HIGHWAY RESEARCH RECORD

Number 163

Highway Safety

6 Reports

Subject Area

51 Highway Safety
52 Road User Characteristics

HIGHWAY RESEARCH BOARD

DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

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Highway Safety

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Foreword

A recent Presidential message to Congress urged a total attack on the traffic safety problem, and requested greater funds for research, accident data collection, driver education and testing and traffic control technology. As a result, highway safety has been emphasized as never before. This RECORD presents some important research milestones in the field and concentrates on various aspects of driver behavior and accidents as well as highway design and its relation to accidents.

The six papers and three discussions will be of general interest, but they will be of prime use to driver educators, safety administrators, highway and traffic officials, enforcement personnel and accident record researchers and specialists.

Baerwald's paper surveys accident records and their use and finds that there is room for much improvement. Locations need to be identified and emphasis should be placed on recording factual information. The author also points out that special forms are needed for research use and that accident statisticians should use electronic processing equipment to a greater extent. Three discussers have also contributed their comments and the author has added a closure.

Three California researchers have studied teen-aged drivers in that state and have reported the findings. As a result of a study of significant relations between exposure, experience and driving record, they discovered a lack of general effectiveness of statewide driver training in reducing accidents. There is also some evidence that immaturity and lack of experience contributed to accidents. Differences between male and female driver behavior are presented in terms of the variables studied.

Peck, Coppin and Marsh in their paper on driver records compared as to age, sex, and marital status find that women drivers have better driving records than men. As age increases, accidents decrease except in advanced age brackets. Marriage evidently helps female drivers achieve better records than their male counterparts, although single female drivers have better records than married male drivers. Over 200, 000 driving records were examined in this comprehensive research.

Some of the problems engendered by extremely long sessions of controlled-access highway driving without sleep were studied by two Ohio researchers. Driver behavior as measured by performance instrumentation does decrease over time, but rest periods tend to bring back part of the decrement in performance. Modest experiments with drugs on one of the research subjects indicated an improvement in performance and increased ability to drive further. Physiological data indicated little change.

Another paper describes freeway ramp studies conducted to determine which geometric features are most closely related with safety. Correlations were found between accident rates and ramp types, relative freeway to ramp grades, fixed objects, speed change lane lengths, possible safe entrance speeds at on-ramp noses, and off-ramp radii. Accident rates of on-ramps were found to be consistently lower than those of off-ramps.

The final paper gives the findings of three California researchers who conducted a reevaluation study of group driver improvement meetings. They learned no accident reduction resulted from such driver improvement meetings, but that such meetings did reduce traffic convictions.

Publication of this RECORD was aided in part by a financial grant from the ENO Foundation for Highway Traffic Control, Inc.

Contents

Traffic Accident Reporting Criteria of Principal Users in Illinois

JOHN E. BAERWALD, Director, Highway Traffic Safety Center, University of Illinois, Urbana

This research indicated that the emphasis in accident report forms should be on the recording of factual information, including accurate identification of the involved traffic units (persons and vehicles) and the location of the probable collision area to the nearest 100 ft. The time and date of the accident occurrence should be reported for legal, administrative, educational, and research purposes. The accident report should cover three types of accident circumstances: (a) the maneuvers and actions of each traffic unit before, at, and following impact; (b) unusual environmental conditions; and (c) accident results.

Immediate attention should be given to development of scales to indicate a quantitative estimate of personal injury and property damage. Studies should be directed toward the development of uniform accident reporting and summary forms which would be of more benefit to a majority of the user groups. The collection of specialized accident data for research uses is not a function of routine accident reports, but such data should be obtained on specifically designed forms. Accident statistical units should be strongly urged to utilize electronic data processing equipment and techniques to a greater extent.

•MANY TRAFFIC accident prevention programs have been based on records of traffic accidents. This concept is based on the theory that accidents tend to repeat and that, if it is possible to identify the factors contributing to accidents which have happened, it is possible through corrective steps to avoid the repetition of such occurrences in the future. Accident records also serve as a measure of the magnitude of the problem, thus enabling the public and government to determine the proper emphasis to be given to various facets of the problem. Similarly, continuous evaluation of records provides trend information so that progress or the lack of it can be measured.

Every national agency in the traffic safety field has acknowledged the significance of traffic accident records, and the use of these records was also recognized by the 1946 President's Highway Safety Conference and all succeeding conferences. Consequently, a section describing traffic accident records is included in the current Action Program of the President's Committee for Traffic Safety (1).

Increasing evidence indicates that traffic accident records in the United States are unsatisfactory. Some of the visible indications of difficulty can be identified as follows:

1. Incomplete or inconsistent national totals,
2. Duplication of effort and excessive costs,
3. Absence of the application of modern techniques for data processing,
4. Lack of inter-governmental or inter-bureau exchange and cooperation,
5. Failure to produce significant facts about accidents, and
6. Absence of a satisfactory rate basis.

Paper sponsored by Committee on Highway Safety and presented at the 45th Annual Meeting.

The National Safety Council estimated that in 1965 there were about 12.5 million motor vehicle traffic accidents in the United States. It is presumed that at least half of these accidents were reported in some form to one or more of the many agencies, both public and private, which are directly interested in traffic accident data.

An individual driver involved in an accident of any consequence may be expected to file, at a minimum, a state traffic accident report and an insurance company report. Depending on local regulations and where the accident occurred, he might also be required to file reports with other authorities such as city police, county sheriffs, and toll authorities. If a commercial vehicle driver is involved in an accident, he might be required to file all of the above reports as well as other reports to his employer, to the state public utilities authority, and to the Interstate Commerce Commission. These accident reports vary in scope, detail, and the urgency for prompt reporting, depending on the interests of the different agencies. Such multiple reporting is, therefore, a problem to the motorist, who can become confused and overburdened with different reports, and to the various agencies, whose different interests may tend to decrease the accuracy and completness of the reports prepared for their use.

The multiple reporting and the lack of uniformity in accident data collection and processing is depriving many agencies of much essential information. Before extensive efforts can be made to minimize the number of accident report forms and obtain greater uniformity in reporting, it is necessary that the reporting criteria for the different traffic accident data users be identified and coordinated wherever possible.

REVIEW OF LITERATURE

Although there have been many publications which discuss traffic accidents, only a few articles go into any detail about traffic accident record systems. "The Federal Role in Highway Safety" (2) devotes considerable attention to traffic accident records. This publication states:

> Foremost and most obvious among the important measures of the status of safety on the Nation's highways is the traffic accident. The specific results of an accident—damage to property, or death or injury to people—have definite meaning to the individuals involved but, for appreciation of their full significance, accidents need much broader interpretation in terms of values to all society. Satisfactory appraisal of the wide range of tangible and intangible effects is well nigh impossible in statistical terms.*
>
> But it is necessary, certainly, to dimension the traffic-accident problem in its relationship to highway transportation and the major characteristics of the population it serves. While a great deal of information is now collected and is useful for this purpose, unfortunately some of it is of questionable validity or value.

Another important publication is "Traffic Accident Records: A Section of the Action Program for Highway Safety" (1). This publication promotes the development and use of traffic accident record systems and also points up the need for increased standardization, simplification, and improvement of traffic accident record systems.

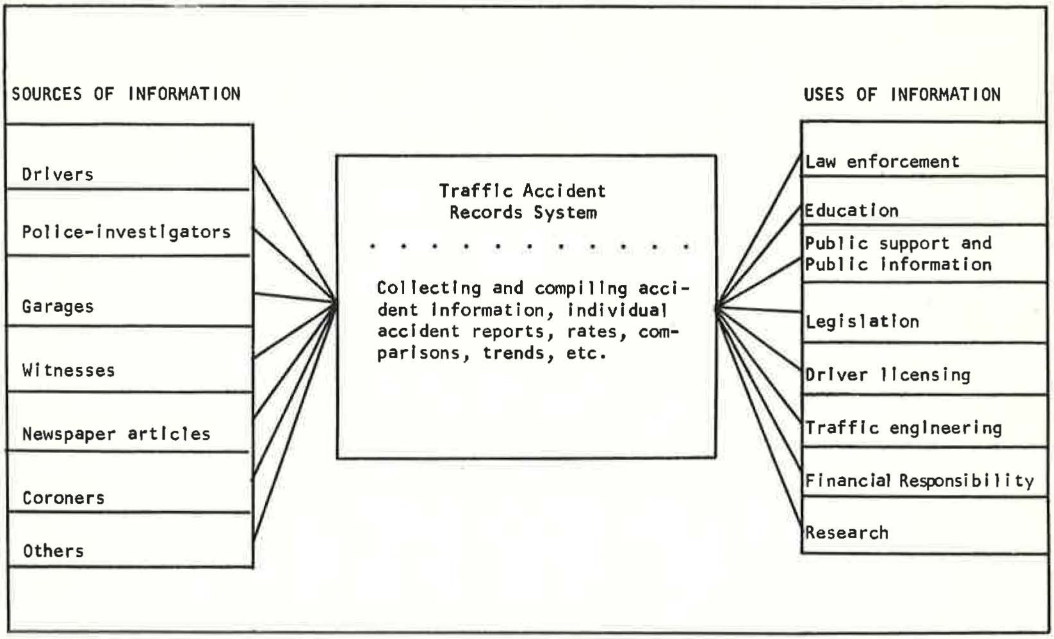
The most recent and most detailed report, "Improvement of the Present System of Traffic Accident Records" (3), was published in 1963. This comprehensive analysis contains many suggestions for improvement of traffic accident records. Other pertinent publications include manuals for compiling (4, 5) and using (6) traffic accident statistics. These and related publications will be referred to when appropriate.

Basic Purposes of Traffic Accident Records

Five distinct, basic purposes of traffic accident records have been identified by J. Stannard Baker (3). These are:

1. To have knowledge of traffic accidents as a cause of mortality, morbidity and economic loss;

*Underlining added for emphasis.



Source: President's Committee for Highway Safety, Traffic Accident Records: A Section of the Action Program for Highway Safety, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 1960, p. 7.

Figure 1. Traffic accident records system as outlined in the action program.

2. To point out where, when, and to whom traffic accidents are a critical problem;
3. To suggest lines of preventive action to be taken;
4. To measure the effect of accident-prevention efforts; and
5. To determine negligence or fault.

Users of Traffic Accident Records

The principal uses of traffic accident information and their sources were summarized in "Traffic Accident Records" as shown in Figure 1. Baker (3) has expanded the listing of traffic accident data users and identified the purposes for which each kind of user desires the information (Table 1). In discussing users of accident records, Baker states:

> In the broadest sense, of course, the purpose of accident records is to meet needs for accident information of agencies with responsibilities for traffic safety. The purposes for which different agencies want information are not necessarily different, although the uses to which they put the information may be. For example, both engineers and enforcement officials want information about location of accidents. Both want it for purposes of determining where accidents are most critical; but one will use it for planning selective enforcement and the other for deciding what points in the road network will benefit most from traffic engineering treatment.

He later says:

> Some agencies with responsibilities for traffic safety make little use of traffic-accident records for any purpose. Vehicle inspection comes to mind as one of these. In most of these cases available records contain little information to suggest preventive action. Furthermore, the records

TABLE 1

PURPOSES OF ACCIDENT RECORDS IN ACCIDENT PREVENTION FUNCTIONS

ACCIDENT PREVENTION	1. Cause of mortality, morbidity	2. Where, when, etc. critical	3. Suggest preventive action	4. Measure effect of effort	5. Determine negligence or fault
Law enforcement					
Police		X	X	X	
Courts				X	X
Education		X	X	X	
Public information	X	X	X	X	
Legislation	X	X	X	X	
Driver licensing					
Examination			X	X	
Improvement		X	X	X	X
Engineering					
Traffic engineering		X	X	X	
Highway design		X	X	X	
Vehicle design		X	X	X	
Vehicle inspection		X		X	
Financial responsibility	X				

are not good enough to demonstrate how effective specific safety measures really are. There seems to be a tendency in connection with accident records for those who want information to think of using only what is available and for records systems to think of producing only what is required.

Data Requirements

The basic accident data required by certain user groups were identified in "Traffic Accident Records" (1), as shown in Table 2. Baker (3) has developed a table (Table 3) which lists the special data requirements for each of the five basic purposes of traffic accident records. In discussing this table he states:

> In such a table, indications of information needed are, of course, matters of judgement (sic) and therefore subject to minor disagreements, but they do serve to illustrate various possible demands on data collection systems. For example, very few facts about each accident are needed to know how traffic accidents compare in frequency with other causes of death; but to determine fault or negligence, data on many specific details of an accident may be required.
>
> Specific needs for data are determined by special uses. Often these might be much more limited than those suggested by the chart of data

needed for various purposes (Table 3). For example, an investigation of the contribution to accidents of mechanical defects in automobiles, would entail very specific descriptions of a vehicle's mechanical condition before and after the accident; but usually few facts about the driver, road, and events of the accident.

Note that Table 3 includes only basic facts needed for various purposes, not conclusions based on the facts. Note also that many of the kinds of facts wanted, as shown in the list across the top, could be subdivided. For example, under detailed information on injury there might be listed the specific nature of the injuries, an estimate of their severity in terms of days of disability, breakdown of medical costs (important in settlement claims) and an evaluation of degree of permanent disability (important in workmen's compensation).

Sources of Traffic Accident Data

Possible sources of traffic accident data have been divided into five general categories by Baker (3). These categories have been identified and subdivided according to their relationship to the events and circumstances of the accident as listed in Table 4 and described below: *

1. Persons there when the accident occurred.

a. Drivers of vehicles involved and injured pedestrians. These are the most important people because they were responsible for direction and control of the traffic units involved.

b. Others involved are usually occupants of vehicles but may also be people accompanying pedestrians.

c. Bystanders and passers-by are people who were in a position to see important events of the accident even though they may not have done so. People who just heard the noise would not be included. Bystanders may have been afoot or in vehicles, standing or moving, and they may have been as much as 500 ft away at the time.

2. People arriving at the scene soon after the accident are those who came to the scene after the accident situation had been stabilized but before vehicles had been moved or the road cleared for traffic. They may have come unexpectedly or may have come to see what the disturbance was. Not included are people called to the scene for particular purposes.

3. People sent to attend the accident.

a. Police with specialized training for work with traffic accidents are generally men assigned to accident investigation units, or highway patrolmen with at least some special accident investigation training. If qualifications consisted only of instruction or experience in completing an accident report form, the police officer would not be in this class.

b. Other police include deputy sheriffs, park rangers and similar officers if they had no special training.

c. Firemen called to the scene.

d. Ambulance drivers and attendants may or may not have medical or first aid training. If police or firemen drive or accompany the ambulance, put them in this class only if their duties in connection with the accident relate to transporting dead or injured. Undertakers who go to the scene are in this category.

e. Tow-truck drivers and helpers include highway department, public utility, and similar employees who go to the scene to help clear the road or roadside.

f. Photographers and newspaper reporters are those who actually get to the scene of the accident before vehicles are removed. Amateur or professional photographers are included if they happen on the scene or go there on their own initiative before vehicles are moved.

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*In accidents involving more than one traffic unit, there may be a separate source for some kinds of information for each traffic unit involved.

TABLE 2

BASIC INFORMATION REQUIRED OF ACCIDENT RECORDS SYSTEMS

		DATA REQUIRED	Enforcement: assignment	Engineering: location, improvement	Education: summaries, rates, trends	Licensing: driver control and improvement	Financial responsibility
For the accident	When	Year, month, day	X	X	X	X	(*)
		Hour of day	X	. . .	X	. . .	. . .
	Where	State and jurisdiction	X	X	X	(*)	(*)
		Road or street	X	X	. . .	(*)	. . .
		Location on road	X	X	. . .	. . .	. . .
	What	Kind of district	. . .	. . .	X	. . .	. . .
		Surface condition	. . .	X	. . .	. . .	. . .
		Type of accident	X	X	X	X	. . .
		Severity of accident	. . .	. . .	X	X	. . .
		Highway type	X	X	X	. . .	. . .
For each involved	Vehicle or Pedestrian	Direction approaching from	. . .	X	. . .	. . .	. . .
		Movement planned	X	X	X	. . .	. . .
		Vehicle type, if any	. . .	. . .	X	. . .	X
		Make, year, number, if motor vehicle	. . .	. . .	. . .	. . .	X
		Vehicle registration, if any	. . .	. . .	. . .	. . .	(*)
		Owner: name, address	. . .	. . .	. . .	. . .	(*)
		Insurer, Policy No., if any	. . .	. . .	. . .	. . .	(*)
		Policy expiration date	. . .	. . .	. . .	. . .	(*)
		Vehicle damage: description, amount	. . .	. . .	. . .	. . .	(*)
		Driver or pedestrian: name, address	. . .	. . .	X	(*)	(*)
		Driver or pedestrian: birth date, sex	. . .	. . .	X	(*)	X
		Driver license number, if any	. . .	. . .	. . .	(*)	(*)
		Policyholder: name, address	. . .	. . .	. . .	. . .	(*)
	Person Injured	Description of injuries	. . .	. . .	. . .	. . .	(*)
		Age, sex	. . .	. . .	X	. . .	. . .
		Name, address	. . .	. . .	X	. . .	X
Non-vehicle damage		Description amount	. . .	. . .	. . .	. . .	(*)
		Owner: name, address	. . .	. . .	. . .	. . .	(*)

X = Administrative requirements for prevention purposes
(*) = Legal requirements to fulfill functions of law

Source: President's Committee for Highway Safety, Traffic Accident Records: A Section of the Action Program for Highway Safety, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1960, p.8

TABLE 3

FACTS NEEDED FOR EACH OF FIVE BASIC PURPOSES OF ACCIDENT RECORDS

BASIC PURPOSES OF TRAFFIC ACCIDENT RECORDS (See more complete description of purposes elsewhere)

BASIC PURPOSES OF TRAFFIC ACCIDENT RECORDS	IDENTIFYING INFORMATION: Place			IDENTIFYING INFORMATION: Time		IDENTIFYING INFORMATION	DESCRIPTION OF RESULTS: General		DESCRIPTION OF RESULTS: Detailed					DESCRIPTION OF EVENTS	
	Geographical area	Highway, street	Exact location	Day, month, year	Hour	Name -driver, pedestrian	Fatal injury	Severity	Injuries	Vehicle damage	Other property damage	Final positions	Marks on road, etc.	Travel direction, etc.	Evasive action taken
1. Cause of mortality, morbidity	X			X			X	X							
2. Where, when, etc. critical — General	X	X		X				X							
2. Specific			X	X	X	X		X						X	
3. Suggest preventive action — Individual acc.								X	X	X	X	X	X	X	X
3. Mass data	X	X		X	X			X	X	X	X			X	
4. Measure effect of effort — General	X	X		X	X			X							
4. Specific			X		X	X		X						X	
5. Determine negligence or fault					X	X			X	X	X	X	X	X	X
Provided in standard report	X	X	X	X	X	X	X	X						X	

BASIC PURPOSES OF TRAFFIC ACCIDENT RECORDS	DESCRIPTION OF ELEMENTS OF THE HIGHWAY TRANSPORTATION SYSTEM — Vehicle	Vehicle: Detailed					Road: General						Road: Specific							
	General type	Design features	Condition, age	Special equipment	Load - kind, weight	Weight of vehicle	Neighborhood charac'r	Surface condition	Raining, snowing, fog	Light available	Signs, signals, etc.	Curves, grades, lanes	Alignment, etc.	Access, land use	Road surface	Visibility	Illumination	Traff. control design	Traffic density	Parking situation
1. Cause of mortality, morbidity																				
2. Where, when, etc. critical — General	X						X	X	X	X	X	X								
2. Specific		X	X	X		X							X	X	X	X	X	X	X	X
3. Suggest preventive action — Individual acc.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3. Mass data		X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X
4. Measure effect of effort — General			X																	
4. Specific		X	X		X	X														
5. Determine negligence or fault		X	X	X	X	X							X	X	X	X	X	X	X	X
Provided in standard report	X							X	X	X	X	X								

BASIC PURPOSES OF TRAFFIC ACCIDENT RECORDS	Driver, pedestrian, etc.: Gross				Driver, pedestrian, etc.: Detailed						DESCRIPTION OF THE TRIP					
	Age	Sex	Occupation	License, restriction	Size, weight, etc.	Driver, ped. cond'on	Knowledge	Skill	Socio-econ. status	Attitude	Purpose of trip	Time since starting	Distance travelled	Interruptions	Urgency of mission	Route choice
1. Cause of mortality, morbidity																
2. Where, when, etc. critical — General	X	X	X	X												
2. Specific						X					X	X				
3. Suggest preventive action — Individual acc.					X	X	X	X	X	X	X	X	X	X	X	X
3. Mass data	X	X	X	X		X	X	X	X		X	X	X		X	
4. Measure effect of effort — General	X	X		X												
4. Specific	X	X		X												
5. Determine negligence or fault				X	X	X	X	X		X	X	X	X	X	X	X
Provided in standard report	X	X	X	X												

Source: "Improvement of the Present System of Traffic Accident Records", Traffic Institute, Northwestern University, Evanston, Illinois, June 1963., pp. 13a-14

TABLE 4

POSSIBLE FIRSTHAND SOURCES OF VARIOUS KINDS OF DATA FOR TRAFFIC ACCIDENT RECORDS

SOURCES OF INFORMATION FOR TRAFFIC-ACCIDENT RECORD (See more complete description of sources elsewhere.)

Identifying information; Description of results of accident; Description of events

Group	Source	Identifying information – Place: Geographical area	Place: Highway or street	Place: Exact location	Time: Day, month, year	Time: Hour	Driver, pedestrian's name	Results – General: Fatal injury	General: Severity rating	Detailed description: Injuries inflicted	Detailed: Damage to vehicle	Detailed: Other property damage	Detailed: Final positions	Detailed: Marks on road, etc.	Description of events: Travel direction, etc.	Events: Evasive action taken
		ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT
THREE	Driver, pedest'n	BAB	BAB	CBB	AAA	AAA	AAA	AAB	BBB						AAA	AAA
THREE	Others involved	BBB	BBB	CBB	AAA	ABA	ABB	ABB	BBB						ABA	BCB
THREE	Bystanders, etc.	CCB	CCB	CCB	BCA	ACA		BCB							BCB	BCB
ARRIVING SOON AFTER		CCB	CCB	CCB	BCA	BCA		CCB								
SENT TO ATTEND	Trained police	AAA	AAA	AAA	AAA	BAA	AAA	AAA	BAA	CBA	ABA	AAA	AAA	ABA		
SENT TO ATTEND	Other police	AAB	AAB	BAA	AAA	BAA	AAB	AAB	BAB	CBB	ABB	AAB	ABB	ABB		
SENT TO ATTEND	Firemen	BCB	BCB	BBB	AAA	BBA		CBB			BCB	BBB	BCB			
SENT TO ATTEND	Ambulance drivers	BBB	BBB	BCB	AAA	BBA	ABB	ABA		BCB						
SENT TO ATTEND	Tow-truck drivers	BBB	BBB	BCB	AAA	BBA	CCB				ACB		BCB	CCB		
SENT TO ATTEND	Newsmen, photogs	ABB	ACB	BBB	AAA	BBA	BAA	CBB								
LATER RELATED DUTIES	Special photogrs	ABB	ABB	BBB												
LATER RELATED DUTIES	Surveyors	AAA	AAA	CAA										BAB		
LATER RELATED DUTIES	Traff. engineers	ABA	AAA	AAA								ABA		BCB		
LATER RELATED DUTIES	Repair mechanics								CCB		ABB					
LATER RELATED DUTIES	Surgeons				AAA		BBA	AAA	CCB	AAA						
LATER RELATED DUTIES	Nurses				AAA		BBA	AAA	CCB	BBB						
LATER RELATED DUTIES	Pathologists				BBA		BBA	AAA	CCB	AAA						
LATER RELATED DUTIES	Undertakers				AAA		BBA	AAA		BCB						
LATER RELATED DUTIES	Fleet supervisor	BBB	BCB	CCB	AAA		AAA	BAB	BBB		ABA					
LATER RELATED DUTIES	Claim investig'r	BAA	BBA	BAA			AAA	BAA	BBB	CCB	BCA	AAA	CBB	BBB		
LATER RELATED DUTIES	Attorneys	CAA		CAA			AAA	BAA	BBB	CCC	BCB	BBB		BBB		
OTHERS	Associates	CCB	CCB	CCB	ACA		ACB	CCB							CCB	
OTHERS	Family doctors						ABA	CCB								
OTHERS	Service places														CCB	
OTHERS	Repair shops														CCB	

Description of elements of highway transportation system involved in accident — Vehicle and Road

Group	Source	Vehicle: General type of vehicle	Vehicle specific: Design features	Condition, age	Special equipment	Load - kind, weight	Weight of vehicle	Road general: Curves, hills, lanes	Kind of neighborhood	Road surface condition	Raining, snowing, fog	Light available	Signs, signals, etc.	Road specific: Road alignment	Access, land use	Road surface condition	Visibility condition	Road illumination	Traffic control design	Traffic density	Parking situation
		ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT
THREE	Driver, pedest'n	AAA		AAB	BBB	ABB	CCB	AAA	ABB	AAA	AAA	AAA	AAA								
THREE	Others involved	ACB		CCB		BCB		BCB	BCB	BCB	ACA	ACA	BCB								
THREE	Bystanders, etc.	ACB		CCB				BCB	BCB	BCB	ACA	ACA	BCB								
ARRIVING SOON AFTER		ACB		CCB				BCB	BCB	BCB	ACA	ACA	CCB								
SENT TO ATTEND	Trained police	AAA	ACB	BBA	BBB	BBA	CBA	AAA	AAA	AAA	AAA	AAA	AAA	ACA	ACA	ACA	ACA	ACB	ACB	ACB	ABA
SENT TO ATTEND	Other police	AAB		BBB	BCB	BBB	CCB	AAA	AAB	AAA	AAA	AAA	AAA	BCB	ACB	ACB	ABB				
SENT TO ATTEND	Firemen	BCB				CCB		BCA	BCB	BCA	BCA	ACA	BCA								
SENT TO ATTEND	Ambulance drivers	BCB						BCA	BCB	BCA	BCA	ACA	BCA								
SENT TO ATTEND	Tow-truck drivers	ABA	ACB	BCB	CCB	CCB	CCA	BCA	BCB	BCA	BCA	ACA	BCA								
SENT TO ATTEND	Newsmen, photogs	BCB				CCB	CCB	BCA	BCB	BCA	BBA	ABA	CCA								
LATER RELATED DUTIES	Special photogrs	BBA						BCA	BCB												
LATER RELATED DUTIES	Surveyors							ACA	AAA					AAA	ABA	AAA		ABB			ABB
LATER RELATED DUTIES	Traff. engineers							ACA	AAA					AAA	ABA	AAA	ABA	ABB	AAA	AAA	AAA
LATER RELATED DUTIES	Repair mechanics	ABA	ACA	ABA	ACB		CCB														
LATER RELATED DUTIES	Surgeons																				
LATER RELATED DUTIES	Nurses																				
LATER RELATED DUTIES	Pathologists																				
LATER RELATED DUTIES	Undertakers																				
LATER RELATED DUTIES	Fleet supervisor	AAA	ABA	AAA	ABA	AAA	AAA	BCA													
LATER RELATED DUTIES	Claim investig'r	AAA	ABB	ABB	BCB	BBA	CBB	ABA	CCB												
LATER RELATED DUTIES	Attorneys	AAA				CBB		ACA	CCB												
OTHERS	Associates	CCA		CCB	CCB	CCB	CCB														
OTHERS	Family doctors																				
OTHERS	Service places	CCA		CCB	CCB	CCB				CCA	CCA	ACA			CCB						
OTHERS	Repair shops	BCA		CCB	CCB																

Description of elements of highway transportation system involved in accident — Driver, pedestrian, etc.; Description of trip

Group	Source	Driver gross descript'n: Age	Sex	Occupation	License, restrictions	Detailed description: Size, weight, etc.	Driver condition	Knowledge	Skill	Socio-economic status	Attitudes	Trip: Purpose of trip	Time since starting	Distance travelled	Interruptions	Urgency of mission	Choice of route
		ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT	ORT
THREE	Driver, pedest'n	AAA	AAA	AAA	AAA	AAA	AAB	ABB	ABB	ABB	BBB	ABA	ABA	ABA	ABA	ABA	ABB
THREE	Others involved	CCB	ACA	BCA	CCB		BCB	CCB	BCB	CCB	CCB	BCB	BCA	BCB	BCB	BCB	BCB
THREE	Bystanders, etc.	CCB	ACA				CCB				CCB						
ARRIVING SOON AFTER		CCB	ACA				CCB										
SENT TO ATTEND	Trained police	AAA	AAA	ACA	AAA	AAA	BBA	CCB		CCB	BCB						
SENT TO ATTEND	Other police	AAA	AAA	BCA	AAB		BBB			CCB							
SENT TO ATTEND	Firemen																
SENT TO ATTEND	Ambulance drivers	CCA	ACA		CCB	BCB	CCB			CCB							
SENT TO ATTEND	Tow-truck drivers	CCA	ACA														
SENT TO ATTEND	Newsmen, photogs	BBA	ABA							CCB							
LATER RELATED DUTIES	Special photogrs																
LATER RELATED DUTIES	Surveyors																
LATER RELATED DUTIES	Traff. engineers																
LATER RELATED DUTIES	Repair mechanics																
LATER RELATED DUTIES	Surgeons					ABA	BCB			CCB							
LATER RELATED DUTIES	Nurses					ABB	BCB				CCB						
LATER RELATED DUTIES	Pathologists					ABA	AAA										
LATER RELATED DUTIES	Undertakers									CCB							
LATER RELATED DUTIES	Fleet supervisor	AAA	AAA	AAA	AAA	BBB	CBB			ABA	ABB	AAA	ABA	ABA	CBA	BBA	AAA
LATER RELATED DUTIES	Claim investig'r	ABA	AAB	ABA	AAA	CCB		CCB		AAA	BBB						
LATER RELATED DUTIES	Attorneys	BBA	AAA	ACA	AAB			CCB		AAA	ABB						
OTHERS	Associates	BCA	ABA	ABA	ACC	BCB	CCB	CCB	CCB			CCB	CCB	CBB		CCB	CCB
OTHERS	Family doctors	ABA	ABA	ABA		BCB	BBA										
OTHERS	Service places					CCB						CCB			BCB	CCB	CCB
OTHERS	Repair shops																

O - Opportunity
- A - good
- B - fair
- C - poor
- D - none (left blank; see text for more detail)

R - Responsibility
- A - special
- B - general
- C - none

T - Training
- A - special
- B - general
- C - none

Source: "Improvement of the Present System of Traffic Accident Records", Traffic Institute of Northwestern University, Evanston, Illinois, June 1963, pp. 16a-17.

4. Later duties related to road, vehicles and people involved.

a. Special photographers called to make pictures of the site or of damage to vehicles include police who are called only to make pictures of the scene, but exclude police who make pictures as a duty in attending the accident.

b. Topographers, surveyors or others who are sent to map the site include police only if they have no other duties in connection with the particular accident.

c. Traffic engineers. Usually their duty is to determine whether traffic control devices were functioning properly. Included are highway maintenance people who repair damage to road, guardrails, traffic control devices, temporary barricades, etc.

d. Repair mechanics and wreckers who repair or disassemble for salvage damaged vehicles after removal from site of the accident.

e. Surgeons who treat injured.

f. Nurses who attend injured at home or in hospitals.

g. Medical examiners, pathologists and coroners are people who examine those people who die soon after an accident. If a coroner mainly transports the dead, consider him an ambulance driver or attendant.

h. Undertakers, morticians and embalmers may be able to give information on injuries. If they only transport the dead from the scene of the accident, consider them as ambulance drivers and attendants.

i. Fleet supervisors in charge of motor-vehicle fleets are from truck or bus companies and may examine road, drivers, or vehicles following an accident. They may have information about loads.

j. Claim investigators.

k. Attorneys anticipating litigation arising from the accident.

5. People who may have useful ancillary information.

a. Relatives, associates, and acquaintances, employers, and employees of persons involved.

b. Family doctors who are familiar with the condition of the driver or pedestrian before the accident. If they treat injuries, consider them surgeons.

c. Service station, bar, restaurant, and similar personnel who might have seen a driver or pedestrian before an accident.

d. Automobile repair and inspection personnel who might know the condition of the vehicle previous to the accident.

Three columns are shown for each type of information in Table 4. They are headed O, R, and T, for opportunity to obtain information, responsibility for obtaining information, and training in observing and recording. The degree of opportunity to get certain information is shown in the first column, O. This degree is shown by letters A, B, and C, which represent, respectively, good, fair, and poor.

The degree of responsibility and training for each person is shown in the next two columns, R and T. The letters A, B, and C represent, respectively, special, general, and none.

Therefore, the best source for any particular fact is marked AAA. Unsuitable sources are left blank.

Baker (3) has proposed that "five types of data collection should be recognized and provided for: (a) motor-vehicle mortality record, (b) basic accident record, (c) auxiliary reports, (d) special records for legal purposes, and (e) special records for technical purposes."

DESCRIPTION OF STUDY

Objective and Scope

The study, cosponsored by the Automotive Safety Foundation and the U. S. Bureau of Public Roads, was to consider in depth the various uses of traffic accident data by principal users in Illinois. The study's objective was to determine the accident data usage criteria (information needed, degree of accuracy, completeness and detail, allowable reporting delay, etc.) of the different data users. After the usage criteria

of these individual interest groups are identified and detailed, the criteria should be combined and correlated in order to establish data usage criteria for a universal traffic accident reporting system, or for better coordination of multiple systems.

In considering the users to be contacted, attention was given to all known user groups, but no effort was made to conduct a statistical evaluation of the usage of traffic accident data by each of the user groups. On the other hand, every effort was made to determine the usage criteria for those user agencies which are doing the most with the information and are best qualified to comment on the need and/or usage of other traffic accident information.

Methodology

In order to determine the accident record users' criteria in Illinois, a study team was appointed consisting of senior faculty members at the University of Illinois. The team members were Charles H. Bowman, Professor of Law; Dr. Marvin J. Colbert, Director of Health Service, and Associate Professor of Medicine, University of Illinois at the Medical Center, Chicago; Ellis Danner, Professor of Highway Engineering; A. E. Florio, Professor of Safety Education; Robert I. Mehr, Professor of Finance; Ervin H. Warren, Director of Police Training Institute; and John E. Baerwald, Director of Highway Traffic Safety Center and Professor of Traffic Engineering—Principal Investigator.

Most of the work of the study team was conducted during the summer and early fall of 1964. After preliminary agreement concerning study procedures, members of the study team individually contacted those agencies within their respective disciplines which appeared to be best qualified to comment on accident reporting criteria and accident record usage. A list of the agencies contacted by the individual members of the study team is included in the Appendix. It may be noted that agencies on all levels of government as well as private agencies with local to national interests were contacted. In general, only agencies operating within Illinois were contacted, and no attempt was made to obtain a statistically reliable sample.

After each member of the study team completed his investigation, he prepared a report which summarized the information he had obtained and formed the basis for his subsequent conclusions and recommendations concerning accident reporting criteria for the user groups contacted. These individual reports were reproduced and distributed to each member of the study team, and subsequent meetings and discussions resulted in the development of a group report and recommendations. The principal conclusions of the individual reports are summarized next. The complete individual reports are included in the final report of the research project (7).

SUMMARY OF INDIVIDUAL REPORTS

The individual reports were prepared by the members of the faculty study team after they had completed their interviews with the agencies within their respective disciplines. These reports followed the general format:

1. Professional uses of traffic data,
2. Professional requirements for traffic accident bits,
3. Professional reporting criteria for primary data, and
4. Discussion and recommendations.

In preparing the reports, the team members were asked to present their own evaluation of the accident reporting situation rather than merely reporting what they found during their field interviews. Therefore, in many cases the conclusions and recommendations contained in their reports are their own, reached as professional persons competent to discuss the particular interest group.

The following sections are intended to highlight the more important aspects of the individual reports.

Education, Research and Driver Licensing

The professional uses of traffic accident data by educators (especially on the college and university level) are to give prospective teachers a background of traffic accidents,

provide for an analysis of accident causation, and enable the interpretation of accident report information.

The driver licensing interest in traffic accident reports primarily relates to an attempt to correlate driver characteristics and behavior with accident causation. In addition to being interested in the typical information (who, what, where, when, why, and how) presently obtained from the accident report form, this professional user group would find the reports more useful if they:

1. Provided a means for reporting the attitude of the person involved;
2. Included questions that will show apparent causes of accidents and the relationship between cause and offense;
3. Provided additional information about the involved drivers, including:

    a. Number of miles of driving experience and data of issuance, if it is the driver's first license,
    b. Occupation and education, and
    c. Nature and kind of driver education;

4. Were supplemented by a photograph of the accident scene and environment when the accident resulted in death or severe personal injury;
5. Included a description of specific legal action taken by the investigating officer and the results of testing for intoxication;
6. Provided more specific information concerning single car accidents;
7. Included a question concerning seat belt placement, both front and rear, and if the belts were being used at the time of the accident; and
8. Were so designed that they could be filled out by a check-off procedure and be tabulated by electronic data processing equipment.

Enforcement

Law enforcement agencies use data from individual accident investigation reports to ascertain as many facts as possible concerning an accident, to determine whether a violation of a law or city ordinance was committed, and if so, to secure evidence to support prosecution of the violator. They also assist state agencies in administering the Safety and Financial Responsibility Laws of the state.

Summary data of accidents which occur within the jurisdiction of the enforcement agency are used for "selective enforcement" assignment of personnel. Police department heads want to determine from accident summaries: (a) the high-accident frequency locations, (b) the times and types of accident occurrence, (c) the primary causes of accidents, and (d) the identity of persons involved in traffic accidents.

County sheriffs have begun to realize that traffic accidents and traffic control should be given some consideration by their office. However, no comprehensive planning for any traffic control program currently exists in any county in Illinois.

Ideally, police agencies should devote more time and effort both to accident investigation and accident reporting. To accomplish this requires more training, education, and research, not only for new officers, but also periodic "retread" schools to inform and inspire all uniformed personnel.

More study should be devoted to events or conditions leading up to the accidents. Furthermore, the police administrators must be convinced that today's traffic problems must be met and handled by the police to a much greater degree. Finally, they should be provided with the tools to do a good job—adequate budgets for necessary equipment and training, and adequate manpower.

The following types of traffic accident data should be collected and used by enforcement agencies:

1. Exact location of accident,
2. Date of accident,
3. Persons involved,
4. Persons killed or injured,
5. Type of accident,
6. Vehicle identification,

7. Weather and road conditions,
8. Traffic controls present,
9. Witness identification,
10. Complete diagram of scene,
11. Description and amount of property damages, and
12. Supplementary or follow-up reports.

Railroad personnel, as a rule, have little reported activity in traffic accident investigation or reporting. Apparently, railroad personnel never file an accident report with the State of Illinois or other states through which their lines travel.

Engineering

Highway engineers should use traffic accident data in many phases of the development of new highway facilities and the improvement of existing facilities. These uses should occur during the planning, design, and maintenance phases of normal activity. The following traffic accident data elements are recommended for highway engineering usage:

1. Location of accident,
2. Type of accident,
3. Nature of vehicle movements at time of accident,
4. Speed of vehicles involved,
5. General traffic conditions at time of accident,
6. Operational conditions affecting traffic movement,
7. Weather conditions,
8. Natural light conditions,
9. Road surface conditions, and
10. Accident result.

A great deal of related information should be obtained from other sources, such as existing records and field investigations.

Field investigations should be made at the locations of fatal accidents as soon as possible after accident occurrence, and a copy of the official report of such an accident should be received by the responsible highway engineering agency within three days after the accident. The exact location of each accident is the prime element in accident reporting for highway engineering uses. For traffic engineering usage, the most important bits of traffic accident information are the location of the accident and what happened.

When accident records are manually filed, they should be filed alphabetically by location, in order to be most useful to the traffic engineer. Otherwise, they should be coded and available through electronic data processing equipment. From a traffic engineering standpoint, it would be ideal if all traffic accidents could be reported, at least to include information concerning the location and what happened.

Because the traffic engineer generally does not have an opportunity to visit the accident site while the vehicles and accident debris are still present, it would be most helpful if the opinions of the investigating officers could be obtained. A number of clear and properly oriented photographs taken at the scene of particularly destructive accidents would also be of value to the traffic engineer. These photographs should be supplemented by accurate measurements of such things as skid marks, struck or damaged objects, and the final position of the vehicles.

Insurance

Insurance companies use traffic accident data for operational and educational uses. They need the following bits of traffic accident information:

1. Time and place of the accident;
2. Road and driving conditions at the time of accident;
3. Traffic violations involved in the accident;
4. Location of the involved vehicles;

5. Location, type, and length of skid marks;
6. Condition of vehicles before and after accident;
7. Condition of drivers before and after accident;
8. If pedestrians were involved, their condition before and after the accident, and their location and activity immediately before the accident;
9. Names and addresses of witnesses and where these witnesses were located at the time of the accident;
10. The names and extent of injuries to passengers in the vehicles involved; and
11. Description of the collision and of the parts of the vehicles that collided.

Perhaps no other user of traffic accident data needs more detail and greater accuracy in the prompt reporting of traffic accidents.

The insurance industry should work with the states in developing a uniform accident report that would be acceptable to all companies and all states, so that only one report had to be made out by each party involved in the accident.

Some way should be found to require that police take photographs at the scene of the accident. Diagrams on the accident report should show the paths of the involved vehicles, obstructions to driver vision, street grades, traffic controls, and the positions of vehicles at impact and when they came to rest.

Legal

The Illinois courts as such do not use traffic accident data, except when it may be presented by the party litigants. It has been estimated that 80 to 85 percent of the cases in our courts arise out of traffic accidents. The Illinois Court Administrator should use general group accident statistics for purposes of determining court case loads and trends.

The need of the county prosecutor for accurate and complete on-the-scene individual reports is immediate in all cases involving law violations. These reports should be received no later than 24 hours after the accident, and preferably within 8 to 12 hours. Group statistics are required quarterly to annually by the prosecutor in order to determine violation trends within his jurisdiction.

The courts need quarterly to annual group statistics to aid in evaluating individual violations for purposes of probation and sentence. The coroner's primary duty is to furnish reports to others in fatal cases. Therefore, when he is making his on-the-scene investigation, he needs an accurate description of how the accident happened in order to determine the cause of death.

Medical

Health agencies do not routinely utilize traffic accident data, but they do collect and utilize data under particular circumstances. Persons in health agencies do not have definite ideas about information they require regarding individual traffic accidents. The only data on individual accidents routinely collected by health agencies (usually only those agencies which are units of government) pertain to deaths from motor vehicle accidents. Health agencies do not believe the routine collection and utilization of traffic accident data is their primary responsibility. The only data routinely collected, those indicating the number of deaths from motor vehicle accidents, are probably not useful except to show the trend of motor vehicle fatalities and to identify the geographical areas of high and low incidence.

Special studies, conducted by or in cooperation with health agencies, should be encouraged. The potential uses of medical information pertinent to traffic accidents have hardly been tapped. Among the types of questions which may be answered through the use of traffic accident data are:

1. With what frequency does the use of drugs by drivers appear to be a factor in traffic accidents?
2. With what frequency do emotional factors in drivers appear to be a significant factor in traffic accidents?

3. With what frequency do physical disabilities in drivers appear to be an important factor in traffic accidents?
4. What is the effect of exterior design of vehicles on injuries, especially to pedestrians, in traffic accidents?
5. What is the effect of interior design of vehicles on injury to occupants?

It is not deemed feasible to correlate all possible medical data for every accident. Studies limited in location and time can and should be undertaken to answer specific medical questions. In most medical studies there is a need for care and detail in reporting, more than for speed; but reporting should not be delayed too long so that sources of information are unavailable or details are forgotten.

Motor Fleet

Motor fleet operators use traffic accident data in extensive safety education programs, which utilize information concerning accident causation, frequency, and severity. This information is obtained from an analysis and interpretation of the accident reports submitted by employees.

In addition to the information presently available on accident report forms, fleet safety supervisors also desire more accurate information concerning accident costs; a larger space on the report form for preparing diagrammatic sketches; and photographs of the accident which would be part of the report and would be taken by the police. Fleet operators find a wide variety of accident report forms in use throughout the country. They believe some uniformity would aid in accuracy and completeness of the reports.

Regulatory Agencies

The Interstate Commerce Commission does have its own investigators who make confidential reports concerning serious accidents.

The Illinois Commerce Commission is not concerned with motortruck accidents, but it is interested in those motor bus accidents which involve carriers subject to the regulations of the Commission. The railroad section section is concerned with railroad grade-crossing accidents.

The Interstate Commerce Commission appears to be better equipped to investigate and study motor vehicle accidents, while the Illinois Commerce Commission seems to have a more routine interest. The latter group does not appear to be as interested in accident prevention as the former, probably because of the vast difference in the number of trained personnel available.

