized in Table 6-2 and results for each individual discriptor are presented in Tables 6-3 through 6-15.

With respect to accident severity in terms of vehicle damage (Table 6-3), it can be seen that while most DLOC accidents involve only minor vehicle damage (levels one through three total seventy-four percent of DLOC accidents), the severe damage categories are the most overrepresented. Thus, while most DLOC accidents do not involve severe damage, they more frequently involve severe damage levels than do accidents generally. Tables 6-4 and 6-5 support the same general conclusions with respect to injury severity.

In both the Texas and CPIR samples the vast majority of DLOC accidents involve multiple vehicles, and the multiple-vehicle category is substantially overrepresented (Table 6-6). In fact, 99.2% of all DLOC accidents in the CPIR file involve multiple vehicles, compared to only 72% of the total CPIR file. This suggests that, in the CPIR coding of errors, single-vehicle run-off-road accidents in which the vehicle ran off the left side of the road or was forced into an accident by a DLOC

TABLE 6-2

SUMMARY OF LARGEST AND MOST OVERREPRESENTED CATEGORIES OF DESCRIPTORS FOR ACCIDENTS INVOLVING DLOC

TABLE NO.	DESCRIPTION	LARGEST CATEGORY(S) INVOLVING DLOC	MOST OVERREPRESENTED DLOC CATEGORY(S)
6-5	SEVERITY-DAMAGE (TEXAS 5%)	MINOR-MODERATE (LEVELS 1-3 TOTAL 74%)	MODERATE TO SEVERE
6-6	SEVERITY-INJURY	NONE (67%)	MODERATE TO FATAL
6-7	SEVERITY-INJURY (CPIR)	MINOR (40%)	MODERATE TO FATAL
6-8	SINGLE VS. MULTIPLE CONFIGURATIONS (CPIR & TEXAS 5%)	TEXAS: MULTIPLE (92%) CPIR: MULTIPLE (99%)	MULTIPLE MULTIPLE
6-9	CONFIGURATION (CPIR)	HEAD-ON (71%)	HEAD-ON
6-10	DRIVER AGE	15-34 YRS. (69%)	15-19, 20-24
6-11	DRIVER SEX	MALE (76%)	MALE
6-12	ROADWAY CLASS (TEXAS 5%)	CITY STREETS (55%)	COUNTY AND STATE SECONDARY ROADS
6-13	ROADWAY LANE CONFIGURATION (CPIR)	2-LANE (66%)	2-LANE
6-14	ROADWAY ALIGNMENT (TEXAS 5%)	STRAIGHT-LEVEL (74%)	CURVE, HILL OR BOTH
6-15	ROADWAY ALIGNMENT HORIZONTAL (CPIR)	STRAIGHT (69%)	CURVE
6-16	ROADWAY ALIGNMENT VERTICAL (CPIR)	Level (64%)	HILL-RELATED
6-17	PRECIPITATION STATUS (CPIR)	NONE (73%)	SNOW

SOURCES: SEE TABLE 4-4

TABLE 6-3

VEHICLE DAMAGE FOR ACCIDENTS INVOLVING "WRONG SIDE" VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE (1976)

	NO DAMAGE	NO DAMAGE						VERY SEVERE DAMAGE
	0	1	2	3	4	5	6	7
DLOC N = 429	.9%	21.9%	27.3%	25.2%	10.0%	7.0%	3.3%	4.4%
TOTAL TEXAS FIVE PERCENT SAMPLE N = 33,096	2.6%	40.1%	28.9%	18.5%	5.7%	2.2%	1.2%	.9%

TABLE 6-4

MAXIMUM INJURY SEVERITY IN ACCIDENTS INVOLVING "WRONG SIDE" VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE (1976)

	NO INJURY	"C" INJURY	"B" INJURY	"A" INJURY	FATAL
DLOC N = 502	67.3%	8.8%	12.2%	7.8%	4.0%
TEXAS 1976 FIVE PERCENT SAMPLE N = 23,257	79.3%	7.5%	9.6%	3.1%	.5%

TABLE 6- 5

MAXIMUM INJURY SEVERITY FOR VEHICLES CITED FOR WRONG-WAY ERRORS COMPARED WITH TOTAL CPIR FILE

	NONE	MINOR	MODERATE	SEVERE	SERIOUS	CRITICAL	FATAL
DLOC N = 357	5.6%	40.1%	19.3%	13.4%	5.0%	9.2%	7.3%
ALL CPIR VERSION 3 N = 8,940	12.9%	49.7%	17.1%	8.9%	3.1%	4.0%	4.2%

TABLE 6- 6

SINGLE-VERSUS MULTIPLE-VEHICLE ACCIDENT TYPES FOR DLOC-RELATED ACCIDENTS AND FOR TOTAL TEXAS FIVE PERCENT (1976) and CPIR FILES

	SINGLE	MULTIPLE
TEXAS DLOC N = 502	7.6%	92.4%
ALL TEXAS FIVE PERCENT N = 23,256	26.0%	74.0%
CPIR DLOC N = 287	.8%	99.2%
ALL CPIR N = 9,219	28.0%	72.0%

TABLE 6-7

COLLISION CONFIGURATIONS OF DLOC-RELATED ACCIDENTS
COMPARED WITH TOTAL CPIR FILE

	HEAD-ON	INTER-SECTION L-TYPE	SIDE-SWIPE	REAR-END	INTER-SECTION T-TYPE
DLOC N = 383	71.1%	8.9%	9.4%	1.0%	10.4%
ALL CPIR N = 6,630	18.6%	30.6%	5.7%	22.3%	22.6%

TABLE 6- 8

AGE DISTRIBUTION OF DRIVERS CITED FOR "WRONG SIDE" VIOLATIONS AND FOR ALL DRIVERS IN THE TEXAS FIVE PERCENT FILE (1976)

DRIVER AGE CATEGORY	TEXAS DLOC SAMPLE N = 457	OVERALL TEXAS FIVE PERCENT SAMPLE N = 37,469
10-14	.7%	.4%
15-19	22.1%	16.8%
20-24	26.5%	20.5%
25-34	20.8%	24.8%
35-44	10.3%	12.8%
45-54	8.5%	10.8%
55-64	6.6%	7.4%
65-74	3.3%	4.7%
75 +	1.3%	2.0%

TABLE 6-9

SEX OF DRIVERS CITED FOR "WRONG SIDE" VIOLATIONS IN THE TEXAS FIVE PERCENT FILE (1976)

	MALE	FEMALE
TEXAS DLOC N = 468	76.3%	23.7%
ALL TEXAS FIVE PERCENT SAMPLE N = 38,344	66.8%	33.2%

TABLE 6-10

TYPE OF ROAD FOR ACCIDENTS INVOLVING "WRONG SIDE" VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE (1976)

	ALLEY	CITY STREET	COUNTY ROAD	STATE SECONDARY	U.S. & STATE TRUNKLINE	INTERSTATE/ TURNPIKE
DLOC N = 502	0%	55.2%	11.6%	9.8%	22.3%	1.2%
N = 23,257	9%	51.6%	3.3%	6.5%	28.8%	9.6%

TABLE 6-11

ROADWAY LANE CONFIGURATION FOR SPEED-RELATED ACCIDENTS AND FOR ALL ACCIDENTS IN THE CPIR FILE

	1-LANE	2-LANE	3-LANE	4+LANE	DIVIDED	OTHER NONROAD
DLOC (WRONGWAY) N = 387	.5%	66.1%	1.6%	18.3%	12.7%	.8%
BASELINE (ALL CPIR ACCIDENTS) N = 9,184	.6%	47.2%	3.2%	25.3%	21.7%	1.9%

TABLE 6- 12

ROAD ALIGNMENT FOR ACCIDENTS INVOLVING "WRONG SIDE" VIOLATIONS AND FOR ALL ACCIDENTS IN THE TEXAS FIVE PERCENT FILE (1976)

	STRAIGHT-LEVEL	CURVE ON HILL OR BOTH
DLOC N = 502	74.1%	25.9%
N = 23,257	95.0%	5.0%

TABLE 6-13

HORIZONTAL ROAD ALIGNMENT OF ACCIDENTS INVOLVING "WRONG WAY" ERRORS COMPARED WITH TOTAL CPIR FILE

	STRAIGHT	CURVE
DLOC N = 386	68.6%	31.4%
N = 9,189	80.6%	19.4%

TABLE 6-14

VERTICAL ROAD ALIGNMENT OF ACCIDENTS INVOLVING "WRONG WAY" ERRORS COMPARED WITH TOTAL CPIR FILE

	LEVEL	HILL-RELATED
DLOC N = 378	64.3%	35.7%
TOTAL CPIR FILE N = 8,892	73.6%	26.4%

TABLE 6-15

PRECIPITATION STATUS FOR ACCIDENTS INVOLVING "WRONG WAY" ERRORS AND FOR TOTAL CPIR FILE

(PERCENT OF ACCIDENTS/CASES)

	RAIN	SNOW	NONE	OTHER
DLOC N = 866	13.0	10.3	73.4	3.2
TOTAL CPIR FILE N = 9,222	13.0	5.5	78.8	2.6

noncontact vehicle, were not included within the meaning of DLOC. Thus, the "wrong way into oncoming traffic" surrogate was not entirely consistent with the proposed DLOC UDA definition.