Safety Responsibility

The relatively simple accident reporting requirements for safety responsibility purposes would be easily satisfied if the accident reports for more intensive users, such as legal agencies, would be properly filled out and if a data processing network would be available for the interchange of information.

Traffic Safety Organizations

Traffic safety organizations are not accident data collection agencies. Therefore, they are dependent on tabulations and summaries prepared by other agencies. Their needs are usually satisfied by the routine tabulations prepared by regular accident data collection agencies. The interest of traffic safety organizations in accident data varies greatly between organizations. They are frequent advocates for the collection of "maybe" data.

DATA ANALYSIS

The individual reports filed by drivers and traffic accident investigators are the two main sources of traffic accident data. The driver reports constitute the majority of the reports received by the Bureau of Traffic, Illinois Division of Highways (the official

state collecting agency). Almost all reports received by enforcement and regulatory agencies are completed by police and other accident investigators from such agencies as the Interstate Commerce Commission and Illinois Commerce Commission. Insurance companies receive their information from the forms completed by their policyholders who have been involved in an accident. Many of the state driver reports are completed in part or in total by insurance agents who interview the policyholder.

The reports completed by investigating officers are generally more complete and reliable in specialized areas than those completed by the participating drivers. However, the validity of the investigator reports varies between different individuals and agencies.

In the reporting of an individual accident, the user groups are generally interested in the answer to the broad questions, Who? When? Why? Where? and How? In order to facilitate the collection and analysis of the study data, the different users of traffic accident data were divided into ten general categories:

1. Education (includes formal education agencies and such public information groups as safety councils),
2. Enforcement (state and local government and railroad police),
3. Engineering (emphasis on highway and traffic engineering),
4. Driver Licensing,
5. Safety Responsibility,
6. Insurance,
7. Legal (includes state and local interests with consideration to judicial, prosecution, and defense uses of accident data),
8. Medical,
9. Motor Fleet, and
10. Regulatory Agencies (includes state and federal commerce commissions and related regulatory bodies).

Individual Information Bits

The professional user group's interest in information bits from individual accident reports is summarized in Table 5. It may be noted that the educational and medical interest in individual accident data only refers to special studies rather than to routine accident reports, because these groups are either concerned with general summary tabulations or with individual data obtained in special studies such as the detailed information obtained in the Cornell crash injury investigations. Conversely, the enforcement, insurance, legal, motor fleet, and regulatory agencies' interest is in all types of information relating to the accident.

The driver licensing use of accident data is mainly in the areas of driver identification and accident causes. The items indicated as secondary in importance help to relate the driver to the particular accident and to determine driver responsibility. The safety responsibility interest is in the driver-vehicle owner identification.

Engineering use of traffic accident data is primarily concerned with identifying the physical circumstances of the accident including the location and time of occurrence, the accident description, site conditions, and certain causes.

Identification.—It is essential that all persons involved in an accident be accurately and completely identified. Basic information should include full name, address, age, and sex. The latter two items could be made available through reference to the driver's license number and issuing state of the driver or other persons involved (if they are licensed drivers). Similarly, much of the basic vehicle information can be obtained from motor vehicle registration records if the state and year of registration, license number, and vehicle make are available on the accident report. The vehicle make serves as a cross check on the accuracy of the reported license plate number.

One of the most frequent sources of error in traffic accident reports is the location of the accident. While the need for an accurate location designation varies between the different professional user groups, it is essential that the location be definitely identified so that the exact location of the accident can be found if further investigation is necessary for engineering, legal, or regulatory purposes. The problem of accurate

TABLE 5

PROFESSIONAL INTEREST IN INFORMATION BITS FROM INDIVIDUAL REPORTS

DATA USER	IDENTIFICATION: Persons (Names, Addresses, Etc.): Drivers	Persons: Victims	Persons: Witnesses	Persons: Person Filling Out Report	Vehicle: License No., State, Year	Vehicle: Motor No. or Other Identification#	Vehicle: Vehicle Make, Type, Year	Location: Street(s), Highways, etc.	Location: City	Location: County	Location: State	Time: Month, Day, Year	Time: Hour (AM-PM), Time Zone
Education	S*	S*	S*	S*	S*	S*	S*	P*	P*	P*	P*	P*	P*
Enforcement	P	P	P	P	P	P	P	P	P	P	P	P	P
Engineering	S*	N	S*	S*	S*	S*	S*	P	P	P	P	P	[illegible]
Driver Licensing	P	N	N	S	S	N	S	S	S	S	S	S	S
Safety Responsibility	P	S	N	S	P	P	P	P	P	P	P	P	P
Insurance	P	P	P	P	P	P	P	P	P	P	P	P	P
Legal	P	P	P	P	P	P	P	P	P	P	P	P	P
Medical	P*	P*	P*	S	S*	S*	S*	S*	S*	S*	S*	S*	P
Motor Fleet	P	P	P	P	P	P	P	P	P	P	P	P	P
Regulatory Agencies	P	S	S	P	P	P	P	P	P	P	P	P	P

DATA USER	ACCIDENT DESCRIPTION: Vehicle and Pedestrian Paths and Behavior: Prior to Impact	Paths: During Impact	Paths: Following Impact	Paths: Final Position	Speeds (Prior to & at Impact): Reported	Speeds: Observed or Estimated	Evidence of Accident: Skid Marks	Evidence: Debris	Evidence: Property Damage	Evidence: Bodily Injury	Evidence: Photographs
Education	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*
Enforcement	P	P	P	P	P	P	P	P	P	P	P
Engineering	P	P	P	P	P	P	P	P	P	P	P
Driver Licensing	S	S	S	S	S	S	S	S	S	S	S
Safety Responsibility	N	N	N	N	N	N	N	N	P	P	N
Insurance	P	P	P	P	P	P	P	P	P	P	P
Legal	P	P	P	P	P	P	P	P	P	P	P
Medical	S*	S*	S*	S*	S*	S*	S*	S*	S*	P*	S*
Motor Fleet	P	P	P	P	P	P	P	P	P	P	P
Regulatory Agencies	P	P	P	P	P	P	P	P	P	P	P

DATA USER	SITE CONDITIONS: Permanent: Physical Features	Permanent: Existing Controls: Regulations (speed, parking, no passing)	Permanent: Existing Controls: Devices (signs, signals, markings)	Temporary: Weather	Temporary: Surface	Temporary: Traffic Volume and Density	Temporary: Light	Temporary: Visibility	Unusual: Construction or Maintenance Activity	Unusual: Obstacles (animate or inanimate)	Unusual: Others (crowds, emergency vehicles, etc.)
Education	S*	S*	S*	S*	S*	S*	S*	S*	S*	S*	S*
Enforcement	P	P	P	P	P	P	P	P	P	P	P
Engineering	P	P	P	P	P	P	P	P	P	P	P
Driver Licensing	S	S	S	S	S	S	S	S	S	S	S
Safety Responsibility	N	N	N	N	N	N	N	N	N	N	N
Insurance	P	P	P	P	P	P	P	P	P	P	P
Legal	P	P	P	P	P	P	P	P	P	P	P
Medical	S*	S*	S*	S*	S*	S*	S*	S*	S*	S*	S*
Motor Fleet	P	P	P	P	P	P	P	P	P	P	P
Regulatory Agencies	P	P	P	P	P	P	P	P	P	P	P

DATA USER	CAUSES: Condition of Driver and Pedestrian: Physical Defects: Permanent	Physical Defects: Temporary: Intoxication	Physical Defects: Temporary: Asleep or Fatigued	Physical Defects: Temporary: Drugs and Seizures	Physical Defects: Temporary: Other	Emotional Dis-Orders: Permanent	Emotional Dis-Orders: Temporary	General Observations: Confused	General Observations: Illiterate	General Observations: Poor Judgment	General Observations: Inexperienced	General Observations: Other	Driver Behavior: Violation	Driver Behavior: Other	Pedestrian Behavior: Violation	Pedestrian Behavior: Other	Condition of Vehicle: Mechanical Failure	Condition of Vehicle: Tire Failure	Unusual Occurrence or Conditions: Falling Objects	Unusual Occurrence or Conditions: Other	SKETCH AND VERBAL DESCRIPTION
Education	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	S*	S*	S*	S*	N
Enforcement	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Engineering	S	S	S	S	S	S	S	S	S	S	S	S	P	P	P	P	S[a]	S	P	P	P
Driver Licensing	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	S
Safety Responsibility	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Insurance	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Legal	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Medical	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	P*	S*	S*	S*	S*	S*
Motor Fleet	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Regulatory Agencies	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

P = Primary Interest
S = Secondary Interest
N = No Interest

* Special Studies Only
# If no license plate required
a Primary Interest for automotive engineering only

location identification is especially great in rural areas where there are less opportunities to relate the accident scene to easily identified landmarks and terrain features. Engineering, insurance, and legal investigations are frequently made at various times after the accident debris has been removed from the scene. Skid marks can become obliterated and damaged property replaced so that unless accurate written records are made, which preferably should be supplemented by competent photography, the accident scene may not be accurately relocated.

The data and time of the accident are necessary to further identify the specific accident, to relate the accident to such environmental variables as light intensity and traffic flow conditions, and to invoke provisions of the Safety Responsibility Law.

Accident Description.—The accident description is an essential element of the accident report because it is here that all available information concerning the accident circumstances should be recorded. Information concerning vehicle and pedestrian paths and behavior, speed of vehicles, and physical evidence of the accident is necessary to a majority of the accident record user groups. While a high degree of accuracy and completeness is desirable, much of the desired information is either not provided on the report or cannot be provided because of the failure of the person completing the report to be able to recall or reconstruct all pertinent details prior to, during, and following the accident.

Participating drivers generally will not disclose improper or illegal behavior on their part, and impartial eyewitnesses are seldom present, or if present they are hesitant to admit their witness status because they do not want to become involved in any subsequent proceedings.

An inherent problem in attempting to obtain answers to non-factual, opinion-type questions is that the answers are more likely to be erroneous. Consequently, having conclusions and subsequent action based on such non-valid answers can be more harmful than if no answers at all were originally available.

Whenever possible the written report should be supplemented by good quality photographs. This is especially true of those accidents investigated by trained personnel, because a standardized set of photographs can minimize the amount of written information, serve as a cross check for reported data, and provide additional information about data not readily reported on a standard form.

Site Conditions.—If the accident scene is properly located, much of the information concerning the permanent site conditions such as physical features and existing regulations and controls should be available from other record sources. Therefore, the accident record should provide an opportunity to record the temporary and unusual site conditions which are variable and subject to change. Closed-type questions are partially applicable, but care must be taken in the choice of possible answers. Although an enumeration of the unusual conditions may not always lend itself to summary tabulations, it may contribute vital information concerning the accident circumstances.

Causes.—One of the principal reasons for maintaining accident record systems is to identify traffic accident causes. When viewed at the accident scene, many of these potential causes are subtle and intangible. Such things as the conditions of the driver and the pedestrian, especially relating to emotional disorders or distracting influences, cannot often be readily identified. Similarly, the condition of the vehicle immediately prior to the collision often cannot be determined because of the cursory examination given following the accident, coupled with the resultant damage to the vehicle.

Very few drivers will admit to having been operating a defective vehicle and unless competent testimony is available from other sources, it is frequently impossible to prove that the vehicle was being operated in a defective condition. In order to determine whether vehicle defects were present before the accident or had been caused or aggravated by the accident, it is necessary to go into detailed and often exhaustive examination by highly specialized personnel. Such examinations are very expensive and, therefore, are very limited in their application. On the other hand there is a definite need for procedures to be developed which would enable trained accident investigators to identify and spot-check principal failure points in order to make preliminary, rapid examination of these areas.

The Sketch and Verbal Description.—The sketch and verbal description of the accident are used to supplement the information contained in other parts of the accident report. It serves to coordinate the reported components of the accident and also to describe the accident factors which have not been previously recorded. The ability of the average driver to describe the accident by either a sketch or verbal description is rather limited, mainly because of his infrequent need for observing and recording traffic accidents coupled with his general lack of information concerning many of the factors relating to the accident. Consequently, the sketches and descriptions found in investigator reports are generally more complete and useful.

Group Data Requirements

There are two main types of group data usage of traffic accident information. The most common type consists of the routine statistical summaries which are compiled and distributed on a periodic basis. These summaries may be made for specialized uses on a daily and weekly basis. A more general distribution is given to summaries on a monthly, quarterly, semiannual, or annual basis. The purpose of this type of summary is to illustrate the magnitude of the accident problem and to indicate changes and trends. Many such summaries include comparable data for a similar period of the previous day or year.

The second, and more specialized, type of group data combines individual records for special analysis purposes. Traffic engineers, for example, collect all of the available records for a given location, and by analyzing these records they attempt to determine if any patterns exist due to the accidents that have occurred. These patterns might be indicated by a similarity in the paths of the vehicles involved, the time when most of the accidents occur, or by some other repetitive event. Enforcement officials use group statistics to plan their selective enforcement programs by determining the time-location-accident characteristics at locations with a high accident frequency.

Generalized group summary statistics are used for educational, insurance, legal, medical, and motor fleet purposes to determine accident frequency and trends. Much of the summary data can be used in public educational activities, as well as in driver education and motor fleet programs.

Summary statistics are desired for legal purposes to enable the prosecuting attorney and the courts to determine violation trends correlated with accident occurrence within their jurisdiction. This information permits improved coordination of the law enforcement activities and more informed recommendations to the court regarding probation and penalties. Group statistics concerning violations and accidents are of direct interest to the court administrator to enable him to evaluate trends and plan for necessary traffic court facilities, personnel, and possible assignment of judges.

In addition to keeping their own group statistics, insurance companies are also interested in summary statistics for the political jurisdictions in which they operate. State and national statistics are very useful if they can be compared with company statistics, in order to evaluate whether company experience is much different from the reported accident activity. A complaint heard from the insurance companies interviewed indicated the need for the establishment of a procedure for summarizing traffic accident data which would be of mutual benefit and which would be changed only infrequently.

Group accident statistics would be useful to insurance companies if these statistics could be broken down into several categories: age of drivers; age of cars; education of drivers; whether the drivers have had formal courses in driver education; the number of times the drivers had been involved in accidents; occupations of the drivers; and the marital status of the drivers. This information is also desired for educational uses. Insurance companies should be encouraged to pool their statistics and to publish information on a group basis, broken down into categories.

It would be desirable if the insurance industry would work with government agencies to develop a common summary form. Some of the group statistics could be used for loss prevention work and others for rating and underwriting purposes. Perhaps if greater equity could be achieved in rating, those driver groups who are responsible

TABLE 6

TIME REQUIREMENTS FOR THE RECEIPT OF INDIVIDUAL AND GROUP REPORTS BY USER GROUP

Time Requirements	Education	Enforcement	Engineering	Driver Licensing	Safety Responsibility	Insurance	Legal	Medical	Motor Fleet	Regulatory Agencies
Urgency of receipt of individual report increases with severity		X	X			X	X		X	X
Immediately after accident occurrence		IA	IS (1)			IS (3)	IS (4)		IS (5)	IS (6)
Within 2 days						IS (3)				
Within 7 days	G	G	G IS (2)	IA	IA				G	
Within 14 days					IA					
Within 15 days										IS (6)
Within One Month	G	G	G	IA		G	G	G	G	
Quarterly	G		G	G		G	G	G	G	
Semi-Annually	G		G	G		G	G	G	G	
Annually	G	G	G	G		G	G	G	G	

IA = Individual reports of all reportable accidents

IS = Individual reports of specific accidents

(1) Fatal and high local interest
(2) Accessibility to all reports of accidents at high frequency locations
(3) Insurants
(4) Where an apparent legal violation has occurred
(5) Employees
(6) Public carriers as required by law or regulation

G = Group statistics (summaries, high accident frequency locations, tabulations, etc. See reports in Appendix C.)

for the greater percentage of accidents would be encouraged to modify their driving behavior in order to achieve a reduction in their insurance costs.

Time Requirements for Receipt of Reports

Obviously, enforcement and insurance agencies must be verbally informed immediately about the occurrence of accidents, which are required to be reported by law, ordinance, or policy provisions. These reporting time requirements were not reviewed by the study team. However, attention was given to the time requirements for the receipt of the completed individual traffic accident report forms and summary reports. As shown in Table 6, the time requirement varies considerably for the different professional data users.

TABLE 7

SECONDARY INFORMATION BEST OBTAINED FROM SOURCES OTHER THAN ACCIDENT REPORTS

Information Bit	Source: Rural Locations	Source: Urban Locations
Physical features of streets and highways	State and local highway and traffic engineering departments	Municipal street and traffic engineering departments
Physical condition on the roadway	State and local highway engineering departments (esp., maintenance unit)	Municipal street departments (esp., maintenance unit)
Intersection design features	State and local highway and traffic engineering departments	Municipal street and traffic engineering departments
Railroad grade - crossing design and control	Engineering department of railroads, state and local highway and traffic engineers, and the state commerce commission	Railroads, municipal street and traffic departments, state commerce commission
Traffic flow characteristics (vehicle volumes, types of vehicles, etc.)	State and local traffic and highway engineers	Municipal traffic engineering and street departments
Utilization of traffic control devices (sign, signals, markings)	State and local traffic engineers	City traffic engineer, public works directors, and police departments
Traffic laws and regulations	State traffic engineers, state police, and county enforcement and legal agencies	Municipal traffic engineering and street department, city police, and city attorney

Information Bit	Sources for Both Rural and Urban Locations
Events or conditions leading to accidents (prevention factors)	Highway and traffic engineers, educators, and special studies
Driver characteristics (age distribution, experience, etc.)	State Motor Vehicle Department (Driver License Division) and special study
Physical condition of drivers or pedestrians (before and after accident)	Attending physicians and hospitals
Fatal accident data (cause of death, etc.)	Attending physician, hospital, and coroner's report
Driver statistics	Secretary of State and insurance company
Driving records of persons involved in accident	Secretary of State
Vehicle use trends, street and highway mileage and type (to develop trend data)	State and federal highway and traffic engineers, municipal street and traffic engineers, Secretary of State, and private and public safety organizations
Mechanical defects of vehicles	Vehicle maintenance records, mechanics who had previously worked on vehicle, or individual owner.
Vehicle design aspects (eg., interior design, reaction to collision forces, etc.)	Automotive engineers and motor vehicle manufacturers
Actions of person(s) involved in accident	Witnesses to the accident and insurance reports if admitted as evidence or exhibits
Factors leading to accidents	Highway and traffic engineers, medical personnel
Supplementary photographs of accident scene	Insurance investigators, press or private photographers, and motor fleet organization investigators
Character and cost of vehicle damage	Insurance company or garages doing repair work
Amount and type of insurance coverage	Insurance agency or company
Legal consequences, court action, etc.	State and city police departments, lawyers, court system

The urgency for the prompt receipt of the written individual reports by legal, enforcement, insurance, engineering, motor fleet, and regulatory agencies increases with accident severity. Review of the completed report facilitates the making of administrative decisions concerning such subsequent actions as requiring follow-up investigations and the repair or replacement of damaged facilities.

Enforcement, engineering, motor fleet, and regulatory users also study the individual reports to identify and evaluate any accident causation factors, to ascertain if any laws or regulations were violated, and to make an initial determination of responsibility.

The time requirement for the receipt of summary reports is less critical. Most of the user groups are satisfied with routine schedules unless unusual tabulations are made as the result of special requests or the normal procedures identify conditions requiring further attention. For example, traffic and highway engineering agencies should be notified by the accident record-keeping unit when the accident frequency at a given location reaches a predetermined total within a specified time period.

Information Available Elsewhere

As previously mentioned, much of the information presently recorded on individual accident reports is, or should be, available elsewhere. Sources of some of the more commonly desired information bits are listed in Table 7. The scope, reliability, and availability of the different items varies between sources, and in some cases there are legal as well as physical limitations to its accessibility.

The development of a standardized accident reporting and analysis procedure, coupled with widespread adoption of electronic data processing equipment, will enhance the utilization of these secondary sources of pertinent information. Therefore, the application of electronic data processing procedures must be accelerated on a coordinated basis by all traffic accident data users, as well as by those service agencies which already routinely obtain data which are pertinent to traffic accident analysis and prevention programs.

The time spent by police and other accident investigators at the accident scene and in data processing must be reduced due to the combined effect of an increasing number of accidents requiring investigation, coupled with a much slower increase in available manpower.

Thus, more of the supplementary data concerning such items as driver characteristics (age, sex, driving record, etc.) and the physical design of the roadway (pavement width and type, alignment, roadside development, etc.) and vehicle (type of body, model, etc.) must be made readily available through a coordinated data processing system.

CONCLUSIONS

The emphasis in the driver and routine investigator accident report forms should be on the recording of factual information. Asking drivers to express opinions when they report accidents is not beneficial because of the strong possibility of biased or erroneous answers.

Although the opinions of investigators would be of interest to engineers, educators, and other data users, the time and experience required to develop valid opinions is not always available, and many investigators are hesitant to express opinions because of the possibility of being subpoenaed to testify in court proceedings. Therefore, the development of investigator opinions concerning accident causation should be the subject of subsequent, rather than the initial, investigation.

The information recorded on the individual report forms should include accurate identification of the involved traffic units (persons and vehicles). The information about involved persons (drivers, injured persons, and witnesses) should include their full name, address, operator's license number and issuing state, age and sex, nature of injuries, relationship to accident (i.e., driver or passenger in vehicle number X, pedestrian, etc.), and location and/or activity at the time of the accident.

The information about involved vehicles should include the license number, issuing state, and year; vehicle identification number; vehicle manufacturer or make; model (vehicle type); model year; and vehicle owner's full name and address.

As motor vehicle administration offices are revamped to fully utilize modern electronic data processing procedures, it will be possible to further reduce the required identification data. For example, driver identification will usually just require the driver's license number and state of issuance, along with the full name as a cross check against the driver's license number. Pedestrians and other human traffic units who cannot be identified by a driver's license number will in all probability have some form of national identification number such as a social security number. Although the United States Internal Revenue Service currently uses the social security number as a means of individual identification, there are indications that a more definite type of identification number assignment will have to be developed because of the ease with which an individual can obtain multiple social security numbers.

Similarly, the minimum vehicle identification will be the vehicle license, issuing state, year of issuance, and vehicle identification number. Most American vehicle manufacturers now follow a standard sequence in their vehicle identification number which includes letters and numerals to indicate the vehicle manufacturer, model (vehicle style and/or type), model year, assembly plant, and sequential production number. Therefore, correct designation of the vehicle identification number could minimize the related vehicle description.

The location of the probable collision area (as indicated by vehicle placement, damaged property, accident debris, etc.) should be designated with the distance measured to a readily identified landmark or permanent object. The measurement should be accurate to the nearest 100 ft. However, accident sites within 100 ft of an intersection can be identified with respect to the intersection, but should not be identified as intersection accidents unless they actually occurred within the intersection proper.

The political subdivision in which the accident occurred should also be identified. The exact location of each accident is of prime concern to highway and traffic engineering agencies. The city of Chicago has a coding system by house numbers and streets which gives excellent location results on the electronic data processing printouts. Authorities responsible for operating expressways and rural highways should develop a uniform system to aid the reporting person in accurately locating accidents on the reports.

The adoption of uniform local road identification systems (8), coupled with reference to such semipermanent objects as numbered utility poles, will facilitate accident site identification on rural routes which are not in a numbered or otherwise identified highway system. Identification of accident sites on freeways and expressways would be facilitated if tenth-of-a-mile indications were installed on delineator supports to supplement mile postings, so that the measurements can be made more readily from these permanent indicators.

After the injured persons are taken care of, the next major effort at an accident site is to clear the roadway so that traffic can resume under at least near-normal conditions. Therefore, vehicles and other accident debris may be moved before any record can be made of their location in respect to the impact area. Subsequent investigations would be expedited if the final positions of the vehicles and pertinent other material were marked on the pavement by means of a pressurized spray paint. For example, the tire locations and vehicle corners can be quickly indicated and the vehicle can then be removed. Except under very poor surface conditions, the spray paint should remain visible at least for a few days and thus be available for follow-up studies.

In some jurisdictions another location problem is encountered—location of all the accident records relating to accidents which have occurred at a specific location. In urban areas where the accident records are manually filed, they should be primarily filed alphabetically by location (9), rather than chronologically or in some other manner.

The time and date of the accident occurrence should be reported for legal, administrative, educational, and research purposes. This information facilitates the identification of a particular accident and provides an index to those conditions which vary with time (available light, traffic volumes, etc.). Summaries of accidents which include listings of accident frequency for different time periods (month, day, and hour) are very useful in planning enforcement activity and developing educational programs to alert drivers to critical driving periods.

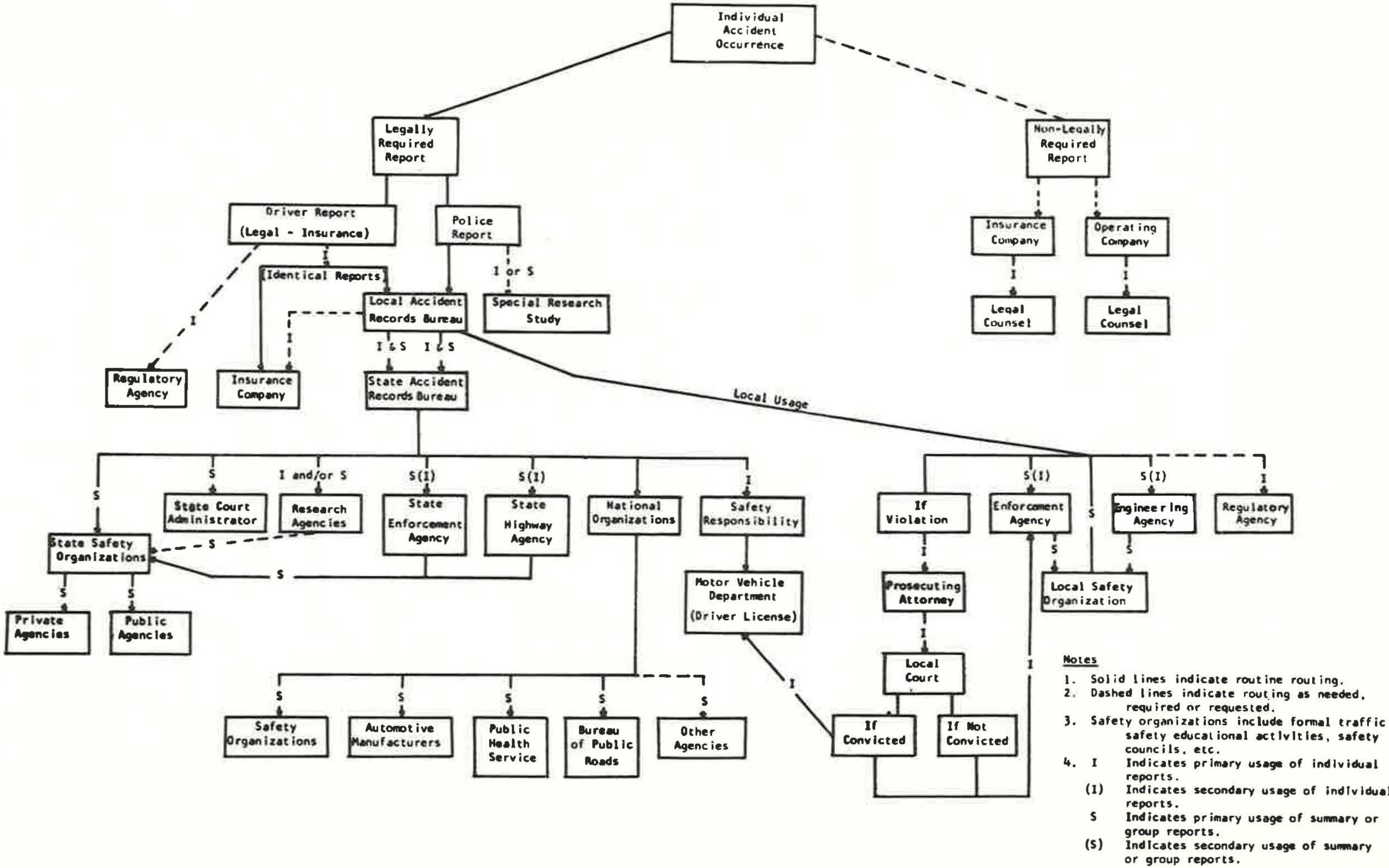

Figure 2. Flow chart of recommended written traffic accident reporting system.

The accident report should cover three types of accident circumstances: the maneuvers and actions of each traffic unit prior to, at, and following impact; unusual environmental conditions; and accident results. In addition, maneuvers and actions of each traffic unit can best be shown by photographs and sketches. Unusual environmental conditions should be reported for such variables as weather (rain, snow, fog, etc.), roadway (pavement failure, obstacle, temporary traffic controls, etc.), pavement surface (ice, loose gravel, chuck holes, etc.), and traffic (special event traffic, unusual vehicle type, stalled vehicle, etc.).

The accident results should include descriptions of personal injury (person injured, apparent extent and nature of injuries, relationship to accident or position in vehicle, etc.), property damage (apparent extent and nature of vehicle damage, description of other damaged property, etc.), and final position of traffic units.

In reporting the accident circumstances, the emphasis should be on obtaining all available information that is unusual, variable, and not available elsewhere. Such reporting will be facilitated by the use of closed-type, precoded questions. This type of answer is desirable if electronic data processing equipment is used. Topics which lend themselves to closed-type questions are: weather conditions, pavement surface conditions, and type and angle of collision.

The increased use of data processing equipment will enable the use of data which are routinely provided elsewhere, thus minimizing the recording of data on the accident report form.

Immediate attention should be given to development of scales to indicate a quantitative estimate of personal injury and property damage, thus facilitating more accurate reporting of these types of accident results. England's Road Research Laboratory has developed a scale for estimating the damage sustained by motor cars after a single impact with another vehicle or object (10). Development of these descriptive scales will facilitate the establishment of a reasonable relationship between injury expectation and vehicle damage—a subject of direct concern to doctors, automotive engineers, and educators.

Standard procedures for photographing accident scenes should be developed so that the amount of written descriptive material can be minimized. Standard operating procedures should specify which accident types should be photographed (i.e., fatal, serious injury, public passenger carriers, etc.). The types of views to be taken should be determined and specified (i.e., front, sides, and rear of vehicles—when damaged; vehicle placement; approach views toward accident scene for each involved driver; skid marks and other accident debris; etc.). The photo technique should provide for the inclusion of measurement reference points so that the scaling of information from the photographs will be made easier and more accurate. In addition to being pertinent to legal and insurance uses, these photographs will be of value for research and educational purposes.

A study should be made of the possibility of modifying the driver report form, which is required by law to be filed for certain types of accidents, so it will also satisfy the insurance reporting requirements. The development of a common form would tend to minimize public objection to the tedious problems commonly associated with filling out a traffic accident report form. An added advantage would be that both the public agencies and the insurance company would have the same information, and the possibility of different reporting to each interested agency would be done away with.

The flow of traffic accident reports should follow that shown in Figure 2. It may be noted that the official part of the driver report form, which is identical to that prepared for insurance company usage, is routed via the local accident records bureau to the state bureau. Such routing, which presumes the establishment of a local bureau, would provide local officials with a more accurate current evaluation of accident occurrence in their area, and would facilitate the completion of reports by the involved drivers. Errors, incomplete or conflicting answers, or other types of improper reporting could be checked out much more readily by having an official review of the report at the local level. In the case of legally reportable accidents, local residents would probably submit the legal copy directly to the accident records bureau and the insurance copy to their insurance agent. Non-local persons could be informed of the

location of the local records bureau by the investigating officer, if there is police investigation, or by the local insurance company representative.

The collection of specialized accident data for research use is not a function of routine accident reports. Such data should be put on forms specifically designed for that purpose. Although it may be argued that the addition of one or two items to a traffic accident report form in order to obtain research data would not materially increase the reporting and tabulation time, experience has shown that this is an undesirable way to obtain research data. One reason is the questionable validity of the answers, and another is the probability that related information is not always available on the forms. Hence, the possibility of standardizing variables is minimized.

Another advantage of having specialized research forms is that the persons completing the forms usually will have the benefit of special instructions, and hopefully they will pay more attention to completing the form than they might if it were just a routine matter.

Studies should be directed toward the development of uniform accident summary forms which would be of more benefit to a majority of the user groups. Insurance interests should be encouraged to pool their statistics within their industry and to work with appropriate governmental and private agencies to permit a better exchange of information.

Summary reports of accident data should receive wider distribution to qualified official and private user groups. Through increased exposure and usage of the summary data, the other user groups will be better qualified to suggest any changes or additional tabulations which may be desirable.

Accident statistical units should be strongly urged to utilize electronic data processing equipment and techniques on a greater, accelerated scale. An increasing number of both small and large governmental units are converting to data processing equipment. By sharing the processing equipment with other governmental uses (such as purchasing, taxation, etc.), the cost of using such equipment for accident data analysis is minimized.

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I also wish to acknowledge the unselfish service provided by Wayne T. Gruen, Research Assistant, Department of Civil Engineering, University of Illinois, who served as secretary of the study team, and the stenographic personnel of the Highway Traffic Safety Center.

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Appendix

AGENCIES CONTACTED

City Agencies

Champaign-Urbana Public Health District, Champaign; City of Champaign: Traffic Engineering Department; City of Chicago: Board of Education (Department of Safety), Chicago Transit Authority, Department of City Planning (Transportation Planning Division), Department of Streets and Sanitation (Bureau of Street Traffic), Police Department; City of Decatur: Police Department; City of Peoria: Health Department, Police Department; City of Springfield: Police Department.

County Agencies

Cook County: Circuit Court, County Coroner, Highway Department (Design Division, Executive Offices, Research Division, Traffic Engineering Division, Traffic Safety Committee), Sheriff's Office; Macon County: Sheriff's Office; Peoria County: County Coroner, Health Department, Sheriff's Office, State's Attorney; Richland County: Highway Department; Sangamon County: Sheriff's Office, State's Attorney.

Private Agencies

Allstate Insurance Company, Skokie; American Medical Association, Chicago (Committee on Medical Aspects of Automotive Safety); Armor & Company, Chicago (Automotive Safety Division); Central Motor Freight Association, Chicago; Chicago Motor Club, Chicago (Safety and Traffic Engineering Department); Citizens Traffic Safety Board, Chicago; Continental Casualty Insurance Company, Chicago; Country Mutual Insurance Company, Bloomington; Illinois Central Railroad, Chicago (Railroad Police); State Farm Mutual Automobile Insurance Company, Bloomington.

State Agencies

Illinois Attorney General's Office, Springfield; Illinois Commerce Commission, Springfield: Motor Bus Division, Railroad Division; Illinois Court Administration, Springfield, Chicago; Illinois Department of Public Health; Illinois Division of Highways: Bureau of Design, Springfield, Paris, Bureau of Maintenance, Springfield, Paris, Bureau of Planning, Springfield, Bureau of Traffic, Springfield, Paris, Safety Responsibility Section, Executive Offices, Springfield, Expressways Division, Chicago, Office of Traffic Safety, Springfield, Operations Division, Chicago; Illinois Secretary of State's Office: Division of Development and Research (including driver licensing); Illinois State Police, Springfield; Illinois State University, Normal: Safety and Driver Education Department; Illinois Superintendent of Public Instruction: Department of Safety and Driver Education; Southern Illinois University, Carbondale: Center for Safety; University of Illinois, Urbana: Motor Fleet Division.

Federal Agencies

Interstate Commerce Commission: Bureau of Motor Carriers, Chicago; Department of Commerce: Bureau of Public Roads, Regional Office, Homewood.

Discussion

EDMUND J. CANTILLI, Engineer of Traffic Safety, Research & Studies, The Port of New York Authority—I found this to be an excellent report, long-needed in the field, imaginative in concept and thorough and competent in execution. My problem would be if it does not become the basis for standardization of accident reporting, not only in Illinois, but throughout the United States. But that is hardly a criticism of the paper.

To begin with, I am glad to see that an omission by the President's Committee on Highway Safety is corrected in this report. Table 2 indicates that hour of day, severity of accident, and vehicle type are not needed for engineering purposes. This is corrected in Table 5.

On the subject of location of accidents: at the Port Authority we have developed a coding system based on arbitrarily designated homogeneous areas, such as intersections, the area immediately before and beyond a point of divergence, etc., such that accidents can be expected to be of similar nature, or related to a single road feature. Of course, this is no help on long tangent sections or long curves, where finer detail is required. On our bridges and at the airports we have numbered lightpoles; within our tunnels we have engineering stationing marks along the tunnel walls at 100-ft intervals. The New York Thruway, the New Jersey Turnpike, and the Garden State Parkway all have mileposts and tenth-of-a-mile markers. In addition, all overpasses on the Turnpike are so marked. The Garden State Parkway doubles and triples its spaced delineators on curves, and New York City has numbered light poles on its expressways.

The point made about the possibility of getting a record of the investigator's opinion is well taken. We have recognized this problem for some time and we are trying to devise some method for obtaining this information without its being made part of the official record.

The report states, "...it would be ideal if all traffic accidents could be reported...." Amen. I would like to say that we at the Port Authority feel we have made a good approach to this desirable goal, probably because our facilities, limited in size, are well patrolled by police officers. Perhaps this hoped-for situation will come to pass through the use of electronic (or other) scanning equipment, including television, and eventual automatic recording of location, positions of vehicles on contact, position of vehicles at rest.

I note the opinion that there is need for "...development of scales to indicate a quantitative estimate of personal injury and property damage...." This same point was made in 1959 in "The Federal Role in Highway Safety," in which it was "...recognized that the number or rate of accidents is not sufficient in itself, because there exist vastly different degrees of accident severity." Reference was made to my paper on this subject, in which a scale was proposed. At the present time we in the Port Authority are using a modified version of this same severity scale to good advantage.

In conclusion, I would repeat that this study should be the base upon which the possibilities for standardization of accident reporting procedures should be explored. As a traffic engineer, I have tended to see only my own needs, and this report puts those needs in proper perspective with the requirements of the other users of accident records.

CHARLES S. MICHALSKI, Director, Traffic Accident Data Project, National Safety Council—At least one authority has identified five distinct, basic purposes of traffic accident records. These are:

1. To have knowledge of traffic accidents as a cause of mortality, morbidity and economic loss.
2. To point out where, when, and to whom, traffic accidents are a critical problem.
3. To suggest lines of preventative action to be taken.
4. To measure the effect of accident prevention efforts.
5. To determine negligence or fault.

Assuming that this list is complete, we have here a set of general specifications for a traffic accident data system. As it is customary to design a machine or system from specifications furnished by a would-be user or group of users, it would appear that this would be a logical approach to the design of a traffic accident data system. However, there seem to be obstacles that preclude application of this logic as we understand it.

Uses of data obtained from traffic accident reports are so numerous and so varied that any one design which would satisfy all needs would be extremely complicated. Furthermore, users are not always aware of all the information that could be reasonably collected and put into the system. In addition, collectors are not always aware of all the user needs. In view of this lack of understanding, the evaluation of user needs for traffic accident data is a difficult task.

In his formal report, Professor Baerwald shows four major headings under which information on traffic accidents is entered: (a) identification; (b) accident description; (c) site conditions; and (d) causes. While there should be no real problem with the nomenclature of the first three headings, there are reservations with regard to "causes." Few, if any, existing reporting systems can be said to reveal causes of accidents. A more appropriate heading would be "attendant circumstances."

User groups may agree on major headings and even some of the subheadings under which accident data are entered. However, there is considerable divergence of opinion on information bits which should be solicited under subheadings. For example, under the general heading of "identification" it is desirable to describe persons, vehicles and locations. In identification of persons there is agreement on the need for names and addresses of people involved. However, beyond this point, desires vary considerably. Some authorities require a description of the driver license, while others require a description of the person's physical features, still others require name and address of employers and other references. The same problem exists with respect to vehicles involved. Frequently a description of the location of the accident requires supplementary information in terms of descriptions of nearby landmarks and road features. These items, which are generally of little consequence to the accident prevention program, may appear to need little effort to acquire. In total, however, they may add significantly enough to the reporting task to cause quality of the more meaningful parts of the report to suffer. In many cases more than half of an investigator's written effort is devoted to identifications.

Under the heading of "accident description" there is general agreement on items pertaining to maneuvers and paths of vehicles and pedestrians involved in accidents. However, there are questions as to the description of accident severity. In most jurisdictions severity of accidents is described in one of the following terms: fatal, non-fatal injury, and property damage. Many agencies subdivide non-fatal injuries in accordance with the three classifications established by the Committee on Uniform Accident Statistics of the National Safety Council's Traffic Conference. There is dissatisfaction with the system because of precedence that certain accidents are given under the present classification. For example, an accident which results in complaints of pain and superficial property damage takes precedence, in the minds of many, over an accident where there was severe property damage and no personal injury. Likewise, a fatal accident resulting from a relatively minor collision takes precedence over most other accidents, in effect, it could be regarded of no more importance, as far as preventative measures are concerned, than any other accident.

Under "site conditions" it is customary to describe such elements as the weather, road surface condition, light and visibility. These are temporary or changing conditions. However, many agencies require full description of physical features of the roadway, traffic regulations, traffic control devices and other permanent features. In most instances this information is available in official records and it seems redundant to require that this information be entered in the accident report form. However, in view of problems encountered in identification of locations, officials insist on description of site to verify location.

The heading "attendant circumstances" covers behavior of driver and pedestrian, condition of vehicle and unusual occurrences or events. This is the most critical area of the accident report. While it does not pinpoint causes, it furnishes clues to causes. Unfortunately, this area is also the weakest part of the reporting system. There is no general agreement on what kind of information should be obtained on the condition or attitude of the driver. Violation ascribed to the driver is generally based on deep-rooted informal policy, rather than evidence. Few officers have sufficient training to detect mechanical defects and few, if any, are competent to describe the condition of a driver or pedestrian. This is the realm in which specialists or technicians are required, but within the present means, the most optimistic outlook is that only a small proportion or sampling of the traffic accidents can ever be scientifically investigated.

A consensus is developing that basic reporting systems be developed to yield data essential to the activities of prime users of case reports and groups of case reports, and that the basic system be supplemented by in-depth systems designed to develop specific information on selected circumstances of the accident. In this way police officers could be trained to look for specific vehicle defects without the necessity of having complete automotive engineering training. The same analogy would apply in cases where data are required on physical or personality traits of drivers involved. Officers would not need a complete education in psychology or medicine to detect carefully defined traits or defects.

Supplemental studies such as these may be carried on by several agencies at the same time, and it would not be necessary to make universal application to yield satisfactory mass statistics on problems that are not being defined in current reporting systems.

JACK L. NOBLITT, Assistant Chief Engineer for Planning and Research, Oklahoma Department of Highways—How long has it been since the accident report form has had major changes made in it? In this age where much information is out of date before it is printed, we have retained an inadequate accident report form whose only virtue is that it is basically uniform among the states. Professor Baerwald's project is an important first step in attempting to modernize our accident report system, and particularly the accident report forms.

It is indeed strange that in a country where we have been killing and maiming more and more people and have been working harder and harder to solve the traffic safety problem, we have not kept the accident report form updated. Traffic safety is one of our most important national problems, and the accident records system is the very foundation of the traffic safety program. Consequently, the accident report form is the single most important item in the accident records system. It is indeed time that the necessary research be conducted and our accident reporting be modernized.

Baerwald brings out many of the improvements which should be made in the accident report form. Such things as reducing the number of forms which must be filled out, making the accident report form more easily coded for use in data processing, along with the use of closed-type precoded questions, will all assist in making the accident report form more valuable in the reduction of traffic accidents. Baerwald lists three basic phases of the accident reporting problem: (a) the drivers involved in accidents must file several reports containing much information, and yet this information is of little value in accident prevention because it is usually biased; (b) reporting officers, although unbiased, are too few in number and do not have enough time to report every

accident; and (c) the many people responsible for preventing accidents, the accident report users, want an infinite amount of information accurately and promptly reported. This study would have satisfied better the need for a modern report form if less attention had been given to the third phase of this problem—the needs of the accident report user—and more attention given to the first two parts of the problem, the accident reporting problems. Perhaps other research covering the other two parts of the problem is being, or will be, conducted in the near future. This study alone will not generate the support nationally that is necessary to modernize the accident report form.

Another area which will have to be thoroughly studied is the assignment of priorities to the information which is to be included on the accident report form. Since the ultimate goal of our traffic safety program is the reduction of highway accidents, and the greatest value of accident records lies in their tremendous potential to assist in this reduction, it would certainly seem that priority should be given to the accident information which makes the greatest contribution toward our goal of reducing accidents.