As indicated in Table 6-7, head-ons comprise the largest share of DLOC accidents in the CPIR file (71%), and both head-on and sideswipe configurations are substantially overrepresented. As might be expected, the rear-end configuration is the most seriously underrepresented, and intersection configurations are substantially underrepresented as well. However, it should be noted that the two intersection categories together total nearly twenty percent; thus, while the head-on category is understandably large, DLOC does result in substantial numbers of oblique and right angle collisions which might tend to be overlooked.

In terms of driver age (Table 6-8), there are no radical differences between the DLOC and total Texas sample. As for the total file, most DLOC drivers (69%) are between the age of fifteen and thirty-four; this compares to sixty-two percent within the same age range for the total file. Only the fifteen to nineteen and twenty to twenty-four year age brackets are overrepresented among DLOC accidents (both by a factor of about 1.3). Thus, as a consequence of their greater involvements in accidents, younger drivers are an appropriate target group for countermeasures aimed at DLOC behavior, although they are only slightly more likely to have an accident by reason of DLOC behavior than accident-involved drivers in other age groups.

For driver sex, however, differences between DLOC and total file accidents are apparent. Males account for the largest share of DLOC violations (76%), and are also overrepresented among such violations. Thus, an accident-involved male is slightly more likely than an accident-involved female to have been involved by reason of DLOC, based on violations in the Texas file (see Table 6-9).

While most DLOC accidents in the Texas file occurred on city streets (55%), accidents occurring on county roads most seriously overrepresented DLOC (11.6% vs. 3.3% expected). Accidents on state secondary roads were also substantially overrepresented (Table 6-10).

The roadway lane configuration descriptor is a special case for DLOC, in that the proposed definition limits the scope of DLOC to those occurring on two-lane, two-way roads where neither passing or turning are involved. Presumably, narrow roads (approaching one lane but intended for two-way travel) could also be included. Under this definition, all DLOC accidents should be recorded under the one- and two-lane categories of Table 6-11. To the extent that this is not the case (only 67% fall under these two headings), the surrogate variable chosen for the CPIR file is shown to be inconsistent with the proposed definition. It is also indicative of the extent to which the definition chosen excludes a substantial portion of accidents caused by a very closely related behavior. It appears that fully one-third of all accidents in the CPIR file involving the "wrong way into oncoming traffic" error would be excluded from DLOC UDA assessment and countermeasure action. While it might have been expected that DLOC could seldom occur on divided highways, note that thirteen percent of accidents in the CPIR file were under this heading.

In summary, based on Table 6-11 the largest proportion of CPIR-DLOC accidents occurred on two-lane roads (66%), and this roadway category was also the most overrepresented.

The roadway alignment comparisons (Table 6-12 through 6-14) are consistent in indicating that a majority of DLOC-related accidents occur on straight and level roads, but are overrepresented on curves and hills. Thus, in the Texas data (Table 6-12), seventy-four percent of the DLOC accidents occurred on straight-level roads, but occurred five times as often as would have been expected on "curve, hill, or both."

Similarly, in the CPIR data (Table 6-13), sixty-nine percent of DLOC accidents occurred on straight road segments, but DLOC occurred about 1.6 times as often as would have been expected on curves. Thus, while most DLOC-caused accidents occur on straight and level roads, in both the Texas and CPIR file (based on both violations and MDAI team-assessed errors), DLOC is indicated to cause a greater proportion of accidents occurring on hills and curves than on straight roads. This is consistent with the proposed definition, which includes both conscious and intended and unconscious and unintended DLOC (the latter often being the result of other errors such as excessive speed). Under this definition it is important that curve-related accidents not be inadvertently ignored on the assumption that they tend to result from speed or control problems rather than an intentional movement left of center.

DLOC accidents do not vary radically as a function of precipitation status (Table 6-15), although overrepresented among accidents occurring during snowfall (10.3% vs. 5.5% expected). The largest proportion of DLOC accidents (73.4%) occur when there is no precipitation.

In summary, DLOC-caused accidents generally involve minor to moderate damage and low levels of injury, but are much more frequently serious and fatal than are accidents generally. They are most frequently multiple vehicle head-ons, and both head-on and sideswipe configurations are overrepresented. DLOC-committing drivers differ little from other accident drivers in terms of age, although the fifteen to nineteen and twenty to twenty-four age groups are slightly overrepresented. Most are male, and males are overrepresented. In the Texas file, DLOC accidents usually occurred on city streets, but county roads and state secondary roads are the most overrepresented. Most occurred on two-lane roads in the CPIR file but, under the preliminary definition, all should have. Most occurred on straight and level roads, but DLOC errors are overrepresented among accidents occurring on curves and hills.

DRIVER CONSCIOUSNESS OF DLOC UDA COMMISSION

As discussed previously and illustrated in Table 6-16, DLOC is generally an unconscious or unintended consequence of other behavioral errors, UDAs or problems. Specifically, twenty-four of the thirty-three DLOC cases reviewed (73%) were of this type. Thirteen of these involved losses of control as a consequence of either excessive speed or other steering performance problems. In seven of these cases, the driver fell asleep or was alcohol-impaired, while in the remaining three, poor visibility led to perceptual problems. Of the remaining nine conscious and intentional DLOC cases, in six the left-of-center driving was compelled by environmental circumstances; in four the driver was taking an avoidance action (e.g., to avoid a bicyclist on the edge of the road); while in the remaining two the drivers failed to move over far enough on narrow gravel roads. Of the remaining three conscious and intentional cases in which the DLOC action was discretionary (i.e., not undertaken for good reason), one was a suicide and in another the reason could not be determined. In the one case remaining, in which the driver was attempting to drive on the left shoulder, enforcement or deterrence efforts could potentially be effective in discouraging the DLOC behavior and hence preventing the accident.

However, it is true that a substantial proportion of accidents involve vehicles that cross the center line in the precrash phase--Figure 6-1 indicates that in 102 of the 384 Indiana accidents (27%) a vehicle crossed the center line precrash—and DLOC countermeasures **can** be developed by focusing on reasons for such events. The problems that led to DLOC in the cases reviewed, and which might be ameliorated through appropriate countermeasures, include the following:

- Problems in curve tracking as a consequence of inattention or skill and performance problems or both;
- excessive speeds;
- avoiding obstacles to the right;
- failing to move over far enough on narrow roads;
- perceptual failures under conditions of limited visibility; and
- alcohol impairment and falling asleep.

Table 6-16 provides further insight regarding reasons for DLOC-type errors. It shows the total number of times that "wrong way into oncoming traffic" appeared in combination with other primary errors in the CPIR file. It represents a cross tabulation of variables 541 and 542, which describe the most responsible driver's primary errors in the CPIR file. It can be obseved that the "wrong way" error is seldom cited except in conjunction with other errors; it appears by itself in only about five percent of cases cited. The most frequent concurrent causes cited with the wrong way error are drinking (29.9% of all wrong way error

TABLE 6-16

MOST FREQUENT COMBINATIONS OF A DLOC-TYPE ERROR (WRONG WAY INTO ONCOMING TRAFFIC) AND OTHER ERRORS FOR THE MOST RESPONSIBLE DRIVER IN EACH ACCIDENT IN THE CPIR FILE

ERRORS	N	PERCENT OF ALL ACCIDENTS INVOLVING WRONG WAY ERROR
WRONG WAY + DRINKING OR DRUGS	108	29.3
WRONG WAY + SPEEDING	68	18.8
WRONG WAY + INATTENTION OR DIVERTED ATTENTION	33	9.1
WRONG WAY + BLACKOUT OR FALLING ASLEEP*	29	8.0
WRONG WAY + AVOIDANCE MANEUVER	24	6.6
WRONG WAY + OVERCORRECTION MANEUVER	19	5.3
WRONG WAY + NO OTHER ERROR	17	4.7
WRONG WAY + ALL OTHER ERRORS	63	17.5
TOTAL WRONG WAY ALONE OR IN COMBINATION	361	100.0%

*For each combination other than blackout/falling asleep, the wrong way error was most frequently cited as primary error one and the second factor as primary error two. Blackout/falling asleep was cited slightly more often as error one.

cases); speeding (18.8%), inattention (9.1%), and blackout (8.0%). Thus, drinking, speeding, inattention, and blacking-out are indicated by this particular analysis to be the major causes of wrong-way-into-oncoming-traffic driving in the CPIR file. Ranking next behind these are avoidance errors and overcorrection.

Further insight based on the same cross-tabulation is provided in Table 6-17. The two left-hand columns indicate that where the wrong-way error is cited as primary error one, there is more frequently a second error coded than for these cases generally (i.e., the "no primary error two" category is substantially underrepresented); while the blackout, drinking, speeding, avoidance maneuver, and overcorrection categories are overrepresented substantially. For example, blackout is coded as "primary error two" in only 1.7% of total cases in the file, but is coded as "primary error two" in 5.4% of all cases where wrong-way is coded as primary error number one.

The two right-hand columns show that the same factors are generally overrepresented as primary error one where wrong-way is coded as the second primary error, with the exception that speeding tends not to be cited as the first primary error when wrong-way is coded as the second error. In other words, in cases involving the wrong-way error and speeding, wrong-way will almost always be coded primary error one and speeding primary error two. Overall, speeding appears only slightly more often in cases where wrong-way is cited as a primary error than in cases generally.

Although inattention was one of the most frequent concurrent causes with the wrong-way error, it is not overrepresented in its occurrence in wrong-way accidents; that is, inattention occurs no more frequently in conjunction with this error than with other errors, generally. Inattention is a frequent cause in accidents (18% of total CPIR cases), which manifests itself in many different ways and in conjunction with many different errors. Driving wrong-way is one of them, but not to an unusual degree.

With respect to drinking, on the other hand, and blacking out, these errors each occur more than twice as often in conjunction with

TABLE 6-17

ACTUAL AND EXPECTED CONCURRENCE OF A DLOC-TYPE ERROR (WRONG WAY INTO ONCOMING TRAFFIC) AND OTHER SELECTED ERRORS OF THE MOST RESPONSIBLE DRIVER IN EACH ACCIDENT IN THE CPIR FILE

(PERCENT OF ACCIDENTS)

OTHER SELECTED CONCURRENT CAUSES	ACTUAL OCCURRENCE IN ACCIDENTS WHERE "WRONG WAY" IS ERROR #1	TOTAL FILE (ERROR #2) EXPECTED VALUE FOR OTHER CAUSE	ACTUAL OCCURRENCE IN ACCIDENTS WHERE "WRONG WAY" IS ERROR #2	TOTAL FILE (ERROR #1) EXPECTED VALUE FOR OTHER CAUSE
NONE	6.6	24.5	0	2.4
BLACKOUT FALLING	5.4	1.7	14.4	6.4
DRINKING OR DRUGS	26.8	14.6	37.5	12.5
SPEEDING	23.3	11.7	7.7	15.6
AVOIDANCE MANEUVER	5.4	2.2	9.6	5.0
OVERCORRECTION MANEUVER	5.1	2.7	5.8	3.3

wrong-way as would be expected based upon their appearance in these files. (Based on its occurrence within primary errors one and two, drinking would have been expected to appear in only about 12.5% of accidents in which wrong-way was cited as an error; instead, drinking appears in 29.9% of all wrong-way coded accidents.)

A similar cross-tabulation of driver violations one and two was attempted with the Texas Five Percent Sample File. In general, inconsistencies between the violation one and two variables rendered the result of minimal utility. However, as in the CPIR data, alcohol was overrepresented in the DLOC-related accidents. Specifically, the driving-under-the-influence-of-alcohol violation was cited for only 3.2% of all drivers in the file but was cited for 14.1% of drivers for which violation one was coded "wrong side, not passing." In general, however, this analysis does not provide strong evidence for the notion that DLOC is usually compounded by other errors; for over 85 percent of the wrong-side violations in the Texas file, no other violation was recorded. Alcohol impairment accounted for nearly all of the remaining cases. Concurrence of errors is best indicated by reference to the CPIR data, above (Table 6-16).

SUMMARY

DLOC was defined as the act of driving a vehicle over or on the center line of a two-way road when not passing or turning. Under this definition, it appears that DLOC (either conscious or as a consequence of other problems) is involved in about ten percent of reported accidents and fifteen to twenty percent of fatalities. Conscious and intentional DLOC, which is not compelled by environmental circumstances, is estimated to be causally involved in less than one percent of reported accidents.

DLOC-caused accidents usually involve only minor to moderate damage and low levels of injury, but are much more frequently serious or fatal than are accidents generally. They are most frequently multiple-vehicle head-ons, and both head-on and sideswipe configurations are overrepresented. DLOC-committing drivers differ little from other accident drivers in terms of age, although the fifteen to nineteen and twenty to twenty-four age groups are slightly overrepresented. Most are male, and males are overrepresented. DLOC accidents usually occurred on city streets, but county roads and state secondary roads are the most overrepresented. Most occurred on straight, level, two-lane roads, but DLOC errors are overrepresented among accidents occurring on curves and hills.

In most of the in-depth accident reports reviewed (73%), DLOC was concluded to be an unconscious and unintended consequence of other behavioral errors, UDAs, or problems. Even where intentional, its commission was usually compelled by environmental circumstances. Only one accident of thirty-three (3%) was found to be caused by conscious and intentional DLOC behavior. DLOC behavior that was conscious and intentional and also was not compelled by environmental circumstances was found to be involved in less than one percent of all accidents.

CHAPTER SEVEN
OPERATIONAL FEASIBILITY OF DEFINITIONS

The development of definitions of the three classes of UDAs was undertaken with the specific objective of producing more useful definitions. The utility of the definitions may be measured in terms of their operational feasibility.

The definitions must allow different observors to reach the same conclusion about the same events. The definitions must be capable of being applied to the general traffic flow—the nonaccident population—so that exposure data may be collected. The definitions must also be applicable to the accident population.

As the definitions were developed in observable terms they are, in general, applicable to the nonaccident population. Data collection will, of course, be constrained by the usual problems associated with observing traffic. For example, it will be necessary to ensure that the measurement process is unobtrusive and does not alter what is being measured.

The real test of the feasibility of the definitions will come in the accident investigation process. Basically, the question is whether accident investigators can reasonably gather data that establish the involvement of the particular UDA in a causal role. The following sections examine each of the definitions to determine the feasibility of using them operationally in accident investigation.

SPEED-RELATED UDAs

Feasibility of Assessment in an Accident Population

Two preliminary definitions of speed-related UDAs were proposed earlier in this report--absolute and relative (see Chapter Four). Determining the **presence** of the absolute-speed UDA requires knowledge of (1) vehicle travel speed upon initiation of accident sequence; and (2) prevailing posted, advisory or statutory speed limits. The relative-speed UDA requires, in addition to precrash travel speed, knowledge as to the speed distribution of other vehicles following the same path (location, lane, etc.) under similar conditions (e.g., same light, traffic volume, and road surface conditions).

The availability of the needed precrash travel speed information for the accident population was assessed through review of forty-eight individual CPIR cases that involved a speeding UDA, through examination of the available literature, and through discussions with HSRI accident reconstruction experts.

It was found that, while many studies of speed in accident risk have made use of precrash travel speed estimates in police and other traffic accident reports (e.g., Solomon 1964) the accuracy of such data has not been studied. Thus, while such data are almost always available, their adequacy must be evaluated primarily on the basis of expert opinion. It may be assumed that estimates derived by qualified reconstructionists employing mathematical reconstruction techniques will be more accurate than those of police accident reports, which generally do not involve quantitative reconstruction of this kind.

Based on the review conducted here, it is estimated that, using optimal available reconstruction techniques, precrash travel speeds for most accidents can be determined within $\pm$ twenty percent, with the mean accuracy being somewhat better. Thus, for a vehicle actually traveling 60 mph, the estimate achieved through accident investigation would be expected to seldom fall outside the limits of 48 to 72 mph, and would usually be within a narrower range.

Approaches to Assessment

There are several sources of information and computational procedures available to accident investigators in arriving at precrash travel speed estimates. Ideally, all of these would be available and used in reconstructing a best estimate for each accident. These include driver, occupant, and witness statements; skid marks and other physical evidence;

vehicle damage; mass-energy-momentum calculations; and computer-based reconstruction programs.

Typically, police reports (the primary inputs to most mass data files) are based on driver and witness statements. The length of skid marks and the extent of damage may often play a role in influencing an investigating officer's estimate of travel speeds (and belief or disbelief of driver or witness statements concerning speed), but we have found that actual quantitative reconstruction is seldom undertaken in routine police investigations.

The various multidisciplinary accident investigation (MDAI) teams funded by the federal government, on the other hand, often attempted mathematical reconstruction. Many of the speeding cases in the CPIR file were based on quantitative reconstruction of accident speeds and, in the Indiana Tri-Level Study (which emphasized investigation of precrash behavior), speed estimates were calculated in nearly all cases where the evidence permitted it.

Mathematical reconstruction of accidents rests on two general principles: (1) the equality of work and change in energy ($Fd = 1/2mv^2$), and (2) conservation of momentum [$(M_1V_1 + M_2V_2)$ precrash = $(M_1V_1 + M_2V_2)$] postcrash. Knowledge of the length of skid marks provides a measure of energy loss and hence of reduction in speed of a skidding vehicle. The effects of a collision between vehicles is handled by assuming that the total momentum (mass times velocity) going into the collision is equal to the momentum following collision. Vehicle damage is generally not used in such calculations, due to lack of knowledge of the force-crush distance relationship (which varies complexly as a function of vehicle make and model, impact location on the vehicle, direction of impact, profile of intruding object, mechanical interactions between vehicles, duration of force, etc.). Vehicle damage is widely agreed not to be a suitable means of estimating precrash travel speeds, except in conjunction with sophisticated computer programs.

Where two vehicles on a collision course brake, skid to impact, collide, and then skid to final rest, the general strategy of reconstruction is as follows: the length of skid marks from final rest back to impact is used to compute an estimate of each vehicle's speed immediately following the collision. This requires an assumption as to the "coefficient of friction" and, hence, braking force generated by the vehicle as it skidded. Given knowledge as to the velocity of each vehicle leaving collision and its weight, conservation of linear momentum in the collision is assumed, thereby providing an estimate of speed **entering** collision. The length of preimpact braking is then used to estimate speed change from start of skid marks to point of impact, and to thereby obtain an estimate of precrash travel speed. Since skid marks are generally not deposited immediately upon initiation of braking, estimates of this type are generally assumed to understate actual travel speeds, although the accuracy of reconstruction techniques, in general, has not been studied.