The last point I would like to mention is that, even though some type of information is desired by an accident data user, it must be practical to obtain. For example, some data users would like to know the speed of the vehicle when the accident occurred. It is almost impossible for the person in the field to accurately know this fact or even closely estimate it. This type of data cannot be included on the accident report form.

In summary, it was high time that somebody undertook a major research project toward the modernization of the accident report form and Baerwald, his sponsors, and his associates should be congratulated for doing so. However, additional research will be needed to serve as the basis for revising the accident report form. Further study will have to be made of such items as manpower and time limitations in the field, the assigning of priorities to types of information sought, and the practical aspects of obtaining the data.

JOHN E. BAERWALD, Closure—As indicated in each of the discussions, the investigation reported in this paper covers only one phase of a much-needed review of the whole traffic accident reporting system. Fortunately, the Traffic Accident Data Project, under Mr. Michalski's direction and with the cooperation of numerous national agencies, is currently engaged in such a comprehensive study.

Mr. Cantilli pointed out the various ways in which the location of accidents can be facilitated. He also described some of the other pioneering work of the Port Authority in the field of accident investigation.

The use of the term "attendant circumstances" instead of the term, "causes," as proposed by Mr. Michalski, is an excellent suggestion. However, the important fact is not what this section of the accident report is called, but rather what information should and can be practically reported to describe the conditions which may have contributed to the accident causation.

Mr. Noblitt identified other areas of research which are necessary for the improvement of procedures for traffic accident data collection and utilization.

The Teen-Aged Driver

An Evaluation of Age, Experience, Driving Exposure and Driver Training as They Relate to Driving Record

G. S. FERDUN, R. C. PECK and R. S. COPPIN, California Department of Motor Vehicles

•ONE OF the most vexing problems currently confronting traffic safety experts, driver licensing administrators, and legislators is the optimal minimum age for issuing driver licenses. The problem is a complex one, involving philosophical, socioeconomic and legal problems as well as traffic safety considerations.

The current minimum age for issuing an unrestricted driver license in California is 16, with parental approval being required until the licensee is 21 years of age. Exceptions to this are emancipated minors, persons who are 18 or above and married. Monetary liability for all others is accepted by parents before the license can be issued.

Over the years there have been a number of attempts to raise the minimum licensing age in California. Proponents of such measures have offered a variety of reasons and advantages for an increase in the minimum age to 18. One of their basic reasons involves the assumption that the average 16-year-old is not sufficiently mature to drive an automobile and, therefore, represents a greater hazard to himself and the public welfare than do drivers in their higher teens.

Although it is an undisputed fact that teenagers have a far higher accident and violation rate than older drivers (Table 1), reliable data for 16-19-year-old drivers by single year of age have been lacking. As a consequence, the California Department of Motor Vehicles, when first confronted in 1963 with attempts to raise the minimum age, had no data to either support or refute the previously stated assumption concerning the 16-year-old driver. The department's Research and Statistics Section therefore undertook a pilot study of the problem in 1963 and shortly thereafter issued a limited number of copies of a report titled "Accident and Violation Experience of California Drivers Aged 16 Through 19." Since 16- and 17-year-olds were found not to have more accidents and violations than 18- and 19-year-olds, the study concluded that: "...there is no evidence, in a review of driving records, to support an increase in the minimum age for driver licensing."

This pilot study presented a reliable evaluation of the age factor solely in terms of driving records which one may define as the "absolute risk potential." However, the lack of exposure data precluded an evaluation of driving performance controlled for differences in mileage between age groups, or what one may define as the "relative risk factor." Also, the sample size was too small to yield sufficiently precise results on certain issues.

Because of these additional considerations and the continuing importance of the problem, it was decided to conduct a large-scale survey, utilizing a much larger sample and collecting data on a number of variables (such as mileage) which are not available from driver record file information. By extending the scope of the study in this fashion, it was hoped that the contribution of such factors as age, experience and immaturity could be separated and individually assessed.

Because some proponents of the age increase are proposing that licensing prior to 18 years of age be contingent on the successful completion of an approved behind-the-wheel driver training course, data were obtained which would allow comparison of this factor with accident and violation records.

Paper sponsored by the Committee on Highway Safety and presented at the 45th Annual Meeting.

TABLE 1

AVERAGE (MEAN) ACCIDENTS AND VIOLATIONS FOR TEEN-AGE AND ADULT DRIVERS

Group[a]	Accidents		Violations	
	Males	Females	Males	Females
Teen-age	0.157	0.074	0.581	0.172
Adult	0.078	0.040	0.258	0.102

[a]Teen-agers are defined here as individuals 16-20 at the beginning of the driver record interval. Adults are individuals over 20 at the beginning of the driver record interval. Source: 1964 Driver Record Study.

The present analysis will proceed in stepwise fashion, with any decision regarding the aforementioned problems being contingent on answers to the following questions:

1. What is the relationship between age and driving record, irrespective of mileage?
2. What is the relationship between age and driving record when variations in exposure are controlled?
3. Are inexperience, immaturity (as measured by age) and parental control important factors in the accident and violation experience of young drivers?
4. Do drivers who have had behind-the-wheel driver training possess better accident and violation records than those who have not taken driver training?

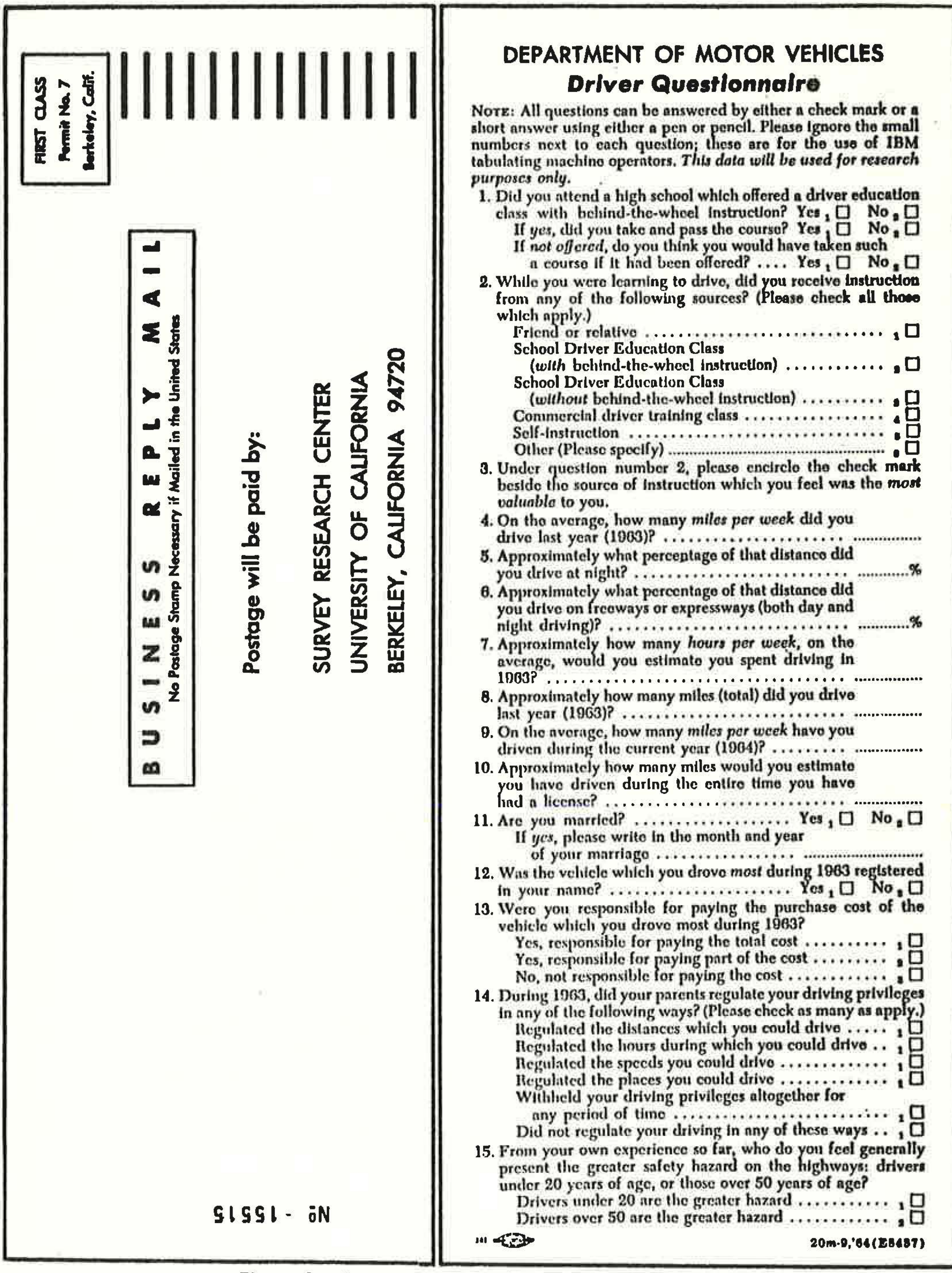
It should be emphasized at the outset that the sole purpose of the study was to test hypotheses relative to the traffic safety aspect of this problem. This study will not attempt to evaluate the sociological, ethical, and economic considerations with which the issue is entwined. This should in no way be construed as a belief on the part of this department or the research staff that these issues are unimportant, but rather that these considerations were not felt to be relevant to the purpose of this study.

METHODOLOGY

Early in 1964, a random sample of 225,000 drivers of all ages was selected from the driver license files in connection with a study unrelated to the present one ("1964 California Driver Record Study"). A large amount of data (including age and driver record) had been collected in connection with the Driver Record Study and stored on computer tape. Inasmuch as these data were already collected and contained in computer processing format, they provided a convenient pool from which a representative sample of teen-age drivers could be extracted. All records belonging to subjects who, at the time of coding, were between 17 and 20½ years of age, who had been licensed for at least one year, and whose license had not expired, were retrieved from the tape and converted to card form. The driving records of 10,250 teen-aged drivers were thus derived for analysis. The recorded driver records of the group correspond to the interval one year prior to the original date of selection, and they represented subjects who were between 16 and 19½ years of age at the beginning of the recorded driving record interval.

The following information for each subject was extracted for subsequent analysis:

1. Age,
2. Months license in force,
3. Age when first licensed,
4. Sex,



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DEPARTMENT OF MOTOR VEHICLES

Driver Questionnaire

NOTE: All questions can be answered by either a check mark or a short answer using either a pen or pencil. Please ignore the small numbers next to each question; these are for the use of IBM tabulating machine operators. *This data will be used for research purposes only.*

1. Did you attend a high school which offered a driver education class with behind-the-wheel instruction? Yes 1 ☐ No 2 ☐
   If *yes*, did you take and pass the course? Yes 1 ☐ No 2 ☐
   If *not offered*, do you think you would have taken such a course if it had been offered? .... Yes 1 ☐ No 2 ☐
2. While you were learning to drive, did you receive instruction from any of the following sources? (Please check all those which apply.)
   Friend or relative .... 1 ☐
   School Driver Education Class (*with* behind-the-wheel instruction) .... 2 ☐
   School Driver Education Class (*without* behind-the-wheel instruction) .... 3 ☐
   Commercial driver training class .... 4 ☐
   Self-instruction .... 5 ☐
   Other (Please specify) .... 6 ☐
3. Under question number 2, please encircle the check mark beside the source of instruction which you feel was the *most valuable* to you.
4. On the average, how many *miles per week* did you drive last year (1963)? ....
5. Approximately what percentage of that distance did you drive at night? ....%
6. Approximately what percentage of that distance did you drive on freeways or expressways (both day and night driving)? ....%
7. Approximately how many *hours per week*, on the average, would you estimate you spent driving in 1963? ....
8. Approximately how many miles (total) did you drive last year (1963)? ....
9. On the average, how many *miles per week* have you driven during the current year (1964)? ....
10. Approximately how many miles would you estimate you have driven during the entire time you have had a license? ....
11. Are you married? .... Yes 1 ☐ No 2 ☐
    If *yes*, please write in the month and year of your marriage ....
12. Was the vehicle which you drove *most* during 1963 registered in your name? .... Yes 1 ☐ No 2 ☐
13. Were you responsible for paying the purchase cost of the vehicle which you drove most during 1963?
    Yes, responsible for paying the total cost .... 1 ☐
    Yes, responsible for paying part of the cost .... 2 ☐
    No, not responsible for paying the cost .... 3 ☐
14. During 1963, did your parents regulate your driving privileges in any of the following ways? (Please check as many as apply.)
    Regulated the distances which you could drive .... 1 ☐
    Regulated the hours during which you could drive .... 1 ☐
    Regulated the speeds you could drive .... 1 ☐
    Regulated the places you could drive .... 1 ☐
    Withheld your driving privileges altogether for any period of time .... 1 ☐
    Did not regulate your driving in any of these ways .... 1 ☐
15. From your own experience so far, who do you feel generally present the greater safety hazard on the highways: drivers under 20 years of age, or those over 50 years of age?
    Drivers under 20 are the greater hazard .... 1 ☐
    Drivers over 50 are the greater hazard .... 2 ☐

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Figure 1. Questionnaire mailed to survey participants.

5. Driver license number,
6. Number of accidents, and
7. Number of violations.

SURVEY OF DRIVING HABITS OF CALIFORNIA DRIVERS

As Chief of the Division of Drivers Licenses I am responsible for the licensing of drivers in California. We are attempting to acquire more information about the driving habits, needs, and opinions of California drivers. The opinions of youth are often overlooked in sampling the thinking of our population. I have asked the Survey Research Center of the University of California to conduct a survey of a selected group of young drivers. I would like to personally ask you to cooperate in this study.

Enclosed with this letter is a questionnaire card for you to fill out. Your answer to question 15 on the relationship between age and driving safety will be of special interest to us. However do not restrict your answers to just this question. Analysis of the data is possible only if the questionnaire is filled out completely. If you are not sure of the correct answer to any of the questions make the best guess that you can. Your responses to the questions will be confidential and will be used for research purposes only. In no way will your answer to any question influence the status of your present license or the issuance of a future drivers license.

Simply fill out the questionnaire card and drop it in the nearest mail box. NO POSTAGE STAMP IS REQUIRED. Our study will be successful only if a large percentage of the young drivers in our sample reply. Your cooperation is appreciated.

Sincerely,

Ronald V. Thunen

RONALD V. THUNEN, Chief
Division of Drivers License

Figure 2. Letter accompanying questionnaire.

Three weeks ago, we sent you a questionnaire asking about your driving habits. You are one of a carefully selected sample of young drivers from whom we are seeking this information. So far, a considerable proportion of the people have returned the questionnaire, but yours has not been received. Please fill out the enclosed questionnaire card and return it to us. NO POSTAGE STAMP IS NECESSARY.

Your answer to question 15 on the relationship between age and driving safety will be of special interest to us. However, do not restrict your answers to just this question. Analysis of the data is possible only if the questionnaire is filled out completely. If you are not sure of the correct answer to any of the questions make the best guess that you can. Your responses to the questionnaire will be confidential and will be used for research purposes only. In no way will your answer to any question influence the status of your present license or the issuance of a future drivers license. Your cooperation is greatly appreciated.

Sincerely,

Ronald V. Thunen

RONALD V. THUNEN, Chief
Division of Drivers License

Figure 3. Follow-up letter mailed to non-respondents.

TABLE 2

RESPONSE CATEGORY BY SEX

Group	Total	Males	Females
Respondents	6,664	3,878	2,786
Non-respondents	2,955	1,835	1,120
Non-recipients	631	360	271
Total	10,250	6,073	4,177

TABLE 3

AVERAGE (MEAN) ACCIDENTS AND VIOLATIONS BY RESPONSE CATEGORY

Group	Accidents	Violations
Respondents	0.126	0.386
Non-respondents	0.131	0.517
Non-recipients	0.090	0.366
Total sample	0.125	0.422

For the purpose of this study, a violation is defined as a moving traffic violation incident reported to the department by any court (juvenile and others) or probation office during the time interval in question. The date of violation was used for placing the violation in time and multiple violations relating to one incident were counted as a single violation.

The Survey Research Center of the University of California was contracted to aid in the constructing of a questionnaire, the mailing of the questionnaire, and the coding and punching of the returned information. The questionnaire (Fig. 1) was designed to tap the following areas:

1. Method of learning to drive;
2. Driver education and driver training experience;
3. Exposure (miles driven, time, and place);
4. Driving experience (total miles driven in life);
5. Marital status;
6. Extent of parential regulation on vehicle use; and
7. Purchase of vehicle and registration thereof.

The questionnaires were mailed with an accompanying letter (Fig. 2) from the Survey Research Center on September 4, 1964. All subjects who had not returned this initial questionnaire by October 5 were mailed a second letter (Fig. 3) and questionnaire. By October 30, the rate of return had decreased to such an extent that it was decided to terminate the sampling and compile all data collected up to that time. Based on the outcome of the mailing, the original sample could be categorized into three distinct groups: respondents, non-respondents, and non-recipients, representing, respectively, 65.0 percent, 28.8 percent, and 6.2 percent of the original pool of subjects (Table 2).

The questionnaire data for each subject were collated with their matching driver record data. In the case of non-respondents and non-recipients, each subject's questionnaire code number was collated with the driver record information, and the fact that the subject was a non-respondent or non-recipient was punched into his data card for later analysis. (Non-recipients include those individuals whose questionnaires

were returned by the Post Office or by parents indicating the subject was in the armed forces, or had moved and could not be reached.) Detailed machine edit checks were then performed on all cards to insure accuracy and any errors discovered were corrected, although no attempt was made to correct inconsistent responses in the questionnaires. The edit checks were performed in order to establish that the coding and keypunching had been performed accurately.

The data regarding the respondents were then analyzed via a multiple regression program. More will be said about this later. In addition, the data (including non-respondents and non-recipients) were tabulated in a variety of ways for additional descriptive and analytic purposes.

Response Bias

The initial step in the analysis was to determine whether a response bias developed, in the sense that those who responded to the questionnaire had different accident and violation records than the non-respondent and non-recipient groups. It was anticipated at the outset that such a response bias would develop, and this was subsequently indicated [F (violation bias) = 32.59 $P < 0.001$; F (accident bias) = 3.16 $P < 0.05$] (Table 3).

Throughout this report a value which has less than 5 chances in 100 of occurring by chance is considered significant. For certain technical reasons, most of the probabilities cited should be considered as approximations. They are, however, of sufficent precision for decision-making purposes.

The respondents had significantly fewer violations on their records than did the non-respondents [$t = 22.2$ $P < 0.01$]; however, the difference between the respondents' and non-respondents' accident records was not significant [$t = 0.61$ $P > 0.50$]. Non-recipients and respondents do not have significantly different violation records [$t = 0.62$ $P > 0.50$], but non-recipients had significantly better accident records [$t = 2.34$ $P < 0.05$]; part of this reduction is probably a result of some of this group having left the state during 1963. Thus, the violation response bias can be attributed to differences between respondents and non-respondents and the accident bias attributed to differences between the respondents and non-recipients.

For comparisons among the various age groups, the existence of a response bias, in itself, is not a particularly relevant factor. What is relevant, however, is whether some age groups are more biased than others. If so, the validity of the entire study would be suspect, since unequally biased age groups would be compared and inferences made on the basis of distorted comparisons. Shown in Table 4 are accidents and violations by age group and response category.

Statistical tests of significance indicate that differences in response bias at various ages can be attributed to chance variation [F (age by violation bias) = 0.523 $P > 0.50$; F (age by accident bias) = 0.772 $P > 0.50$]. Thus, we can conclude that the relationship between age and driver record found for respondents can be generalized to the overall population of teen-aged drivers. For all other relationships the effects of a possible response bias could not be assessed. On logical grounds, however, there is no reason to suspect that these other relationships have been appreciably affected by a response bias.

Since a large amount of the data was obtained via questionnaire, some comments concerning the validity and reliability of this technique seem in order. Although such techniques are invariably subject to a certain amount of random and nonrandom errors relative to the items being measured, it is generally safe to assume that the questionnaire responses are highly correlated with the actual behavior under consideration. Our confidence here lies with the fact that strong emotional areas were not under measurement in this study. A further assumption which must be made is that the amount of response error is uniformly distributed over the independent variables being considered. The authors are confident that these assumptions have been adequately met and that the data have provided an accurate measurement of the relationships under consideration.

TABLE 4

ACCIDENTS AND VIOLATIONS BY AGE AND RESPONSE CATEGORY

Age at Beginning of Driver Record Period	Violations								Accidents							
	Total Sample		Respondents		Non-Respondents		Non-Recipients		Total Sample		Respondents		Non-Respondents		Non-Recipients	
	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.
All Ages	0.422	10,250	0.386	6,664	0.517	2,955	0.366	631	0.125	10,250	0.126	6,664	0.131	2,955	0.090	631
16 years (0-2) months	0.371	426	0.343	327	0.489	92	0.143	7	0.141	426	0.148	327	0.120	92	0.143	7
16 years (3-5) months	0.324	633	0.281	467	0.479	142	0.250	24	0.136	633	0.133	467	0.134	142	0.208	24
16 years (6-8) months	0.386	630	0.338	423	0.511	186	0.238	21	0.106	630	0.109	423	0.102	186	0.095	21
16 years (9-11) months	0.382	663	0.304	451	0.560	184	0.464	28	0.136	663	0.135	451	0.152	184	0.036	28
17 years (0-2) months	0.352	628	0.335	430	0.367	166	0.500	32	0.134	628	0.140	430	0.127	166	0.094	32
17 years (3-5) months	0.392	719	0.373	466	0.437	213	0.375	40	0.125	719	0.120	466	0.146	213	0.075	40
17 years (6-8) months	0.458	773	0.443	508	0.489	229	0.472	36	0.138	773	0.144	508	0.114	229	0.222	36
17 years (9-11) months	0.463	790	0.406	498	0.590	239	0.434	53	0.149	790	0.131	498	0.197	239	0.113	53
18 years (0-2) months	0.423	826	0.380	518	0.534	253	0.309	55	0.136	826	0.139	518	0.134	253	0.109	55
18 years (3-5) months	0.526	823	0.442	525	0.720	243	0.473	55	0.115	823	0.112	525	0.132	243	0.073	55
18 years (6-8) months	0.469	823	0.425	543	0.596	223	0.386	57	0.109	823	0.099	543	0.139	223	0.088	57
18 years (9-11) months	0.427	827	0.439	503	0.420	257	0.358	67	0.116	827	0.113	503	0.125	257	0.104	67
19 years (0-2) months	0.426	813	0.421	489	0.486	249	0.253	75	0.123	813	0.137	489	0.120	249	0.040	75
19 years (3-5) months	0.435	876	0.417	516	0.498	279	0.333	81	0.099	876	0.114	516	0.090	279	0.037	81

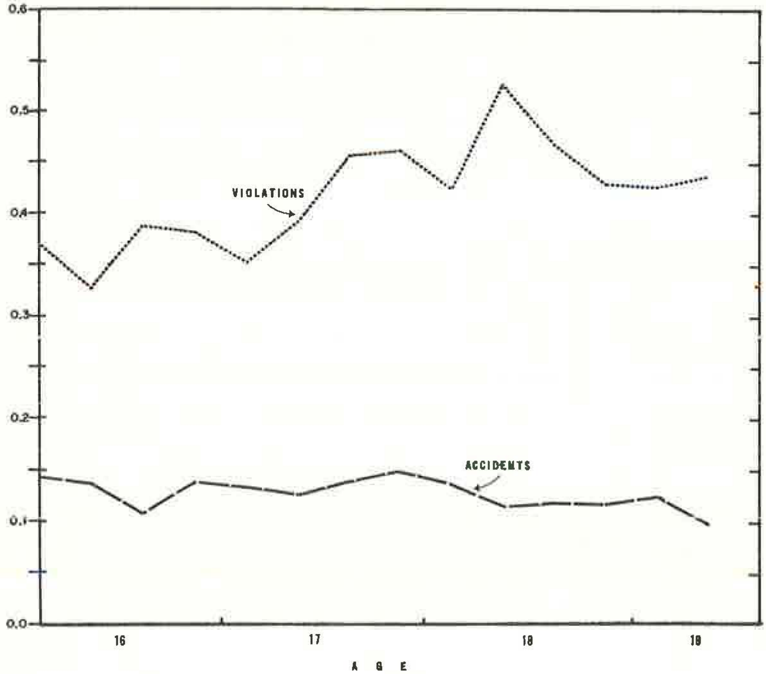

Figure 4. Average (mean) number of violations and accidents by age (1-yr record).

RESULTS

Age in Relation to Absolute and Relative Risk Potential

Are there any differences in the conviction and accident frequency among the various ages comprising the teen-age group? We have referred to such an index as absolute risk because the sole criterion is the frequency of certain types of events on each subject's driving record, regardless of the existence of significant exposure differences. The authors feel this absolute risk factor is the most relevant criterion for evaluating the present licensing age procedures inasmuch as it involves an evaluation of the risk which a given age group represents to the public. For example, if one age group is having twice as many accidents as another then that group represents twice the hazard or risk to the public, regardless of whether that group drives twice as many miles as the other.

Shown in Figure 4 and Table 5 are the average (mean) number of accidents and violations by sex for the various age groups comprising the study. For purposes of precision, the ages 16 years zero months through 19 years 5 months have been broken down into 14 three-month age groupings.

Statistical tests performed on the data indicated that accident frequency for both males and females is unrelated to age [Males: $r = -0.015$ $P > 0.05$; Females: $r = 0.006$ $P > 0.05$]. There is however, a significant relationship between violation frequency and age for both males and females. Analysis of the direction of the relationship indicates that as age increases, violations increase [Males: $r = 0.076$ $P < 0.05$; Females: $r = 0.055$ $P < 0.05$].

From this consideration alone, there is no evidence to support the assumption that 16-17-year-old drivers constitute a greater risk to the public than do drivers in their older teens. This, incidentally, is consistent with the conclusions of the previously mentioned study.

Do the age groups differ with respect to their violation and accident rates when the effects due to miles driven are controlled? This question is more closely related to

TABLE 5

ACCIDENTS AND VIOLATIONS BY AGE AND SEX

Age at Beginning of Driver Record Period	Males			Females		
	No.	Accidents per Person	Violations per Person	No.	Accidents per Person	Violations per Person
All ages	3,878	0.162	0.541	2,786	0.075	0.169
16 years (0-2) months	201	0.199	0.478	126	0.063	0.127
16 years (3-5) months	291	0.165	0.375	176	0.080	0.125
16 years (6-8) months	256	0.156	0.449	167	0.036	0.168
16 years (9-11) months	282	0.174	0.401	169	0.071	0.142
17 years (0-2) months	249	0.181	0.462	181	0.083	0.160
17 years (3-5) months	276	0.159	0.533	190	0.063	0.142
17 years (6-8) months	299	0.167	0.652	209	0.110	0.144
17 years (9-11) months	282	0.163	0.560	216	0.088	0.204
18 years (0-2) months	304	0.184	0.559	214	0.075	0.126
18 years (3-5) months	293	0.147	0.587	232	0.069	0.259
18 years (6-8) months	309	0.117	0.631	234	0.077	0.154
18 years (9-11) months	284	0.148	0.620	219	0.068	0.205
19 years (0-2) months	268	0.175	0.627	221	0.090	0.172
19 years (3-5) months	284	0.151	0.595	232	0.069	0.198

TABLE 6

MILES DRIVEN IN 1963 BY AGE AND ACCIDENT RATE[a]

Age at Beginning of Driver Record Period	Total Sample			Males			Females		
	Average* Miles Driven	Miles per Accident	Accidents per 100,000 Mi	Average* Miles Driven	Miles per Accident	Accidents per 100,000 Mi	Average* Miles Driven	Miles per Accident	Accidents per 100,000 Mi
All ages	7,548	59,905	1.78	9,557	58,994	1.78	4,643	61,907	1.77
16 years (0-2) months	4,668	31,541	3.46	5,685	28,568	3.74	2,916	46,286	2.52
16 years (3-5) months	4,637	34,865	3.00	5,343	32,382	3.19	3,422	42,775	2.49
16 years (6-8) months	5,571	51,110	2.07	7,165	45,929	2.27	2,989	83,028	1.32
16 years (9-11) months	6,178	45,763	2.35	7,647	43,948	2.40	3,632	51,155	2.15
17 years (0-2) months	6,629	47,350	2.25	8,345	46,105	2.26	4,114	49,566	2.24
17 years (3-5) months	7,159	59,658	1.77	8,872	55,799	1.87	4,578	72,667	1.49
17 years (6-8) months	7,156	49,694	2.10	9,568	57,293	1.79	3,506	31,873	3.40
17 years (9-11) months	8,327	63,565	1.68	10,822	66,393	1.56	4,828	54,864	2.03
18 years (0-2) months	8,160	58,705	1.79	10,322	56,098	1.86	5,004	66,720	1.60
18 years (4-5) months	9,107	81,313	1.32	11,594	78,871	1.35	5,941	86,101	1.25
18 years (6-8) months	9,027	91,182	1.17	11,498	98,274	1.05	5,597	72,688	1.50
18 years (9-11) months	8,991	79,566	1.39	11,865	80,169	1.37	5,230	76,912	1.45
19 years (0-2) months	8,910	65,036	1.63	11,870	67,829	1.55	5,213	57,922	1.87
19 years (3-5) months	9,127	80,061	1.31	11,714	77,576	1.35	5,944	86,145	1.22

[a]Based on 6,244 respondents.
*Arithmetic means.

TABLE 7

MILES DRIVEN IN 1963 BY AGE AND VIOLATION RATE[a]

Age at Beginning of Driver Record Period	Total Sample			Males			Females		
	Average* Miles Driven	Miles per Violation	Violations per 100, 000 Mi	Average* Miles Driven	Miles per Violation	Violations per 100, 000 Mi	Average* Miles Driven	Miles per Violation	Violations per 100, 000 Mi
All ages	7, 548	18, 389	5.44	9, 557	16, 863	5.93	4, 643	25, 173	3.97
16 years (0-2) months	4, 668	12, 379	8.08	5, 685	11, 132	8.98	2, 916	19, 863	5.04
16 years (3-5) months	4, 637	15, 785	6.34	5, 343	13, 823	7.23	3, 422	25, 509	3.92
16 years (6-8) months	5, 571	15, 504	6.45	7, 165	15, 328	6.52	2.989	16, 229	6.16
16 years (9-11) months	6, 178	18, 986	5.27	7, 647	18, 069	5.53	3, 632	23, 304	4.29
17 years (0-2) months	6, 629	18, 507	5.40	8, 345	17, 343	5.77	4, 114	23, 124	4.32
17 years (3-5) months	7, 159	18, 143	5.51	8, 872	15, 995	6.25	4, 578	29, 841	3.35
17 years (6-8) months	7, 156	15, 425	6.48	9, 568	14, 328	6.98	3, 506	22, 553	4.43
17 years (9-11) months	8, 327	19, 209	5.21	10, 822	18, 630	5.37	4, 828	21, 286	4.70
18 years (0-2) months	8, 160	20, 380	4.91	10, 322	17, 730	5.64	5, 004	37, 067	2.70
18 years (3-5) months	9, 107	19, 275	5.19	11, 594	18, 537	5.39	5, 941	21, 388	4.68
18 years (6-8) months	9, 027	19, 968	5.01	11, 498	17, 513	5.71	5, 597	33, 269	3.01
18 years (9-11) months	8, 991	18, 591	5.38	11, 865	17, 461	5.73	5, 230	23, 013	4.35
19 years (0-2) months	8, 910	10, 938	5.02	11, 870	18, 088	5.53	5, 213	28, 121	3.56
19 years (3-5) months	9, 127	20, 929	4.78	11, 714	18, 853	5.30	5, 944	28, 557	3.50

[a]Based on 6,244 respondents.
*Arithmetic means.

TABLE 8

ACCIDENTS AND VIOLATIONS PER 100,000 MILES BY MILES DRIVEN IN 1963

Miles Driven During 1963	Males		Females	
	Accidents per 100,000 Mi	Violations per 100,000 Mi	Accidents per 100,000 Mi	Violations per 100,000 Mi
Under 1,500	15.71	43.29	7.29	12.29
1,500-2,999	6.82	18.27	3.18	7.82
3,000-4,499	2.92	10.05	1.73	4.08
4,500-5,999	2.62	8.98	1.35	3.06
6,000-7,499	2.21	7.02	1.27	3.25
7,500-8,999	1.87	7.15	0.95	2.38
9,000-10,499	1.60	5.77	1.13	2.93
10,500-11,999	2.13	5.79	1.34	2.23
12,000-13,499	1.74	4.91	1.17	2.82
13,500-14,999	1.85	5.28	1.65	2.49
15,000-16,499	1.11	3.75	1.12	2.25
16,500-17,999	1.01	4.05	0.65	1.94
18,000-19,499	1.12	3.43	1.34	3.12
19,500-20,999	1.05	3.95	0.57	2.66
Over 20,999	0.84	3.39	1.21	2.14

the performance factor than was the previous question, but is further removed from the absolute accident or violation probabilities that each age group represents.

Table 6 shows the effect of a single variable, "total miles in year," on the relationship between accidents and age. Even a cursory glance at this table indicates that younger teen-aged drivers have a higher accident rate per mile driven. Younger teen-agers also tend to have a slightly higher violation rate per mile driven than do older teen-age drivers (Table 7).

Most of the relationship found here is not due to age alone, but is a result of the fact that those individuals who drove less during 1963 had a higher accident and violation rate per mile driven (Table 8). This could be due to a number of factors which are related to annual mileage such as additional exposure variables, skill, experience, and inaccurate responses to the questionnaire. Because younger drivers as an age group drove less than older teen-agers (Fig. 5), this factor is a primary contributor to their poorer driver record per mile driven.

A stratification procedure was employed to remove the aforementioned effect, and statistical analysis of the data through correlational techniques and analysis of variance procedures was employed. The results of this mileage-controlled analysis can be summarized as follows:

1. Although the difference between the age groups is not as dramatic as indicated by the previous ratios, younger teen-age males still have a higher accident rate than their older counterparts [Males: R Age Accidents · Mileage = -0.039 $P < 0.05$].

2. No significant relationship between age and accidents was revealed for females [Females: R Age Accidents · Mileage = -0.019 $P > 0.05$].

3. No significant relationship between age and violations was noted for either males or females [Males: R Age Violations · Mileage = 0.027 $P > 0.05$; Females: R Age Violations · Mileage = 0.028 $P > 0.05$].

From these results alone, it can be seen that the controlling of even one exposure variable can have dramatic effects. The possibility, however, that other exposure variables (type, time, and place of driving) also influence the results cannot be dismissed. Thus, before a final decision can be made regarding the relative risk of these age groups, it will be necessary to hold constant some additional exposure variables.

Is the age-driver record relationship obtained above affected by taking into account the effects of additional exposure variables? The present study included several measures of exposure in addition to miles driven per year. These variables were miles

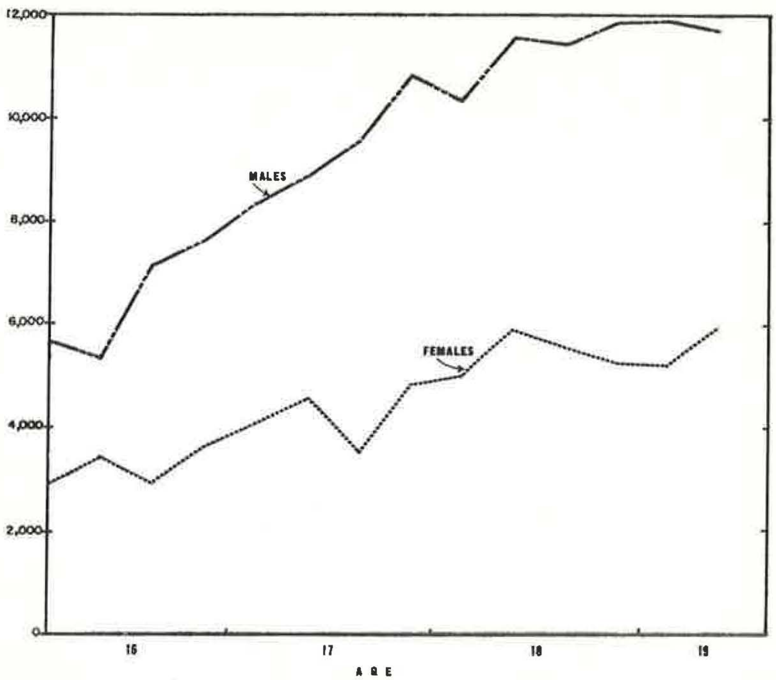

Figure 5. Average (mean) number of miles driven per year by age.

driven at night, miles driven on freeways and expressways, total hours per week, and total miles per week. Before a final conclusion can be formulated as to the relationship between age and driving record, with variations due to exposure controlled, it is necessary that the effects of these variables be removed. In order to do so, the authors resorted to the use of a multi-variate analysis technique (multiple regression analysis).

The first step in such an analysis is to determine the interrelationships (correlations) between all of the variables under consideration (Tables 9, 10). The multiple regression analysis then allows one to determine which of the exposure variables contributes uniquely to predictions of driver records, and results in a determination of the relationship between driver record and age with the effects of the exposure variables controlled.

In Table 11 are the findings with respect to age and the exposure variables. An S indicates that the variable made a significantly unique contribution while NS indicates that the variable did not make a significantly unique contribution.

In some instances certain mathematical assumptions underlying the use of correlational and regression analysis have been violated (linearity, normality, homoscedasticity, and continuity). The basic effect of such violations is to render probability levels approximate rather than exact.

The exposure variables total hours per week and total miles per week were found to make significantly unique contributions above and beyond the contribution of total miles in 1963; however, for both sexes, the findings concerning age are identical to those cited earlier when only one exposure variable was controlled. Age was found to be significantly related to male accident frequencies alone. Our multiple regression runs also showed (Tables 12 to 15) that, within the age groups under consideration here, exposure was a more important factor than age in accident prediction.

Age Driving Performance and Associated Factors

The third question raised in the introductory section of this report relates to the importance of inexperience, immaturity and parental control as factors in determining the driver records of teen-agers.

TABLE 9

SIMPLE CORRELATION COEFFICIENTS (MALES)[a]

	Criterion Variables		Miles per Week	Hours per Week	Total Miles in Year	Total Miles in Life	Age	Months License in Force	Parental Regulation
	Accidents	Violations							
Accidents	—								
Violations	0.146*	—							
Miles per week	0.089*	0.186*	—						
Hours per week	0.085*	0.149*	0.324*	—					
Total miles in year	0.096*	0.200*	0.647*	0.304*	—				
Total miles in life	0.045*	0.145*	0.371*	0.209*	0.505*	—			
Age	-0.014	0.076*	0.234*	0.084*	0.249*	0.246*	—		
Months license in force	-0.005	0.069*	0.247*	0.063*	0.253*	0.248*	0.797*	—	
Parental regulation	-0.011	0.001	-0.216*	-0.097*	0.196*	0.132*	-0.305*	-0.292*	—

[a]Based on 3,385 subjects.
*Correlations over ± 0.037 are significant beyond the 0.05 level.

TABLE 10

SIMPLE CORRELATION COEFFICIENTS (FEMALES)[a]

	Criterion Variables		Miles per Week	Hours per Week	Total Miles in Year	Total Miles in Life	Age	Months License in Force	Parental Regulation
	Accidents	Violations							
Accidents	—								
Violations	0.155*	—							
Miles per week	0.108*	0.149*	—						
Hours per week	0.044*	0.077*	0.248*	—					
Total miles in year	0.142*	0.160*	0.632*	0.203*	—				
Total miles in life	0.059*	0.122*	0.461*	0.156*	0.586*	—			
Age	0.006	0.055*	0.186*	0.018	0.174*	0.264*	—		
Months license in force	-0.030	0.067*	0.131*	-0.012	0.142*	0.260*	0.726*	—	
Parental regulation	-0.027	-0.014	-0.145*	-0.054*	-0.176*	-0.176*	-0.287*	-0.249*	—

[a]Based on 2,255 subjects.
*Correlations over ± 0.037 are significant beyond the 0.05 level.

TABLE 11

RESULTS OF MULTIPLE REGRESSION-AGE AND ALL EXPOSURE VARIABLES

Predictor Variables	Accidents		Violations	
	Males	Females	Males	Females
Age	S	NS	NS	NS
Total miles in 1963	S	S	S	S
Total hours per week	S	NS	S	NS[a]
Total miles per week	NS	NS	S	S
Miles driven at night	NS	NS	NS	NS
Miles on freeways and expressways	NS	NS	NS	NS

[a]Approaches significance.

TABLE 12

ACCIDENT PREDICTION WITH ALL VARIABLES (MALES)

Predictor Variables	Regression Coefficient	$\underline{F}$	Probability
Constant term	1.8236×10^{-1}	27.413	$P < 0.001$
Total hours per week	1.7480×10^{-3}	11.910	$P < 0.001$
Total miles in 1963	3.5868×10^{-6}	22.423	$P < 0.001$
Age[a]	-1.4096×10^{-3}	5.283	$P < 0.05$

[a]Age equals number of months of age in excess of 14 years.
Note: $R = 0.119$

TABLE 13

ACCIDENT PREDICTION WITH ALL VARIABLES (FEMALES)

Predictor Variables	Regression Coefficient	$\underline{F}$	Probability
Constant term	7.8669×10^{-2}	24.274	$P < 0.001$
Total miles in 1963	8.1128×10^{-6}	50.144	$P < 0.001$
Months license in force	-1.3070×10^{-3}	6.010	$P < 0.05$

Note: $R = 0.151$

TABLE 14

VIOLATION PREDICTION WITH ALL VARIABLES (MALES)

Predictor Variables	Regression Coefficient	$\underline{F}$	Probability
Constant term	8.0779×10^{-2}	0.927	$P > 0.25$
Total miles per week	5.0231×10^{-6}	12.766	$P < 0.001$
Total hours per week	5.3571×10^{-3}	22.765	$P < 0.001$
Total miles in 1963	9.4942×10^{-6}	18.986	$P < 0.001$
Total miles in life	6.6062×10^{-7}	5.424	$P < 0.05$
Parental regulations	5.0003×10^{-2}	12.477	$P < 0.01$
Age[a]	2.5045×10^{-3}	3.182	$P < 0.1$

[a]Age equals number of months of age in excess of 14 years.
Note: $R = 0.240$

TABLE 15

VIOLATION PREDICTION WITH ALL VARIABLES (FEMALES)

Predictor Variables	Regression Coefficient	F	Probability
Constant term	2.8863×10^{-2}	0.992	P > 0.25
Total miles per week	3.7306×10^{-6}	6.297	P < 0.05
Total hours per week	1.6406×10^{-3}	3.338	P < 0.1
Total miles in 1963	9.7320×10^{-6}	14.675	P < 0.001
Months license in force	1.9469×10^{-3}	4.450	P < 0.05

Note: R = 0.181

TABLE 16

RESULTS OF MULTIPLE REGRESSION—ALL VARIABLES

Predictor Variables	Accidents		Violations	
	Males	Females	Males	Females
Age	S	NS	NS[a]	NS
Total miles in 1963	S	S	S	S
Total hours per week	S	NS	S	NS[a]
Total miles per week	NS	NS	S	S
Months license in force	NS	S	NS	S
Miles in life	NS	NS	S	NS
Parental regulation	NS	NS	S	NS

[a]Approaches significance.

Two variables were used in an attempt to measure the effect of driving experience on driving record: total miles driven in life and months license was in force. It was hypothesized that those individuals who had driven less in their life and who had possessed a driver license for a shorter period of time would be the less experienced drivers. (One must remember that the entire study group was limited to drivers with a minimum of one year driving experience at the time of coding and that, therefore, the effects of less than one year's experience could not be assessed.)

Immaturity could not be assessed directly from the information obtained in the questionnaire; consequently, an indirect assessment of this factor was made by controlling all available variables which are related to age but which were not considered to be immaturity factors. Any relationship between age and driving record which remained was then attributed to immaturity. Such a definition, of course, ties this concept directly to chronological age and results in a variable which encompasses somewhat more than the concept of psychological immaturity.

Parental regulation was measured by determining the number of ways (indicated by questionnaire responses) that each subject's driving behavior had been regulated by his parents. Since it has been suggested that increased parental control could result in younger teen-agers driving more carefully, it was hypothesized that this factor would be related to both age and driving record.

In order to evaluate the effects of the three aforementioned factors, it was necessary to again resort to a multiple regression analysis. In this analysis exposure, experience, age, and parental regulations were included. The results (Table 16) indicate that the same exposure variables continue to be predictors of violations and accidents. The significant exposure variables will be listed but not discussed.