The accuracy of accident reconstruction based on mass-energy-momentum principles depends primarily on the quality of information available to support the calculations, and many factors may render a reconstruction impossible. Where all four tires fail to deposit skid marks under heavy braking, assumptions must be made about the braking effort being provided by the nonmarking wheel. Where heavy braking short of locked-wheel skidding occurs, no speed loss computation is possible. Where vehicles roll over or impact with small posts, trees, etc. during the accident sequence, the amount of energy loss may be difficult to account for. And, where a collision causes the driver's foot to slip off the brake or to render him unconscious, the lack of postimpact braking may preclude a travel speed calculation.

One of the pioneers of accident reconstruction, Baker, has written:

> The availability of information about traffic accidents being what it is, many attempts to reconstruct accidents will inevitably fail . . . investigators are again and and again hopefully presented with reconstruction problems for which no practical solution can be expected from anybody. (Baker 1960)

Information on the availability of information needed to calculate speed estimates was reported by Tumbus, Treat, and McDonald (1974). In a group of 215 accidents that were broadly representative of all police-reported accidents occuring in the study area, it was found that only 109 (51%) involved maximal preimpact braking (i.e., such that at least one vehicle in the accident was skidding preimpact as a result of brake application). Within these 109 skidding accidents, the necessary decrease in stopping distance to prevent or reduce the severity of the accident was calculable in only 89 accidents. Thus, **a reasonable mathematical reconstruction of precrash travel speeds was found possible in only 89 of 215 accidents (41%).** Since these investigations involved immediate on-site response to document physical evidence and obtain information, this probably represents an upper bound as to the applicability of reconstructive techniques (where accidents of all severity are considered). In addition, accidents occurring on dry road surfaces were overrepresented among those that were calculable; thus, the reconstruction of travel speeds in accidents occurring on wet road surfaces (reducing the clarity of skid marks and other physical evidence) may be particularly restricted.

Within the past five years, computer programs have been developed to assist in the reconstruction of traffic accidents; probably best known among these is CRASH (McHenry and Lynch 1976). Like the standard reconstruction techniques, these programs take into account energy loss through skidding and assume conservation of momentum. However, they also take into account energy losses through vehicle crush. Given vehicle damage ("crush") data alone, the CRASH program creates an estimate of the change in velocity (delta V) of each vehicle during its collision. If, in addition, it is also provided with information on the length and trajectory of skid marks from impact to final rest, it can provide an estimate of each vehicle's speed immediately prior to impact. This preimpact-speed estimate can then be used in a standard hand computation of travel speed based on length of preimpact skid marks.

Accuracy of Approaches

The unreliability of speed estimates provided by drivers and witnesses is well known to accident investigators, and are seldom taken at face value. Drivers have obvious reasons to be nonobjective in their reporting, even assuming they were aware of their travel speeds, and witness estimates have been shown to vary substantially, depending on the way in which questions about an accident are asked (Baker 1960a). Studies comparing driver and witness statements and reconstructed speeds for a group of accidents could be easily accomplished, but we are aware of no such study to date. Similarly, although the limitations of mathematical reconstruction are widely discussed (e.g., Baker 1960b), they do not appear to have been systematically studied or quantified.

In the forty-eight CPIR cases read as part of this study, it was found that investigators had used information from the physical evidence, the police, witnesses, and drivers in developing speed estimates. In some cases, mathematical estimates had been made. Based upon examination of these case files, and discussion of the issue with HSRI accident reconstruction experts, the review team concluded that the precrash travel speeds of accident-involved vehicles could be estimated to within at least twenty to twenty-five percent of their values, with somewhat better accuracy expected in most cases.

The accuracy of CRASH and similar programs in reconstructing accidents has not yet been fully established. The principal use to date in the National Crash Severity Study (NCSS) and the National Accident Sampling System (NASS) has been to determine the change in velocity (delta-V) of vehicles during collision. Such usage has been based on delayed-response, technician-collected data rather than on-scene multidisciplinary investigations, and determination of precrash travel speeds has not been an objective. Thus, the potential of CRASH in this application has not been fully investigated.

In the first sixteen months of the NCSS program, CRASH runs to obtain estimates of delta-V were able to be performed for 57.5% of the case vehicles studied (4,634 of 8,057). The majority of these were based on damage inputs only, which result in delta-V estimates useful in reconstruction but which do not directly lead to travel speed estimates. So-called trajectory runs, providing a direct estimate of each vehicle's velocity going into collision, have been performed in about 20 percent of cases. Although these programs have not yet been applied as an integral part of an in-depth/multidisciplinary investigation program, they would definitely be useful in reconstruction and could probably be applied in a greater proportion of cases.

In addition to their limited rate of applicability, the overall accuracy of the existing programs has not yet been established. The CRASH 2 Users Manual (McHenry and Lynch 1976) reports that:

> An overall accuracy range of approximately ± 12% was indicated in initial trial applications to staged collisions . . . however, the present level of accuracy, with the trajectory-testing option and other refinements is believed to be significantly better than the earlier findings. The potential accuracy, with planned refinements in the stored vehicle parameter data and empirical coefficients, is expected to approach the range of ± 5.

Most users, however, are much more conservative in their accuracy estimates. Personnel in NHTSA's National Center for Statistics and Analysis responsible for the NCSS and NASS programs estimate the accuracy of their "delta-V" data obtained using the CRASH program as ± twenty percent. They note that the program's accuracy in field use is influenced both by measurement errors in the input data and approximation errors within the model itself.

Based on a recent study conducted by Volkswagenwerk AG investigating the application of CRASH and a similar program (SMAC), Loeck and Seiffert (1978) reported that:

> In normal, simple accidents such as front-end, rear-end, or side impacts, the SMAC-CRASH simulations allow the operator to predict delta-V's with a fidelity of some ± 15%.

They further noted, however, that in multiple-collision accidents, such as run-off-road accidents with impact against another object, the difficulties for reconstruction increase remarkably.

It must be remembered that knowledge of delta-V alone does not provide an estimate of precrash travel speed. Given knowledge of a vehicle's velocity immediately prior to collision, it is necessary to go back in time to reconstruct a precrash travel speed. Errors associated with the required measurements and estimates must be added to those associated with the delta-V calculations of the current programs. Indeed, there is also a problem in defining the relevant point in time that marks the start of the accident sequence, and at which the travel speed is to be estimated.

Speed Assessment Summary

Prior studies of the relationship between speed and accident risk have used travel speed estimates for the accident population of unknown accuracy. Application of state-of-the-art, mathematical, and computer-assisted reconstruction techniques can only improve the accuracy of such travel speed estimates.

The optimal procedure within the current state of the art would involve the assimilation of computer-assisted reconstruction with standard mathematical techiques. This should be facilitated by on-scene data collection and evaluation of the accident by a multidisciplinary team. Precrash travel speed estimates can be expected to be in error by less than $\pm$ twenty percent in nearly all cases, and would usually be within a substantially narrower range.

Data obtained through such a procedure would be much superior in terms of travel speed estimates to those data used in prior speed/risk studies, which were obtained from mass-data files. **In this context, it is concluded that precrash travel speeds can be obtained from the accident population with sufficient accuracy for purposes of documenting speed-risk relationships and evaluating potential countermeasures.**

FOLLOWING-TOO-CLOSELY UDA

Feasibility of Assessment in an Accident Population

There are a number of possible approaches to measurement of following distances and separation times between vehicles in a traffic flow. These range from a sophisticated vehicle-sensor system buried in the roadway to simple stopwatch measurements of elapsed time between the rear of one vehicle and the front of a following vehicle passing the same point. However, lacking a completely instrumented road network for the study of accidents, it is necessary to seek comparable data on following distance in accidents through the cumbersome and inexact process of investigating and reconstructing accidents. In order to determine the occurrence of the FTC UDA in the accident population, it is necessary to determine:

- the vehicle types involved;
- road surface condition;
- that it was a vehicle-following situation (i.e., that the vehicles were traveling in the same lane and at about the same speed); and
- separation time between vehicles at the moment the lead vehicle began to slow down.

In addition, if calculations are to be made to better assess the occurrence or nonoccurrence to the FTC UDA, it would be necessary to calculate or estimate vehicle precrash travel speed. The reconstruction may require knowledge of skid-mark lengths, vehicle weights, collision angles, skid-mark trajectories, etc.

Determination of the separation time poses the greatest difficulties for accident reconstruction. This is especially so in applying the "narrow" proposed definition. In the review of case reports, it was found that many rear-end collisions coded as involving FTC actually did not involve FTC, in terms of its proposed meaning. Included among cases judged not to involve this type of FTC were those that involved large speed differences (and consequently were not vehicle-following situations), skidding (following distance adequate but improper technique extended stopping distance), and inattention or miscomprehension (resulting in an extended reaction time). The large speed differences included cases where one or both of the vehicles were simply traveling too fast or too slow relative to the traffic flow (relative speed UDA), or vehicles stopping or traveling slowly in the roadway (e.g., to make a left turn). Application of the narrow FTC definition requires that the accident investigation be capable of discriminating such cases from that of the FTC, in addition to identifying separation time.