Presented are the variables which were found to make a statistically significant contribution in accounting for the accident and violation frequencies of either males, females, or both. For males, an experience variable, miles in life, makes a unique contribution to our ability to predict violations, and the direction of the relationship is a positive one. That is, as experience increases, violation frequency also increases. This variable, however, was unrelated to accidents. For females, months license in force, also an experience variable, is significantly related to both accidents and violations. Here the direction of the relationship with respect to experience and violations is positive, in that increased experience is associated with increased violation frequency. The relationship between accidents and experience is in the opposite direction; as experience increases, accident frequency decreases.

One would speculate from these findings that greater experience results in increased confidence, which in turn results in a subsequent relaxation of compliance to traffic laws. This violation tendency does not necessarily result in a positive relationship between accidents and experience because the tendency for increased violations to produce a comparable increase in accidents is offset by an increase in driving skill.

Immaturity (defined in terms of the remaining age effect) appears as a significant factor in accidents for males, with less mature (younger) teen-age males having more accidents. This factor also approaches significance in our attempt to predict violations, but with the tendency being for more mature (older) teen-age drivers to have more violations. One possible explanation of this apparent contradiction is that younger drivers are more concerned with obeying traffic laws but lack the psychological maturity necessary for proper defensive driving. For females immaturity (age) was not found to be relevant to either accidents or violations.

Parental regulation was related only to violation frequency for males, and the direction of the relationship was such that increased regulation was associated with increased violation frequency. One should not confuse the cause and effect relationship, however, since it is highly probably that increased violations caused increased parental control rather than the converse.

The Influence of Driver Training On Accident and Violation Rates

In this section, an attempt will be made to answer two basic questions:

1. Do drivers who have taken behind-the-wheel driver training have significantly better subsequent driving records than those who have not taken such training?
2. To what extent can subsequent driver record differences be attributed to the effects of driver training?

The task of evaluating the effects of driver training on accident and violation rates is a difficult one. To adequately determine the effect of this type of instruction on subsequent driving behavior, it would be necessary to use a random assignment technique—randomly assigning subjects to a driver training course and a control group for later comparison. To our knowledge, no such controlled experimentation has been done. Instead, comparisons have been made between the driver records of subjects who have volunteered to take driver training classes with those who have not. In general, it has been shown that individuals who are volunteers have different characteristics than those who are not volunteers. In the case of driver training, a number of characteristics have been found to differentiate volunteers for driver training classes from non-volunteers; in some cases, these same characteristics are related to driving performance (1). For example, the New York Department of Motor Vehicles has established that whether a person takes a driver education class or not (in New York) is related to his scholastic standing and, furthermore, that scholastic standing is related to accident and violation records (3). It has also been suggested that because of socioeconomic and exposure differences, individuals who attend schools which do not offer driver training may have poorer driver records than individuals who attend schools which do offer such a course. It has been shown, for example, that drivers from lower socioeconomic backgrounds are more frequently negligent drivers than those with higher socioeconomic backgrounds (2).

TABLE 17

HIGH SCHOOL DRIVER TRAINING BY VIOLATIONS AND ACCIDENTS

Driver Training Status	Males			Females		
	No.	Average Violations (mean)	Average Accidents (mean)	No.	Average Violations (mean)	Average Accidents (mean)
Total	3,878	0.541	0.162	2,786	0.169	0.075
School offered driver training class	3,198	0.522	0.157	2,296	0.164	0.076
Did take and pass	2,514	0.498	0.158	1,795	0.154	0.076
Did not take	684	0.611	0.154	501	0.202	0.074
School did not offer driver training class	447	0.642	0.186	337	0.199	0.080
Status undetermined	233	0.601	0.185	153	0.183	0.059

To support the view that driver training is effective in reducing accident rates, it has often been pointed out that some insurance companies give rate reductions to teen-agers who have taken a behind-the-wheel course. This does not necessarily provide evidence in support of the effectiveness of driver training. If teen-agers that have completed a driver training course actually do have a superior driving record, it is possible that the difference is as much due to their personal characteristics as to the effectiveness of the course.

When the DMV driver questionnaire was designed, it was decided to include questions which would identify whether or not the subjects had taken driver education and training. It was hoped that the information gathered would aid attempts to evaluate behind-the-wheel training in general. Due to the previously mentioned selection factor (volunteer bias), it was realized at the outset that a completely definitive result could not be obtained.

In Table 17 and Figures 6 and 7, the driving records of the individuals who took and passed the driver training course (trained) are compared with those who attended a school which offered driver training but did not take the course, and those individuals who did not attend a school which offered driver training. These last two groups will be referred to, collectively, as untrained drivers. The difference with regard to violations is statistically significant in favor of the trained group [F (violations) = 6.64 P < 0.01]. This is consistent with findings from other studies, although the difference is not as marked as reported by some investigators (5, 6).

Data released by the California State Department of Education indicate that 63.5 percent of California high school students received driver training in the 1963-1964 school year. Our sample data match this figure almost exactly and provide rather convincing evidence for the validity and representativeness of the sample in this respect.

As for accidents [F (accidents) = 0.64 P > 0.50], it can be seen from Table 17 and Figure 7 that the performance of the groups is similar. The differences which do exist are not statistically significant. In fact, the two largest components—"did take" and "did not take"—are almost identical. This is indeed a surprising finding. Previous research has shown that subjects who take driver training have personality characteristics and socioeconomic backgrounds which are related to safe driving habits, so it would seem that any subsequent comparison, if anything, should favor the driver training group, if only because of these initial personality and cultural differences (4).

Before coming to a final evaluation of driver training effectiveness, it will first be necessary to examine some possible sources of bias which may have introduced distortions into the data. These possible biases can be categorized as follows:

1. Exposure differences between the trained and untrained groups.
2. Age differences between trained and untrained groups.

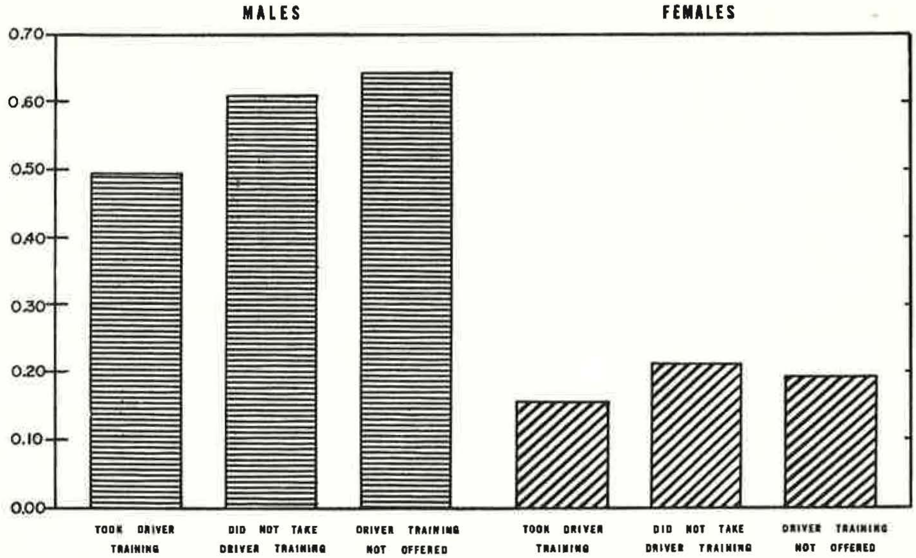

Figure 6. Average (mean) number of violations for trained and untrained drivers by sex (1-yr record).

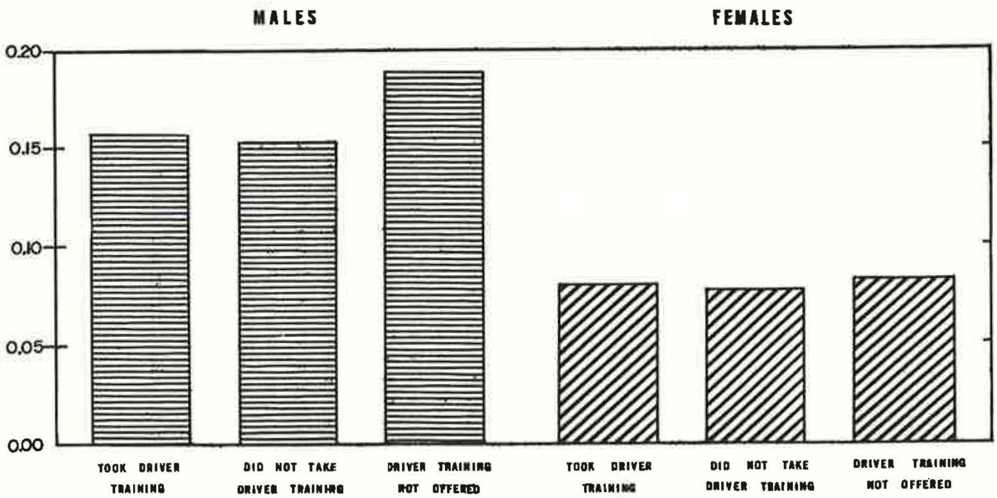

Figure 7. Average (mean) number of accidents for trained and untrained drivers by sex (1-yr record).

TABLE 18

ANNUAL MILEAGE—1963 BY DRIVER TRAINING STATUS

Driver Training Status	Mean Annual Mileage, 1963	
	Males	Females
Took and passed	9,489	4,596
Did not take	10,751	4,394
Could not take	10,641	4,971

3. Indeterminancy as to when driver training occurred in relation to the driving records of the trained groups. (For the 16-year-old group, there is a possibility that some of the drivers comprising the trained group had their driver training during or after the recorded "subsequent" driving record. If so, the distinction between the trained and untrained group might have been blurred and any effectiveness spuriously diminished.)

4. Differential response bias between the trained and untrained groups (i.e., the possibility that limiting the study to respondents favored one group more than the other).

In order to determine whether any mileage differences existed between the trained and untrained groups, the distribution of each group by sex with regard to annual mileage was determined (Table 18) and the respective averages computed for comparison. If the trained group had driven a significantly greater number of miles, any failure to find a lower accident frequency for the trained group could possibly be explained by the greater exposure of this group.

Statistical tests of significance indicated that the trained males actually drove significantly fewer miles than did the untrained males [t (took vs didn't take) = 9.06 $P < 0.001$; t (took vs couldn't take) = 2.42 $P < 0.01$]. For females, the small differences in mean miles driven are not statistically significant [t (took vs didn't take) = 0.68 $P > 0.40$; t (took vs couldn't take) = 1.08 $P > 0.20$]. Thus, if anything, the trained male group should have been favored in any driving record comparison and the trained females unaffected. This fact renders the superior violation record of the trained males as somewhat uncertain. On the other hand, the failure to find an accident reduction for the trained group becomes even more conclusive.

To test for the possible effects of an age bias between the trained and untrained groups, an analysis of variance procedure was employed in order to determine whether the comparative accident frequencies were similar at all age levels. In effect, such a procedure allows one to measure the effectiveness and stability of a treatment (e.g., driver training) at various levels (e.g., age) and to determine what variables are exerting significant effects on the data. The effect of training was constant at all age levels [F (age by training) = 0.857 $P > 0.25$]. Consequently, there is no reason to suspect that the previous findings with regard to accidents and driver training were contaminated by an age bias.

This same procedure also answers our third possibility of distortion—temporal indeterminancy. Since the effectiveness (or ineffectiveness) of training was constant at all ages, there is no reason to suspect that the occurrence of driver training for some of the younger drivers during or after the recorded driving record interval biased the outcome against the trained group. Had such a bias resulted, one would expect the older teen-age drivers to have done relatively better than their younger counterparts, but such was not the case.

As to the fourth possible source of bias, the reader is referred to our earlier finding concerning the overall response bias. It will be recalled that the respondents and non-respondents were almost identical with respect to accident frequency (Mean = 0.126 and 0.131, respectively).

Since this indicated no significant bias to begin with, it is doubtful the data could have been distorted by limiting the samples to respondents.

After considering all the facts available from this study, the authors can find no evidence that, on a statewide basis, behind-the-wheel driver training is effective in reducing the frequency of accidents. (It was not possible, incidentally, to analyze any differences between ages or training groups as they may relate to accident severity.)

Due to the aforementioned exposure and violation bias which would tend to favor the trained group, the significance of the violation reduction becomes somewhat more uncertain. We therefore cannot determine from this study whether driver training, per se, results in a reduction in violation frequency.

The authors wish to emphasize that the present study has dealt with driver training as a whole, on a statewide basis. It is entirely possible that some effective programs do exist within the system, but are too insignificant in number to have appreciably affected the overall statewide accident average of the trained group.

TABLE 19

RESULTS OF STATISTICAL TESTS BY SEX

Variables Controlled	Accidents		Violations	
	Males	Females	Males	Females
Uncontrolled for mileage	Age not significant	Age not significant	Age significant[b]	Age significant[b]
Controlled for mileage variable (e.g., total miles in 1963)	Age significant[a]	Age not significant	Age not significant	Age not significant
Controlled for all mileage variables with significant predictor variables listed	Age significant[a] Total hours per week[b] Total miles in 1963[b]	Age not significant Total miles in 1963[b]	Age not significant Total miles in 1963[b] Total hours per week[b] Total miles per week[b]	Age not significant Total miles in 1963[b] Total miles per week[b] Total hours per week approaches significance[b]
Controlled for mileage and other factors related to age with significant predictor variables listed	Age not significant[a] Total hours per week[b] Total miles in 1963[b]	Age not significant Total miles in 1963[b] Months license in force[a]	Age approaches significance[b] Total hours per week[b] Total miles in 1963[b] Total miles per week[b] Parental regulation[b] Total miles in life[b]	Age not significant Total miles in 1963[b] Total miles per week[b] Months license in force[b] Total hours per week approaches significance[b]

[a]Negative.
[b]Positive.

Note: A positive relationship indicates that as the variable increases in value the criterion variable (accidents or violations) increases. A negative relationship indicates that as the variable increases in value the criterion variable decreases in value.

Future research in this area should be oriented toward determining which (if any) of the present programs are effective. In any event, the research effort described herein should not be considered an end in itself, but rather a beginning to the scientific development and evaluation of driver training programs in this state.

SUMMARY

In terms of driver record alone (uncontrolled for mileage differences), statistical analysis of the data indicated accident frequency for both teen-age males and females is unrelated to age. Violation frequency for both males and females, however, increases as age increases.

In order to adequately control the effects of differences in exposure between age groups and to determine the relationship between relative risk and age, it was necessary to resort to a multiple regression analysis (Table 19). This analysis established: (a) exposure was a more important factor than age in determining accident and violation rates and (b) age was related only to male accident rates, with older males having fewer accidents.

To determine the effects of inexperience, immaturity (as measured by age) and parental control on accident and violation records, it again was necessary to resort to a multiple regression analysis.

For males, in addition to two exposure variables which were found to be positively related to accidents, age was found to be a predictor of accidents, with older males having fewer accidents. From this result, it was concluded that some intrinsic components of age (e.g., immaturity) were factors in the accident frequency of the younger male teen-aged driver.

Male violation frequencies were found to be related to three exposure variables, miles in life (experience) and parental regulations. More experienced drivers and more regulated drivers had more violations. It was concluded that regulations came as a result of violations rather than the converse. Age (immaturity) approached significance, and the direction of the relationship was a positive or increasing one. Some possible explanations of these findings were offered previously.

For females one exposure variable and an experience variable (months license in force) were found to be significantly related to accidents, with more experienced drivers having fewer accidents. Three exposure variables and the experience variable (months license in force) were found to be significantly related to violations—the more experienced female drivers having more violations. Parental regulations and age (immaturity) made no contribution to accident or violation records for females.

In terms of absolute risk, the authors can find no evidence to support a raise in the minimum licensing age in California. In terms of relative risk, however, there is some evidence, for males, that younger drivers are more predisposed to accidents than drivers in their older teens. Any final decision concerning a raise in licensing age must be based upon the relative merits of these two methods of comparison.

The sample of teen-aged drivers was broken into three groups (did take, didn't take and couldn't take) on the basis of their answer to the questionnaire item regarding the completion of a behind-the-wheel driver training course. When the three groups were compared, the trained group had fewer violations, but no significant differences were found between the trained and untrained groups on accidents. Although it is entirely possible that some programs in certain individual school districts are effective, this finding raises serious questions about the general effectiveness of statewide driver training in reducing accidents.

ACKNOWLEDGMENTS

This study could not have been completed within the restricted time limit without the aid of high-speed computer programs and processing. Appreciation is expressed to Harry M. Hughes, Ph.D., Chief of Data Processing, U. S. A. F. School of Aerospace Medicine, for the computer programs used in the multiple regression analysis. For other computer programs and data processing, we must express appreciation to Don McNally, Chief of Data Processing, Division of Registration, and his staff, namely, Tom Chinn, James Lai and E. Kodama.

In appreciation for the many demands placed on the Survey Research Center, University of California, and which were met by their staff, we thank Roderick Frederickson, who directed the questionnaire phase. To the many others who cooperated so generously, and who are too numerous to name individually here, go our sincere thanks—without all of this help the completion of the study could not have been accomplished.

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Driver Record by Age, Sex and Marital Status

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•THIS PAPER summarizes the data analyzed as Part 5 of the 1964 California Driver Record Study which was released in a somewhat lengthier form by the California Department of Motor Vehicles in June 1965. The present version of Part 5 corresponds closely with the original, except that most of the 34 tables appearing in the original version are not included.

The 1964 California Driver Record Study can be characterized as a multi-part, large-scale survey of the California driving population, as defined by driver record data contained in the California Department of Motor Vehicle's mammoth driver record file. Based on a random sample of 225,000 records (1/50 sampling ratio), the study was undertaken to provide data for three basic purposes: (a) operational and budgetary planning; (b) basic descriptive research oriented toward construction of normative data and estimation of various driver and driver record parameters; and (c) analytical research oriented toward the isolation of accident correlates and possible causative factors.

Because the California driver record file is a manual operation consisting of over 40,000,000 documents, collecting biographical and driver record data was a difficult and time-consuming task, requiring a total of six months (140 man-months) for completion. However, the subsequent data analysis has been greatly facilitated by converting all data to tape input for processing on the department's Philco 2000 computer.

While similar to an earlier study in general purpose (1958 Driver Record Study), the 1964 study represents a considerable extension of the earlier effort, not only in terms of comprehensiveness but also in terms of analytical complexity. This increase in complexity is well evidenced by the fact that the 1958 Study was issued as one small report, whereas the present study will entail 15 separate parts, each dealing with a different facet of the data.

It has been known for some time that age, sex, and marital status are related to driving record. Despite this, there has been comparatively little research—even of a descriptive nature—published concerning the exact magnitude and shape of this relationship. Much of what has been done is either dated or fraught with various limitations, such as inadequate sample size.

Because of the demand of the subject matter, it was decided to publish this part of the study in a basically descriptive form, without employing complex mathematical curve-fitting procedures. The specific shapes of the trends and relationships should therefore be considered descriptive of this particular sample and caution exercised in generalizing specific findings to the overall population of drivers. In certain cases, however, appropriate statistical procedures have been applied to some of the variables, in order that inferential statements of a general nature could be made concerning the relationships under consideration. The statistical treatment, incidentally, has been separated from the descriptive text by placing it in the Appendix, where it need not concern the non-technically oriented reader. It was felt that such a procedure would facilitate reading and comprehension, without sacrificing statistical rigor.

It is hoped that the data presented herein will contribute toward filling the void which presently exists in our knowledge of important driver characteristics and their relation to driving record.

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METHODOLOGY

Throughout this report, driver record relationships will be depicted in terms of two periods of time—a one-year interval and a three-year interval. The sizes of the samples, therefore, vary somewhat depending on the type of driving record presented. In those tables limited to data concerning only a one-year driving record, the sample consisted of 97,281 males and 68,562 females. Where data for a complete three-year driving record are presented, the sample size decreased to 86,717 males and 61,273 females.

The one-year record represents a 12-month interval of time (1962), and only subjects who possessed unexpired licenses during the entirety of this interval were included in the analysis. The three-year interval represents approximately the years 1961 through 1963, and again only those subjects who were licensed during the entirety of the interval were included for analysis. More comprehensive discussions concerning the sample selection, data collection and terminology were presented in Parts 1 and 2 of the study.

The ages referred to in this report represent the age attained by the licensees on their birthdays in 1962. However, since age has been keyed to the midpoint of the tabulated driving record intervals, all ages actually represent age as of nearest birthday. For example, persons who were between 16.5 and 17.5 years of age at the midpoint of their 1962 driving record interval were classified as 17-year-olds. This procedure is consistent with the continuous (non-discrete)nature of age and also serves to counteract systematic bias, since the driver record interval is equally divided on each side of a given age point[1]. Age with respect to the three-year driving record was treated in the same manner, except that the longer period resulted in an 18-month interval on each side of any given age point. For example, persons who were between 19.5 and 20.5 at the midpoint of their recorded three-year driver record intervals were tallied as 20-year-olds, although their ages extended approximately 18 months on each side of their midpoint age. Thus, a subject whose midpoint age was exactly 20 years would, in actuality, vary from 18.5 to 21.5 during his recorded three-year driver record. Because of this increased variation, the one-year driver record data probably reflect the more precise representation of age-driver record relationships. The reader should note that the age intervals used for one- and three-year distributions are slightly different. This difference was dictated, in part, by the greater length of the three-year intervals, which made it more expedient to begin the three-year record distributions at 21 rather than 20.

Marital status represents each driver's reported status as of the issuance date of his current license at time of coding. For most of the sample, this data could vary from 1958 through 1963. Drivers who indicated they were divorced or widowed were coded as single. The marital status data were felt to be insufficiently reliable to have warranted a finer breakdown. It should be emphasized that subsequent unreported changes in marital status would not be reflected in the present data. Therefore, a person's marital status does not in all cases coincide with his actual status at the time of the recorded driver record interval. This fact would tend to obscure any relationship which might exist between marital status and driver record, especially with regard to the three-year driving record. This difficulty would be most frequent in the younger age groups where the majority of marriages first occur.

RESULTS AND FINDINGS

Shown in Tables 1 and 2 are the one-year driver record sample by age, sex and marital status. In addition to defining the stratification of the sample in terms of these subject variables, Table 1 also depicts some interesting, though not unexpected,

[1]The reader who prefers to conceptualize age as a discrete measure (age as of last birthday) may do so by shifting the entire age distribution back one year. In so doing, the resultant age distribution would then be keyed to the beginning rather than the midpoint of the tabulated driving record interval. For example, a person who was 16.7 years of age and classified in this report as a mid-interval 17-year-old would be a 16-year-old in terms of his last birthday as of the beginning of the interval in question. In the case of age by three-year driver record intervals, a two-year back shifting would be necessary.

TABLE 1

PERCENTAGE DISTRIBUTION OF MALE LICENSEES BY AGE AND MARITAL STATUS, 1962[a]

Age	Total (N = 97,281)	Married (n = 72,937)		Single (n = 24,344)	
	Percent	Percent of Total	Percent of Married	Percent of Total	Percent of Single
All ages	100.00	74.98	100.00	25.02	100.00
Under 20	4.98	0.32	0.43	4.66	18.60
17	1.21	0.03	0.03	1.18	4.73
18	1.83	0.09	0.12	1.75	6.94
19	1.94	0.20	0.28	1.73	6.93
20-24	10.25	3.85	5.14	6.40	25.55
20	2.01	0.37	0.50	1.63	6.53
21	1.84	0.56	0.75	1.28	5.10
22	2.03	0.77	1.02	1.27	5.06
23	2.16	0.97	1.30	1.19	4.76
24	2.21	1.18	1.57	1.03	4.10
25-29	11.04	7.48	9.97	3.56	14.24
25	2.19	1.33	1.77	0.87	3.47
26	2.12	1.38	1.84	0.75	2.99
27	2.32	1.57	2.09	0.75	3.00
28	2.25	1.61	2.15	0.62	2.49
29	2.16	1.59	2.12	0.57	2.29
30-34	11.47	9.11	12.15	2.36	9.43
35-39	11.63	9.93	13.24	1.70	6.77
40-44	11.54	10.24	13.65	1.31	5.24
45-49	10.07	8.93	11.91	1.14	4.56
50-54	8.40	7.45	9.94	0.95	3.80
55-59	6.84	5.97	7.96	0.87	3.48
60-64	5.26	4.57	6.09	0.69	2.78
65-69	3.94	3.39	4.52	0.55	2.21
70-74	2.69	2.25	3.01	0.43	1.73
75 and over	1.89	1.49	1.99	0.40	1.61

[a]Sample limited to drivers who possessed an unexpired driver license during the entirety of the 12-month interval corresponding approximately to the 1962 calendar year.

TABLE 2

PERCENTAGE DISTRIBUTION OF FEMALE LICENSEES BY AGE AND MARITAL STATUS, 1962[a]

Age	Total (N = 68,562)	Married (n = 53,785)		Single (n = 14,777)	
	Percent	Percent of Total	Percent of Married	Percent of Total	Percent of Single
All ages	100.00	78.45	100.00	21.55	100.00
Under 20	4.64	1.48	1.89	3.16	14.62
17	1.03	0.13	0.17	0.90	4.16
18	1.62	0.44	0.56	1.19	5.48
19	1.99	0.91	1.16	1.07	4.98
20-24	10.51	7.49	9.55	3.02	14.00
20	2.18	1.21	1.54	0.98	4.51
21	1.96	1.33	1.70	0.63	2.94
22	2.05	1.54	1.96	0.51	2.37
23	2.15	1.68	2.14	0.47	2.17
24	2.17	1.73	2.21	0.43	2.01
25-29	10.87	9.37	11.95	1.49	6.94
25	2.12	1.76	2.25	0.35	1.65
26	2.15	1.83	2.34	0.31	1.45
27	2.17	1.86	2.37	0.31	1.44
28	2.22	1.97	2.51	0.26	1.20
29	2.21	1.95	2.48	0.26	1.20
30-34	11.86	10.55	13.45	1.31	6.10
35-39	13.32	11.79	15.02	1.53	7.11
40-44	12.99	11.45	14.58	1.56	7.22
45-49	10.75	9.09	11.59	1.66	7.69
50-54	8.51	6.79	8.65	1.72	7.98
55-59	6.34	4.61	5.88	1.73	8.03
60-64	4.40	2.91	3.71	1.49	6.94
65-69	3.10	1.71	2.18	1.39	6.46
70-74	1.74	0.86	1.10	0.87	4.05
75 and over	0.97	0.35	0.45	0.62	2.86

[a]Sample limited to drivers who possessed an unexpired driver license during the entirety of the 12-month interval corresponding approximately to the 1962 calendar year.

TABLE 3

AVERAGE (MEAN) NUMBER OF TOTAL REPORTED ACCIDENTS BY AGE, SEX AND MARITAL STATUS[a]

Age	Total			Males			Females		
	Total	Married	Single	Total	Married	Single	Total	Married	Single
All ages	0.074	0.065	0.103	0.094	0.085	0.122	0.045	0.038	0.071
Under 20	0.139	0.110	0.145	0.178	0.244	0.174	0.079	0.069	0.085
17	0.146	0.122	0.147	0.172	0.200	0.172	0.101	0.100	0.101
18	0.138	0.107	0.143	0.181	0.253	0.178	0.069	0.063	0.071
19	0.137	0.110	0.146	0.180	0.245	0.172	0.077	0.067	0.086
20-24	0.095	0.077	0.115	0.125	0.118	0.128	0.055	0.047	0.075
20	0.112	0.081	0.128	0.145	0.141	0.146	0.068	0.055	0.084
21	0.103	0.084	0.120	0.143	0.140	0.145	0.051	0.052	0.048
22	0.104	0.083	0.128	0.132	0.129	0.134	0.066	0.051	0.109
23	0.081	0.072	0.094	0.106	0.111	0.103	0.045	0.040	0.062
24	0.079	0.070	0.095	0.101	0.100	0.102	0.047	0.041	0.071
25-29	0.082	0.075	0.105	0.108	0.107	0.111	0.045	0.039	0.082
25	0.083	0.080	0.090	0.105	0.114	0.090	0.052	0.045	0.091
26	0.079	0.071	0.100	0.107	0.105	0.111	0.039	0.036	0.061
27	0.085	0.074	0.118	0.113	0.105	0.129	0.043	0.037	0.080
28	0.088	0.081	0.116	0.121	0.120	0.125	0.041	0.036	0.085
29	0.075	0.068	0.103	0.095	0.091	0.106	0.047	0.040	0.096
30-34	0.073	0.067	0.103	0.096	0.092	0.109	0.042	0.036	0.089
35-39	0.066	0.061	0.093	0.087	0.084	0.102	0.039	0.034	0.079
40-44	0.065	0.062	0.090	0.084	0.082	0.100	0.042	0.037	0.078
45-49	0.067	0.064	0.090	0.085	0.081	0.115	0.044	0.040	0.067
50-54	0.062	0.061	0.070	0.079	0.078	0.087	0.039	0.034	0.057
55-59	0.065	0.063	0.073	0.081	0.079	0.090	0.042	0.034	0.062
60-64	0.062	0.060	0.070	0.075	0.073	0.086	0.040	0.030	0.060
65-69	0.057	0.056	0.059	0.065	0.063	0.076	0.042	0.036	0.049
70-74	0.055	0.047	0.075	0.060	0.052	0.100	0.044	0.030	0.058
75 and over	0.059	0.059	0.059	0.061	0.062	0.059	0.051	0.037	0.059

[a]Based on 1-year record of 165,843 licensees.

TABLE 4

AVERAGE (MEAN) NUMBER OF COUNTABLE CONVICTIONS + MOVING FTA'S BY AGE, SEX AND MARTIAL STATUS[a]

Age	Total			Males			Females		
	Total	Married	Single	Total	Married	Single	Total	Married	Single
All ages	0.241	0.202	0.369	0.328	0.277	0.479	0.118	0.098	0.190
Under 20	0.486	0.330	0.517	0.687	0.823	0.679	0.179	0.178	0.179
17	0.400	0.330	0.405	0.555	0.840	0.549	0.142	0.189	0.135
18	0.492	0.333	0.522	0.694	0.879	0.684	0.169	0.166	0.170
19	0.531	0.330	0.599	0.765	0.795	0.761	0.206	0.182	0.227
20-24	0.403	0.308	0.505	0.573	0.545	0.590	0.168	0.136	0.252
20	0.476	0.342	0.548	0.690	0.715	0.685	0.197	0.178	0.220
21	0.466	0.348	0.567	0.685	0.686	0.685	0.173	0.146	0.230
22	0.397	0.292	0.517	0.573	0.536	0.596	0.150	0.120	0.240
23	0.368	0.296	0.469	0.509	0.507	0.510	0.166	0.123	0.320
24	0.321	0.290	0.378	0.435	0.463	0.403	0.156	0.123	0.289
25-29	0.295	0.262	0.394	0.415	0.406	0.436	0.120	0.099	0.252
25	0.298	0.267	0.369	0.423	0.442	0.392	0.116	0.081	0.288
26	0.294	0.252	0.414	0.427	0.405	0.466	0.109	0.087	0.238
27	0.309	0.287	0.374	0.425	0.423	0.429	0.133	0.125	0.183
28	0.301	0.273	0.407	0.431	0.425	0.448	0.115	0.095	0.266
29	0.268	0.231	0.414	0.371	0.340	0.454	0.126	0.105	0.287
30-34	0.243	0.217	0.379	0.341	0.317	0.436	0.108	0.093	0.232
35-39	0.218	0.202	0.319	0.303	0.289	0.383	0.113	0.099	0.219
40-44	0.206	0.139	0.295	0.279	0.269	0.352	0.115	0.100	0.228
45-49	0.188	0.177	0.260	0.250	0.237	0.351	0.105	0.092	0.173
50-54	0.174	0.164	0.230	0.228	0.219	0.289	0.100	0.079	0.184
55-59	0.173	0.167	0.201	0.224	0.216	0.277	0.095	0.076	0.147
60-64	0.159	0.152	0.186	0.192	0.179	0.273	0.104	0.092	0.127
65-69	0.131	0.122	0.160	0.148	0.141	0.191	0.103	0.072	0.142
70-74	0.136	0.134	0.141	0.155	0.150	0.184	0.093	0.076	0.110
75 and over	0.123	0.119	0.131	0.136	0.124	0.179	0.087	0.087	0.087

[a]Based on 1-year record of 165,843 licensees.

Note: A countable conviction is one which involves the safe operation of a motor vehicle as defined in Section 12810 of the California Vehicle code. These convictions count toward determining a subject's negligent operator point count. A moving FTA is a citation for a moving traffic violation on which the subject has failed to appear in court as scheduled.

TABLE 5

AVERAGE (MEAN) NUMBER OF TOTAL ACCIDENTS BY AGE, SEX AND MARITAL STATUS[a]

Age	Total			Males			Females		
	Total	Married	Single	Total	Married	Single	Total	Married	Single
All ages	0.204	0.185	0.275	0.260	0.241	0.324	0.126	0.108	0.197
Under 21	0.363	0.280	0.392	0.468	0.526	0.460	0.209	0.180	0.233
17[b]	0.600	0.250	0.727	0.737	0.333	0.875	0.250	—	0.333
18	0.417	0.319	0.434	0.532	0.667	0.524	0.213	0.187	0.224
19	0.371	0.303	0.394	0.476	0.599	0.460	0.219	0.200	0.235
20	0.324	0.256	0.359	0.419	0.458	0.410	0.198	0.165	0.237
21-25	0.256	0.216	0.305	0.332	0.333	0.331	0.138	0.116	0.215
21	0.290	0.239	0.333	0.396	0.403	0.393	0.149	0.143	0.160
22	0.275	0.212	0.348	0.355	0.322	0.376	0.163	0.135	0.250
23	0.234	0.206	0.277	0.308	0.326	0.293	0.129	0.106	0.219
24	0.236	0.217	0.272	0.311	0.332	0.285	0.126	0.105	0.224
25	0.229	0.211	0.272	0.301	0.315	0.277	0.123	0.099	0.255
26-30	0.219	0.198	0.299	0.290	0.278	0.323	0.118	0.105	0.219
26	0.221	0.197	0.291	0.298	0.289	0.317	0.113	0.100	0.198
27	0.223	0.200	0.296	0.288	0.281	0.305	0.124	0.103	0.263
28	0.221	0.193	0.333	0.310	0.284	0.381	0.094	0.085	0.167
29	0.218	0.201	0.285	0.279	0.273	0.295	0.132	0.116	0.255
30	0.214	0.199	0.290	0.277	0.265	0.321	0.129	0.119	0.207
31-35	0.198	0.186	0.263	0.256	0.252	0.271	0.119	0.105	0.243
36-40	0.193	0.182	0.269	0.250	0.242	0.305	0.122	0.110	0.219
41-45	0.182	0.173	0.253	0.231	0.225	0.274	0.122	0.106	0.231
46-50	0.188	0.182	0.229	0.234	0.229	0.273	0.126	0.114	0.190
51-55	0.177	0.174	0.197	0.226	0.224	0.245	0.108	0.099	0.160
56-60	0.185	0.184	0.190	0.224	0.225	0.215	0.124	0.105	0.173
61-65	0.186	0.183	0.197	0.226	0.220	0.269	0.118	0.097	0.154
66-70	0.165	0.164	0.169	0.193	0.186	0.233	0.112	0.095	0.132
71-75	0.165	0.153	0.196	0.179	0.171	0.220	0.136	0.086	0.181
76 and over	0.185	0.189	0.178	0.200	0.199	0.201	0.142	0.117	0.154

[a] Based on 3-year record of 147,990 licensees.

[b] The means for 17-year-olds on all three-year data are based on a very small number of subjects and are therefore unstable. This reduction resulted from the method of defining age herein, which, when applied to three-year data, required that a subject receive his license prior to his 16th birthday in order to be classified as a 17-year-old.

TABLE 6

AVERAGE (MEAN) NUMBER OF COUNTABLE CONVICTIONS + MOVING FTA'S BY AGE, SEX, AND MARITAL STATUS[a]

Age	Total			Males			Females		
	Total	Married	Single	Total	Married	Single	Total	Married	Single
All ages	0.681	0.588	1.022	0.918	0.803	1.315	0.347	0.294	0.557
Under 21	1.444	1.077	1.573	2.021	2.421	1.963	0.597	0.529	0.654
17[b]	1.733	1.500	1.818	2.273	1.667	2.500	0.250	1.000	—
18	1.448	1.070	1.511	1.932	2.397	1.902	0.591	0.566	0.601
19	1.485	1.081	1.621	2.084	2.587	2.021	0.615	0.553	0.667
20	1.403	1.074	1.569	2.018	2.342	1.945	0.586	0.503	0.682
21-25	1.092	0.897	1.380	1.551	1.546	1.555	0.439	0.343	0.780
21	1.368	1.100	1.592	2.012	2.261	1.909	0.503	0.416	0.680
22	1.162	0.886	1.485	1.675	1.629	1.703	0.454	0.369	0.718
23	1.087	0.884	1.388	1.519	1.520	1.518	0.471	0.359	0.903
24	0.986	0.885	1.184	1.353	1.430	1.259	0.448	0.349	0.907
25	0.892	0.810	1.089	1.274	1.332	1.179	0.327	0.245	0.766
26-30	0.831	0.743	1.155	1.177	1.130	1.297	0.340	0.293	0.681
26	0.899	0.806	1.173	1.293	1.284	1.310	0.351	0.301	0.683
27	0.862	0.796	1.065	1.210	1.214	1.202	0.333	0.298	0.563
28	0.846	0.749	1.217	1.204	1.140	1.377	0.334	0.291	0.667
29	0.802	0.705	1.191	1.116	1.041	1.328	0.362	0.310	0.758
30	0.750	0.671	1.136	1.066	1.007	1.281	0.319	0.266	0.747
31-35	0.680	0.620	1.008	0.949	0.897	1.172	0.315	0.282	0.603
36-40	0.615	0.581	0.852	0.840	0.812	1.023	0.339	0.304	0.608
41-45	0.575	0.539	0.852	0.774	0.742	1.038	0.326	0.279	0.653
46-50	0.548	0.521	0.727	0.712	0.685	0.929	0.325	0.284	0.542
51-55	0.506	0.488	0.606	0.648	0.630	0.785	0.305	0.261	0.471
56-60	0.496	0.481	0.561	0.619	0.599	0.757	0.304	0.256	0.425
61-65	0.481	0.463	0.546	0.576	0.548	0.761	0.320	0.267	0.414
66-70	0.417	0.397	0.476	0.467	0.445	0.597	0.323	0.254	0.406
71-75	0.389	0.391	0.382	0.447	0.437	0.502	0.264	0.220	0.304
76 and over	0.376	0.354	0.421	0.410	0.372	0.553	0.272	0.234	0.292

[a] Based on 3-year record of 147,990 licensees.

[b] The means for 17-year-olds on all three-year data are based on a very small number of subjects and are therefore unstable. This reduction resulted from the method of defining age herein, which, when applied to three-year data, required that a subject receive his license prior to his 16th birthday in order to be classified as a 17-year-old.

Note: A countable conviction is one which involves the safe operation of a motor vehicle as defined in Section 12810 of the California Vehicle Code. These convictions count toward determining a subject's negligent operator point count. A moving FTA is a citation for a moving traffic violation on which the subject has failed to appear in court as scheduled.

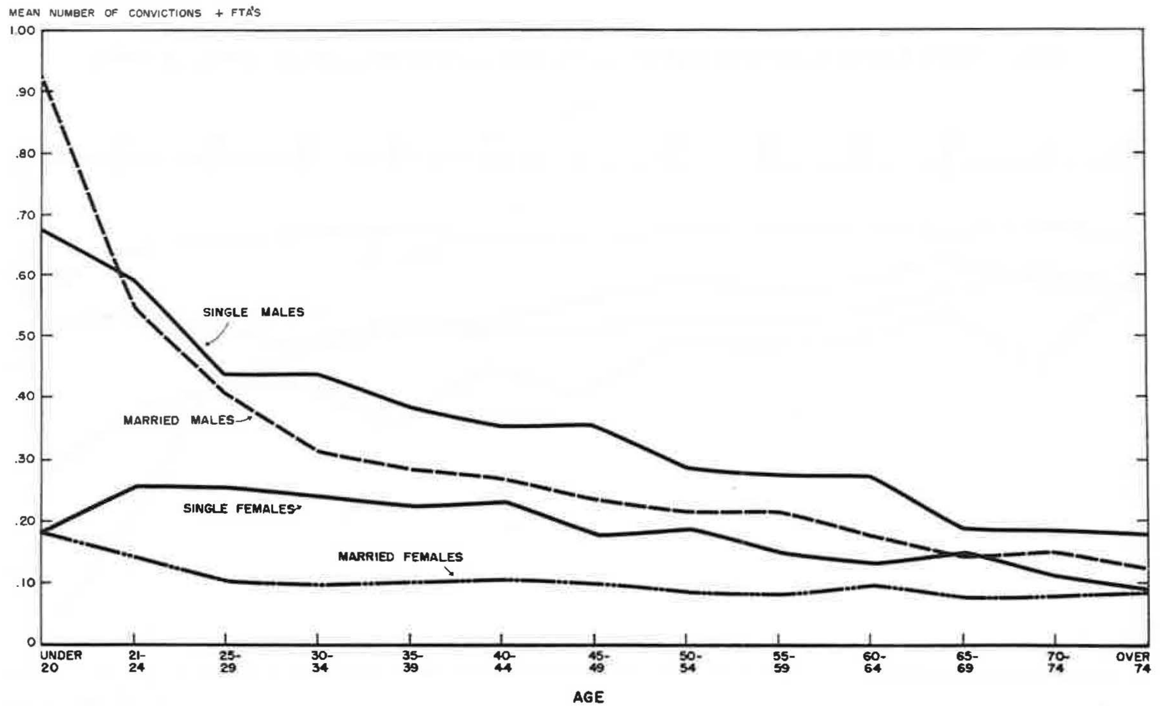

Figure 1. Mean citation frequency (countable convictions + moving FTA's) by age, sex and marital status (1-yr driving record, 1962).

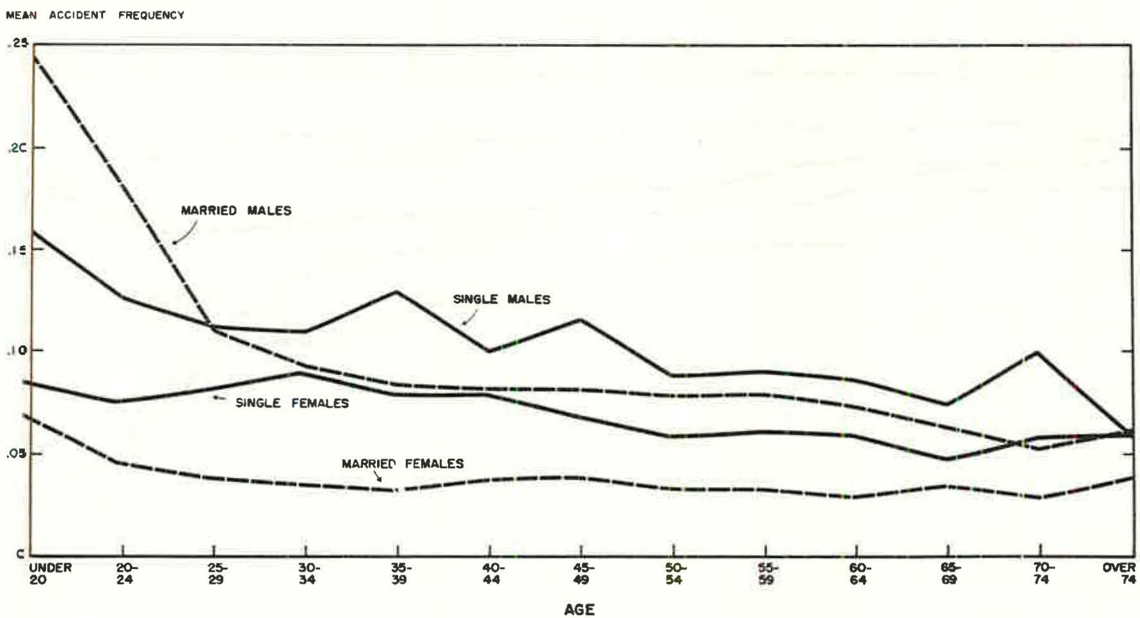

Figure 2. Mean accident frequency by age, sex and marital status (1-yr driving record, 1962).

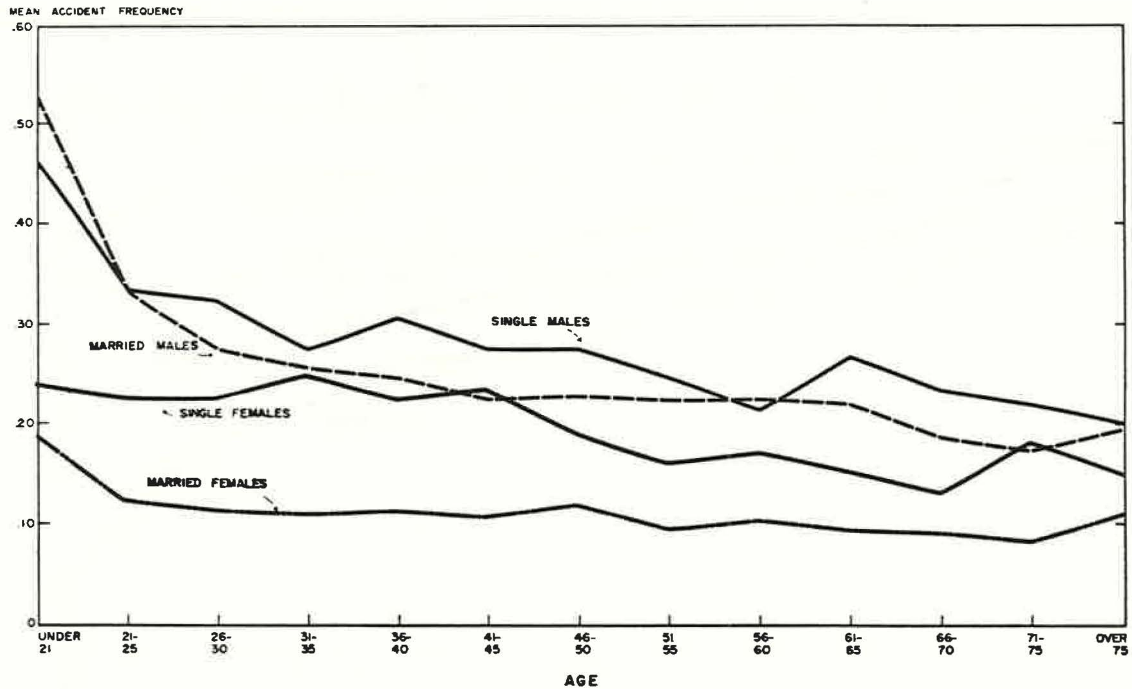

Figure 3. Mean accident frequency by age, sex and marital status (3-yr driving record, 1961-1963).

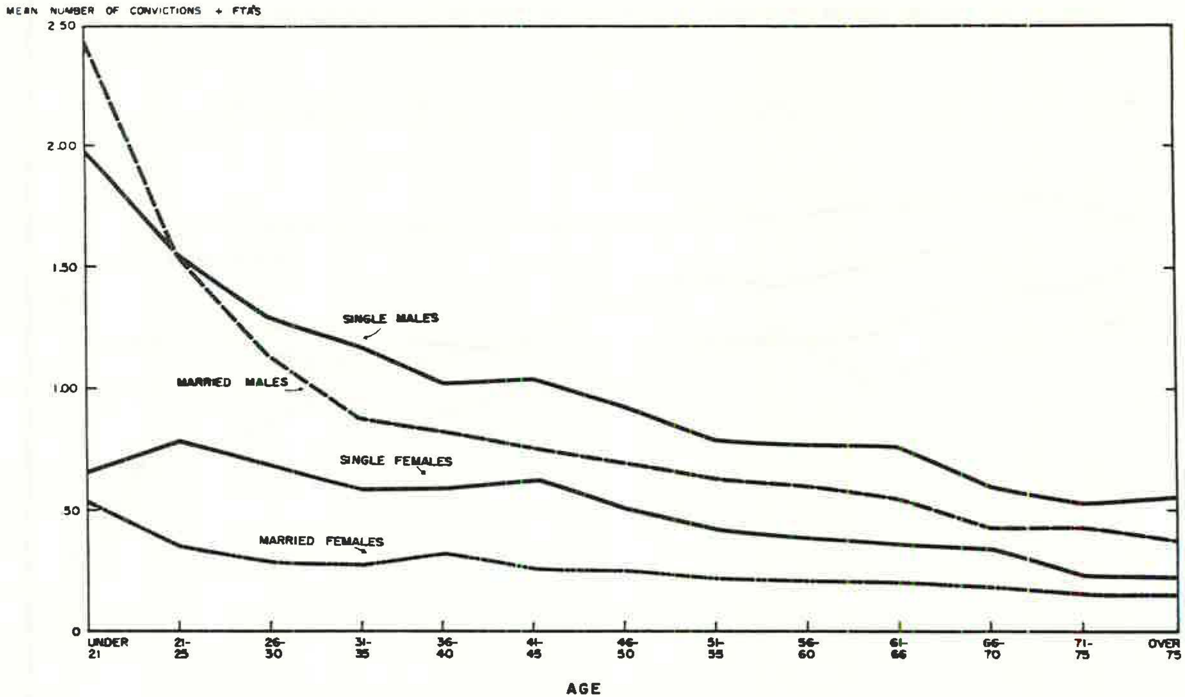

Figure 4. Mean citation frequency (countable convictions + moving FTA's) by age, sex and marital status (3-yr driving record, 1961-1963).

relationships. For example, females are shown to become married at an earlier age than males. Also, a greater proportion of males remained unmarried throughout the entire age distribution. Overall, 75.0 percent of the entire male sample was married, compared with 78.5 percent for the females. The relative proportion of subjects in each age group who were married increased with age, peaking at ages 40-54 for males and ages 30-34 for females. After peaking, the proportion of males and females classified as married decreased with advancing age.

Presented in Tables 3 through 6 and Figures 1 through 4 are detailed graphical and tabular presentations of various types of driver record counts by age, sex and marital status. For a comprehensive definition of the driver record counts and data collection methods, the reader should consult Parts 1 and 2 of the study. For sake of convenience, most of the written presentation will center around accident and citation frequency. Since negligent operator counts are composed mainly of citations, all trends with regard to negligent operator counts closely parallel those regarding citation frequency.

The following is a list of the more pertinent driver record trends apparent in the data. The general statements apply to the one-year and three-year data as a whole, whereas specific numerical examples were derived from the one-year distributions. The stated relationships can be most easily comprehended in conjunction with Figures 1-4.

1. Accidents and citations tend to decrease with age, except at extremely old ages where there was a tendency for accidents to increase slightly. The decrease in accident and citation frequency with age was much sharper for males than for females, the age by driver record curves for the latter being almost flat. For males, the largest proportion of reduction occurred prior to age 30, after which the decrement became much more gradual.

2. Married female drivers had driving records that were superior to those of the single female driver. This finding held true for all age groups. On most driver reord variables, single females had approximately twice the accident and violation incidence of their married counterparts.

3. A finding similar to the preceding was observed concerning the male drivers with a few exceptions noted in the younger age categories, where married male drivers had the poorer driving records.

4. Throughout the age distribution, driving record differences between marital status categories (single vs married) were greater for females than for males. For example, single and married females differed with respect to accident and citation frequency by factors of 1.0;[2] for males (single vs married), the comparative marital status difference factors relative to accident and citation frequency were, respectively, 1.4 and 1.7.

5. Both married and single female drivers had driving records that were markedly superior to those of their respective male counterparts. In general, single and married males had over twice as many driver record incidents (accidents, citations, etc.) as their respective female counterparts.

6. Relative to both citation and accident frequency, the greatest similarity between males and females involved the married male-single female comparisons. At most ages, the driving record of the single female was only slightly superior to that of the married male; furthermore, there was a definite tendency for driving record differences between these two groups to decrease with age.

7. Driving record differences with respect to sex tended to decrease with age. In the under-20 age group, for example, males and females differed with respect to accident and citation frequency by factors of 2.3 and 3.8, respectively; for the 75 and over groups, these respective sex difference factors shrank to 1.2 and 1.6. With the exception of the younger age groups, there was a similar, though less dramatic, tendency

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[2]These factors refer to proportional differences (times as many) between the components being compared. For example, the 1.9 factor cited for females means that one female marital status category had 1.9 times the citation and accident rate of the other.

for marital status differences regarding accident and citation frequency to shrink with age.

8. For most age, sex and marital status comparisons, driver record differences with respect to citations were greater than differences with respect to accidents. For example, males had slightly over twice as many reported accidents as females, but almost three times as many reported citations.

For a more technical treatment of these relationships, the reader is referred to the Appendices at the end of the test. In the next section, some ramifications of the present findings will be discussed.

DISCUSSION

It may have been noted from the previous section that the authors have consistently used the term driving record, rather than driving performance. This usage does not reflect a mere word preference; rather, it was dictated by the fact that the term driving performance often implies that exposure to accidents and traffic citations has been held statistically constant, and the comparative performance of the various groups evaluated on the basis of accident and citation rates. No such control was possible here, although there is considerable evidence that exposure differentials exist as a function of age, sex and marital status. Because of this, a definitive evaluation of driving performance cannot be arrived at on the basis of the present analysis. Given knowledge that exposure is correlated with accident and citation frequency, and also with age, sex and marital status, it is safe to assume that the driver record differences reflected in the present data would shrink if corrected for differences in exposure. For instance, the comparatively superior record of the married female over all other groups might be largely a result of the relatively low exposure (miles driven, etc.) of married females to accidents and citations. The extent to which such differences will shrink when corrected for exposure remains to be seen.

Regardless of the effects of other uncontrolled variables, the tabulated accident and citation frequencies presented herein represent the absolute frequency of accident and violation occurrence relative to any given age by sex by marital status stratification. Thus, while a theoretical and causal interpretation of these data is limited, it presents a statistical profile of considerable predictive and practical significance.

It will be the future task of this department's research staff—and hopefully of other researchers as well—to derive reliable exposure data for use in extending the significance of this and similar data. Regardless of whatever ramifications such exposure information may prove to have on the present data, this report's contribution toward providing absolute citation and accident frequencies will in no way be preempted or made less significant.

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Appendix A

INFERENTIAL ANALYSIS

In order that at least some of the aforementioned descriptive findings and trends could be generalized for the overall population of drivers, it was necessary to employ statistical tests of significance. The specific purpose of such tests is to quantify the effects of random sampling variation (chance) so that probability statements can be

TABLE 7

ANALYSIS OF VARIANCE: AGE BY MARITAL STATUS (WITHIN SEX)

Source of Variation	Sums of Squares	df	Mean Square	F	P
(a) Original Analysis: Three-Year Criterion Measures					
Males (accidents):					
Age	215.0	12	17.9	59.3[a]	P < 0.001[a]
Maritial status	12.8	1	12.8	424.0[a]	P < 0.001[a]
Age × maritial status	6.6	12	0.468	1.55[a]	P < 0.10[a]
Males (citations):					
Age	9,193.0	12	765.0	424.0	P < 0.001
Marital status	260.0	1	260.0	145.0	P < 0.001
Age × marital status	276.0	12	23.0	12.8	P < 0.001
Females (accidents):					
Age	15.5	2	1.30	9.38	P < 0.001
Marital status	68.3	1	68.3	495.0	P < 0.001
Age × marital status	7.74	12	0.645	4.67	P < 0.001
Females (citations):					
Age	221.3	12	18.4	32.8	P < 0.001
Marital status	627.0	1	627.0	1110.0	P < 0.001
Age × marital status	105.0	12	8.75	15.6	P < 0.001
(b) Supplementary Analysis: One-Year Accident Records					
Males:					
Age	39.45	12	3.29	31.9	P < 0.001
Marital status	2.00	1	2.00	19.4	P < 0.001
Age × marital status	3.29	12	0.274	2.66	P < 0.005
Females:					
Age	2.67	12	0.223	4.75	P < 0.001
Marital status	10.24	1	10.24	218.0	P < 0.001
Age × marital status	1.22	12	0.102	2.17	P < 0.02

[a]F & P values on the transformed scale are: Age (F = 33, P < 0.001); Marital Status (F = 23.69, P < 0.001); Interaction (F = 2.5, P < 0.01).

TABLE 8

ANALYSIS OF VARIANCE: SEX BY AGE (OVERALL SAMPLE)

Source of Variation	Sums of Squares	df	Mean Square	F	P
(a) Criterion Measure: Three-Year Accident Record					
Age	263.7	12	21.9	93.5	P < 0.001
Sex	648.3	1	648.3	2760.0	P < 0.001
Age × sex	65.60	12	5.47	23.3	P < 0.001
(b) Criterion Measure: Three-Year Citation Record					
Age	9,541.0	12	795.1	613.0	P < 0.001
Sex	11,993.0	1	11,993.0	9247.0	P < 0.001
Age × sex	3,624.0	12	302.0	233.0	P < 0.001

TABLE 9

ANALYSIS OF VARIANCE: SEX BY MARITAL STATUS (OVERALL SAMPLE)

Source of Variation	Sums of Squares	df	Mean Square	F	P
(a) Criterion Measure: Three-Year Accident Record					
Sex	623.7	1	623.7	2647.0[a]	P < 0.001[a]
Marital status	179.7	1	179.7	762.7[a]	P < 0.001[a]
Sex × marital status	0.215	1	0.215	0.913[a]	P > 0.30[a]
(b) Criterion Measure: Three-Year Citation Record					
Sex	11,302.0	1	11,302.0	8347.0[b]	P < 0.001[b]
Marital status	4,279.0	1	4,279.0	3160.0[b]	P < 0.001[b]
Sex × marital status	369.0	1	369.0	273.0[b]	P > 0.001[b]

[a]F&P values on the transformed scale are: Marital Status (F = 759, P < 0.001); Sex (F = 2700, P < 0.001); Interaction (F = 4.5, P < 0.05).

[b]F&P values on the transformed scale are: Sex (F = 8145, P < 0.001); Marital Status (F = 1809, P < 0.001); Interaction (F = 1463, P < 0.001).

made as to the confidence one can place in generalizing sample findings to some underlying population—in this case, the overall population of licensed California drivers. If the probability of a certain difference occurring by chance is small, it is conventionally accepted as being significant, or highly probable of accurately reflecting the overall population or universe from which the sample was drawn. If the probability of chance occurrence is high, the difference is conventionally termed nonsignificant, because one cannot be sufficiently confident that the sample data represent a true difference in the underlying population. The 0.05 and the 0.01 levels of confidence are the most commonly used levels for statistical decision-making purposes. In this study, all results which reflected a chance probability of less than 5 in 100 (0.05 level) were termed significant.

For the purpose of evaluating the effects of age and marital status on driving record, a within-sex analysis of variance was employed (Table 7). Afterwards, in order to isolate and assess the effects of sex as a variable, additional analyses of variance were performed on the overall sample, with sex as one of the basic dimensions (Tables 8, 9).

In most cases, only the three-year accident and citation counts were subjected to the analysis. The results are summarized below. The probability levels and critical ratios associated with the analyses appear in Tables 7, 8 and 9.

1. All sex differences were highly significant, with males having by far the greater number of accidents and citations.

2. For both sexes, age was found to have exerted a significant effect on driving record (both accidents and citations). Increased age was generally associated with decreased accident and citation frequency.

3. For both sexes, marital status was found to have exerted a significant effect on driving record (both accidents and citations). Generally speaking, single drivers had a higher accident and citation frequency than married drivers.

4. For females, there was a significant interactive effect between age and marital status on both driving record variables. In other words, the effect of marital status on driving record was not constant at all age levels. For males, this interaction (age × marital status) was significant for citations but not for three-year accident frequency. An analysis of variance tests on the one-year male accident frequencies did, however, indicate the presence of a significant interaction between the age and marital status variables.

Although the three-year driving record interval yields a measure which has greater overall reliability, it would also tend to obscure meaningful relationships—especially with regard to a changing status variable like marital status. Consequently, the one-year data may represent the more accurate reflection of marital status relationships. Therefore, in those situations where statistical tests on the non-transformed three-year driver record data were marginally significant, the one-year records were also subjected to statistical analysis.

5. For citations alone, there was a significant interactive effect between sex and marital status, indicating that the overall effect of marital status on citation frequency was not constant for both sexes. For accidents, statistical tests of significance on the sex by marital status interaction failed to approach significance on the original scale. For reasons discussed in Appendix B, the accident scale was transformed to a more appropriate form and the analysis of variance replicated on the transformed data. The transformed data yielded a significant interaction, indicating the sex and marital status did exert an interactive effect on accident frequency.

6. For both accidents and citations, there was a significant interaction between marital status and age, indicating that marital status did not exert a constant effect on driver record throughout the age distribution.

7. Although certain technical difficulties precluded a statistical evaluation,[3] inspection of the data indicated the possible existence of a 3-way interactive effect (sex by age by marital status) on accident and citation frequency. By this, the authors

[3]Because of unequal and nonproportional subgroup totals, a 3-way analysis of variance (least squares corrected) could not be accomplished within the deadline established for this study.

mean that the effects of sex on driver record did not appear to be constant at all age-within-marital status levels. This phenomenon was portrayed most dramatically in Figure 2, where there was a convergence and crossing over of the male marital status dimensions at age 25-29, while at the same time the female marital status dimensions were diverging. Throughout most of the remaining age levels, married and single females were more divergent with respect to driving record than were their male counterparts.

Appendix B

VIOLATIONS OF ASSUMED MATHEMATICAL MODEL

Due to violations of assumptions implicit in the use of the analysis of variance technique, probability levels should be regarded as approximations—particularly with regard to the original, non-transformed accident and citation scales. Specifically, the original data scales (accidents and citations) were such that the means and variances were highly correlated and heterogeneous (non-homoscedastic). Although prior empirical research (e.g., Norton) has shown the F distribution to be very robust with regard to violations of assumptions, decisions regarding marginally significant values can be affected by extreme deviation from the postulated analysis of variance model—particularly when the model is a complex one. The situation was especially acute with regard to the present data, because all distributions were markedly non-normal, variances were heterogeneous, means and variances were correlated, and main effects were extremely large in relation to interactive effects. Thus, any distortion of error variance or additivity (partitioning of effects) would have a much more dramatic effect on interaction terms than on main effect terms. In order to check this assumption empirically, a square root transformation $(X + 0.5)^{1/2}$ was applied to the original accident and citation scale for the data reflected in Table 9, and the analysis of variance was then reapplied to the transformed data. As one might expect, the main effects were virtually unaffected; however, interactions were substantially increased. To verify the generality of the transformation, the same procedure was applied to the three-year male accident data reflected in Table 7. The results were identical—interaction was substantially increased while main effects were only negligibly affected. In fact, the effects of the transformation appeared to be completely generalizable within the range of distributions comprising the criterion measures of the analyses. Furthermore, because the transformed data reduced heterogeneity of variance and mean-variance correlation, inferences derived from the transformed scale should be regarded as the more accurate.

Performance Decrement in Twenty-Four Hour Driving

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•THE INCREASING use of multilane interstate highways has caused attention to be focused on the problem of remaining awake behind the wheel. Whether this increased interest is due to an increase in the number of "driver asleep" accidents, or to a decrease in other types of accidents on the freeway, is not known. Whatever the reason for the increased attention, the problem does exist and is likely to become more acute as more people use the freeways for faster and longer trips. As the freeways become more crowded, the single car accidents resulting from drivers falling asleep might be replaced by multi-car accidents resulting from the same cause. This problem is not limited to the superhighway. Performance decrement or decrement in ability to perform can result in just as serious, if not more serious, accidents on our urban and rural roadways.

Results from research in the area of performance decrement in long-term driving might be useful not only in alleviating these driving problems, but also in solving problems existent in areas sharing common factors with the driving task. Some other problem areas might include long-term monitoring of low probability events, the operation of aircraft, or the navigation of ocean vessels or spacecraft for long periods of time. It is evident that the research findings in these latter fields can also be used in the solution of highway problems.

An example of this type of transfer of results is the application of the findings of studies dealing with vigilance effects to highway research. This application is appropriate if we consider that driving on modern freeways and turnpikes is in many respects similar to the low probability event detection tasks employed in many monitoring tasks.

Operational Definitions of Fatigue

One of the most difficult problems and, yet, a basic problem associated with any study of fatigue is in the definition of fatigue. Typical of the many different definitions that are given for fatigue is the one proposed by Bartlett (1).

> Fatigue is a term used to cover all those determinable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal operational conditions, and which can be shown to lead either immediately or after delay, to deterioration in the expression of that activity, or, more simply, to results within the activity that are not wanted.

This definition presupposes that fatigue is undesirable, although there were some authors, most of whom wrote about 30 or 40 years ago on physical fatigue, who described it as a "rather pleasurable sensation," which is not necessarily undesirable. The onset of fatigue, though undesirable, often serves the human operator with a signal warning him of his state of decreased activity, allowing him to stop before complete breakdown occurs.

Paper sponsored by Committee on Highway Safety and presented at the 45th Annual Meeting.

STUDIES OF FATIGUE IN DRIVING

Crawford (2) states that the definition frequently given for fatigue (deterioration in the performance of an activity as a direct result of being engaged in the performance of the activity) is too narrow for describing fatigue in driving. An applicable definition, Crawford feels, should include the possibility of drivers being fatigued from other causes before they start to drive.

Crawford further states that it would appear that there are interrelated aspects of the practical problems of driving and fatigue, namely the fatigue arising from driving, operational fatigue, and the effect of fatigue, from whatever, source, on driving. Crawford then cites several examples of driving research that have been conducted in the past with special emphasis on findings in the areas of fatigue. Jones et al. (5) investigated 889 interstate truck drivers who were stopped after varied lengths of driving and given several psychophysical tests. When these data were compared to data obtained from a control group which had been awake for equal lengths of time, several differences were found. There was a more or less consistent decrease in psychomotor ability with the increasing amount of time on the task. Lauer and Suhr (6) suggest that frequent rest stops while driving are helpful in minimizing the breakdown in performance occurring from driving for extended periods of time. McFarland and Mosely (7) observed bus drivers for 3½-hour periods. They found that steering wheel movements (which occurred about 10 times as often as all other movements) were considerably reduced in the last half hour as compared to the first half hour. Herbert and Jaynes (4) conducted an experiment in which Army and Air Force truck drivers were given tests of driving skill after having actually driven a truck for lengths of time ranging from 0 hours to 9 hours. They found that these skill measures correlated significantly with the hours of fatigue driving. Their results indicated a progressive loss in performance through 7 hours of driving with a slight increase in performance during the ninth hour. The authors of this article explain the increase at the end by suggesting that in the first 7 hours fatigue "builds" unconsciously, but after 8 hours or so, the fatigue is noticeable and the subjects make a conscious effort to combat it and, thus, improve their performance.

Potts (9) and McFarland and Mosely (7) studied near accidents encountered by long haul truck drivers. Twenty drivers were studied over a total distance of 5,000 miles. A total of 48 near accidents were observed during this time. Their findings indicated that the greatest number of near accidents occur within the first couple of hours of driving. It should be noted that Crawford does not mention whether each hour of the distribution was equally represented in the study. Also, no mention is made about what constitutes a near accident. These later results, if they are a valid representation of the actual driving situations on the highway, suggest that an increase in driving time results in a reduction of near accidents and, therefore, a possible reduction in the probability of being involved in an actual accident.

This rather unexpected result is also substantiated by another study reported by McFarland and Mosely (7). These researchers found from insurance records that in 1949, 60 percent of all long haul truck accidents occurred within the first 3½ hours of driving. Again, Crawford does not give the distribution of the number of hours per truck trip so it is not known whether each hour is equally represented in this study.

Crawford also suggests that since many experiments conducted on automobile driving in actual traffic fail to show the effects of fatigue on driving, perhaps these effects should be sought on performance in tasks similar to driving, such as flying for long periods of time.

Drew (3), for example, found in aircraft simulator experiments that performance and accuracy decreased with time, and that instruments outside the immediate range of attention were practically ignored. There was also a tendency for subjects to relax and neglect the task at hand when the end of the experiment was in sight.

Platt (8) states that the following assumptions can be taken to describe the performance of a fatigued driver.

1. Driver fatigue will have an effect on the steering wheel reversal rates, speed change rates, and the average speed of the vehicle.

Figure 1. The instrumented passenger vehicle.

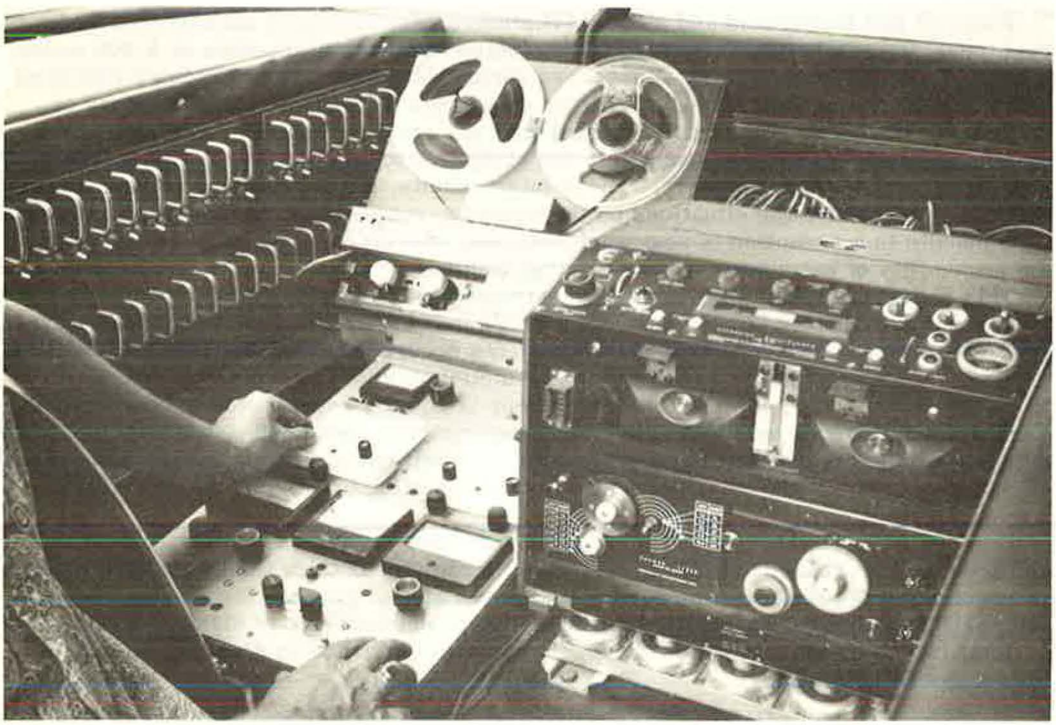

Figure 2. The experimenter's console and the oscillograph recorder.

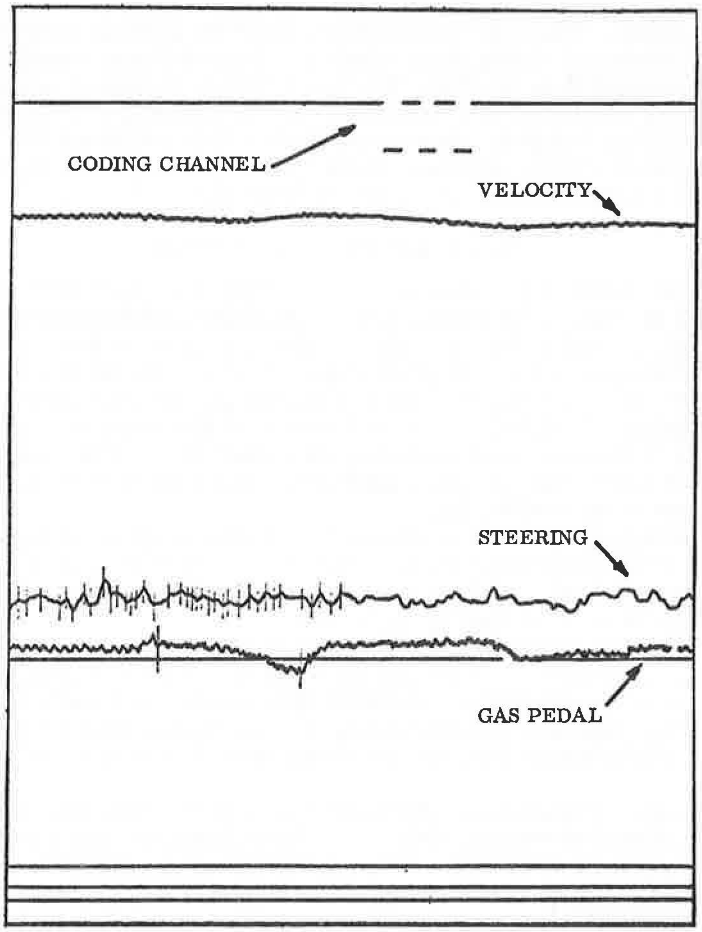

Figure 3. Sample of oscillograph trace.

2. As the driver becomes fatigued, he will accept wider tolerances of both vehicle tracking and speed control.
3. As the driver gets tired, his speed may increase or decrease depending on whether his sensitivity to speed change or steering reversal rate is lost first.
4. The driver will usually take more risks as he becomes more fatigued. This will be indicated by an increase in tracking tolerance, and consequently by a decrease in steering reversals if the vehicle is constant.
5. As the driver becomes tired, his speed change rate increases but he compensates for this by modifying his accelerator reversal rate.
6. The most severe fatigue is encountered when the speed change rate increases and the accelerator reversal rate decreases. This indicates that the driver has ceased to care about controlling his speed.

These assumptions suggest that a study of driving fatigue should utilize recordings of the subject driver's velocity, steering wheel activity, and gas pedal activity.

In all of the research reviewed by the experimenters, none was found where the subject drivers were forced to drive for extremely long times or where they were forced to drive until they broke down. The experiment we conducted was aimed at simulating the situation where a driver attempts to drive "cross country." This type of situation is typified by the serviceman who attempts to drive thousands of miles on a two- or three-day pass to visit his family. This research placed test subjects in

"on-the-road" driving situations and measured the performance of the system of which they are a component. This approach does not allow the precise control over variables that might be available in a laboratory situation. Nevertheless, results which are obtained on the highway have the distinct advantage of face validity and of being more readily interpreted into meaningful conclusions. The philosophical problems and stark practical uncertainties which are ever-present when extrapolations are attempted from laboratory simulation results into real-world contexts are minimized, when studies are conducted in a setting in which they are to be interpreted.

EXPERIMENTAL PROCEDURE

The automobile used in this study was a 1963 Chevrolet sedan (Fig. 1), which had been modified to be used in the experiment. The major modification was the installation of an oscillograph recorder (Fig. 2), which yields a permanent trace of the vehicle and driver performance parameters on photographic paper. The parameters that were recorded include: vehicle velocity, gas pedal position, steering wheel position, and brake pedal position. In addition to these 4 traces, 4 other traces were available for manual encoding of events occurring during the experiment. The events encoded were the beginning and end of data sampling intervals, and encounters of the experimental vehicle with other vehicles (Fig. 3).

Another modification was the installation of a device enabling an experimenter riding in the back seat of the automobile to short out one or two of the spark plugs in the automobile engine, and thus, induce a "miss" into the engine. This was used to test for the effects of fatigue on a "vigilance" type task.

Seven subjects were required to drive for 24-hour periods with rest breaks only at refueling stops. In addition, one subject attempted the experiment under the added condition of prior sleep deprivation and once again under prior sleep deprivation plus the use of the drug, dextroamphetamine sulfate. During the 24-hour period, the subject's vehicular performance was measured continuously with the use of the oscillograph recorder.

Subjects who participated in the experiment were paid volunteers, and all but 2 were students at Ohio State University. One of the other 2 subjects was a male auto mechanic of college age, while the other was a 51-year-old traveling salesman. Each subject was verbally informed, prior to volunteering, about what would be expected of him during the experimentation.

The subjects were told that the amount of money they received would depend on the length of time that they continued driving. They were promised 50 dollars for completing the experiment in its entirety. If they did not finish, they were told they would be paid a lesser amount that would depend on the experimenter's subjective opinion of how hard they had tried to finish.

Seven different subjects, in 9 runs, were tested in this study. The first subject was used solely to test the experimental procedure. Of the remaining 6 subjects, 3 managed to complete the prescribed experimental task in full. One of these did, in fact, volunteer to continue driving beyond the prescribed experiment for extra monetary considerations. A fourth subject was forced to quit because of extremely bad weather. The experimenters made a fifth subject stop, when his performance deteriorated to the point that the experimenters felt that it was unsafe to let him continue. The sixth subject, the 51-year-old salesman, quit $^{3}/_{4}$ of the way through the experiment when he felt that it would be detrimental for him to continue.

The typical period of experimentation was conducted in the following manner. The subjects reported to the experimenters at 6:00 a.m. on the day of the experimentation. On arrival they were given a complete vision test including tests for: acuity, phoria, and depth perception. Also a critical flicker fusion rate test was given and the subject's pulse and systolic blood pressure were measured. In addition, they completed the first of the forms designed to obtain the subject's subjective opinion of his own feeling of tiredness. The subject was then shown the experimental vehicle and was instructed to drive it to the intersection that marked the beginning of the test site.

The test site used in this experiment was a section of I71 between Columbus and Cincinnati—chosen because of the lack of geometric and landscape variations. This

lack of variation helped to make the task as boring and, hence, as tiring as possible. On arriving at the test site the subject was given the following instructions:

> During the testing period you will be asked to drive this vehicle from here to the outskirts of Cincinnati, a round trip distance of approximately 160 miles, a total of 8 times. Each trip will last about two and one-half hours. At the end of each trip, we will stop for a rest period of about 15 minutes. If at any point during a run you should notice that the automobile engine is behaving erratically, we would like you to report it to the experimenter.

Prior to the start of each journey or run either north or south on the freeway, the subject was given one of the following two sets of instructions:

Normal Velocity Control Instructions

> During this next run I would like you to drive this vehicle in your normal manner at about the speed limit, 70 miles per hour. I would like you to obey the rule that requires you to stay in the right hand lane except when passing other vehicles. I would also request that you refrain from conversing with either experimenter during the run.

or

Constant Velocity Control Instructions

> During this next run I would like you to drive this vehicle at a constant speed of 70 miles per hour (i.e., I want you to hold it as close to 70 miles per hour as you can at all times). I would like you to obey the rule which requires you to stay in the right hand lane except when passing other vehicles. I would also request that you refrain from conversing with either experimenter during the run.

The experimenters also refrained from conversing with the subjects to help make the task even more boring, although the subject had use of the car radio.

The run to which the normal or constant velocity condition was assigned was determined randomly and the design was balanced so that in the 8 trips, 4 of the south runs and 4 of the north runs were "normal" runs, while the other 4 were "constant velocity" runs. This helped to further eliminate any directional biases.

Rest Periods

At the turn around point on the southern side of the test section of highway, the subject stopped only long enough to receive the instructions pertaining to the northern run.

When a trip down and back on the test site was completed, the subject drove the vehicle to a filling station adjacent to the exit of the freeway. Before disembarking from the automobile he was given forms with which to rate his performance and wakefulness and the physiological tests were repeated. After this test was administered, he was allowed to leave the car while it was refueled. The entire break, including testing and refueling, lasted about 15 minutes. At this time the subject was given any food or nonalcoholic beverage he requested.

Use of Drugs

As mentioned previously, the seventh subject repeated the experiment 3 times. In the last 2 repetitions of the experiment the conditions under which the subject performed were slightly different. On the first day that this subject was required to drive, the experimental procedure was the same as that employed on all other subjects.

The procedure employed in the second repetition of the experiment was essentially the same as the procedure employed previously, except that the subject was kept awake a full 24 hours before he started to drive. An experimenter remained with the subject to make certain that he did not sleep. Under these conditions, the subject was able to complete four trips to Cincinnati and back before he felt it necessary to quit (approximately 12 hours).

The subject was also kept awake for a full 24 hours prior to driving in the third trial of the experiment. On this trial, one hour prior to driving and every 4 hours thereafter, the subject was given a 5-mg tablet of dextroamphetamine sulfate. This dosage was prescribed by a physician after a physical examination of the subject. The subject was, in this case, able to complete all 8 prescribed trips to Cincinnati and back. Results of these special tests are described in the next section.

DATA ANALYSES AND RESULTS

The 4 main performance measures which were obtained from the data collected during the experimentation, velocity means, velocity variances, steering wheel reversals, and gas pedal reversals, were subjected to several regression analyses. The purpose of these analyses was to see if any performance changes appeared to be expressed in these measures as a function of time engaged in task performance.

In the first regression analysis (Table 1), the values of the 4 measures were computed for each trip. A regression line was then found which related the dependent performance measure with time measured in "trips." For this first analysis the values of the performance measures were computed from all data collected during the trip. No distinction was made between data collected during the "constant velocity" portion of the trip and data collected during the "normal" portion of the trip. Table 1 shows quite a difference between subjects, with respect to the correlation of the performance measures with the passage of time. For example, the correlation of gas pedal reversals with time ranges from a value of - 0.818 for subject 2 to a value of 0.921 for subject 7, under conditions of prior sleep depreivation. Similarly, the correlation of velocity mean with driving time ranges from - 0.766 for subject 7 under standard experimental conditions to 0.811 for subject 3. Velocity variance ranged from - 0.947 for subject 7 with prior sleep deprivation to 0.863 for subject 6.

The correlation of steering wheel reversals to the passage of time yielded the most uniform set of correlations. Even so, these correlations range from 0.267 for subject 2 to 0.971 for subject 7 under conditions of prior sleep deprivation and the use of drugs.

These results would seem to indicate that an increase or a decrease in the value of any of these 4 variables cannot be accepted as a universal measure of fatigue. Some of the high correlations suggest that for individual subjects certain of these measures might validly reflect the changed performance state of that driver with the passage of time.

It is interesting to note that the regression lines for subject 7 under conditions of prior sleep deprivation account for a greater amount of variance of the performance measures than do the regression lines for any other subject. This fact might indicate that the 4 performance measures are more valid indicators of fatigue when the fatigue is more extreme than that produced in the normal operating conditions of this experiment, or when activity prior to driving has not been too fatiguing.

Further regression analyses were performed with the data separated by the conditions, constant velocity or normal. The results of these analyses exhibit much the same variation as the first regression analysis. The correlations of velocity variances to the passage of time are, in general, with the exception of the replicate runs on subject 7, higher for the constant velocity condition than for the normal condition. This fact, plus the fact that all correlations are positive, would seem to indicate that the more precise or demanding the experimental task, the more likely decrement in performance, as reflected in the increase of velocity variance, will be related to the passage of time.

Intra-Trip Variability

When the 4 major performance measures were plotted against time for each of the subjects, a sawtooth type pattern was noted in the graphs, which suggested that perhaps the individual trips and even the periods of time between turn-around points should be examined for evidences of performance decrement trends. Evidence of this intra-trip decrement was found when the periods of time between turn-around points, for normal conditions only, were examined.

TABLE 1

REGRESSION ANALYSIS RESULTS FOR CONDITIONS COMBINED

Subject	Variable	Correlation[a]	Equation	Std. Error
2	Vel. $\bar{x}$	-0.605	- 0.666x + 72.521	0.438
	Vel. σ^2	0.676	0.666x + 2.697	1.470
	Steer.	0.267	4.228x + 458.533	7.619
	Gas	-0.818	- 29.457x + 415.266	10.363
3	Vel. $\bar{x}$	0.811	0.235x + 70.395	0.120
	Vel. σ^2	0.689	0.234x + 2.150	0.173
	Steer.	0.567	25.900x + 403.500	26.613
	Gas	-0.510	- 3.600x + 167.500	4.291
4	Vel. $\bar{x}$	-0.040	- 0.003x + 70.742	0.028
	Vel. σ^2	0.608	0.248x + 1.748	0.122
	Steer.	0.768	23.466x + 520.111	7.406
	Gas	0.739	6.950x + 82.694	2.393
5	Vel. $\bar{x}$	0.365	- 0.176x + 73.052	0.224
	Vel. σ^2	0.027	—	—
	Steer.	0.906	32.771x + 548.800	7.633
	Gas	0.729	12.771x + 202.133	5.990
6	Vel. $\bar{x}$	0.154	0.031x + 71.236	0.082
	Vel. σ^2	0.863	0.674x + 0.986	0.160
	Steer.	0.838	52.904x + 690.928	14.056
	Gas	-0.717	- 9.607x + 204.107	3.814
7 Cond. 1	Vel. $\bar{x}$	-0.766	- 0.258x + 72.117	0.088
	Vel. σ^2	0.476	0.422x + 4.725	0.322
	Steer.	0.320	18.345x + 853.321	22.167
	Gas	0.533	2.488x + 111.678	1.612
7 Cond. 2	Vel. $\bar{x}$	0.421	0.234x + 75.145	0.356
	Vel. σ^2	-0.947	- 0.718x + 10.270	0.172
	Steer.	0.739	50.200x + 228.000	32.406
	Gas	0.921	4.400x + 228.000	1.311
7 Cond. 3	Vel. $\bar{x}$	0.384	0.080x + 73.130	0.078
	Vel. σ^2	0.624	0.053x + 4.753	0.270
	Steer.	0.971	176.130x + 1232.285	17.711
	Gas	0.171	1.416x + 230.250	3.323

[a]Any correlation above ±0.600 is statistically significant.

The values of the 4 major variables were computed for each of these 3 intervals. These values were then ranked. The interval with the highest value of the variable in question was assigned a rank of 3, and the other interval was assigned a rank of 2. This ranking was done separately for each of the 4 variables. The ranks assigned to the first, second, and third intervals were then totaled separately for each variable across all subjects (Fig. 4).

As can be seen from this graph, the lines for velocity, variance, steering reversals, and gas pedal reversals exhibit an increasing trend. This trend, which is significant at the 0.05 level, indicates that within a trip, between turn-arounds, there is a general tendency for velocity variance, steering wheel reversals, and gas pedal reversals to increase. The velocity mean has a tendency to decrease with a trend significant at the 0.05 level within the same period of time.

When these results are viewed at the same time as the results of the regression analysis which yielded some rather high correlations in various directions, it would appear that performance measures might be expected to demonstrate an increase or decrease over time with a sawtooth type variation imposed over the generalized trend (Fig. 5).

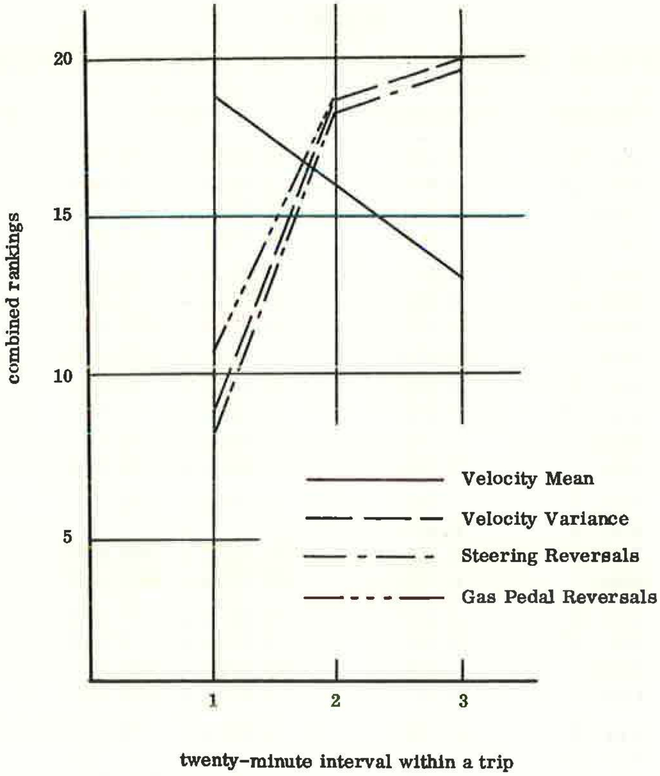

Figure 4. Intra-trip effect.

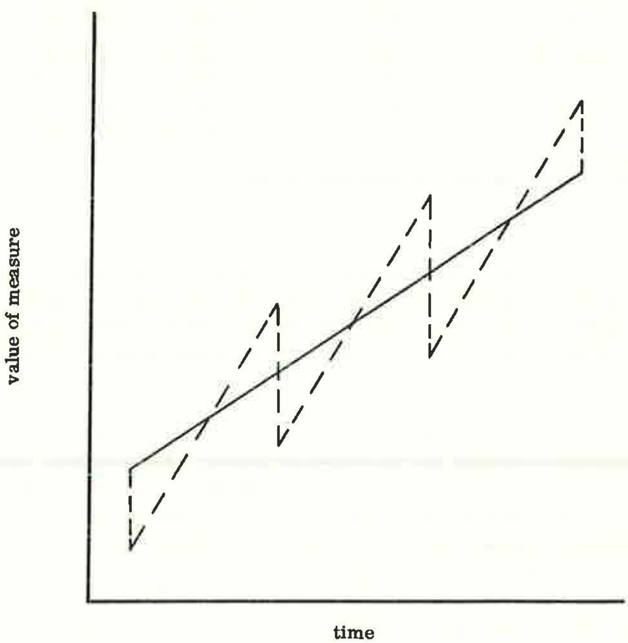

Figure 5. Idealized example of generalized trend with superimposed intra-trip variability.