No studies have been identified that have assessed the accuracy of the accident-reconstruction process in determining separation times or other aspects of the following-too-closely behavior. The difficulty is obvious. A lead vehicle begins to decelerate at an unknown rate and location. Unless the lead vehicle immediately brakes so hard as to lock its wheels and deposit skid marks (very unlikely), there is no means of measuring or quantitatively estimating braking rate or point of brake application. The driver is unlikely to be able to specify the precise location or distance from impact at which braking was initiated, and the driver of the following vehicle is ill-equipped to describe how far back he was following. Although in perhaps half of the accidents he would eventually lock his tires and deposit skid marks, we must rely on his qualitative account as to how long he waited before beginning to brake, whether he engaged in light or moderate braking before deciding that maximum braking was necessary, etc.

The difficulties in reconstructing these questions were apparent to the case reviewers as they carefully examined the forty-six CPIR and Indiana FTC and rear-end collision cases. Based upon their review of case files, and discussion of these issues with HSRI reconstruction experts, the review team concluded that separation time estimates had to be based on driver estimates in most cases, and that these were of very questionable accuracy.

Ideally, the relationship of following distance to risk would be expressed as a continuous function of (at least) speed and following distance. This would require that a reasonably precise estimate of precrash time separation be obtained in each accident. It is unlikely that a sufficiently accurate estimate can be obtained to develop such a relationship. However, a less complete assessment of FTC risk can be developed based on probable FTC involvements in accidents. Estimates of involvement can be developed through a process of elimination, and supporting time-distance calculations are sometimes possible. The process involves (1) determining if the accident involves a car-following situation, and if so, (2) assuming that FTC is involved unless there is evidence of (a) delayed perception or response; (b) absence of braking or poor braking technique; or (c) poor braking performance. If not eliminated, the case would be considered to involve FTC. Errors will therefore tend to be in the direction of identifying FTC when it is not in fact present. This would lead to an overstatement of the risk generated by FTC, and the result would consequently be useful only in estimating the upper bounds of FTC risk.

In somewhat greater detail, the procedure would be as follows: the process of elimination begins by assuming that, where vehicles are traveling in the same lane and at about the same speed and the following vehicle contacts the lead vehicle, the FTC UDA is involved unless there is some other reason responsible that would indicate that a greater time separation existed than the definition requires. Based on the manual review, it appears that information from drivers, witnesses, etc., is usually adequate to identify the vehicle-following situation (i.e., to indicate if vehicles were in the same lane and whether they were moving relative to one another when the lead vehicle began to slow down).

In a car-following situation where one vehicle has collided with the rear of another vehicle it is following, it is logical to assume that the time separation was less than that ordinarily required for reaction and braking, unless there has been some other factor acting to increase reaction time or stopping distance. Accordingly, in this situation the investigation would focus on identifying whether any of the following were involved:

- Delayed perception or response to the deceleration of the lead vehicle--Interviews may indicate the driver was inattentive or distracted, and hence delayed in response. Also, inoperable brake lights in the lead vehicle could account for an excessive delay in response. Or, the interview may indicate that the driver was aware of his close proximity to the lead vehicle and watching it intently, thereby negating the likelihood of FTC.

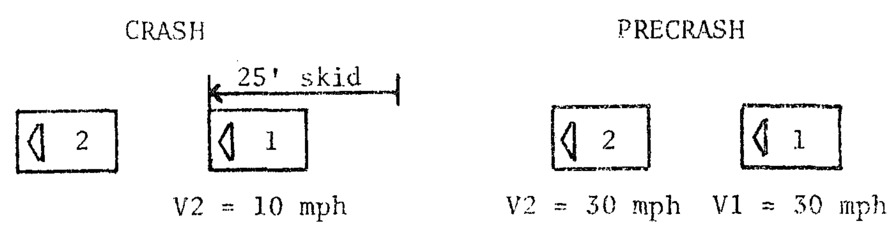
- Poor braking technique—particularly on slippery surfaces, a significant difference may exist between the peak and sliding coefficients of the tires. Accordingly, modulation of braking force by the lead vehicle and a locking-up of brakes by the following vehicle can lead to collision under circumstances where the time separation would otherwise be adequate. Ordinarily, relatively low impact speeds would be expected in such cases (i.e., differences in stopping performance should not be large).

- Poor braking performance--poor brakes can greatly extend stopping distances. A number of clues may exist to poor braking system performance. This would include lack of dark skid marks from all tires where the pavement is dry and the driver claims to have made a maximum effort to stop; a brake pedal that goes to the floor postcrash; and visible brake fluid or axle grease leakage on the tires and wheels.

Thus, the FTC-oriented investigation must focus on the possibility of distractions or delays in response, and on braking performance and techniques, through driver and witness interviews, vehicle inspection, and examination of skid marks and other physical evidence.

Quantitative estimates can be used in support of interviews and other information. However, adequate data would ordinarily not be available to support such calculations and, even where possible, will necessarily be rough estimates of unknown accuracy.

An example of such a calculation is as follows:



It is reliably established that Vehicle 2 was moving 10 mph at impact, that Vehicle 1 skidded twenty-five feet to impact, and that both were moving 30 mph before Vehicle 2 started braking. Vehicle 1 claims to have braked moderately--about "half as hard as I could've." Driver 1 claims he was back "plenty far" but was distracted. He says he looked up, saw Vehicle 2 stopping, and hit his brakes as hard as he could.

If we assume a fairly conservative braking rate for Vehicle 2 of .2 Gs, then:

Veh 2 braking distance = $\frac{Vorig^2 - Vimpact^2}{(30)(.2)} = \frac{30^2 - 10^2}{(30)(.2)} = 133'$

At an average speed of $\frac{30 + 10}{2}$ = 20 mph, covering this 133'

takes $\frac{133}{(20)(1.47)}$ = 4.5 seconds.

Therefore, Vehicle 2 began braking as early as 4.5 seconds before impact. Where was vehicle 1 at this time?

The twenty-five foot skid of Vehicle 1 to impact consumed some of this 4.5 seconds. Assuming a braking rate of .7 G:

- Vimpact = $\sqrt{Vorig^2 - 30\ d\ G} = \sqrt{900 - (30)(25)(i7)}$ = 19.36 mph
- Avg Velocity = $\frac{30 + 19.36}{2}$ = 24.68 mph
- Δ Time (skidding) = $\frac{25}{(24.68)(1.47)}$ = .69 seconds

Since Vehicle 2 began slowing at 4.5 seconds from impact and Vehicle 1 began skidding .7 seconds from impact, 3.8 seconds elapsed in the interim. Assuming a maximum reaction time of 2 seconds for Driver 1, it appears that 1.8 seconds is unaccounted for. He could well have been distracted.

If Vehicle 2 was instead braking at the fairly severe level of .4 G, on the other hand:

- Vehicle 2 braking distance = $\frac{30^2 - 10^2}{(30)(.4)}$ = 67 feet
- Average velocity = 20 mph
- Time braking = $\frac{67}{(20)(1.47)}$ = 2.3 seconds

Thus, Vehicle 2 would have begun braking at 2.3 seconds from impact. Vehicle 1 would still use .7 seconds in skidding, leaving 1.6 seconds difference during which Driver 1 could recognize the need for braking, react, and initiate it. This is about the time required for an alert driver to react, so that it would be unlikely that any distraction was involved. Vehicle 1 was simply following too closely behind Vehicle 2.

In summary, it appears unlikely that time separation information can be obtained from the accident population with sufficient accuracy to provide for an expression of accident risk as a continuous function of following distance. However, by a process of elimination, and sometimes with the benefit of confirming calculations, the occurrence of FTC can be usefully estimated; such estimates will tend to overstate the involvement of FTC and, consequently, risk calculations based on such estimates will suggest an upper bound in terms of relative risk of FTC.

DRIVING LEFT-OF-CENTER UDA

Feasibility of Assessment in an Accident Population

When a left-of-center vehicle collides with another vehicle, its lateral placement at impact can usually be determined by accident investigators with little difficulty. There are numerous potential indicators of at-impact placement, and by implication of preimpact trajectory. These include:

- **Skid marks:** skid marks from a left-of-center vehicle provide positive evidence of DLOC. Tires may also mark during and after collision, providing additional evidence. Where vehicles have struck head-on or sideswiped, preimpact skid marks from the struck vehicle showing it was in its own lane are also evidence of DLOC. Skid marks may also provide evidence as to the duration and extent of the DLOC behavior.

- **Vehicle damage:** where vehicles collide head-on on a two-lane road, it is nearly certain that one or both were left of center. Information as to the location of one vehicle at impact can be used together with the vehicle damage profiles to indicate the other's at crash position.

- **Gouge marks:** the frames and suspension members of vehicles that collide head-on are often deflected down into the pavement, providing evidence of at-impact position. These marks do not, however, indicate the duration or extent of DLOC behavior.

- **Fluid spillage and other debris:** radiator, engine oil, head or tail lamp lenses, window glass, underbody dirt, etc., may all be dislodged on impact and useful in assessing lane placement. However, these do not indicate duration or extent of DLOC behavior.

- **Driver and witness statements:** these may be the only evidence of DLOC where a left-of-center vehicle causes an accident but is not involved in the collision. They may also provide a means, even in multivehicle collisions, of quantifying the duration (e.g., total distance traveled left-of-center prior to impact) and extent (e.g., path traveled and degree of intrusion into oncoming lane prior to impact) of the DLOC UDA behavior.