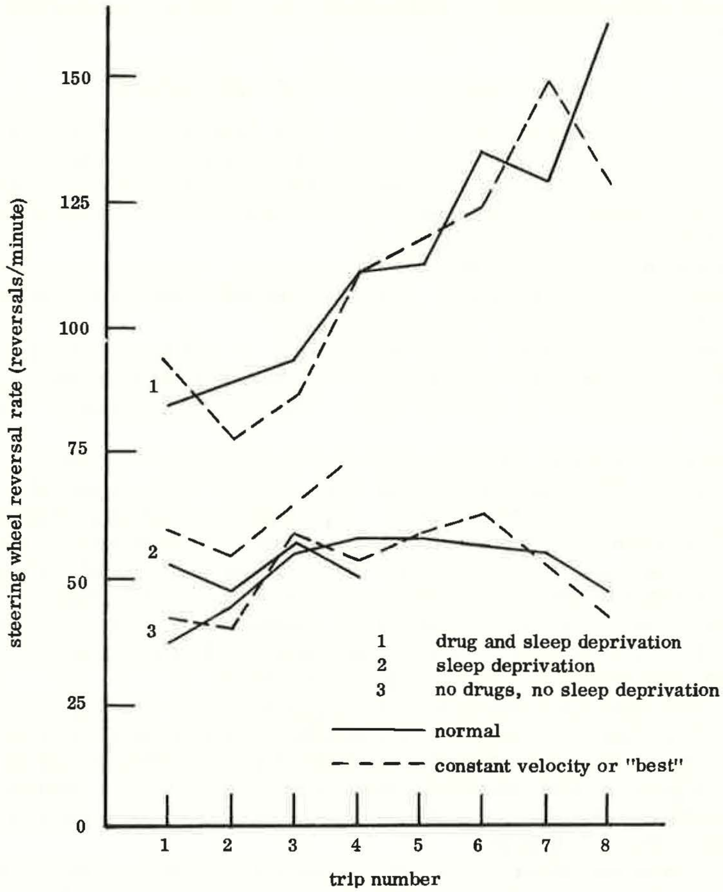

Figure 6. Effect of drug and sleep deprivation on subject driver.

The results of the spark plug miss detection test failed to show any difference with the passage of time. In almost all cases the subjects were able to detect the malfunction. A difference was shown to exist at the 0.10 level of significance for the performance of subject 7 with and without drugs. The drugs noticeably improved his performance on the task.

The forms which the subjects filled out to rate their performance and their state of wakefulness indicated that they felt they were becoming more tired as the experiment progressed. Most subjects continually rated their performance unaffected until the very end of the experiment. This is possibly due to the fact that they might have thought that they would be forced to quit if they gave themselves bad ratings.

The results obtained from the physiological data collected during the experiment were of interest primarily because virtually no change was noticed in any of the measures with the passage of time in the experimental task.

Effects of Drugs on Steering Wheel Reversals

The most marked effect of the drugs was on the number of steering wheel reversals exhibited by the subject who was tested with and without drugs. Figure 6 shows the steering wheel reversal rate of subject 7 under all three experimental conditions. As can be seen from this graph, the use of drugs resulted in a much larger steering wheel reversal rate than was exhibited in either of the other two cases. In this case the steering wheel reversal rate was more than double that previously exhibited.

The upward trends exhibited by the graphs of steering wheel reversal rate under the use of drugs are both significant, when tested via a T-Test for trend at the 0.01 level of significance.

DISCUSSION AND INTERPRETATION

One of the most interesting facts to come from this research is that the subject drivers were able to drive as long and as satisfactorily as they did. This is even more surprising when we consider the fact that the subjects engaged in no conversation, received little stimulation from the highway environment, and had virtually no rest except at the brief stops at gasoline stations.

Of the 7 subjects who participated in the research, only 2 were unable to finish the prescribed task of driving 24 hours. These 2 subjects managed to drive for about 21 hours each before they asked or were told to stop.

The fact that most subjects did not break down or fall asleep during the experimental task does not enable the subjects' data to be scrutinized for a pattern in the performance measures, which might be used to foretell a complete breakdown or cessation of performance.

The regression analyses performed on 4 major dependent variables, velocity means, velocity variances, steering wheel reversals, and gas pedal reversals, indicate the degree to which such trends are present. The high correlations obtained for some measures of the dependent variables, with the passage of time for several of the subjects, indicate that such trends do exist. The lack of universality of trends and the fact that the trends for the same variable can be in either direction means that an increase or decrease in the value of one of the dependent variables cannot be taken as an indication of the onset of fatigue, without knowing the specific characteristics of the subject driver that produced the increase or decrease.

The intra-trip effect mentioned earlier suggests that a rest period of a few minutes duration, such as that experienced at the southern turn-around, is nearly as beneficial as the longer gas station rest period experienced at the northern end of the highway. These findings suggest that the policy adopted by some Highway Patrols in the western states of stopping motorists and making them walk around their cars is of some value in reducing the effect of fatigue.

The most prominent effect of the administration of drugs to subject 7 on his third replication, was that he was able to drive twice as long as he had been able to without drugs. In both the drug test and the test previous to the drug test, the subject had been kept awake for 24 hours prior to starting the experiment. On the day the subject took drugs, he claimed that he felt much better than he had on the day when he was not given the drugs. Of interest, also, is the positive effect of drugs on the subject's steering wheel reversals with the passage of time. It is also interesting to note that this subject responded faster to the simulated engine malfunction detection signals when under the influence of drugs than he did under either previous run. This supports the conclusion of researchers who report that drugs maintain high levels of performance in vigilance tasks over extended periods. During the experimentation other phenomena were observed. For example, it was obvious to the experimenters that after several hours of driving, one of the subjects began to exhibit some paranoid-like symptoms.

This subject, as well as other subjects, exhibited a tendency to rely on the edge-stripe on the highway for lateral placement, although on very few occasions did they hit the shoulder. This became obvious when the car passed an exit ramp where the line disappeared and the driver tended to swerve to the right. The tendency appeared to increase with the passage of time, which possibly indicates that the subjects were concentrating on a few visual cues (tunnel vision). This is supported by previous studies (1).

This tunnel vision effect might explain the increase in velocity variance with the passage of time that many subjects exhibited (i.e., tunnel vision resulted in the speedometer being sampled less frequently, and therefore, speed control diminished).

It is possible that the specification of 24 hours of driving served as a goal to the driver. If in future experimentation the length of time that the driver was expected to drive was not specified prior to the start of the experimentation, fatigue effects might be realized earlier in the experiment.

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The Effect of Ramp Type and Geometry On Accidents

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This study was made to learn more about freeway ramps, to determine which geometric features play important roles in ramp safety, and to classify these features according to ramp type and relative safety merits.

The study involved 722 freeway ramps. In a period of about 3 years, over 2 billion vehicles used these ramps, and during this time 1643 accidents occurred.

The accident rates of on-ramps were consistently lower than off-ramp accident rates. (Accident rate = number of ramp accidents per million vehicles using the ramp.) The average on-ramp rate is 0.59 Acc/MV (accidents per million vehicles), whereas the average off-ramp rate is 0.95 Acc/MV. The on-ramp rates vary from about 0.40 Acc/MV to about 0.93 Acc/MV depending on the type of ramp. The off-ramp rates vary from about 0.62 Acc/MV to about 2.19 Acc/MV.

Ramps were classified as to type (diamond, trumpet, cloverleaf, etc). Accident rates were determined for each ramp type and further subdivided by on- or off-ramp, and by the relative freeway-to-ramp grades.

Correlations were found between accident rates and ramp type, relative freeway-to-ramp grades, fixed objects, speed-change lane lengths, possible safe entrance speeds at on-ramp noses, and off-ramp radius.

No correlation was found to exist, or the study was unable to determine if a correlation existed, between ramp accident rates and on-ramp curvature, ramp lighting, ramp traffic volumes, and the magnitude of the ramp central angle.

•PRESENT-DAY geometric standards of ramps were developed through a long process of evolution involving experience in both design and operation. This study was initiated as a continuing effort to increase our knowledge of ramp operations and to better understand the effect of the design on ramp safety.

The 722 ramps involved are primarily located on the same freeways used in the "Comparative Freeway Study" (1). Figure 1 shows the general location of the ramps. The descriptions of the locations and the study periods used are listed in the Appendix.

The Appendix is divided into two parts, A and B. For group A ramps, the specific ramp geometry was not readily ascertainable. However, it was known whether the accidents occurred on the ramp proper or its speed change lane section. For group B ramps, the geometric details were determined, but it could not be readily determined (without reading several hundred reports) whether the accident occurred on the ramp proper or on its speed change lane.

The study period was from 1958 through 1962, with 3 years of experience available for most locations. Approximately 2 billion vehicles used these ramps, and 1643 accidents occurred during the study period.

Paper sponsored by Committee on Highway Safety and presented at the 45th Annual Meeting.

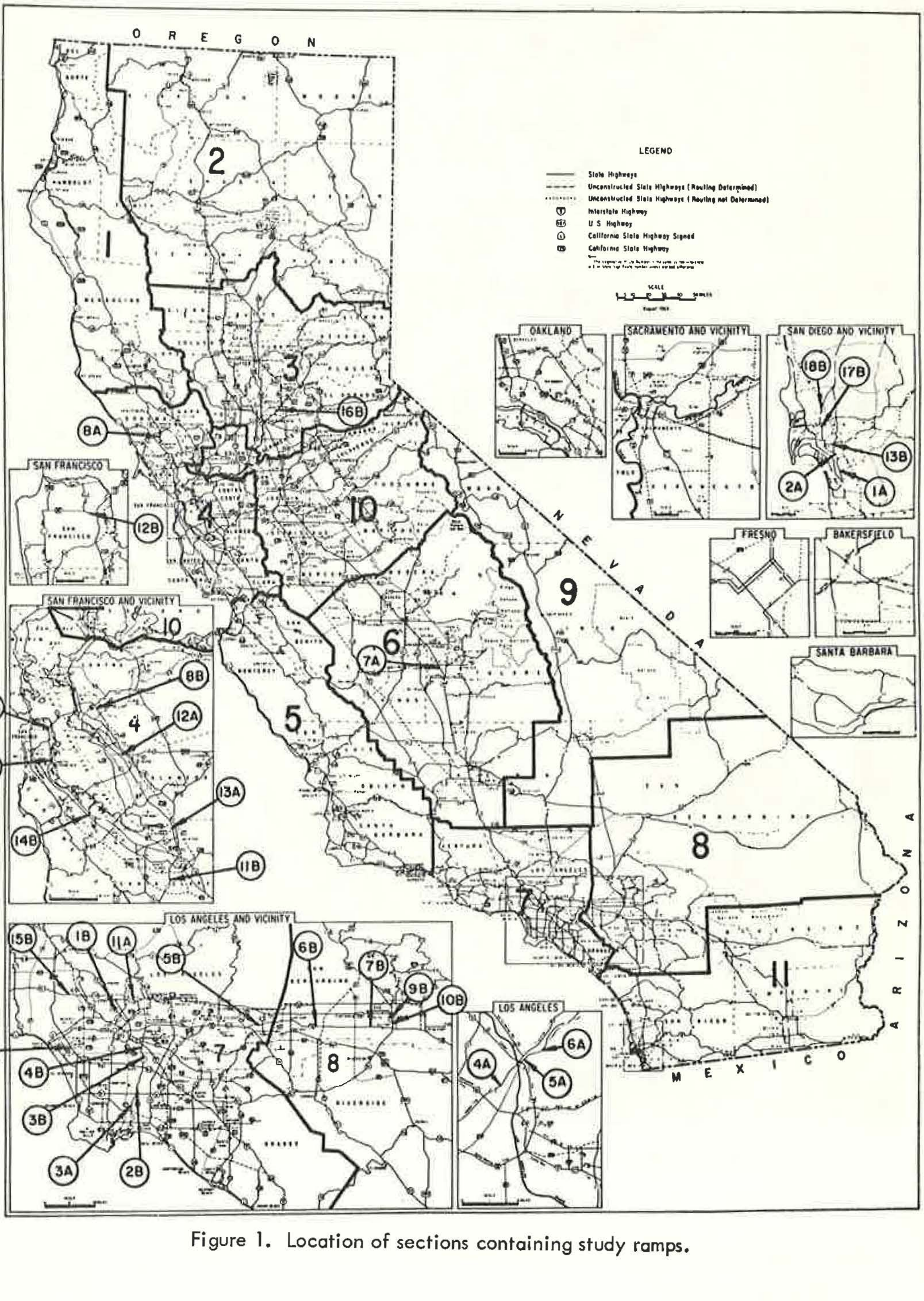


Figure 1. Location of sections containing study ramps.

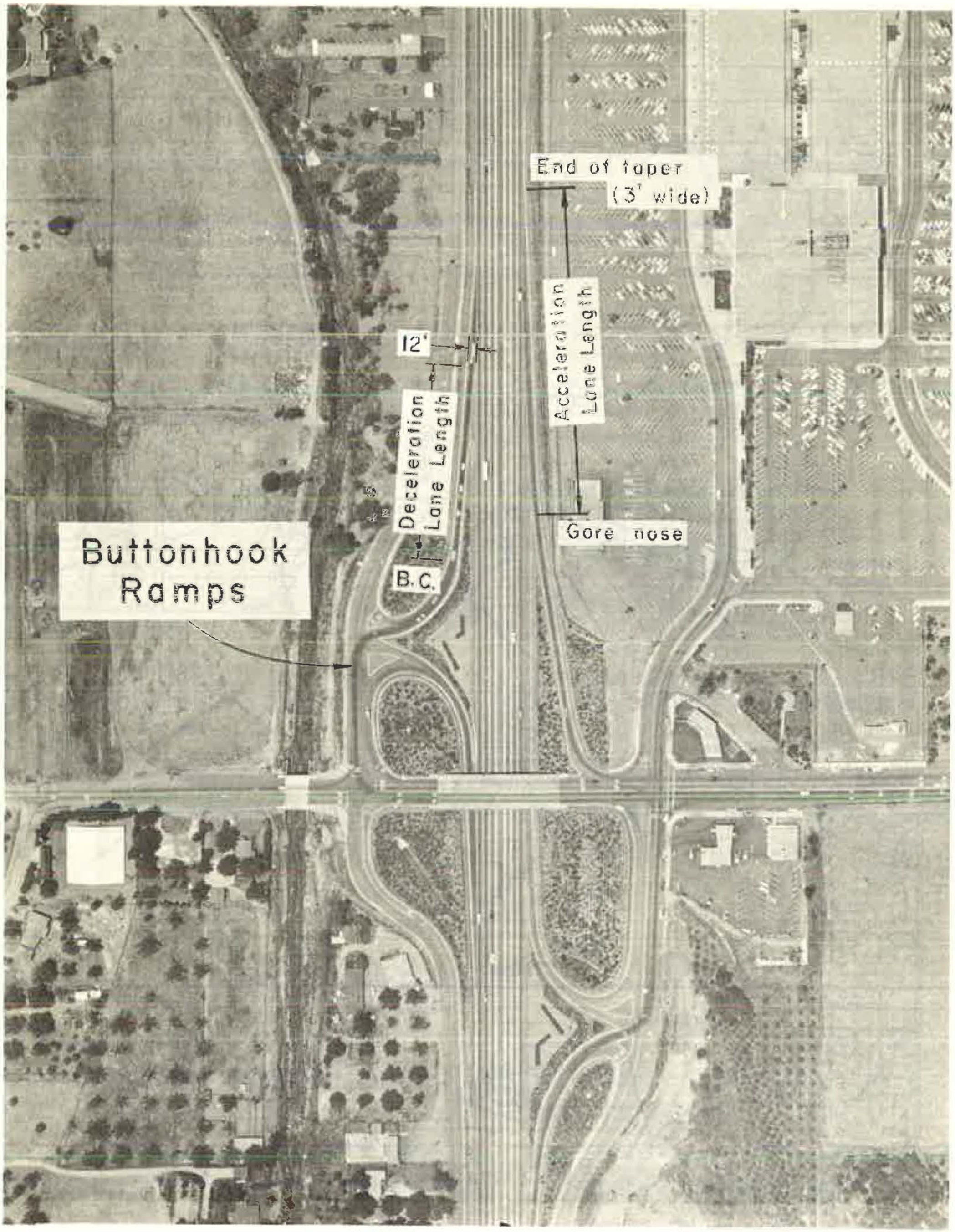


Figure 2. Example of modified diamond ramp and typical buttonhook ramp.

STUDY METHODS

The ramps were grouped into 10 basic types:

1. Diamond ramps,
2. Trumpet ramps,
3. Cloverleaf ramps without collector-distributor roads,

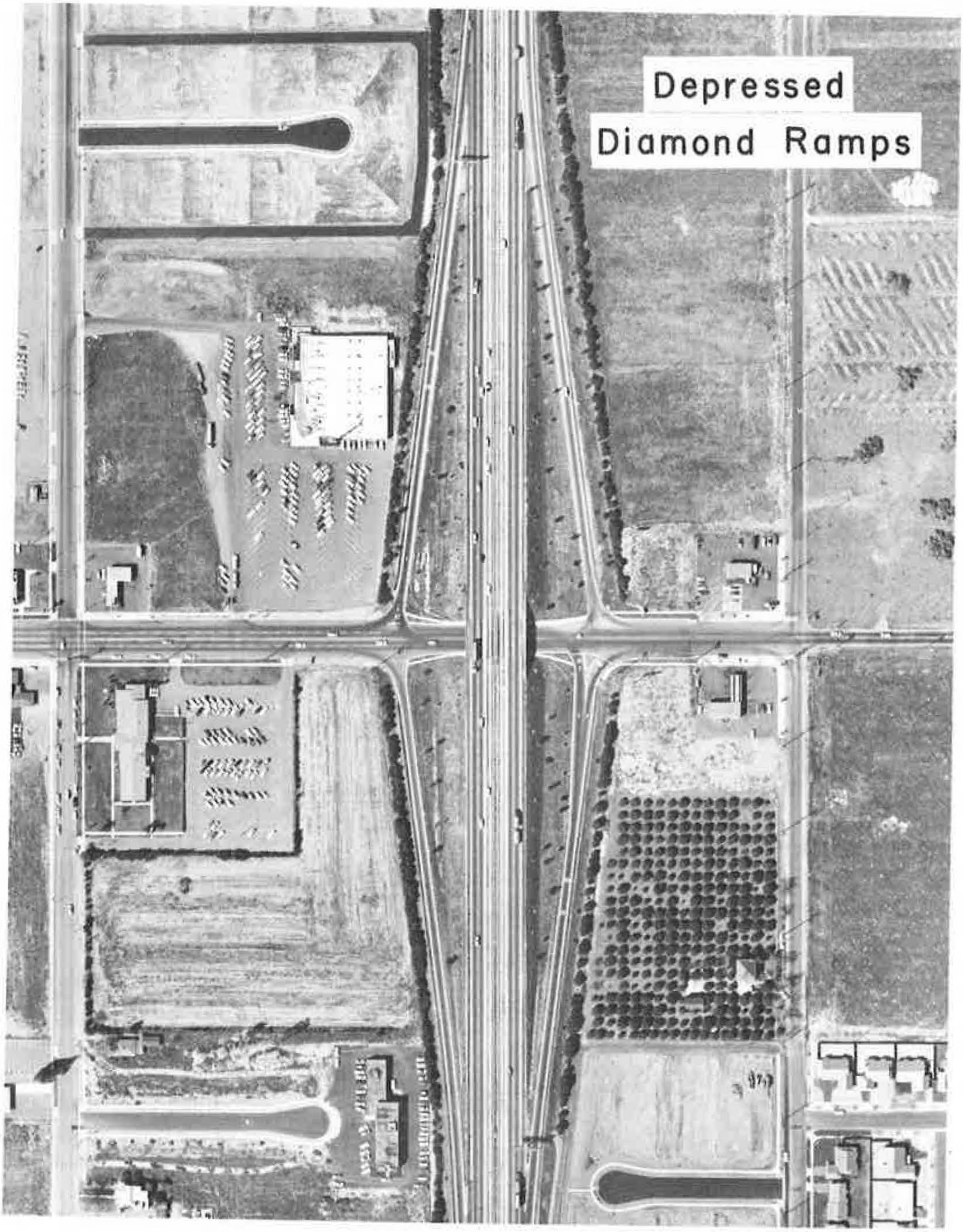


Figure 3. Depressed diamond ramp connecting to cross street.

4. Cloverleaf ramps with collector-distributor roads,
5. Loops without collector-distributor roads,
6. Cloverleaf loops with collector-distributor roads,
7. Left side ramps,
8. Direct connections,
9. Buttonhook ramps, and
10. Scissors ramps.

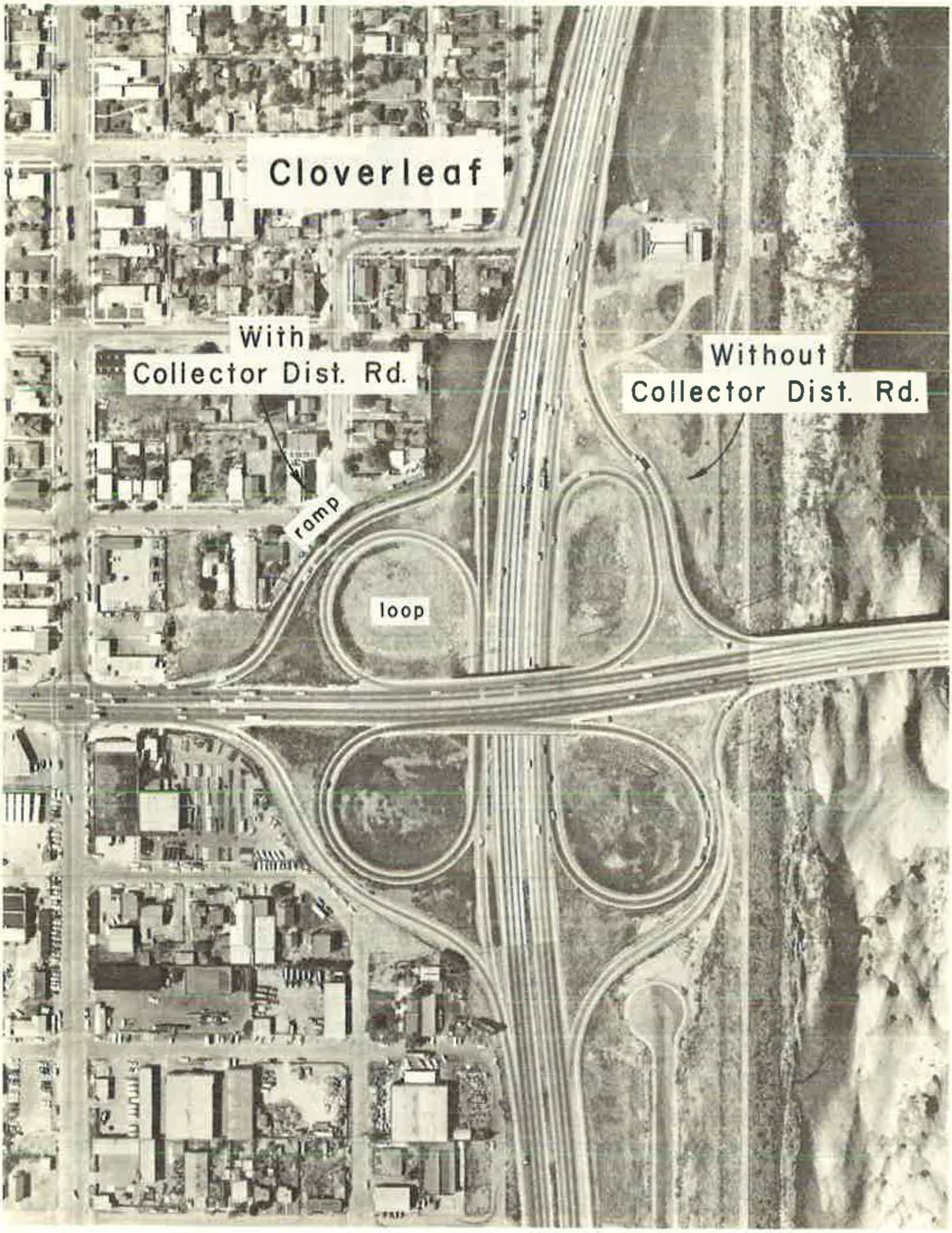


Figure 4. Cloverleaf ramps and loops with and without collector-distributor roads.

A right-turning ramp with over 180 deg of curvature and which connects crossing roadways is called a loop. Loop ramps are normally associated with cloverleaf and trumpet type interchanges; this distinction has been made in the above classifications. All loops that connected to collector-distributor roads were the cloverleaf type. No. 5 loops without collector-distributor roads are made up of both cloverleaf and trumpet loops.

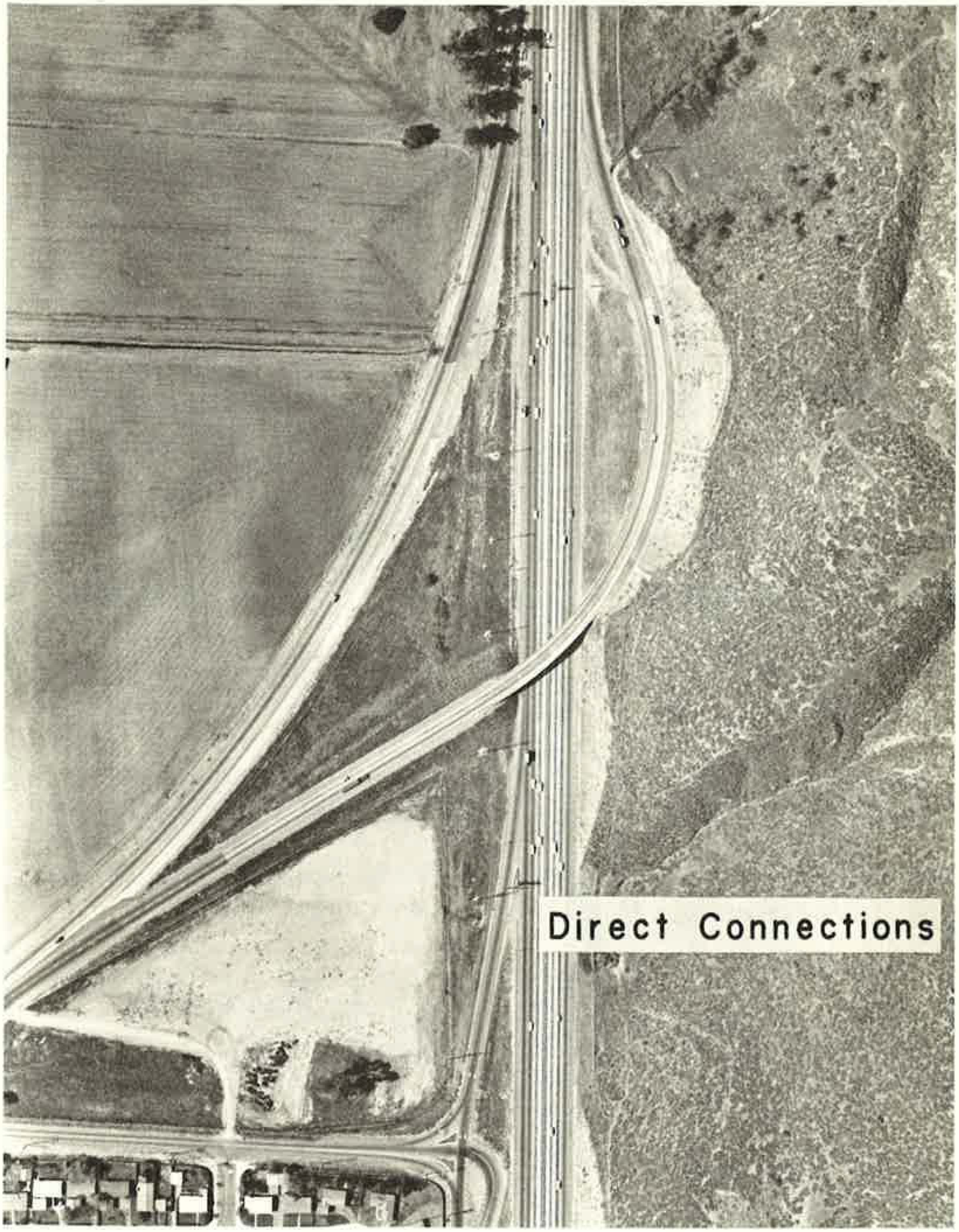


Figure 5. Example of direct connection designed for high-speed maneuvers.

The ramps are not necessarily classified by interchange types because some interchanges are mixtures of 2 or more ramp types. For example, Figure 2 shows a modified diamond ramp on the right side and 2 pairs of typical buttonhook ramps on the lower right and upper left sides. The diamond ramp is basically straight and always connects to the cross street as shown in Figure 3. The buttonhook ramps usually are not associated with a crossing structure or are at a considerable distance from the

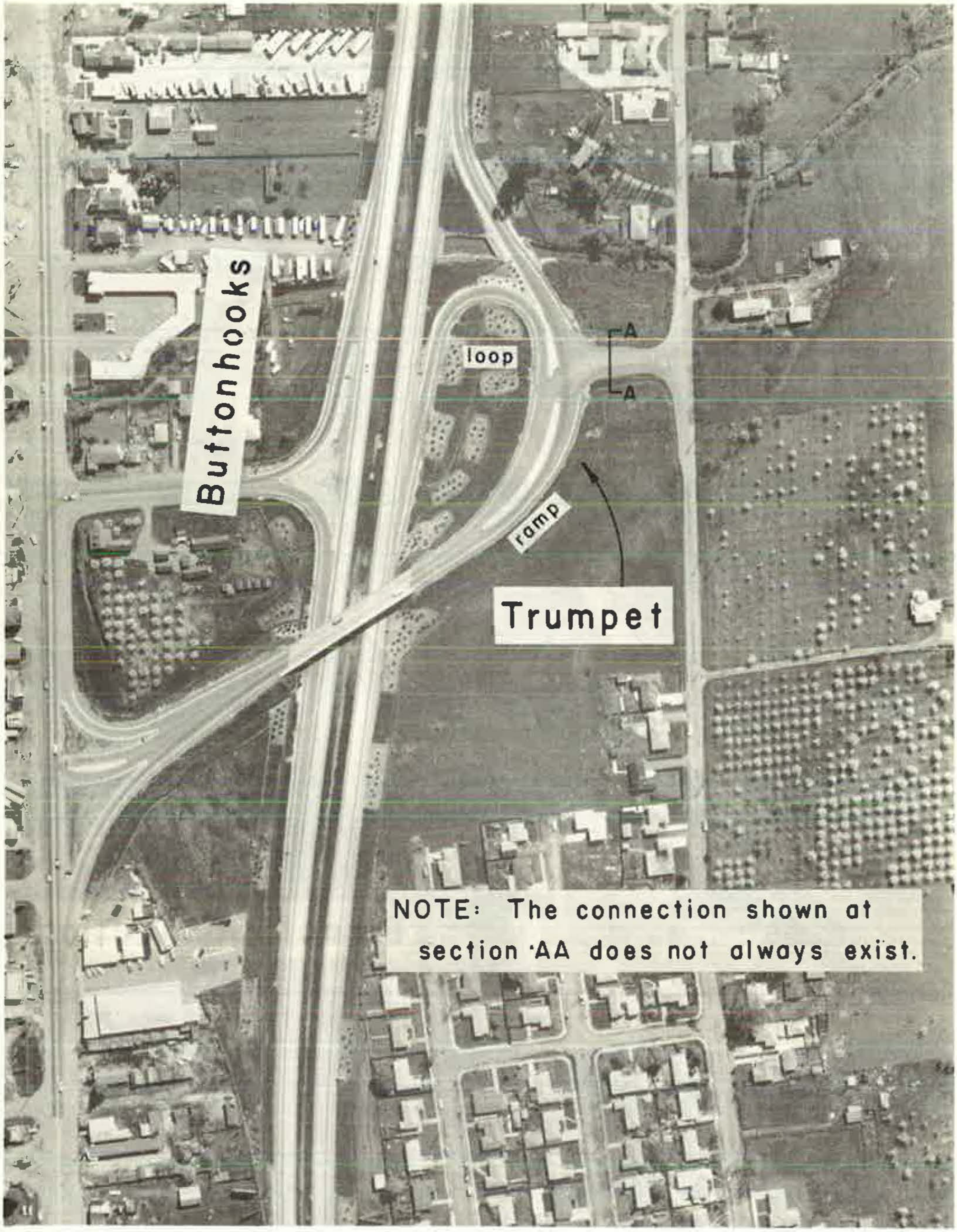


Figure 6. Direct connection to trumpet loop.

structure. In many cases, there is no structure at all and the ramps simply serve as access to or from the adjacent land on one side of the freeway only.

The cloverleaf ramps and loops are illustrated in Figure 4. The left half of the interchange employs a collector-distributor road and the loops connect to the collector-distributor road. The right side of the interchange does not employ the collector-

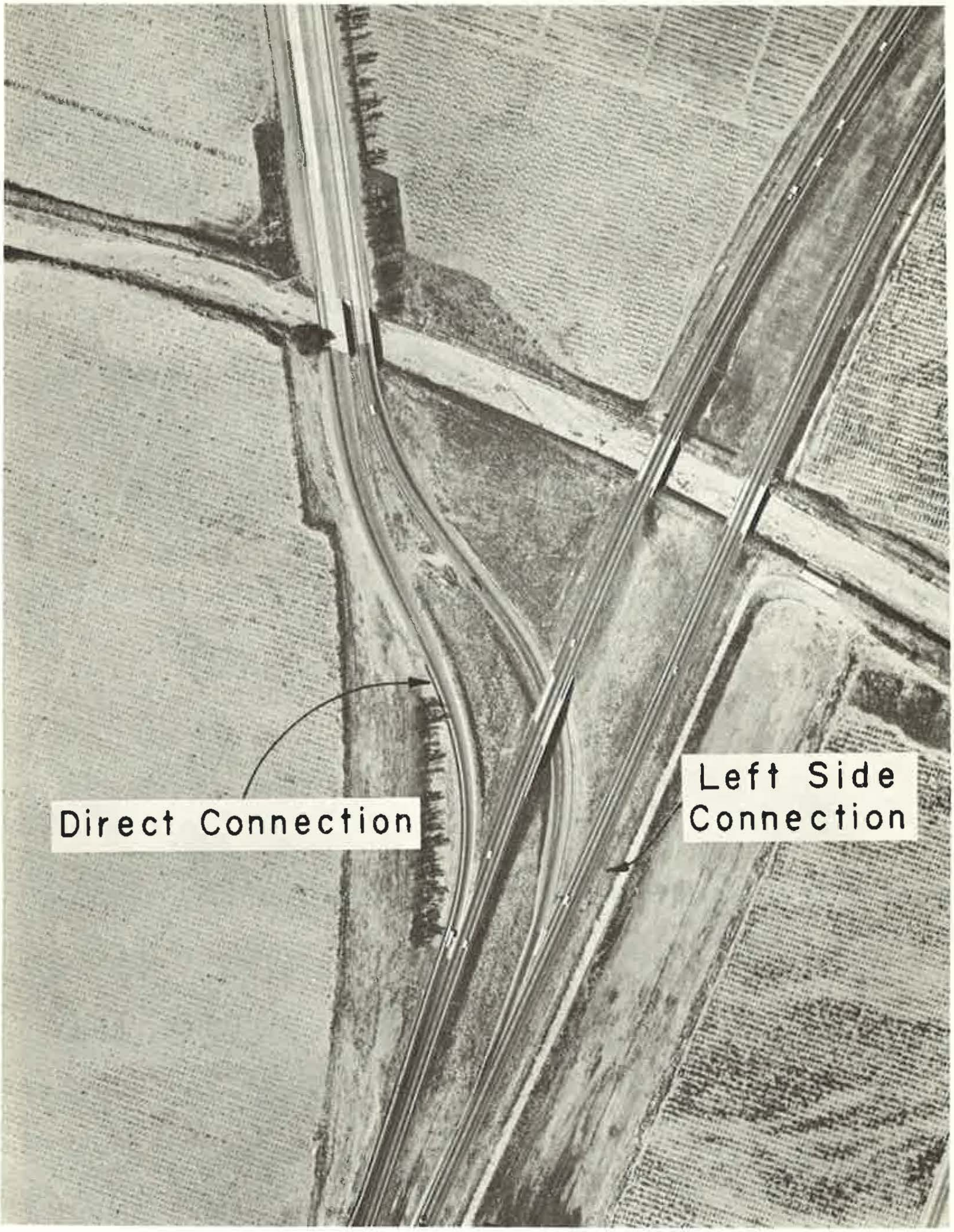


Figure 7. Example of left side connection.

distributor road, and the loops connect directly to the freeway. The loops are not necessarily circular, and the cloverleaf ramps do not always reverse curvature to bypass the loop.

Direct connections (Fig. 5) are usually designed for high-speed maneuvers. If an off-ramp loop were employed such that two-way traffic would result on the overcrossing,

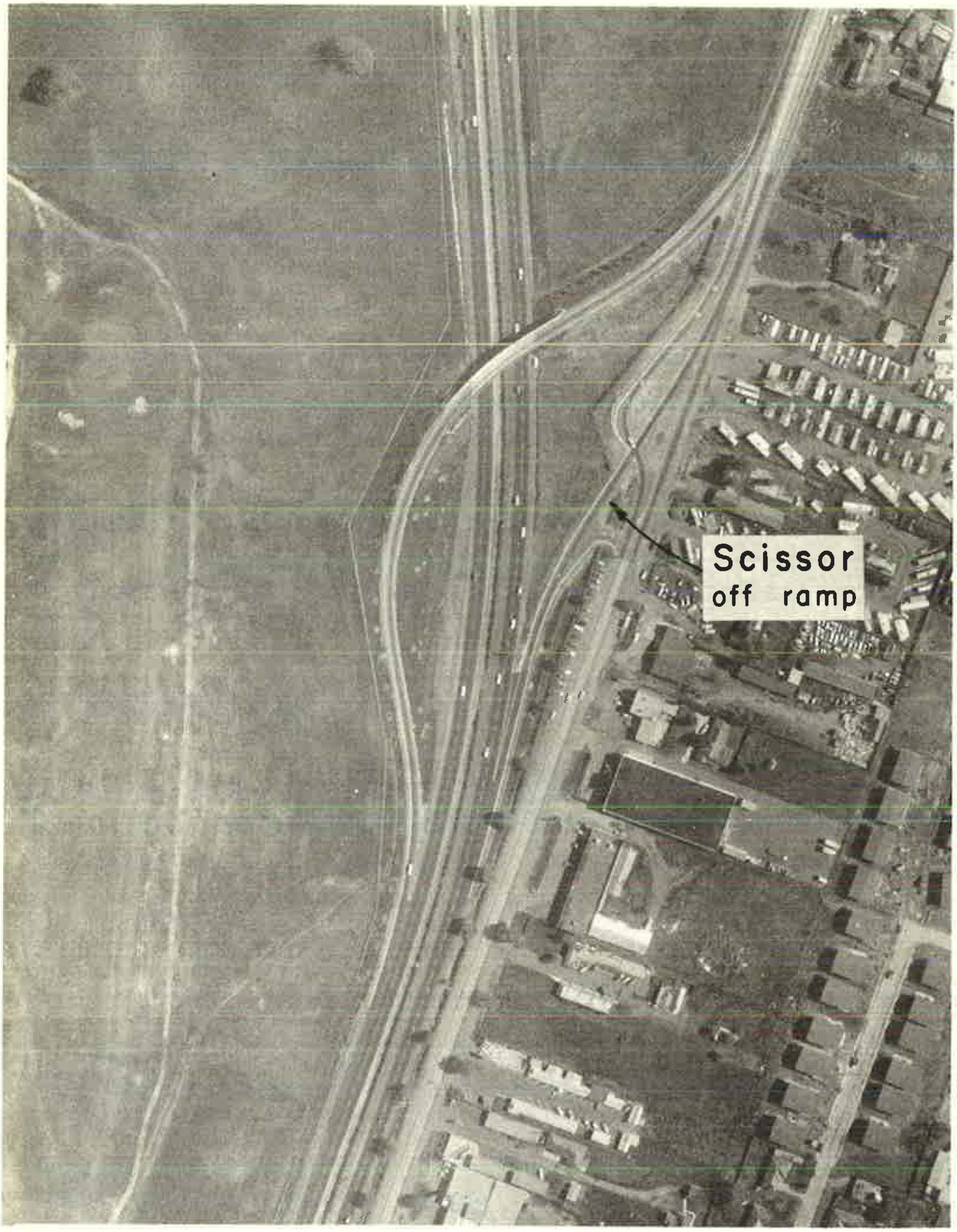


Figure 8. Example of scissor ramp.

the arrangement would become a trumpet ramp and a trumpet loop (Fig. 6). The ramp on the far left would remain a direct connection.

Any ramp that connects to the inside (high-speed) lane of the freeway is called a left side connection (Fig. 7). A scissor ramp (Fig. 8) is one that has opposing traffic crossing the ramp traffic. The ramp traffic has the right of way and a stop sign is placed to stop the crossing vehicle.

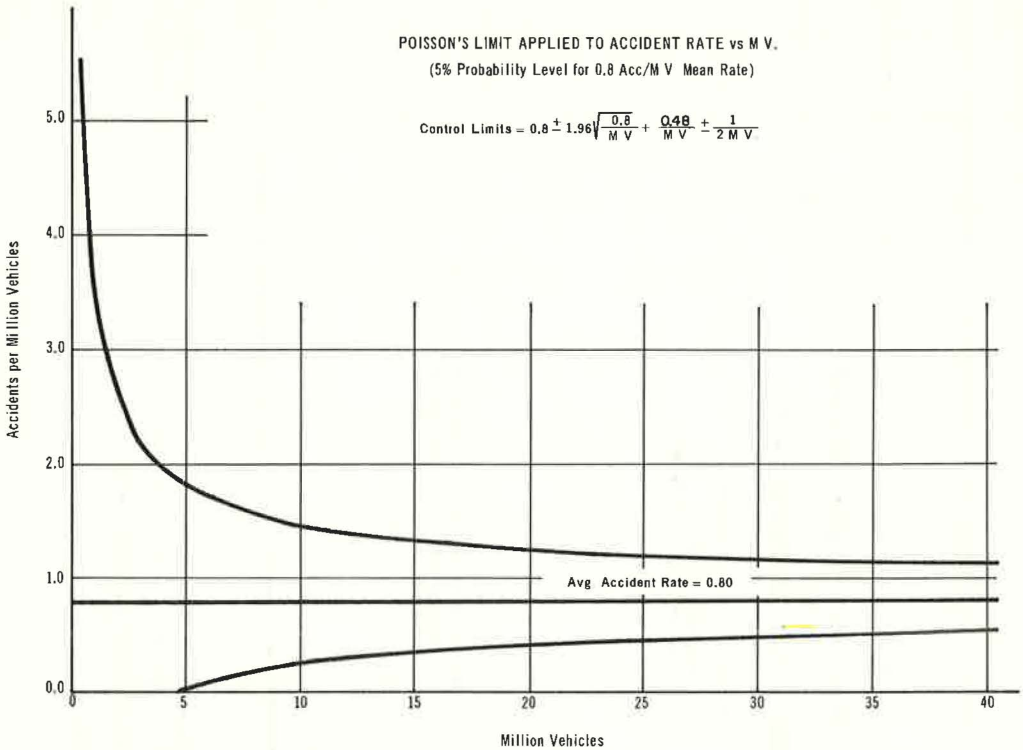


Figure 9.

Million vehicle miles of experience is normally used as the denominator in the calculation of accident rates. In this study, the ramp accident rates have been calculated on the million ramp vehicle basis. The assumption is that the ramp experience is essentially related to the number of vehicles entering or leaving without regard to the distance traveled.

The accuracy of the accident rate, Acc/MV (number of accidents per million vehicles using the ramps), depends on the accuracy of the accident counting, and on the accuracy of the estimated amount of exposure, MV. Extreme care was taken in determining these values to assure a reasonable degree of accuracy.

The accident rate depends on the chance occurrence of accidents. The present accepted method of reducing the effect of chance occurrence is to use a large volume of experience, thus overshadowing the factor of chance. This study does contain a fairly large amount of experience (2 billion ramp vehicles), but unfortunately this experience is in many instances spread thin due to the sorting of ramps by geometric features and types, etc. The question then becomes: what amount of experience is necessary to obtain a reasonably reliable accident rate?

The Poisson distribution was used for estimating the probability of chance occurrence and the relative stability of the calculated rates. Figure 9 is a plot of this distribution using a 95 percent confidence level. The accident rate is plotted as the ordinate and the amount of experience (measured by number of vehicles) is the abscissa. The distribution was plotted for a mean accident rate of 0.80 accidents per MV. This rate was used since it closely represents the average rate for ramps based on our experience of 2 billion vehicles.

To understand the significance of this graph, let us assume that in a large number of ramps, each has an exposure of 5 MV. Let us further assume that the mean accident rate of the group is 0.80 Acc/MV. If the accident rate for each individual ramp

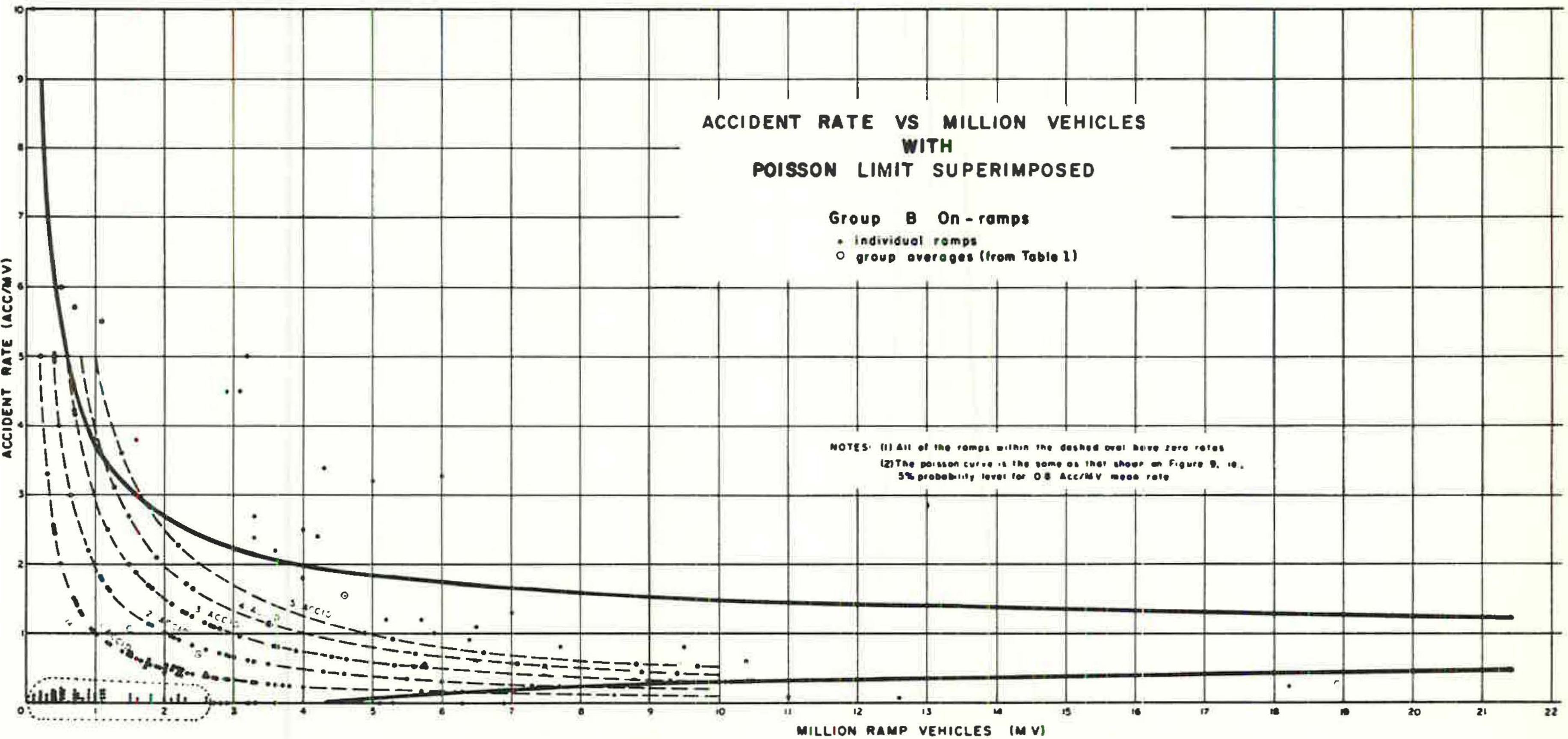

ACCIDENT RATE VS MILLION VEHICLES
WITH
POISSON LIMIT SUPERIMPOSED
Group B On-ramps
• individual ramps
○ group averages (from Table 1)
NOTES: (1) All of the ramps within the dashed oval have zero rates
(2) The poisson curve is the same as that shown on Figure 9, 10,
5% probability level for 0.8 Acc/MV mean rate
ACCIDENT RATE (ACC/MV)
MILLION RAMP VEHICLES (M V)

Figure 10.

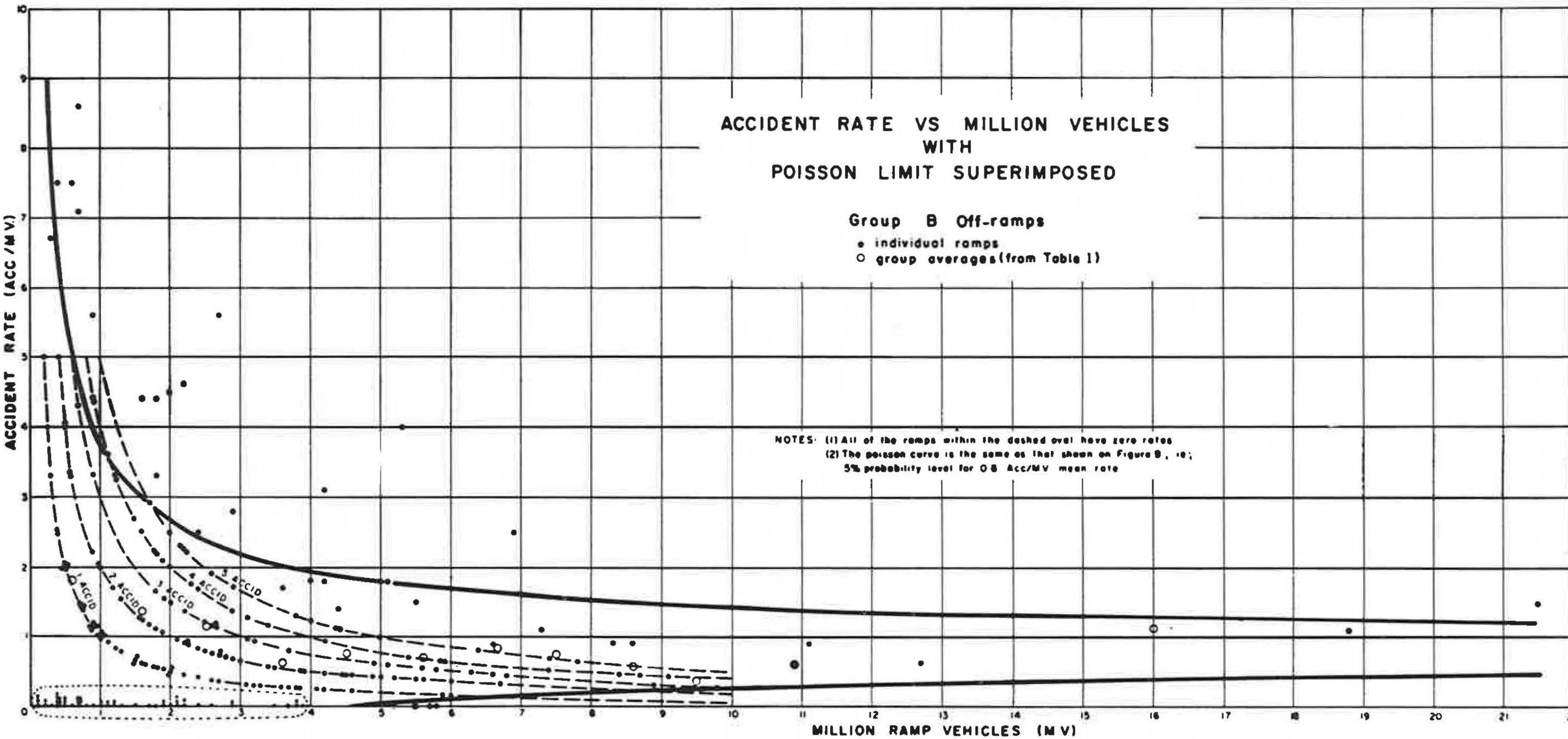

ACCIDENT RATE VS MILLION VEHICLES WITH POISSON LIMIT SUPERIMPOSED
Group B Off-ramps
• individual ramps
○ group averages (from Table 1)
NOTES: (1) All of the ramps within the dashed oval have zero rates
(2) The poisson curve is the same as that shown on Figure 9, 10;
5% probability level for 0.8 Acc/MV mean rate
1 ACCID
2 ACCID
3 ACCID
4 ACCID
5 ACCID
ACCIDENT RATE (ACC/MV)
MILLION RAMP VEHICLES (MV)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

Figure 11.

TABLE 1

RAMP ACCIDENT RATES FOR 1 MV INCREMENTS OF EXPERIENCE—GROUP B RAMPS

M.V. Groups	Ramps		Accidents		M.V		Avg. M.V.		Avg. Rate	
	On	Off	On	Off	On	Off	On	Off	On	Off
0 to 1 M V	66	65	39	74	36.4	39.9	0.6	0.6	1.07	1.85
Over 1 to 2 M V.	50	45	60	104	77.5	73.7	1.57	1.6	0.77	1.41
Over 2 to 3 M.V	45	40	63	124	111.4	99.6	2.5	2.5	0.57	1.24
Over 3 to 4 M V.	23	23	71	53	81.3	83.5	3.5	3.6	0.87	0.63
Over 4 to 5 M V	7	14	46	38	32.2	63.0	4.6	4.5	1.43	0.60
Over 5 to 6 M V	15	19	45	74	83.7	105.9	5.6	5.6	0.54	0.70
Over 6 to 7 M V	8	7	29	39	52.2	46.3	6.5	6.6	0.56	0.84
Over 7 to 8 M V	5	4	18	22	37.3	29.9	7.5	7.5	0.48	0.74
Over 8 to 9 M V	3	5	10	25	26.3	42.9	8.8	8.6	0.38	0.58
Over 9 to 10 M V	4	2	20	7	38.0	18.9	9.5	9.5	0.53	0.37
Over 10 to 11 M V	3	1	10	6	31.5	10.9	10.5	10.9	0.32	0.55
Over 11	3	4	14	71	56.8	64.1	18.9	16.0	0.25	1.11
TOTALS	232	229	425	637	664.6	678.6	2.8	2.9	0.64	0.94

is then plotted on the vertical line representing 5 MV on the graph, 95 percent of these points would be expected to fall within the confidence limits of 0.06 and 1.83 Acc/MV. In other words, the accident rates of 95 percent of the ramps each having an exposure of 5 MV would be expected to fall between these limits.

On the other hand, if the experience is 35 MV per ramp, the expected fluctuation is not as great (0.52 to 1.14). In essence, the element of chance is overshadowed as more experience is gained; the graph serves to indicate the expected accuracy of accident rates based on various amounts of experience.

In this report, the tables showing accident rates also show the amount of experience on which the rates are based. If the rate is obviously unstable (under 10 MV), it was either omitted or some statement concerning the confidence level is made. It is felt that the various rates given in this report are significant.

NON-GEOMETRIC FACTORS

The ramps in this study accounted for approximately 18 percent of the accidents on the freeways which they serve. In 1963, ramp accidents on all the freeways in California accounted for 14.4 percent of the freeway accidents.

Out of 722 ramps studied, 232 (32 percent) were accident free. However, these accident-free ramps carried only 327 MV or 16 percent of the total ramp experience. No particular design differences were noted between ramps that had no accidents and ramps that did. However, a large percentage of accident-free ramps might be expected because the average experience per ramp was only 2.9 MV for the 722 ramps studied and only 1.4 MV for the 232 accident-free ramps.

Figures 10 and 11 are plots of the accident rate vs exposure in million ramp vehicles for all of the group B ramps. The Poisson distribution has been superimposed to show that a large percentage of zero rates can be expected in the low exposure range. The large circles represent the group average accident rate for the various million vehicle (MV) groups shown in Table 1.

Accident Severity

A breakdown in ramp accidents by severity (Table 2) shows no significant difference in percentage occurrence between the ramp and the main line accidents, or between

TABLE 2

RAMP ACCIDENTS BY SEVERITY

Category	Percent of Total Accidents		
	On-Ramps	Off-Ramps	Freeway Avg.
Fatal accidents	1.5	1.5	1.8
Injury accidents	42.5	41.5	42.9
Property-damage only accidents	56.0	57.0	55.3
Total	100.0	100.0	100.0
Number of injuries per accident	0.58	0.58	0.74

TABLE 3

SINGLE AND MULTIPLE VEHICLE ACCIDENTS

Type	Total Accidents (percent)			Accident Rates (Acc/MV)	
	On-Ramps	Off-Ramps	Freeway Avg.[a]	On-Ramps	Off-Ramps
Single vehicle	31	51	28	0.18	0.48
Two vehicle	57	43	53	0.34	0.41
Three or more vehicle	12	6	19	0.07	0.06
Total	100	100	100	0.59	0.95

[a]Taken from Table 10, p. 168, Ref. (1).

on-ramps and off-ramps. The ramp accidents do, however, seem to have fewer injuries per accident. This is probably due, in part, to the lower ramp speeds.

Ramps, especially off-ramps, have a large number of fixed objects adjacent to them (Figs. 12, 13 and 14). Because of this, one would expect the ramps to have a higher proportion of injury accidents than the main line sections of the freeways. This is not the case, however, probably because of the lower speeds associated with ramps.

Single and Multiple Vehicle Accidents

A breakdown by single and multiple vehicle accidents (Table 3) revealed that, in general, there is a higher percentage of single vehicle accidents on ramps than the normal freeway average. This increased percentage in the single vehicle category is primarily offset by a decrease in 3-or-more vehicle accidents. A closer look reveals that about the same breakdown exists at on-ramps as the freeway average, but there is a considerably higher percentage of single vehicle accidents at off-ramps.

If the ramp rates from Table 10 are split according to the given percentages, the rate for single, 2 vehicle, and 3-or-more vehicle accidents can be obtained. This breakdown is also shown in Table 3 and it reveals a very low rate for single vehicle, on-ramp accidents. The on-ramps also show a higher multiple vehicle rate, but the primary difference in the total on- vs off-ramp rates (on = 0.59; off = 0.95) is due to single vehicle off-ramp accidents. In other words, if the off-ramps had the same vehicle rate as the on-ramps, the total rate would be 0.18 + 0.41 + 0.06 = 0.65 Acc/MV as compared to the 0.59 Acc/MV on-ramp rates.

Assuming that the single vehicle accident is most likely to occur on the ramp proper (as opposed to the diverging area), it might be concluded that the off-ramp geometry is

TABLE 4

RAMP FIXED OBJECTS AS PERCENTAGE OF TOTAL FREEWAY FIXED OBJECTS[a]

Type	On-Ramps	Off-Ramps	On + Off
Guardrail[b]	13.7	15.5	29.2
Light standards	10.3	12.9	23.2
Signs[c]	1.8	6.1	7.9
Piers, abutments, and bridge rails	1.9	1.3	3.2
Total, ramp	27.7	35.8	63.5
Freeway fixed objects			36.5
Total			100.0

[a]From Table 6, p. 166, Ref. (1).
[b]Guardrail was counted in 50-ft lengths as one fixed object.
[c]Includes wood or steel posts, with or without guardrail.

TABLE 5

RAMP FIXED OBJECTS AS A PERCENT OF TOTAL RAMP FIXED OBJECTS

Type	On-Ramps	Off-Ramps	On + Off
Guardrail[a]	49.5	43.2	45.9
Light standards	37.2	36.0	36.5
Signs[b]	6.6	17.0	12.5
Piers, abutments, and bridge rails	6.7	3.8	5.1
Totals	100.0	100.0	100.0

[a]Guardrail was counted in 50-ft lengths as one fixed object.
[b]Includes wood or steel posts, with or without guardrail.

TABLE 6

FIXED OBJECT ACCIDENTS VS TOTAL FIXED OBJECTS

Type	a Fixed Object Accidents (%)	b Total Fixed Objects (%)	$\frac{a}{b}$
	On-Ramps		
Guardrails	49.3	49.5	1.00
Light standards	16.4	37.2	0.44
Signs	32.8	6.6	4.97
Piers, abutments, and bridge rails	1.5	6.7	0.22
Totals	100.0	100.0	
	Off-Ramps		
Guardrails	43.3	43.2	1.00
Light standards	10.4	36.0	0.29
Signs	38.8	17.0	2.28
Piers, abutments, and bridge rails	7.5	3.8	1.97
Totals	100.0	100.0	

difficult to maneuver. In other words, to maneuver through curves, etc., while the vehicle is decelerating requires more precise judgment than the same maneuver would involve if the vehicle were accelerating. This is also indicated by the fact that 22 percent of the off-ramp accidents involved a driver who had been drinking, whereas only 15 percent of the on-ramp accidents involved drinking drivers, indicating that the "had been drinking" driver can negotiate the on-ramp easier than the off-ramp.

An investigation concerning straight ramps and curved ramps is presented later in this report under sections entitled "Ramp Curvature" and "Off-Ramp Geometry."

Fixed Objects

Some 28 percent of all freeway (including ramps) accidents involve fixed objects. Fixed objects are involved in about 22 percent of all on-ramp accidents and about 42 percent of all off-ramp accidents. About 64 percent of all freeway fixed objects are located in the ramp areas. Off-ramp areas contain about 36 percent of the total freeway fixed objects and the on-ramp areas contain about 28 percent (Table 4).

Table 4 shows the percentage of the 4 most prevalent types of objects as compared to the total of other types on freeways. Table 5 was made by assuming that these 4 types of fixed objects represented 100 percent of the total ramp fixed objects. The percentage values in Table 4 were then adjusted so that the totals would equal 100 percent.

Accidents involving fixed objects were tabulated for both on- and off-ramps. Table 6 is a comparison between fixed object accidents and the total fixed objects in place.

The comparisons in Table 6 are based on relatively small samples of exposure. Therefore, the figures are at best approximate. The percentages could change considerably depending on what length of guardrail is chosen as one fixed object. The 50-ft guardrail length was selected to give a value of 1.00 for guardrail in the a/b column. Regardless of the chosen guardrail length, the signs appear, in both the on- and off-ramp situations, to be the most vulnerable type of fixed object (a/b = 4.97 and 2.28). Signs are normally placed on the outside edge of curves and in the ramp gore nose. Out-of-control vehicles normally leave the roadway on the outside edge of the curve rather than on the inside edge; and, in the case of off-ramps, the gore is extremely vulnerable to drivers who misjudge the ramp exit.

Piers, abutments and bridge rails are more vulnerable in the off-ramp situation than in the on-ramp situation. This is not surprising since, in a normal interchange situation, the off-ramp vehicles will have a structure dead ahead more often than the on-ramp vehicles. It also seems that the decelerating vehicle is harder to keep in control than the accelerating vehicle.

Examples of situations involving fixed objects are shown in Figures 12 through 20. Figure 12 also shows a location where the alignment and pavement texture give the appearance that the ramp is the main line. Guardrail is frequently used as delineation (Fig. 13). It would seem that something less rigid (and not as expensive) could be substituted if delineation is the prime objective. Curbs are also used for delineation as well as for drainage purposes. A curb can act as a fulcrum when struck by a vehicle skidding broadside and cause the vehicle to overturn.

Ramp Lighting

Light standards represent about 36 percent of the ramp fixed objects, and they are involved in about 10 to 16 percent of the ramp fixed object accidents. The elimination of the standards would no doubt reduce the total fixed object accidents, but the absence of the illumination which the standards support might well cause an increase in total accidents.

Table 7 shows the percentage of all types of accidents which occurred under various light conditions. A large percentage of the total freeway accidents are "dark—no street lights." This is because only the interchanges have lighting. For the ramps, a low percentage is in this category because very few ramps are without lighting. A rough comparison between the ramps and the total freeway shows the total freeway can be considered as being partly illuminated, and the ramps as being almost totally illuminated.

Figure 12. Numerous fixed objects and also the pavement texture and alignment which makes the ramp appear to be the mainline.

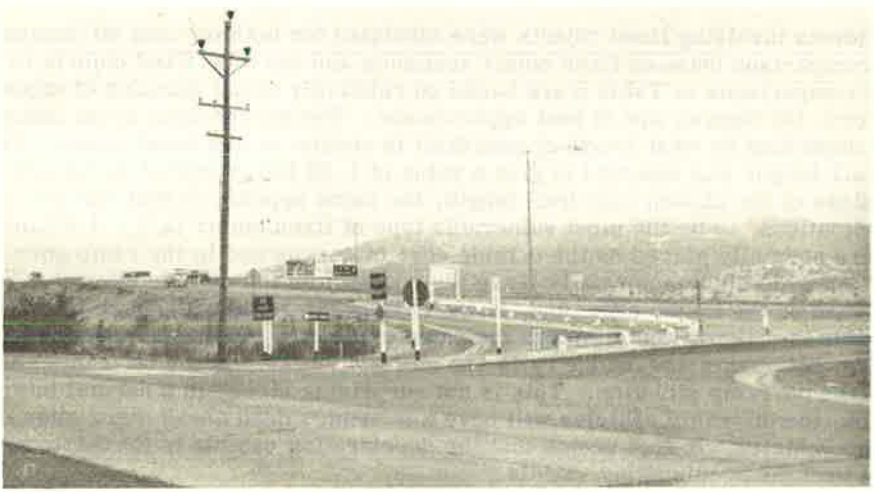


Figure 13. Guardrail used as delineation.

Figure 14. Cure as bad as the disease—guardrail needed only around sign post.

Figure 15. Is the guardrail necessary where the embankment is shallow?

Figure 16. Why the guardrail in the gore?

Figure 17. Curbs used for drainage, delineation and barrier.

Figure 18. Light standard on outside of curve (not present design practice, however).

Figure 19. Except for the light standard, there is ample unobstructed recovery space here.

Figure 20. Tree protected guardrail.

TABLE 7

ACCIDENTS UNDER VARIOUS LIGHT CONDITIONS

Light Conditions	Percent of Accidents		
	On-Ramp	Off-Ramp	Total Freeway
Daylight	66	57	52
Dusk or dawn	5	3	3
Dark—no street lights	6	8	25
Dark—with street lights	23	32	20
Totals	100	100	100
Total dark (all except daylight)	34	43	48

TABLE 8

ACCIDENT RATES—DAYLIGHT, NIGHT, COMBINED

Type	"All Day" (24-hr) Accident Rate[a]	Daylight	Nighttime	Percent Increase Night/Day
		$\frac{\%}{\%}$ Rate	$\frac{\%}{\%}$ Rate	
On-ramps	0.59 Acc/MV	$\frac{0.66}{0.70}$ 0.56	$\frac{0.34}{0.30}$ 0.67	20
Off-ramps	0.95 Acc/MV	$\frac{0.57}{0.70}$ 0.77	$\frac{0.43}{0.30}$ 1.36	77
Total freeway	1.29 Acc/MV	$\frac{0.52}{0.70}$ 0.96	$\frac{0.48}{0.30}$ 2.06	115

[a]See Table 10.

Traffic count data show that roughly 70 percent of freeway travel occurs during daylight and the remaining 30 percent occurs during dawn, dark or dusk hours. Assuming that the same breakdown for day-night exposure exists for the ramps as the main line, then a day and a night accident rate can be calculated for the ramps and the total freeway by multiplying the actual accident rate by the percentage of accidents and dividing the product by the percentage of exposure. For example,

$$\text{accident rate} \times \frac{\%\text{ of daylight accidents}}{\%\text{ of daylight exposure}} = \text{daylight accident rate}$$

Table 8 indicates that nighttime accident rates are higher than daylight rates and that a substantial percentage decrease in nighttime rates is realized in ramp areas (where illumination is present). It is difficult to determine exactly how much of this decrease, if any, is attributable to lighting. A more detailed study (2), recently completed, did not show conclusively that lighting does or does not reduce the occurrence of nighttime accidents.

Effect of Ramp Traffic Volumes

Table 9 shows ramp accident rates for various ramp volume groups. The data shown in the table were taken from group B ramps.

Figure 21 was obtained by plotting the accident rate as the ordinate and the volume as the abscissa. The MV used to calculate each coordinate is printed next to the coordinate it represents. Figure 21 shows a decrease in accident rate with increasing

TABLE 9

RAMP ACCIDENT RATES (ACC/MV) VS RAMP VOLUMES—GROUP B RAMPS

ADT[1] Groups	ON					OFF					TOTALS				
	No. of Ramps	Acc	M V	Rate	Avg. ADT	No. of Ramps	Acc	M V	Rate	Avg ADT	No. of Ramps	Acc	M V.	Rate	Avg. ADT
0 – 1,000	54	35	26.2	1.34	518	54	60	30.0	2.00	594	108	95	56.2	1.69	557
1,001 – 2,000	63	62	94.2	0.66	1,530	49	94	71.7	1.31	1,496	112	156	165.9	0.94	1,516
2,001 – 3,000	38	58	93.1	0.62	2,440	39	123	91.7	1.34	2,379	77	181	184.8	0.98	2,407
3,001 – 4,000	29	85	95.3	0.89	3,442	34	90	116.4	0.77	3,485	63	175	211.7	0.83	3,456
4,001 – 5,000	10	50	45.8	1.09	4,488	13	46	62.8	0.73	4,407	23	96	108.6	0.88	4,442
5,001 – 6,000	15	49	89.8	0.55	5,520	17	40	96.5	0.41	5,417	32	89	186.3	0.48	5,465
6,001 – 7,000	7	21	48.6	0.43	6,677	8	47	54.1	0.87	6,478	15	68	102.7	0.66	6,571
7,001 – 8,000	3	10	21.5	0.47	7,356	7	50	52.6	0.95	7,563	10	60	74.1	0.81	7,501
8,001 – 9,000	7	31	61.8	0.50	8,464	3	10	27.8	0.36	8,497	10	41	89.6	0.46	8,474
9,001 – 10,000	2	9	20.5	0.44	9,350	1	6	10.9	0.55	9,933	3	15	31.4	0.48	9,543
10,001 – 11,000	1	1	11.0	0.09	10,053	1	10	11.1	0.90	10,150	2	11	22.1	0.50	10,102
11,001 – 12,000	1	1	12.6	0.08	11,560	1	8	12.7	0.63	11,566	2	9	25.3	0.36	11,563
Over 12,000	2	13	44.2	0.29	20,000	2	53	40.3	1.32	18,412	4	66	84.5	0.78	19,203
TOTALS	232	425	664.6	0.64	2,811	229	637	678.6	0.94	2,903	461	1,062	1,343.2	0.79	2,857

(1) Average daily traffic

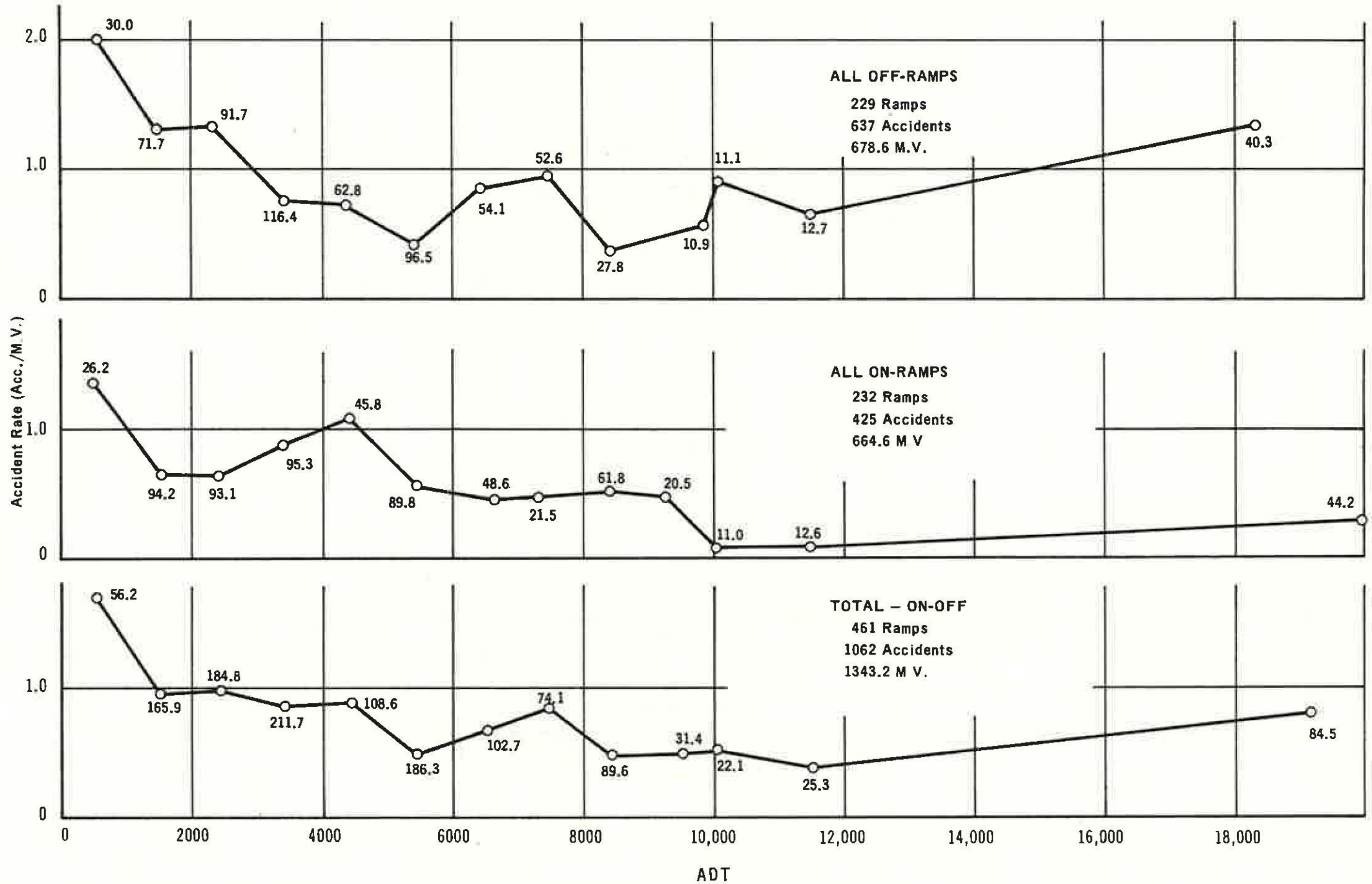


Figure 21. Accident rate vs average daily traffic.

TABLE 10

RAMP ACCIDENT RATES (ACC/MV) BY RAMP TYPE

Type of Ramp	Overcrossing b								Undercrossing b								Sub-Total								Total			
	On				Off				On				Off				On				Off							
	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate	No. Ramps	No. Acc.	M V	Rate
Diamond Ramps	53	44	124.9	0.35	45	67	99.4	0.67	32	44	95.4	0.46	44	73	109.8	0.66	85	88	220.3	0.40	89	140	209.2	0.67	174	228	429.5	0.53
Trumpet Ramps	9	22	28.7	0.77	7	21	24.6	0.85	2	5	3.5	1.43	0	-	-	-	11	27	32.2	0.84	7	21	24.6	0.85	18	48	56.8	0.85
Cloverleaf Ramps without Collector Distributor	48	83	111.2	0.75	59	135	155.8	0.87	27	72	105.4	0.68	19	86	76.0	1.13	75	155	216.6	0.72	78	221	231.8	0.95	153	376	448.4	0.84
Cloverleaf Ramps with Collector Distributor	15	37	73.3	0.50	16	56	82.0	0.68	5	2	14.3	0.14	5	3	13.0	0.23	20	39	87.6	0.45	21	59	95.0	0.62	41	98 a 13 111	182.6	0.61
Loops without Collector Distributor	46	64	84.2	0.76	34	59	70.7	0.83	17	44	53.7	0.82	19	47	50.0	0.94	63	108	137.9	0.78	53	106	120.7	0.88	116	214	258.6	0.83
Cloverleaf Loops with Collector Distributor	9	14	36.3	0.39	10	19	36.5	0.52	5	3	8.0	0.38	5	1	13.2	0.08	14	17	44.3	0.38	15	20	49.7	0.40	29	37 a 28 65	94.0	0.69
Left Side Ramps	5	14	18.9	0.74	11	81	46.4	1.74	2	11	8.0	1.38	4	124	47.0	2.64	7	25	26.9	0.93	15	205	93.4	2.19	22	230	120.3	1.91
Direct Connections	14	55	101.2	0.54	11	53	61.5	0.86	2	10	28.6	0.35	2	30	29.9	1.00	16	65	129.6	0.50	13	83	91.4	0.91	29	148	221.2	0.67
Buttonhook Ramps																	62	77	120.8	0.64	67	111	115.1	0.96	129	188	235.9	0.80
Scissor Ramps																	3	8	9.7	0.88	8	27	18.3	1.48	11	35	27.4	1.28
TOTALS	264	418	708.6	0.59	268	629	710.3	0.89	92	191	316.9	0.60	98	364	338.9	1.07	356	609	1025.5	0.59	366	993	1049.2	0.95	722	1643	2074.7	0.79

a Accidents occurring on collector Distributor Roads

b If the crossroad crosses under the freeway (main line), the ramps are associated with an undercrossing. If the crossroad crosses over the freeway (main line), the ramps are associated with an overcrossing.

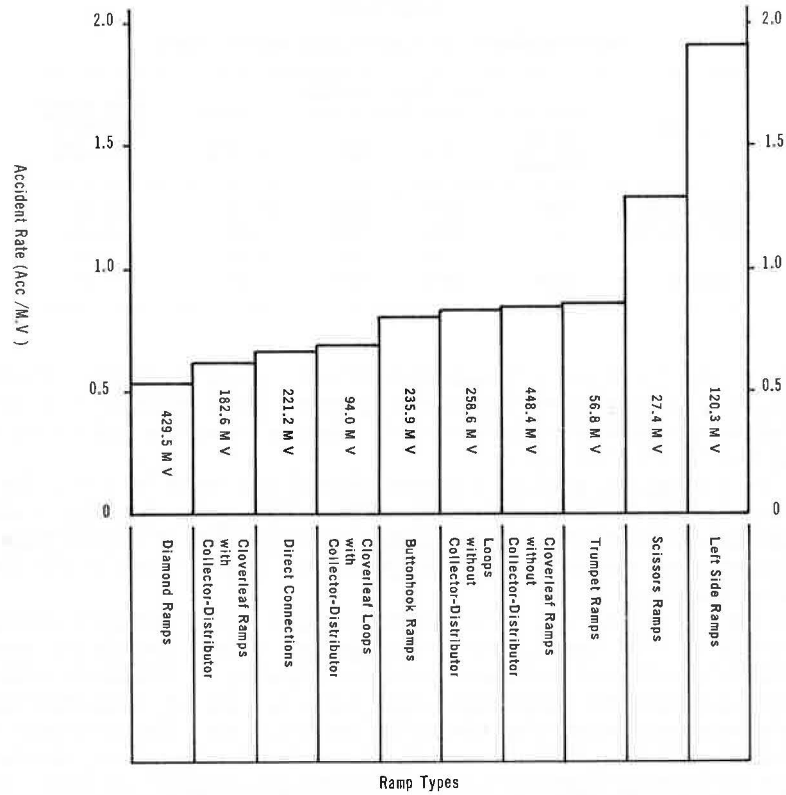


Figure 22. Accident rates by ramp types (total of on and off).

ramp volumes. However, it is felt that this decrease is not entirely attributable to the volume as such because the ramps that carry high volumes were designed to carry these volumes and, therefore, generally have better design standards than the low volume designs. An attempt was made to correlate accident rate and traffic volumes for each of the 10 ramp types, but the experience (MV) for each average daily traffic (ADT) group was too small. This attempt ended in extreme rate fluctuations and a trend was not observed.

EFFECT OF GEOMETRIC FACTORS

Ramp Type

The accident rates calculated for the 10 basic types of ramps are listed in Table 10. The diamond ramps have the lowest over-all rate (0.53 Acc/MV). The direct connections and the cloverleaf ramps and loops with collector-distributor roads have rates between 0.6 and 0.7 Acc/MV. The buttonhook, trumpet and cloverleaf ramps without collector-distributor roads and the loops without collector-distributor roads have rates between 0.8 and 0.9 Acc/MV. The scissors and left side ramps have the highest rates (1.28 and 1.91, respectively). Figure 22 is a bar graph illustrating the over-all rates for each ramp type.

The accident rate calculated for the scissors type ramps is probably not as accurate as the rates calculated for the other ramp types because (a) the sample is small in comparison with the other types, and (b) it is difficult to determine the actual number of accidents that occurred. The scissors type ramp is normally crossed by a facility that is not maintained by the California Division of Highways. The reports of the

TABLE 11

COMPARISON OF RAMP ACCIDENT DATA

Type	Los Angeles Data				This Study
	No. of Ramps	Acc	MV	Acc/MV	Acc/MV
On-ramps	140	147	272	0.54	0.59
Off-ramps	134	252	244	1.03	0.95
Total	274	399	516	0.77	0.79

accidents that occurred at these crossings were not always available. An attempt was made to obtain accidents reports from other agencies but it is difficult to determine the completeness or reliability of the records. In any case, the calculated rates shown are probably low rather than high.

On scissors ramps, the primary concentration of accidents occurs at the scissor or cross-over (ramp with local road) facility. From reading the reports, it was apparent that the collisions usually involve faulty judgment on the part of the frontage road drivers as to the ramp vehicle's speed of approach. This is true for both the on-ramp and off-ramp situation.

The ramp type accident rates shown in this section and in Table 10 are average rates for the ramps only. The rates or relative magnitude of the rates do not necessarily reflect the relative safety of various interchange types; e.g., the diamond ramp has a lower rate than the cloverleaf ramp and loop, but this does not mean that diamond interchanges are necessarily safer than cloverleaf interchanges. The reason is that this ramp study shows the rates for ramp accidents only and does not include the crossroad accidents and the freeway mainline accidents within the interchange area. It is quite possible, for instance, that there may be a greater number of accidents on the crossroad with diamond interchanges (due to left-turning vehicles), than with cloverleaf interchanges, and that this difference in accidents on the crossroad is greater than the increase in accidents on the cloverleaf ramps and loops.

On-Ramps vs Off-Ramps

Table 10 also has an on-ramp vs off-ramp breakdown. The on-ramps as a group have an accident rate of 0.59 Acc/MV, which is 38 percent lower than the off-ramp group (0.95 Acc/MV). These rates are similar to those obtained in another study by the Los Angeles District of the California Division of Highways in 1962, using 1961 data for the following freeways in the Los Angeles area:

1. LA-11-Harbor Freeway (Milepost 1.7 to 23.7)—the 22-mile portion between the beginning of the freeway in Wilmington and the 4-level structure.
2. LA-110, 10-San Bernardino Freeway (Milepost 0.0 to 0.7 on Route 110; Milepost 18.4 to 26.8 on Route 10)—the 9.1-mile portion between the Santa Ana Freeway and Rosemead Boulevard.
3. La-101-Hollywood Freeway (Milepost 1.6 to 11.4)—the 9.8-mile portion between the 4-level structure and the Ventura Freeway.
4. LA-101-Ventura Freeway (Milepost 11.4 to 21.7)—the 10.3-mile portion between the Hollywood Freeway and the Wilbur Avenue undercrossing.

The data are summarized in Table 11. It is interesting to note that the on-ramp rates are consistently lower than the off-ramp rates even when the ramps are split by type. The trumpet ramps are an exception with both the on- and off-ramp rates approximately 0.85 Acc/MV.

Figure 23 shows the accident rates by ramp type for both on- and off-ramps. Both the scissors and left side ramps have a large difference in on-ramp vs off-ramp rates. The ramps and loops with collector-distributor roads are not shown in this figure

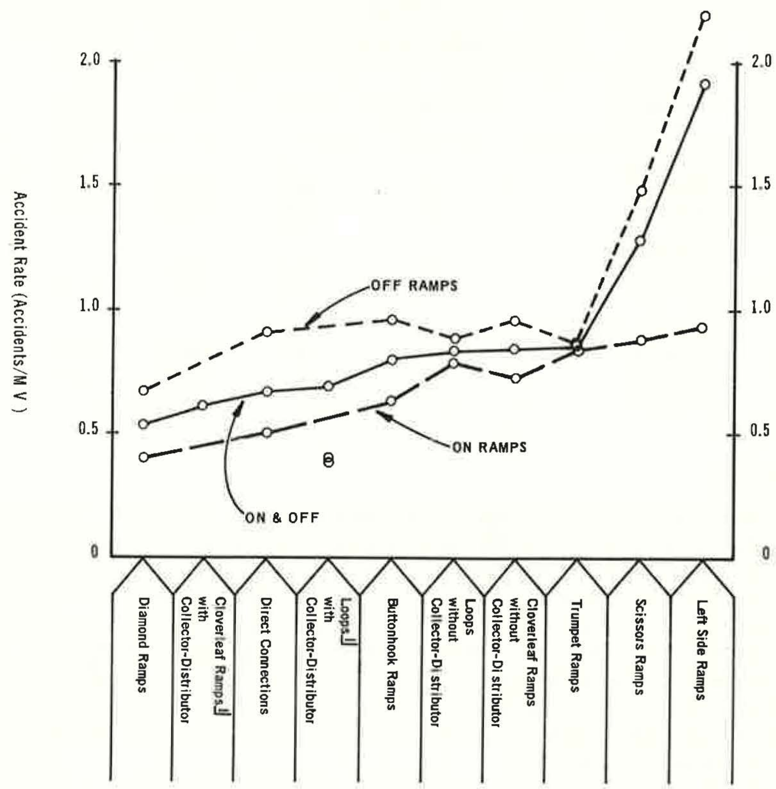


Figure 23. Accident rates by ramp type. (On-off split not shown because collector road accidents cannot be charged to either.)

because the accidents that occurred on the collector-distributor roads cannot be charged to the total or combination of the two.

Overcrossing vs Undercrossing

If a ramp grade approaches the main line from some level above the main line, the ramp is associated with an overcrossing. With this arrangement, an on-ramp vehicle will be on a downhill grade relative to the main line when using an overcrossing facility. The off-ramp vehicle will be on an uphill grade relative to the main line.

If the ramp grade approaches the main line from some level below the main line, the ramp is associated with an undercrossing. The undercrossing situation places the on-ramp vehicle on a relative upgrade and the off-ramp vehicle on a relative downgrade.

Table 10 has an undercrossing vs overcrossing breakdown. Overall, the on-ramps seem to have the same rates for both the downgrade (0.59 Acc/MV) and upgrade (0.60 Acc/MV) situations. The uphill off-ramps have a combined rate of 0.89 Acc/MV compared to a rate of 1.07 Acc/MV for the downhill ramps. The difference in off-ramp rates may be due to the gravity aid in deceleration in the case of the uphill off-ramps. Gravity, of course, hinders deceleration when the grade is downhill. It is true, however, that many of these ramps are on a true flat grade and the main line has a downhill grade. At attempt was made to sort those ramps with a true uphill or downhill grade. However, only a few actually possessed level grades and the rates were approximately the same.

TABLE 12

RAMP CURVATURE

Ramp	No. of Ramps	Acc	MV	Acc Rate
On-ramps				
Straight	180	282	524.5	0.54
Curved	150	229	335.2	0.68
Off-ramps				
Straight	188	420	536.0	0.78
Curved	142	258	310.1	0.81
Total on and off				
Straight	368	702	1060.5	0.66
Curved	292	487	645.3	0.75

Ramp Curvature

Table 12 was compiled by grouping the ramp types in Table 10. The diamond and cloverleaf (with or without collector-distributor[1]) ramps were considered basically straight. The loops (with or without collector-distributor[1]) along with the trumpet and buttonhook ramps were taken as basically curved. The scissors and left side ramps along with the direct connections were omitted from the tabulation because they are not basically straight or curved. It should be noted that the table represents a mere generalization since the standards for straight or curved are not rigidly set and there is some deviation within the ramp types. The generalization made in classifying ramp curvature by ramp type undoubtedly has caused a decrease in the difference in rates for the curved vs straight ramps.

The results of this tabulation show that the straight ramps have a 12 percent lower overall (on and off) accident rate than the curved ramps. The straight off-ramps have only a 4 percent lower rate than the curved off-ramps.

It might be suspected that the difference in the on-ramp and off-ramp rates would be due to the difficulty in negotiating the off-ramp turns. Table 12 does not bear this out, but other investigations (discussed later) show slight trends in this direction.

Location of Ramp Accidents

The accident data available for the group A[2] ramps were such that a breakdown by merging area was possible. A merging area is defined as the area between the ramp gore nose and the end of the speed change lane taper. The ramp area is behind the gore nose and on the ramp itself.

Table 13 is a percentage breakdown of accidents occurring in the merging area and in the ramp area. The point of impact determined the area in which the accident was assigned. Undoubtedly some of the accidents assigned to the ramp area were actually caused by some disturbance in the merging or diverging area. An example would be an accident caused by a vehicle running into the rear of another vehicle, which was stopped because of freeway congestion. If an accident occurred in the merging area but was not caused by a merging movement, it was excluded from the study.