Immediate response to the accident scene is necessary to document spillage and debris and to maximize witness information. Accordingly, investigations to document DLOC occurrence should involve such response if possible, rather than delayed response based on sampling of police accident reports or accident logs.

Documentation of DLOC is also often straightforward in many single vehicle accidents, where the DLOC vehicle deposits skid or skuff marks in crossing the opposing lane of travel, or impacts a vehicle or other object off the left side of the road.

In the general population, it would be possible to describe a DLOC UDA in considerable detail. Details of interest might include the amount of time or distance spent left-of-center within a particular segment, maximum intrusion into oncoming lane, angle or suddenness of entry and exit into opposing lane, etc. Ideally, we would like to have similar details on DLOC in the accident population. Short of an instrumented roadway network in a special accident study area, however, no means of obtaining such information with comparable accuracy has been identified. Thus, where the DLOC vehicle is involved in the collision, its DLOC status can nearly always be determined, but only partial information of varying accuracy on the extent and duration of such behavior can be expected (based on driver and witness statements and preimpact skid marks from the DLOC vehicle, if present).

In addition, a particular problem exists with respect to the DLOC noncontact vehicle. A so called "phantom vehicle" may force another driver to swerve (possibly into a fixed object or another vehicle) or to brake suddenly (possibly being rear-ended as a consequence), without itself being involved in the ensuing collision. Accident investigators are suspicious whenever noncontact vehicles are alleged to have caused a problem, since this provides a convenient means, particularly in single-vehicle accidents, for drivers to avoid culpability (and hence embarrassment and insurance consequences). There is no doubt, however, that substantial numbers of such accidents do occur and that left-of-center driving is likely to be a factor (although difficult to document) in many of these.

With all appropriate skepticism and requirements for confirming information, Indiana's in-depth (Tri-Level) team concluded that, among 420 accidents investigated, "noncontact vehicle caused problem" was a certain causal factor in 4 accidents (1.0%); a certain or probable cause in 16 accidents (3.8%); and a certain, probable, or possible cause in up to 29 accidents (6.9%). Results from the technician teams, based on 2,258 accidents were similar; **noncontact vehicles were possible causes of up to 112 accidents (5.0%).**

Based on the incidence data reported in Section 6.3, above, it thus appears that noncontact vehicles may account for one-third or more of the total DLOC problem.

Assessment of DLOC in such cases is at best difficult. The noncontact vehicle (NCV) will generally not leave skid marks, and the statements of witnesses must be given even less weight than in most other accident situations.

A process of elimination is sometimes useful in investigating such an accident. For example, a vehicle may give evidence (through skid marks or otherwise) of having suddenly braked, swerved, etc. If no other explanation can be found (e.g., showing off, dropped cigarette, swerved to avoid pedestrian or bicyclist), allegations of a noncontact vehicle's involvement may take on added credibility.

An indication of the results to be expected from such an approach is provided by the Indiana Tri-Level Study. It is unknown how often the involvement of an NCV was claimed, but the in-depth team concluded NCV involvement to be at least possible in 29 accidents out of 420 (6.9%). In only about half of these (16) did they believe the NCV involvement probable (i.e., 80% assuredness of involvement), and in only about one-seventh (four accidents) were they certain of NCV involvement. Based on this, it is estimated that an affirmative conclusion about DLOC occurrence can be made with reasonable assurance in about one-third to about one-half of all alleged noncontact DLOC vehicle involvements

The review of CPIR and Indiana DLOC cases by the human factors review team, and their discussion of these cases with HSRI reconstruction experts, provided additional insight into the feasibility of DLOC assessment under the proposed definition. They concluded that, depending on the amount of information that was available at the scene, there is "more than an eighty percent chance" of determining if an accident-involved vehicle crossed the center line. However, they concurred in the extreme difficulty of verifying involvement of DLOC when committed by the driver of a noncolliding vehicle.

In summary, there is little difficulty in determining that an accident vehicle was DLOC if:

- it strikes another vehicle while left-of-center;
- it deposits skid or skuff marks while left-of-center; or
- it strikes an object off the left side of the road.

However, in another group of cases roughly equal in size, it is likely to be claimed that a noncontact vehicle caused the accident. Documentation of such a vehicle's probable involvement can be expected in about one-third to one-half of such cases, and many of these may involve DLOC behavior. A conservative assessment of claimed NCV involvement is warranted in such cases, but might result in total DLOC incidence being understated. Risk calculations comparing accident and exposure data would accordingly understate the DLOC risk. Accident information will tend to be limited to DLOC occurrence or nonoccurrence, and will thus provide less detail than can be measured for the general driving population.

SUMMARY

The definitions developed appear operationally feasible. The definitions can be applied to collect exposure data. They also can be applied in the accident investigation process, although less precision can be expected.

Precrash speeds in accidents can be estimated with an error of less than ± twenty percent in nearly all cases, with most cases within a substantially narrower range. In the context of this study, precrash travel speeds can be obtained from the accident population with sufficient accuracy to establish the relative risk of speed-related UDAs and to evaluate potential countermeasures.

Determination of following-too-closely involvement will be more difficult. It is unlikely that precise information on the time separation between accident-involved vehicles can be consistently obtained by accident investigation. However, by a process of elimination and through the use of confirming calculations, the occurrence of FTC can be usefuly estimated. The estimates are likely to represent overestimates and thus will constitute an upper bound in computing the relative risk of FTC.

The occurrence of driving-left-of-center can be determined with reasonable certainty if the DLOC vehicle was directly involved in the crash. However, case reports indicate that noncontact vehicles are claimed to cause accidents through DLOC with about the same frequency that DLOC is noted as physically involved in crashes. While involvement of noncontact vehicles may be documented in some accident investigations, estimates are likely to be conservative. Thus, risk calculations that used accident data that included DLOC cases involving contact and noncontact estimates would be likely to understate the DLOC risk. Such understatement is not believed likely to be significant for current applications. It is, however, a longer-term constraint.

In summary, the definitions developed appear to be operationally feasible for application in exposure data collection and in accident investigation. Further, the data collected will support the development of relative risk statements about the UDAs of interest and support countermeasure development and evaluation.

CHAPTER EIGHT
OPERATIONAL DEFINITIONS OF SPEEDING, FTC, AND DLOC

The preceding sections have generated preliminary definitions of the three subject UDAs and have then examined these definitions in more detail using data from HSRI's accident files and the literature. This section reexamines the preliminary definitions in light of the findings of the more detailed analysis. The preliminary definitions are revised where necessary and stated in more detail where possible. Preliminary estimates of unconditional risk are also reconsidered and refined as a result of the later findings on the incidence of the three UDAs as causal factors in crashes. Finally, related characteristics of each UDA are summarized, and the degree to which the UDAs that caused crashes were conscious and intentional is discussed.

SPEEDING

The dichotomous classification of speeding UDAs as either relative or absolute is retained in the refined definition. However, the more detailed analysis indicates the need to explicitly define another top-level variable for classifying UDAs. This variable is also dichotomous and classifies all speed UDAs is either speed-too-fast or speed-too-slow. Thus, four types of speed UDAs are identified:

Type 1 - too fast, absolute
Type 2 - too fast, relative
Type 3 - too slow, absolute
Type 4 - too slow, relative

Additional classification rules are needed to make these four types of speed UDAs mutually exclusive. The rules are:

Rule 1: The absolute-speed condition dominates the relative-speed condition for maximum speed limits.

Rule 2: The relative-speed condition dominates the absolute-speed condition for minimum speed limits.

Rule 3: Poor driving conditions (e.g., icy roads) remove minimum speed limits.

The results of applying these rules to various combinations of conditions are summarized in Table 8-1.

The definition of relative-speed UDAs in terms of the 5th and 95th percentile speeds of traffic is also retained, although some difficulty can be expected in applying that definition to risk analysis. A combination of instrumented roadways and clinical analyses of crashes on those roadways will be required for accurate estimates of unconditional and conditional risk posed by UDAs defined in this way.

Expanding the types of UDAs from two to four makes it necessary to restate the estimates of unconditional risk and conditional risk presented in Table 2-1. Data from Chapters Two and Four are needed for the new estimates. Actually, the more detailed analysis of Chapter Four provides additional information on unconditional risk only, because only accidents were analyzed in that section. Chapter Four used incidence of the UDA as a surrogate for unconditional hazard rate, but the translation of incidence to hazard rate is elementary if it is assumed that the incidence figures apply nationwide.

Table 8-2 shows the new estimates of unconditional hazard rate for the four types of speed UDAs. Assumptions used in arriving at the estimates are indicated in the notes to the table. The combined unconditional hazard rate for all types of speed UDAs is now estimated at 1,100 to 3,900 crashes per year per 100,000 population or 14% to 48% of all crashes.

Note that the speed-too-slow UDAs are estimated to be much less risky to the general population than was indicated by the preliminary analysis in Chapter Two. A possible reason for the higher rates in Chapter Two is that some of the crashes that contributed to higher hazard rates at low speeds were not actually caused by the speed-too-slow UDA. Because of the lack of reliable clinical data on speed-too-slow, our present estimates of associated hazard rates should be

TABLE 8-1

CLASSIFICATIONS OF POSSIBLE SPEED-RELATED UDAs

Absolute Speed of Subject Vehicle	Classification		
	Mean Traffic Speed Higher Than Maximum Limit	Mean Traffic Speed Lower Than Minimum Limit	Mean Traffic Speed Within Both Limits
Higher Than Maximum Limit	Absolute (too fast)	Absolute (too fast)	Absolute (too fast)
Lower Than Minimum Limit	Absolute (too slow) Under Good Conditions; Relative (too slow) Under Poor Conditions	Relative (too fast or too slow)	Absolute (too slow) Under Good Conditions; Relative (too slow) Under Poor Conditions
Within Both Limits	None	Relative (too fast)	Relative (too fast or too slow)

TABLE 8-2

REFINED ESTIMATES OF UNCONDITIONAL HAZARD RATES FOR SPEED UDAs

TYPE OF SPEED UDA	PERCENT OF ALL CRASHES	ESTIMATE OF[1] UNCONDITIONAL HAZARD RATE
1 - Too fast, absolute	4-16[2]	300-1,300
2 - Too fast, relative	5-12[3]	400-1,000
3 - Too slow, absolute	Not Known	Not Known
4 - Too slow, relative	Not Known	Not Known
All too fast (Types 1 and 2)	9-28	700-2,300
All too slow (Types 3 and 4)	5-20[4]	400-1,600
All absolute (Types 1 and 3)	Not Known	Not Known
All relative (Types 2 and 4)	Not Known	Not Known
All types	14-48	1,100-3,900

Notes

1. Crashes of all severities per year per 100,000 population
2. Upper figure from Chapter Four; lower figure from Lohman et al. 1976
3. Upper figure adjusted upward from Chapter Four value of 7% to reflect 1977 data from Treat et al. 1980; lower figure from Lohman et al. 1976
4. Based on considerations discussed in Chapter Four but adjusted upward

regarded as primarily subjective and very rough. No useful estimate of the hazard rates of the components of the speed-too-slow UDAs (i.e., types 3 and 4) are possible at present.

The new estimates of conditional risk are based on the data in Chapter Two because only accident data were analyzed in Chapter Four. These new estimates are not "refined" in the sense of being improved by additional information. Instead, they are preliminary estimates of the risk associated with the four types of speed UDAs that have now been defined rather than the two types of speed UDAs that were defined in Chapter Two.

Table 8-3 presents these new estimates. The table assumes that the conditional hazard rate for the speed-too-fast, absolute-speed UDA (Type 1) is approximately equal to the conditional hazard rate for the speed-too-fast, relative-speed UDA (Type 2) as estimated in Table 2-1. The assumption is made because of the common practice among police agencies of enforcing maximum speed limits at about the 90th to 95th percentile speed (Joscelyn, Jones, and Elston 1970). The conditional hazard rate for either of these two types of UDA is estimated at about 100-200 crashes per year per 100 million miles driven while committing either UDA.

The estimated conditional hazard rate for the speed-too-slow, relative-speed UDA (Type 4) is about ten to twenty times that of the speed-too-fast, relative-speed UDA (Type 2). The Type 4 rate shown in Table 2-1 was adjusted downward to account for factors discussed in Chapter Four. It was not possible to develop an estimate of the conditional hazard rate for the speed-too-slow, absolute-speed UDA due to the lack of a common policy for setting and enforcing minimum speed limits.

Factors associated with certain classes of speed UDAs were also identified from the analysis of accident files. Table 8-4 summarizes the characteristics most common among all types of crashes that were caused by speed-too-fast UDAs (i.e., Types 1 and 2). Characteristics that tend to distinguish crashes caused by speed-too-fast from all other crashes are also listed in the table.

TABLE 8-3

PRELIMINARY ESTIMATES OF CONDITIONAL HAZARD RATES FOR FOUR TYPES OF SPEED UDAs

TYPE OF SPEED UDA	CONDITIONAL HAZARD RATE[1]
1. Too fast, absolute	100-200[2]
2. Too fast, relative	100-200[3]
3. Too slow, absolute	Not Known
4. Too slow, relative	1,000-2,000[4]

Notes for TABLE 8-3

1. Number of crashes of all severities per year per 100 million miles driven while committing the UDA
2. From Table 2-1. See discussion in text.
3. From Table 2-1.
4. From Table 2-1, adjusted downward

TABLE 8-4

CHARACTERISTICS OF SPEED-TOO-FAST UDAs

VARIABLE	MOST FREQUENT VALUE	MOST FREQUENT VALUE RELATIVE TO VALUE FOR CRASHES IN GENERAL
Crash Severity	Low	Very High
No. of Vehicles in Crash	About the same for one and more than one	One
Impact Configuration	Intersecting	Sideswipe, rearend
Driver Age	Young	Young
Driver Sex	Male	Male
Road Type	City Streets	Secondary and Interstate
Road Lane Configuration	Two-lane	Four-lane divided and Two-lane
Road Alignment	Straight and level	Curves and/or hills
Precipitation	None	Rain & Snow

A detailed breakdown of all the characteristics of each of the four types of speed UDAs was not possible due to coding inconsistencies and practices of the cases in the accident files. For example, speed-too-slow UDAs could not readily be filtered out of the mass data files. However, it is possible to get a rough idea of how Type 1 and Type 2 speed-too-fast UDAs differ with respect to certain variables. These differences are summarized in Table 8-5.

Finally, our analyses indicate that speed-too-fast UDAs are overwhelmingly conscious and intentional. This is true for speed-too-fast, absolute-speed UDA (Type 1) and the speed-too-fast, relative-speed UDA (Type 2). Our clinical assessments suggest that impairment of drivers (e.g., by alcohol) is a major factor in the relatively small percentage of unconscious and unintentional speed-too-fast UDAs that cause crashes.

FOLLOWING TOO CLOSELY

The preliminary definition is retained, but the difficulty of precisely determining separation time between following vehicles in clinical assessments is noted. Instrumented roadways would be needed to determine the separation time of accident-involved vehicles and of vehicles not involved in accidents. Also, it is important that the preliminary definition explicitly excludes instances of "gross inattention" from the FTC category. The definition should specifically note that the term "reaction time" includes a component for allowing a driver to **recognize** a stopping maneuver by a lead vehicle.

The more detailed analysis of the crash risk posed by the FTC UDA did not result in any significant change over that estimated in Chapter Two. Our final estimate (for this project) is that about one percent of all crashes are caused by FTC as defined herein. This corresponds to an conditional hazard rate of the order of 100 crashes per year per 100,000 population. No estimate of unconditional hazard rate was possible, because exposure data were not analyzed in Chapter Five.

The characteristics of FTC crashes are summarized in Table 8-6. The data show that such crashes are predominantly low-severity, rear-end crashes involving young males on straight and level stretches of

TABLE 8-5

COMPARISON OF CHARACTERISTICS OF
TYPE 1 AND TYPE 2 SPEED UDAs

VARIABLE	RELATIVE FREQUENCY OF VARIABLE VALUES
Crash Severity	Higher severities more frequent among Type 1 crashes than among Type 2 crashes.
No. of Vehicles in Crash	Single-vehicle crashes more frequent among Type 1 crashes; multiple-vehicle crashes more frequent among Type 2 crashes.
Driver Age	Younger drivers more likely to be involved in Type 1 than in Type 2.
Driver Sex	Male drivers more likely to be involved in Type 1 than in Type 2.
Type of Road	City streets, county roads, and state secondary roads more frequent among Type 1 crashes than among Type 2; U.S. and state trunklines and interstate turnpikes more frequent among Type 2 crashes than among Type 1.
Road Alignment	Curves and/or hills more frequent among Type 1 crashes than among Type 2. Straight-level roads more common among Type 2 crashes than Type 1.

TABLE 8-6

CHARACTERISTICS OF FTC UDAs

VARIABLE	MOST FREQUENT VALUE	MOST FREQUENT VALUE RELATIVE TO VALUE FOR CRASHES IN GENERAL
Crash Severity	Low	Low
No. of Vehicles in Crash	Multiple	Multiple
Impact Configuration	Rear end	Rear end
Driver Age	Young	Young
Driver Sex	Male	No difference with respect to sex
Road Class	City Streets; U.S. & state turnpike	Interstate & turnpike U.S. & state turnpike
Road Lane Configuration	Four or more lanes, divided and nondivided	Four or more lanes, divided and nondivided
Road Alignment	Straight and level	Straight and level
Precipitation	None	Rain

four-or-more-lane city streets and turnpikes.

The small sample of FTC-caused crashes reviewed precludes any statistically reliable statements about the degree to which such crashes are the result of conscious and intentional driver actions. However, all of the drivers in the seven cases studied were found to have consciously and intentionally committed the UDA.

DRIVING LEFT OF CENTER

Again, the preliminary definition of DLOC set forth in Chapter Two is retained. However, there are several pitfalls in classifying DLOC behavior from observations of DLOC in the general population and from accident data. We offer the following clarifications and guidelines for making these assessments. For observations of DLOC these are:

- Count as a DLOC UDA each vehicle whose wheels ride on or over the center line anytime during the vehicle's transit through the observed road segment. Highways with any form of median barrier or clear zone are excluded from consideration.

- Assign severity gradings for each infraction. The gradings should be based on depth of penetration into the oncoming lane and the amount of time spent there.

- Note observable extenuating circumstances (potholes, bumps, narrow road section, parked vehicles, etc.) as they apply to each UDA occurrence.

- Record separately DLOC incidents that either result in a collision involving the offending vehicle or precipitate other collisions.

In classifying DLOC from accident analysis, investigators must confirm that:

- At least one vehicle must have been on or across the center line at the time of the crash.

- Such vehicle(s) must not have been engaged in passing or turning left at the time of the crash.

- If allegations that a noncontact ("phantom") vehicle engaged in DLOC caused the crash are verified, that crash may be counted as involving a DLOC UDA. Physical evidence, such as skid marks from the noncontact vehicle, or corroborating witness statements should be used in verifying the DLOC UDA in such instances.

After examining the HSRI accident files, we conclude that about ten percent of all crashes are caused by DLOC as defined in Chapter Two. This number falls within the four to twelve percent range estimated in Chapter Two and corresponds to an unconditional hazard rate of about 800 crashes per year per 100,000 population. No estimates of DLOC conditional risk can be made at present.

DLOC crashes examined in Chapter Six tended to be much more severe than other types of crashes, due no doubt to the predominance of head-on impact configurations in DLOC crashes.. (More than 71% of DLOC-related crashes filtered out of the CPIR file were head-on; see Table 8-7). Most often, DLOC-caused crashes involved more than one vehicle on two-lane, straight-and-level city streets in dry weather. However, DLOC-caused crashes occurred more frequently on curved or hilly country roads and state secondary roads than did crashes in general. Snowy weather was also overrepresented in DLOC-caused crashes. Furthermore, data from the Texas Five Percent Sample File showed that drivers in DLOC caused crashes were about four times as likely to be cited for drunk driving as drivers in crashes in general.

While a significant percentage of all crashes appear to be caused by DLOC, few crashes (about three percent) involve a **conscious and intentional** commission of DLOC. DLOC-caused crashes that are conscious and intentional, but not due to environmental factors (e.g., poor visibility, need to avoid bicyclists) are still rarer (less that one percent of all crashes).

TABLE 8-7

CHARACTERISTICS OF DLOC UDAs

VARIABLE	MOST FREQUENT VALUE	MOST FREQUENT VALUE RELATIVE TO VALUE FOR CRASHES IN GENERAL
Crash Severity	Low to moderate	Very high
No. of Vehicles in Crash	Multiple	Multiple
Impact Configuration	Head-on	Head-on; Sideswipe
Driver Age	Young	Young
Driver Sex	Male	Male
Road Class	City streets	County roads; state secondary roads
Road Lane Configuration	Two-lane	Two-lane
Road Alignment	Straight and level	Curve, hill, or both
Precipitation	None	Snow

CHAPTER NINE
CONCLUSIONS AND RECOMMENDATIONS

This document has developed operational definitions of three unsafe driving actions (UDAs): speed, following too closely (FTC), and driving left of center (DLOC). Characteristics associated with each of the UDAs were described, and the degree to which the UDAs were conscious and intentional was estimated. The definitions provide a basis for developing driver-oriented countermeasures in the General Deterrence project and for analyzing enforcement procedures in the Police Enforcement project.

DEFINITIONS

Two basic classes of speed UDAs were defined, an absolute-speed UDA and a relative-speed UDA. Their operational definitions are as follows:

- An **absolute-speed UDA** is the act of driving a vehicle at a speed in excess of an appropriately established maximum speed limit or, in a normal driving environment, at a speed below an appropriately established minimum limit.

- A **relative-speed UDA** is the act of driving a vehicle at a speed that is so different from the speeds of vehicles around it that the risk of a crash exceeds that which is societally acceptable. Preliminary data indicate that speeds less than the fifth percentile speed of traffic or greater than the 95th percentile speed of traffic are societally unacceptable.

Each of these two classes of speed UDAs can be further defined as either speed-too-fast or speed-too-slow UDAs, resulting in a total of four types of speed UDAs, viz.:

Type 1 - too fast, absolute
Type 2 - too fast, relative
Type 3 - too slow, absolute
Type 4 - too slow, relative

The analysis of FTC resulted in the following operational definition:

- The **FTC UDA** is the act of driving a vehicle following another vehicle such that the time separation between the two vehicles is so short to create a societally unacceptable level of crash risk. Preliminary data indicate that time separations of less than one to two seconds are societally unacceptable.

This definition closely follows the legal definition of FTC in many states. It explicitly does not include **all** types of driving behavior that cause rear-end crashes. Many of such behaviors would be classified as other types of UDAs not involving the car-following relationships and associated surveillance activity by following drivers.

For DLOC, the operational definition is:

- The **DLOC UDA** is the act of driving a vehicle over or on the center line of a two-way road when not passing or turning.

INCIDENCE AND RISK

The **speeding UDA** is estimated to be a causal factor in fourteen to forty-eight percent of all traffic crashes. More than half of these are caused by speed-too-fast (Types 1 and 2 combined). The speed-too-fast, absolute-speed UDA (Type 1) causes an estimated four to sixteen percent of all crashes, and the speed-too-fast, relative-speed UDA causes an estimated five to twelve percent of all crashes. The speed-too-slow UDA (Types 3 and 4 combined) is estimated to be a causal factor in five to twenty percent of all crashes. No meaningful estimate of the incidence of speed-too-slow, absolute-speed UDA (Type 3) or the speed-too-slow, relative-speed UDA (Type 4) can be made at this time.

Crashes caused by speed-too-fast UDAs tend to be much more severe than crashes as a whole; crashes caused by speed-too-slow UDAs tend to be less severe than the speed-too-fast crashes. Most speed-too-fast UDAs are conscious and intentional.

The **FTC UDA** is estimated to be a causal factor in about one percent of all crashes. FTC-caused crashes tend to be less severe than crashes as a whole. Our findings on the degree to which FTC UDAs are conscious and intentional are inconclusive but suggest that most of these UDAs are deliberate.

The DLOC UDA is estimated to be a causal factor in about ten percent of all crashes, and DLOC-caused crashes tend to be much more severe than crashes in general. Only about three percent of all crashes appear to involve a conscious and intentional commission of a DLOC UDA, and most of these are due to environmental factors.

Lack of data on exposure makes it impossible to estimate the conditional risk of any of the subject UDAs except three of the four types of speed UDA. Both types of speed-too-fast UDAs are estimated to have a conditional hazard rate of the order of one hundred to two hundred crashes of all severities per 100 million miles driven while committing the UDA. The conditional hazard rate of the speed-too-slow, relative-speed UDA is estimated to be the order of ten times this figure. No estimate of the conditional hazard rate of the speed-too-slow, absolute-speed UDA can be made because of a lack of data.

Note that these estimates of conditional hazard rates are for crashes of all severities. For more severe crashes the differences between the conditional hazard rates for the speed-too-slow, relative speed UDA become smaller. These two rates appear to be about equal for fatal crashes.

CONCLUSIONS

We conclude that of the UDAs examined in this report, **speed-too-fast UDAs** should have the highest priority for the types of countermeasures that fall within the scope of the General Deterrence and the Police Enforcement projects. These UDAs are a causal factor in a large percentage of crashes. These crashes tend to be more severe than crashes as a whole. **Speed-too-slow UDAs** should also be of high, but somewhat less, priority than speed-too-fast UDAs. The main reason for this lower priority is that speed-too-slow UDAs tend to cause less severe crashes than speed-too-fast UDAs.

The **DLOC UDA** is ranked next highest of the three UDAs considered here. This UDA contributes to a substantial percentage of all crashes (i.e., the order of ten percent), and many of these crashes are much more severe than crashes as a whole. However, DLOC UDAs appear less amenable to countermeasures that would be appropriate for this project, because these UDAs are usually not conscious and intentional.

The **FTC UDA** is ranked as the lowest priority of the three UDAs analyzed in this report. This UDA contributes to a very small percentage of crashes (about one percent) most of which are of relatively low severity.

We also conclude that the operational definitions developed in this report are feasible for use in analyzing the UDAs and their effects. Their use in retrospective studies will require that the determinations of their role in causing crashes be more subjective than the determinations made in prospective studies. In the latter type of study, arrangements can be made to obtain some of the information necessary to determine the values of the observable risk variables (for example, instrumentation for measuring the speed distribution of vehicles on a segment of roadway). Such prospective studies might include problem definition analyses and evaluations of the effect of a countermeasure on the incidence of the target UDA.

RECOMMENDATIONS

The principal recommendation of this definitional study is that both the General Deterrence and the Police Enforcement projects be restricted to the speeding UDA. Both speed-too-fast and speed-too-slow UDAs should be studied, with the former to be given first priority.

FTC and DLOC should be analyzed further in NHTSA's National Analysis of Unsafe Driving Actions and Behavioral Errors in Accidents (DOT-HS-8-02023). Also, additional data on the unconditional and conditional risk posed by all four types of speeding UDAs should be developed in the National Analysis. Particularly, more information is needed to determine the risk due to the speed-too-slow, absolute-speed UDA and the speed-too-slow, relative-speed UDA.

Although DLOC is not an appropriate target for this project, the overall risk it creates is sufficiently high to consider it a candidate for other types of countermeasures. Countermeasures aimed at the roadway environment could be effective for dealing with this UDA.

Finally, at this juncture we do not recommend any significant new countermeasure effort for FTC. Violations of existing statutes relating to FTC should continue to be enforced, but large-scale, nationwide campaigns and large expenditures of funds for manpower and equipment are not indicated.

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