Table 13 shows an on-ramp accident split of about 52 percent merge and 48 percent ramp. The off-ramp split is about 44 percent diverge and 56 percent ramp.

Table 14 is the result of splitting the accident rates from Table 10 according to the percentage in Table 13. The loops with collector-distributor roads and the scissors ramps are missing because the group A ramps did not contain ramps of this type. The trumpet, left side and cloverleaf ramps without collector-distributor samples are also

[1]The accidents that occurred on the collector road were omitted in this tabulation.

[2]The sections listed in the Appendix are designated either A or B. The form in which the accident data were available allowed a precise accident location for the A section ramps.

TABLE 13

MERGING AND DIVERGING ACCIDENTS VS RAMP ACCIDENTS—GROUP A RAMPS

	Number of Accidents									% of Total Accidents					
	ON			OFF			TOTAL			ON		OFF		TOTAL	
Type of Ramp	Merge	Ramp	Total	Diverge	Ramp	Total	Merge & Diverge	Ramp	Total	Merge	Ramp	Diverge	Ramp	Merge & Diverge	Ramp
Diamond Ramps	17	18	35	22	33	55	39	51	90	48.6%	51.4%	40.0%	60.0%	43.3%	56.7%
Trumpet Ramps	2	0	2	4	2	6	6	2	8	100%	—	66.7%	33.3%	75.0%	25.0%
Cloverleaf Ramps without Collector Distributor	26	14	40	15	36	51	41	50	91	65.0%	35.0%	29.4%	70.6%	45.1%	54.9%
Cloverleaf Ramps with Collector Distributor	2	4	6	9	5	14	11	9	20	33.3%	66.7%	64.3%	35.7%	55.0%	45.0%
Loops without Collector Distributor	13	17	30	4	12	16	17	29	46	43.3%	56.7%	25.0%	75.0%	37.0%	63.0%
Loops with [*] Collector Distributor	—	NA	—	—	NA	—	—	NA	—	—	NA	—	NA	—	NA
Left Side Ramps	2	9	11	81	50	131	83	59	142	18.2%	81.8%	61.8%	38.2%	58.5%	41.5%
Direct Connections	16	11	27	14	21	35	30	32	62	59.3%	40.7%	40.0%	60.0%	48.4%	51.6%
Buttonhook Ramps	18	15	33	8	40	48	26	55	81	54.5%	45.5%	16.7%	83.3%	32.1%	67.9%
Scissors Ramps [*]	—	NA	—	—	NA	—	—	NA	—	—	NA	—	NA	—	NA
Total Ramps	96	88	184	157	199	356	253	287	540	52.2%	47.8%	44.1%	55.9%	46.9%	53.1%

[*] The loops with collector-distributor roads and the scissors ramps are missing because the "Group A" ramps did not contain ramps of this type.

TABLE 14

ACCIDENT RATES: MERGING VS RAMP

	ON RAMPS					OFF RAMPS					TOTAL ON+OFF				
	% Split(1)		Acc. Rates			% Split(1)		Acc. Rates			% Split(1)		Acc. Rates		
	Merge	Ramp	Total(2)	Merge	Ramp	Merge	Ramp	Total(2)	Merge	Ramp	Merge	Ramp	Total(2)	Merge	Ramp
Diamond Ramps	49	51	0.40	0.20	0.20	40	60	0.67	0.27	0.40	43	57	0.53	0.23	0.30
Trumpet Ramps	100 (3)	0	0.84	0.84	0.00	67 (3)	33	0.85	0.57	0.28	75	25	0.85	0.64	0.21
Cloverleaf Ramps without Collector Distributor	65	35	0.72	0.47	0.25	29	71	0.95	0.28	0.67	45	55	0.84	0.38	0.46
Cloverleaf Ramps with Collector Distributor	33 (3)	67	0.45	0.15	0.30	64 (3)	36	0.62	0.40	0.22	55	45	0.61	0.34	0.27
Loops without Collector Distributor	43	57	0.78	0.34	0.44	25 (3)	75	0.88	0.22	0.66	37	63	0.83	0.31	0.52
Loops with Collector Distributor	N.A.	←												→	N.A.
Left Side Ramps	18 (3)	82	0.93	0.17	0.76	62	38	2.19	1.36	0.83	58	42	1.91	1.11	0.80
Direct Connections	59	41	0.50	0.30	0.20	40	60	0.91	0.36	0.55	48	52	0.67	0.32	0.35
Buttonhook Ramps	54	46	0.64	0.35	0.29	17	83	0.96	0.16	0.80	32	68	0.80	0.26	0.54
Scissors Ramps	N.A.	←												→	N.A.
Total Ramps	52	48	0.60	0.31	0.29	44	56	0.86	0.38	0.48	47	53	0.78	0.37	0.41

(1) From Table 2; (2) From Table 3; (3) Calculated from very weak sample

TABLE 15

STANDARDS FOR LENGTH OF SPEED CHANGE LANES—SUPERSEDED PRACTICE

		HIGHWAY DESIGN SPEED (V) M.P.H.		
		40	50	60
Average Speed of Travel (0.7V)		28	35	42
		TAPER-FEET		
DECELERATION		120	150	180
ACCELERATION		180	240	270
Turning Speed	Minimum Curve Radius	DECELERATION LANE-FEET - Including Taper -		
20	100	140	230	300
30	200	120	150	240
40	400	120	150	180
50	600		150	180
		ACCELERATION LANE-FEET - Including Taper -		
20	100	180	410	750
30	200	180	240	510
40	400	180	240	270
50	600		240	270

very small. The results are in accordance with the analysis of single vs multiple vehicle; i.e., the primary difference in on-ramp and off-ramp accident rates lies in the increase in the accidents on the off-ramp proper.

Table 14 also shows that although the left side off-ramps experience most of their trouble in the diverge area, even the ramp proper possesses a higher rate than any other type ramp. (The on-ramp sample is too small to be reliable.) The buttonhook off-ramp seems to have an extremely good diverging rate and the ramp proper is responsible for the majority of the accidents. This is not true in the case of the buttonhook on-ramps where the merge area has a higher rate than the ramp.

Acceleration Lane Length

Acceleration lane length is measured from the on-ramp gore nose to the point where the acceleration lane taper is 3 ft wide (Figs. 2, 24, 25). Present California practice provides for over 900 ft of acceleration lane and this appears to be quite adequate.

The acceleration and deceleration lengths of most ramps included in this study were based on the old AASHO standard, which based these lengths on distances required to accomplish the speed change between 70 percent of the freeway design speed, and the maximum safe speed of the ramp curve at the ramp nose (Table 15 and Fig. 24). California standards have since been made considerably more generous (Fig. 25). The old practice provided variable acceleration lengths, whereas the present practice provides a single standard length. Table 15 does, however, represent minimum standards, and actual lengths frequently exceeded the 750 ft shown in the table.

Table 16 and Figures 26 and 27 illustrate the results of an investigation involving the group B on-ramps plus 13 other on-ramps located near Ontario on the San Bernardino Freeway. During the study period, the 13 ramps had extremely short acceleration lanes and extremely high accident rates. The ramps are basically of the diamond type and the entrance speeds (speed at the gore nose when entering the freeway) are approximately 40 mph. The 13 on-ramps experienced a rate of 3.32 Acc/MV during the

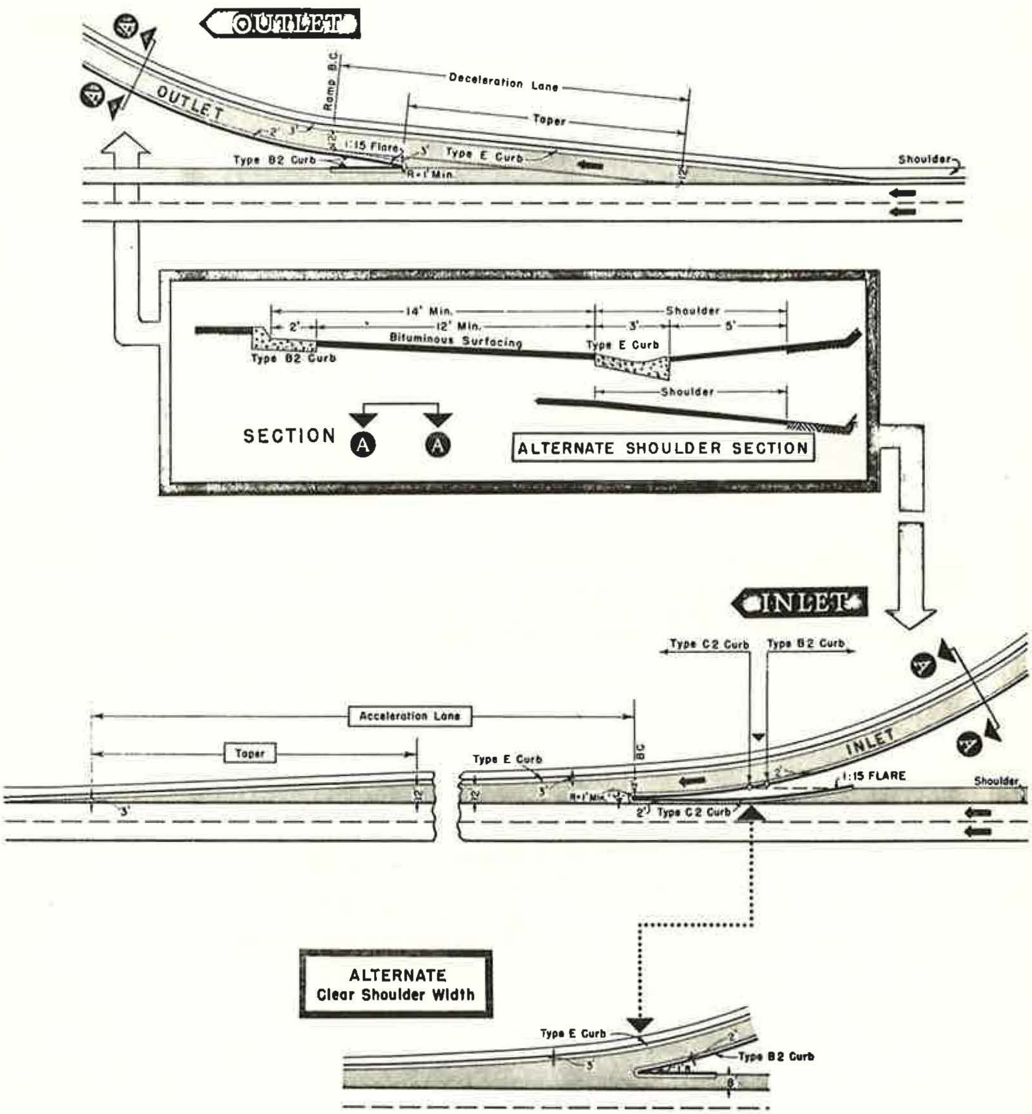
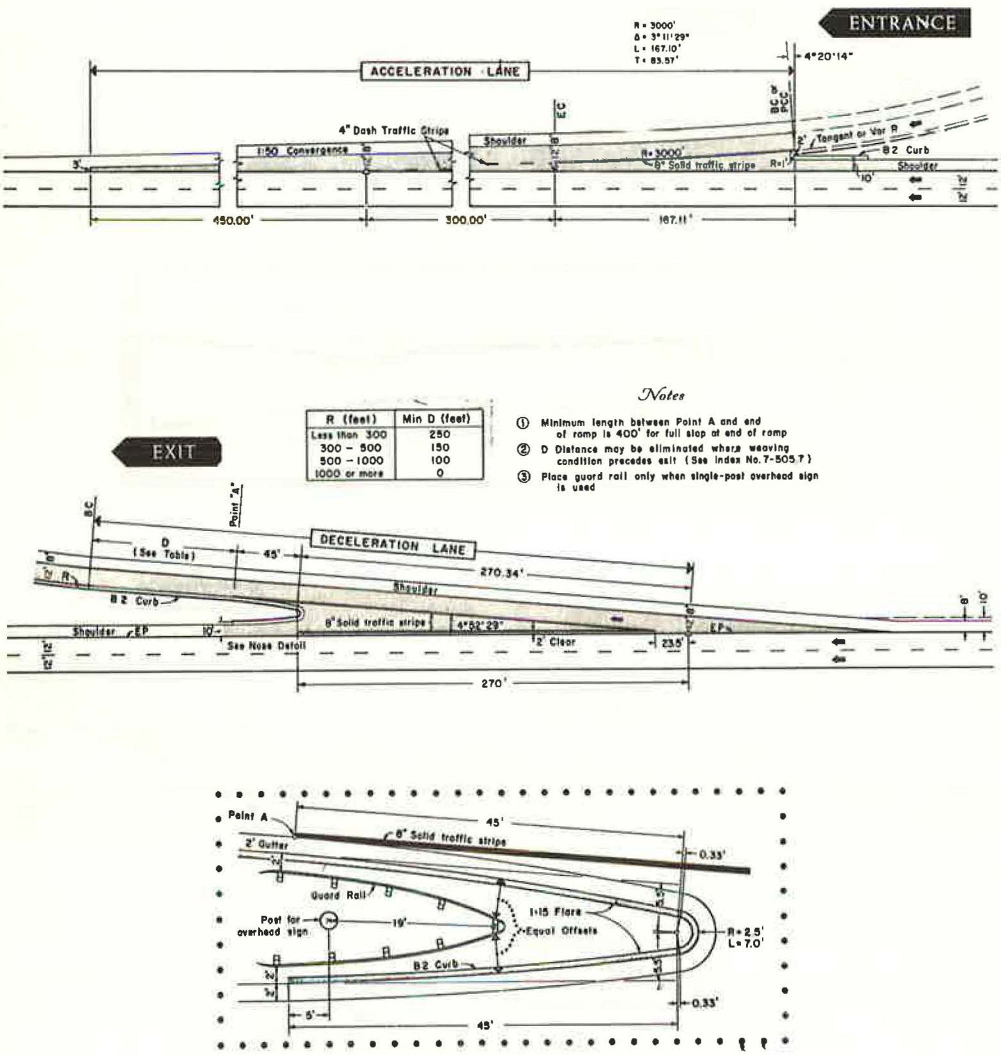


Figure 24. Ramp designs (superseded practice).



R (feet)	Min D (feet)
Less than 300	250
300 - 500	150
500 - 1000	100
1000 or more	0

Notes

① Minimum length between Point A and end of ramp is 400' for full stop at end of ramp

② D Distance may be eliminated where weaving condition precedes exit (See Index No. 7-505.7)

③ Place guard rail only when single-post overhead sign is used

Figure 25. Ramp designs (present practice).

TABLE 16

RAMP ACCIDENT RATE VS RAMP ACCELERATION LANE LENGTH

Speed @ Nose →	0 to 25 MPH					30 to 35 MPH					40 to 50 MPH					TOTALS				
Acceleration Length ↓	NO. RAMPS	ACC	M V	RATE	AVG ACCEL. LENGTH	NO. RAMPS	ACC	M V	RATE	AVG ACCEL LENGTH	NO RAMPS	ACC	M V.	RATE	AVG ACCEL LENGTH	NO. RAMPS	ACC	M V	RATE	AVG ACCEL LENGTH
0 - 100 ft.																				
101 - 200	4	5	9.3	0.54	190						5	24	8.0	3.00	184	9	29	17.3	1.68	187
201 - 300	5	13	8.6	1.51	258						17	73	37.3	1.96	269	22	86	45.9	1.87	267
301 - 400	4	14	12.3	1.14	385	3	7	4.5	1.56	363	8	29	21.2	1.37	367	15	50	38.0	1.32	371
401 - 500	6	6	14.7	0.41	460	3	13	10.7	1.21	480	8	28	21.1	1.33	456	17	47	46.5	1.01	462
501 - 600	9	24	24.1	1.00	570	22	26	43.5	0.60	548	27	41	74.0	0.55	568	58	91	141.6	0.64	561
601 - 700	9	13	15.1	0.86	671	9	26	32.0	0.81	662	18	28	73.8	0.38	658	36	67	120.9	0.55	662
701 - 800	12	19	21.1	0.90	743	5	20	12.2	1.64	736	12	29	39.7	0.73	740	29	68	73.0	0.93	740
801 - 900	2	1	2.2	0.45	875	3	5	9.4	0.53	867	10	4	6.4	0.63	875	15	10	18.0	0.56	873
901 - 1000	4	0	1.9	0	973	2	3	4.7	0.64	955	3	1	11.8	0.08	930	9	4	18.4	0.22	954
1001 - 1100	2	1	1.0	0.83	1040						2	10	28.6	0.38	1060	4	11	29.6	0.37	1050
1101 - 1200						2	5	13.9	0.36	1200	1	1	2.0	0.50	1200	3	6	15.9	0.38	1200
1201 - 1300	2	1	3.0	0.33	1280						2	1	3.0	0.33	1280	2	1	3.0	0.33	1280
1301 - 1400											1	0	3.6	0	1400	1	0	3.6	0	1400
1401 - 1500																				
1501 - 1600																				
1601 - 1700											1	2	5.7	0.35	1660	1	2	5.7	0.35	1660
1701 - 1800											1	3	5.3	0.57	1800	1	3	5.3	0.57	1800
1801 - 1900						1	1	2.1	0.48	1900	1	0	0.5	0	1840	2	1	2.6	0.39	1870
1901 - 2000											4	3	16.0	0.19	1938	4	3	16.0	0.19	1938
2001 - 2100											1	3	4.4	0.68	2080	1	3	4.4	0.68	2080
2101 - 2200											2	1	4.9	0.20	2130	2	1	4.9	0.20	2130
2400											1	6	6.4	0.94	2400	1	6	6.4	0.94	2400
2520											1	2	5.5	0.36	2520	1	2	5.5	0.36	2520
Full Lanes	1	1	0.7	1.43	FULL LANE	1	1	0.7	1.43	FULL LANE	10	25	68.7	0.36	FULL LANE	12	27	70.1	0.39	FULL LANE
TOTALS	60	98	114.0	0.86		51	107	133.7	0.80		134	313	444.9	0.70		245	518	692.6	0.75	

1959-1961 period. These ramps have, therefore, been omitted in the main body of this study because the accident rates due to the short acceleration lengths would bias the sample of diamond ramps. They were included in this portion of the study because the acceleration lane length is the variable being examined.

The safe entering speed was first determined for each on-ramp by driving the ramp several times and observing the entering speed. Three speed groups were used: (a) 0-25 mph at the nose; (b) 30-35 mph at the nose; and (c) 40-50 mph at the nose.

Table 16 is a tabulation of the ramp data by speed group. It arrays the ramps in order of increasing acceleration lane lengths. The average rate shown in the table (0.75) is higher than shown in Table 10 because the 13 extra ramps (with short acceleration lanes) have high rates.

Figures 26 and 27 show the accident rate vs acceleration lane length curves. The curves are free-hand fits in which an attempt was made to give more weight to the large MV values and less weight to the small MV values.

The average on-ramp rate (0.59 Acc/MV) from Table 10 was plotted to show that:

1. Below average accident rates can be expected on ramps with acceleration lanes greater than 750-800 ft.

2. If the acceleration lane is less than 750-800 ft, the ramps with the high entrance speeds can be expected to have higher accident rates than those with low entrance speeds.

Off-Ramp Geometry

Off-ramps have higher accident rates than on-ramps, and the higher rate is primarily due to accidents which occur on the ramp proper rather than in the diverging area. Figure 28 is the result of an attempt to relate various off-ramp characteristics to the off-ramp accident rate. The figure shows that straight ramps (zero central angle and infinite radius) have the lowest rates. Those ramps with long (900 ft or more)

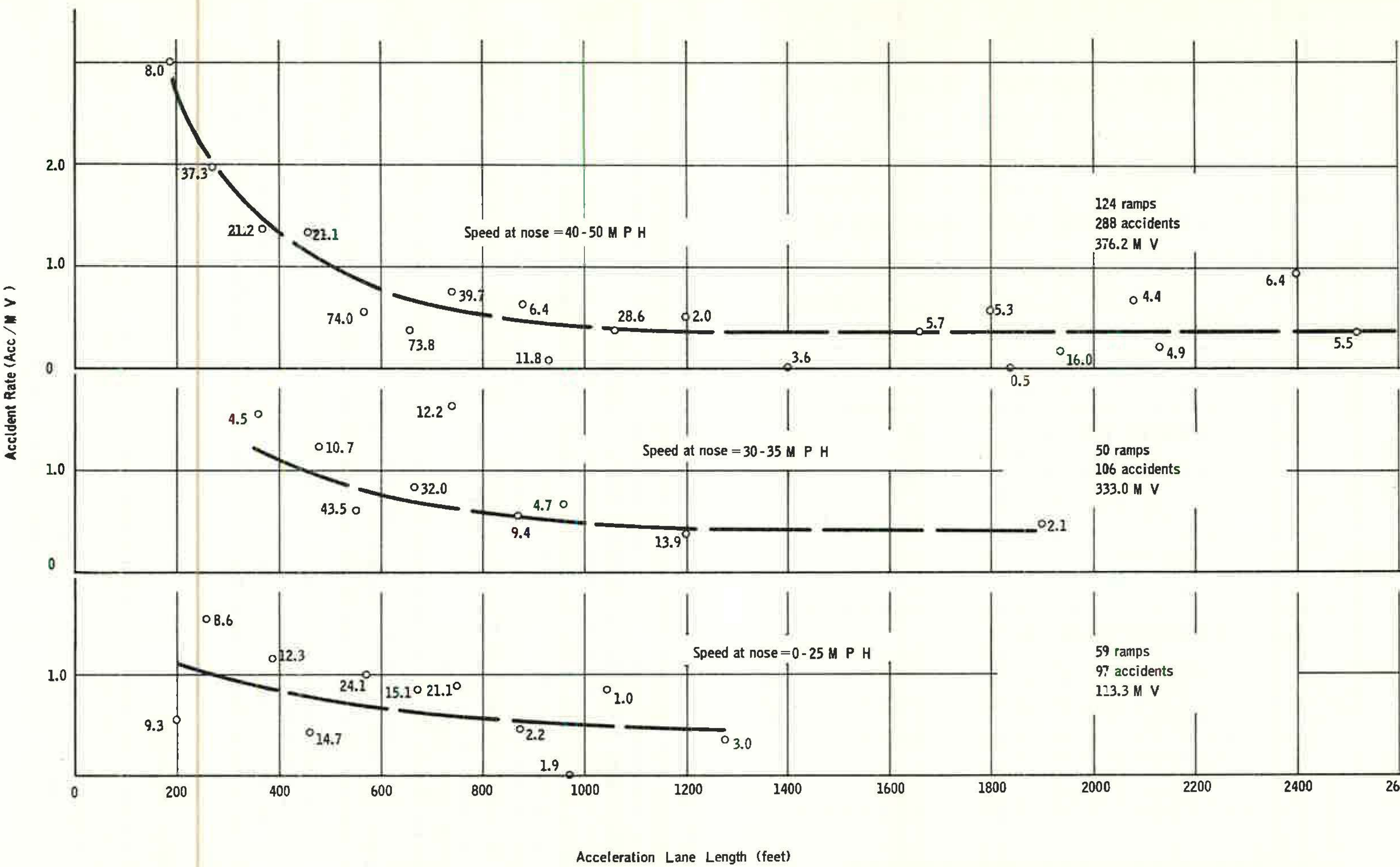


Figure 26. On-ramps: accident rate vs acceleration lane length.

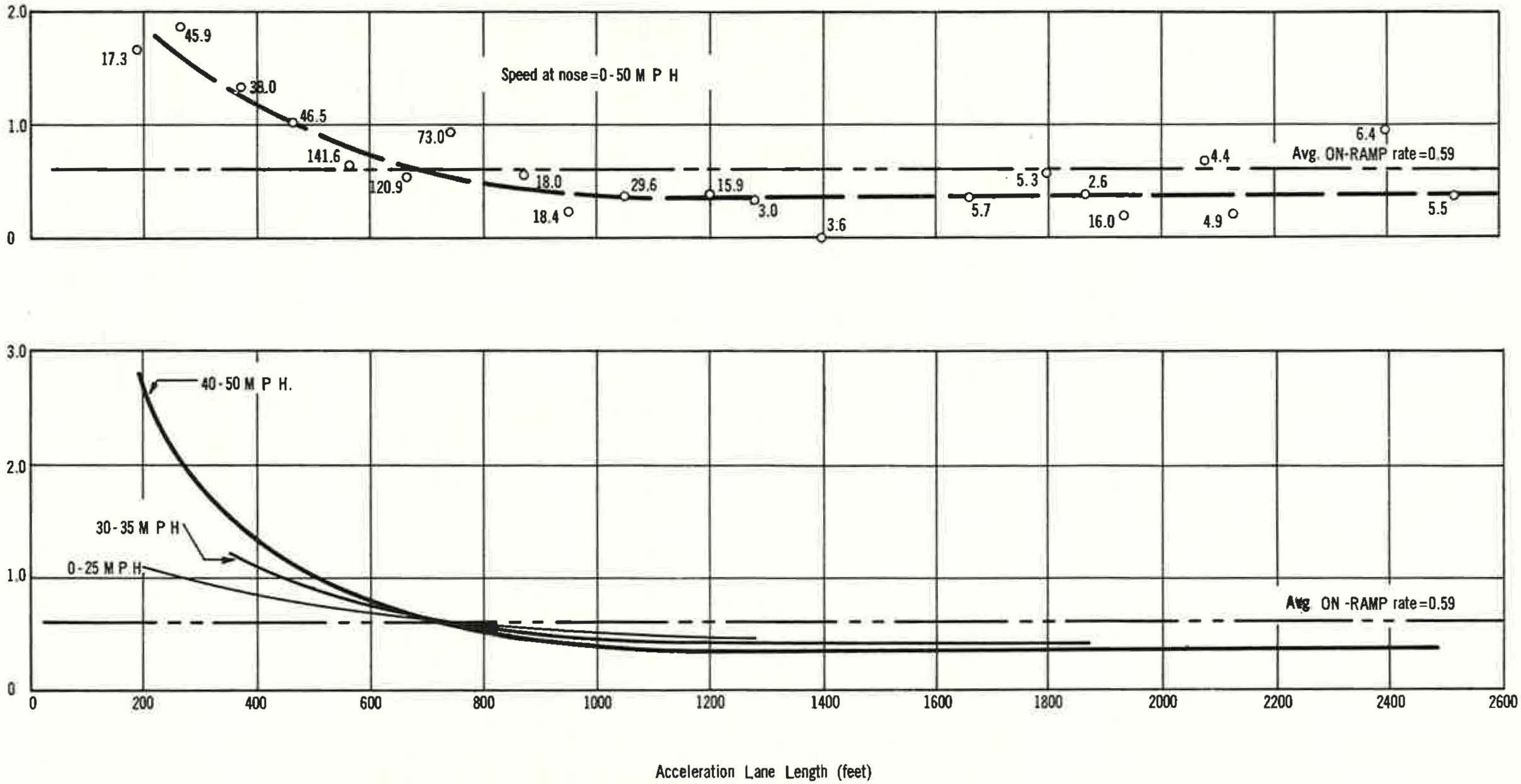


Figure 27. On-ramps: accident rate vs acceleration lane length (233 ramps, 491 accidents, 622.5 MV).

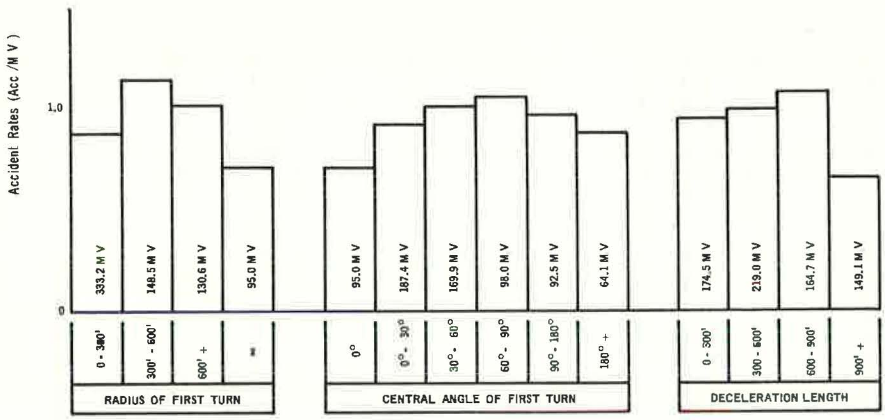


Figure 28. Off-ramps: accident rates for group B ramps as grouped by first curve radius, first curve central angle, and deceleration lane length.

deceleration lengths seem to have lower rates than those with shorter deceleration lengths. Table 15 and Figure 24 show the old deceleration lane standards and Figure 25 shows the new standards.

The distance used as the deceleration length was all the available tangent distance from where the deceleration off-ramp taper became 12 ft wide (Fig. 24) to the beginning of the first ramp curve. If no curve exists on the ramp, such as is the case with some diamond ramps, the distance was measured to the end of the ramp at the crossroad. In the case of cloverleaf loops, the distance between the on-ramp loop nose and the off-ramp loop nose was considered to be available for deceleration. If a collector-distributor road was available, the distance between the nose of the right turning off-ramp at the collector road to the off-ramp loop nose was considered to be available for deceleration.

The short radius, large central angle ramps seem to have lower rates than the ramps with medium range radii and central angles (Fig. 28). This is perhaps a case where the tight turns appear as an obvious hazard to the drivers and they take the necessary precautions, whereas the medium range curves do not appear dangerous and the driver does not compensate.

This analysis is based on a simple, one independent and one dependent variable technique. All of the off-ramps were arrayed in some sequence of an independent variable (radius, delta, etc.) and the bar graphs were constructed by calculating the dependent variable (accident rate) for predetermined groups of the independent variable. An attempt to unite combinations of independent variables produced extremely small samples and resulted in large accident rate fluctuations (Fig. 29). An analysis through the use of multiple regression techniques could prove beneficial in this area. However, larger and more detailed samples would be necessary to obtain reasonable accuracy from the program.

At this point we might, at best, say that the large radii, small central angles, and long deceleration lengths appear to provide the safest ramp designs.

SUMMARY

During a period of approximately 3 years, the 722 study ramps experienced 18 percent (1,643) of the accidents occurring on the freeways which they served. During this period, the ramps carried over 2 billion vehicles.

Most of the ramps had very few accidents. In fact, of the 722 ramps studied, 232 (32 percent) of them were accident-free. No design differences were noted between the accident-free ramps and those ramps with accidents.

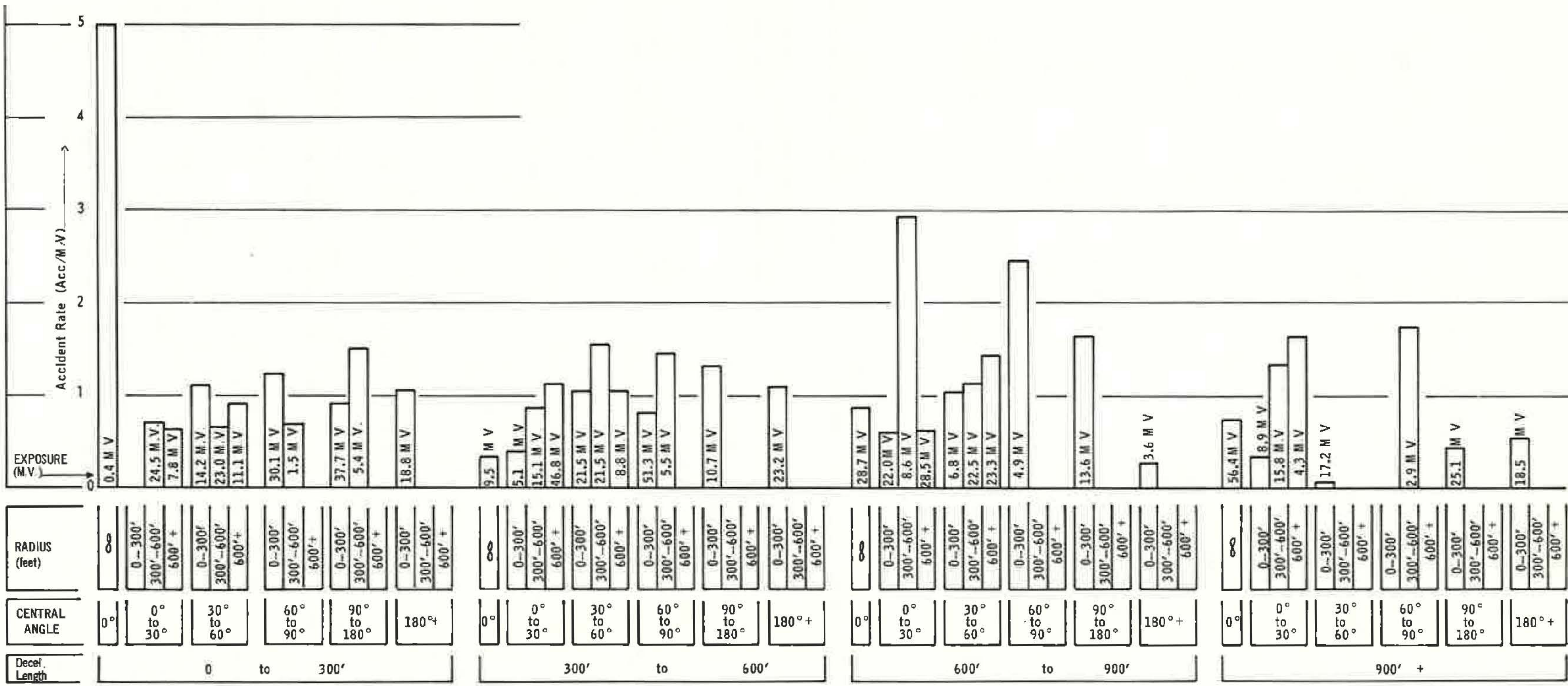


Figure 29. Off-ramps: accident rates for group B grouped by deceleration lane length, central angle and radius of the first curve.

TABLE 17

ACCIDENT RATES (ACC/MV)

Ramp Type	On	Off	On + Off
1. Diamond ramps	0.40	0.67	0.53
2. Trumpet ramps	0.84	0.85	0.85
3. Cloverleaf ramps without collector-distributor roads	0.72	0.95	0.84
4. Cloverleaf ramps with collector-distributor roads[a]	0.45	0.62	0.61[a]
5. Loops without collector-distributor roads	0.78	0.88	0.83
6. Cloverleaf loops with collector-distributor roads[a]	0.38	0.40	0.69[a]
7. Left side ramps	0.93	2.19	1.91
8. Direct connections	0.50	0.91	0.67
9. Buttonhook ramps	0.64	0.96	0.80
10. Scissors ramps	0.88	1.48	1.28
Average	0.59	0.95	0.79

[a]Only the On + Off rate includes the accidents occurring on the collector-distributor roads.

The ramp accident severity ratios are approximately the same as those associated with the freeway main line, i.e., 1.8 percent fatal, 42.9 percent injury and 55.3 percent property damage only.

Table 17 gives the average accident rates, as calculated for the ten basic ramp types.

Off-ramp rates are consistently higher than the on-ramp rates. The off-ramps have more single vehicle accidents, and these accidents produced the primary difference between the on-ramp and off-ramp accident rates.

These average accident rates are also subject to certain variations. If the ramps are associated with an overcrossing, they may be expected to have slightly lower rates, especially the off-ramps. If they are associated with an undercrossing, the rates may be slightly higher.

Accidents on ramps, especially off-ramps, have a greater proportion of single vehicle involvement than accidents on the freeway mainline. In fact, approximately half (51 percent) of the off-ramp accidents are single vehicle accidents (vs 38 percent of freeway mainline accidents). The primary factor in the difference in rates between on-ramps (0.59 Acc/MV) and off-ramps (0.95 Acc/MV) is the single vehicle accident rate (0.18 Acc/MV for on-ramps and 0.48 Acc/MV for off-ramps).

About 64 percent of all freeway fixed objects are located in the ramp areas. About 36 percent of these fixed objects occur adjacent to off-ramps and about 28 percent are adjacent to on-ramps. These fixed objects are involved in 42 percent of the off-ramp accidents and 22 percent of the on-ramp accidents.

Signs generally are placed in the most vulnerable locations (in the gore nose and on the outside edge of curves) in both the on- and off-ramp situations. Piers, abutments and bridge rails are more exposed to the off-ramp vehicle than to the on-ramp vehicle. Light standards have a low accident involvement, and this is probably because they are no longer placed on the outside portion of curves.

Nighttime accident rates are normally higher than daytime rates. However, the increase in nighttime rates for ramps (generally illuminated) was less than the increase on freeways (generally not illuminated). This would indicate that lighting is beneficial. It is difficult, however, to determine exactly how much of this decrease is attributable to the lighting.

An investigation of ramp average daily traffic as related to ramp accident rates showed a decrease in accident rate with an increase in daily traffic. However, it is

felt that the decrease is not entirely attributable to the volume as such but rather to the better design standards of the high-volume ramps.

On the average, about 52 percent of the on-ramp accidents occur in the merging area (adjacent to the main line) and about 44 percent of the off-ramp accidents occur in the diverging area.

On the accident per million vehicle basis, it was found that the off-ramp diverging rates are only 23 percent higher than the on-ramp merging rates, whereas the accident rates for the off-ramps proper (from the gore nose to the cross-street terminal) are 65 percent higher than for the on-ramps proper. In other words, accidents on the turning roadways are primarily responsible for the difference.

On-ramps with acceleration lane lengths greater than 800 ft can be expected to have below average accident rates. If the acceleration lane is less than 800 ft, the rate will probably be greater than average, especially if the geometry upstream of the nose is such that a high-speed approach is possible.

The off-ramps with the long (900 ft +) deceleration lane lengths have lower rates than the ramps with shorter deceleration lengths. The short radius, large central angle curved off-ramps seem to have lower rates than the ramps with median range radii and deltas. This is perhaps a case where the tight turns appear as obvious hazards to the drivers and they take the necessary precautions, whereas the medium range curves do not appear dangerous and the drivers do not compensate. The straight ramps have lower rates than any of the curved classifications.

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2. Johnson, Roger T., and Tamburri, Thomas N. Continuous Freeway Illumination. Calif. Div. of Highways, May 1965.

Appendix A

LOCATION OF GROUP A RAMPS

Sec. No.	Freeway Name	Study Period	Location	On Ramps				Off Ramps				Total Ramps			
				No of Ramps	Acc.	M V	Acc / M V	No of Ramps	Acc	M V	Acc / M V	No of Ramps	Acc.	M. V.	Acc. / M V
1 A	Montgomery	1958–1959–1960	SD-5-SD, ChV, G, NatC San Ysidro Jct. to S.C.L. of National City	22	23	31.4	0.73	21	28	28.0	1.00	43	51	59.4	0.86
2 A	Balboa Bypass	1958–1959–1960	SD-5-SD 1 mile South to 0.65 mile North of Balboa Ave.	2	4	15.6	0.26	3	6	14.0	0.43	5	10	29.6	0.34
3 A	Long Beach	1958–1959–1960	LA-7-LBch, A, Com, Lyn, SGt Pacific Coast Hwy. to Atlantic Ave.	16	16	56.5	0.28	17	27	57.8	0.47	33	43	114.3	0.38
4 A	Pasadena	1958–1959–1960	LA-11-LA 4-Level Structure to Jct. Interstate 5 (Golden State Fwy.)	9	40	63.2	0.63	8	147	62.6	2.36	17	187	125.8	1.49
5 A	Pasadena	1958–1959–1960	LA-11-LA Jct. Interstate 5 (Golden Gate Fwy.) to Ave. 64	0	0	0	0	4	5	15.2	0.33	4	5	15.2	0.33
6 A	Pasadena	1958–1959–1960	LA-11-LA, SPas Ave. 64 to Orange Grove Ave.	1	1	7.5	0.13	5	5	11.8	0.42	6	6	19.3	0.31
7 A	U. S. 99	1958–1959–1960	Tul-99-F Visalia Airport Interchange to 1 mile No. of Goshen	7	10	6.2	1.61	8	10	5.3	1.89	15	20	11.5	1.74
8 A	Petaluma	1958–1959–1960	Son-101-F, C 2.23 mile No. of Marin Co. Line to S.C.L. of Santa Rosa	21	8	13.9	0.58	20	20	12.3	1.63	41	28	26.2	1.07
9 A	Bayshore	1958–1959–1960	SM-101-Var. Branston Rd. to N.C.L. of South San Francisco	28	57	110.0	0.52	31	77	113.3	0.68	59	134	223.3	0.60
10 A	Bayshore	1958–1959–1960	SM, SF-101-F; SF N.C.L. of South San Francisco to 3rd St. in San Francisco	2	9	12.2	0.74	2	8	10.6	0.75	4	17	22.8	0.75
11 A	Colorado	1958–1959–1960	LA-134-LA, Pas, SPas Eagle Vista Drive to Holly St.	5	4	22.3	0.18	5	6	18.1	0.33	10	10	40.4	0.25
12 A	Castro Valley Link	1958–1959–1960	Ala-238-A, SLn Jct. Interstate 17 (Eastshore Fwy.) to Jct. Interstate 580	4	2	10.3	0.19	5	12	12.2	0.98	9	14	22.5	0.62
13 A	Nimitz	1958–1959–1960	SCl, Ala-680-SJs, A; Fmt Interstate 101/680 Separation to Warm Springs Separation	7	10	11.8	0.85	8	5	9.4	0.53	15	15	21.2	0.71
	Totals			124	184	367.1	0.50	137	356	370.6	0.96	251	540	737.7	0.73

Appendix B

LOCATION OF GROUP B RAMPS

Sec. No	Freeway Name	Study Period	Location	On Ramps				Off Ramps				Total Ramps			
				No of Ramps	Acc	M V	Acc. / M V	No of Ramps	Acc	M V	Acc / M V	No of Ramps	Acc	M.V	Acc / M.V.
1B	Golden State	1959–1960–1961	LA-5-LA, Gndl, LA Glendale Blvd. to Burbank Blvd.	16	29	59.7	0.49	17	29	57.4	0.51	33	58	117.1	0.51
2B	Long Beach	1959–1960–1961	LA-7-Com, A, Lyn, SGt. Atlantic Ave. To Firestone Blvd.	15	38	61.0	0.62	15	43	58.6	0.73	30	81	119.6	0.68
3B	Long Beach	1959–1960–1961	LA-7-Bell, B, Ver Firestone Blvd. to No. Jct. Atlantic Blvd.	6	15	27.3	0.55	7	14	31.0	0.45	13	29	58.3	0.50
4B	Long Beach	1959–1960–1961	LA-7-Bell, B, Ver, Cmrc No. Jct. Atlantic Blvd. to Olympic Blvd.	3	14	33.6	0.42	3	41	28.9	1.42	6	55	62.5	0.88
5B	San Bernardino	1959–1960–1961	LA-10-Cla, Pom, C, W. Cov Citrus St. to San Bernardino County Line	16	30	30.3	0.99	15	38	34.2	1.11	31	68	64.5	1.05
6B	San Bernardino	1959–1960–1961	SBd-10-Mcl, Upl, Ont, D Los Angeles County Line to Live Oak Ave.	15	11	16.3	0.67	16	22	17.4	1.26	31	33	33.7	0.99
7B	San Bernardino	1960–1961	SBd-10-D, Ria, Col Live Oak Ave. to 5th St. in Colton	9	6	8.9	0.67	10	10	10.4	0.96	19	16	19.3	0.83
8B	Warren	1960–1961	Ala-13-Oak Redwood Rd. to Thornhill Rd.	3	0	2.7	0.00	4	3	3.4	0.88	7	3	6.1	0.49
9B	Riverside	1960–1961	SBd-395,15-F, Col, SBd Riverside County Line to Jct. Interstate 10 and 650' So. of Mill St. to Jct. Interstate 15	17	22	24.3	0.91	15	27	23.2	1.16	32	49	47.5	1.03
10B	Riverside	1960–1961	SBd-15-F, Col, SBd Jct. Interstate 10 (San Bernardino Fwy.) to 650' So. of Mill St.	8	5	13.9	0.36	8	37	14.7	2.52	16	42	28.6	1.47
11B	Los Gatos	1960–1961	SCl-17,280-LGts, D, Cmb, SJs; D, SJs Santa Clara Ave. to the Alameda	23	32	40.6	0.79	19	39	39.6	0.98	42	71	80.2	0.89
12B	Central	1960–1961	SF-80,101-SF Jct. Interstate 80 (Bayshore Fwy) to Turk St.	2	10	28.6	0.35	2	30	29.9	1.00	4	40	58.5	0.68
13B	I-94	1960–1961–1962	SD-94-SD West of 25th St. O.C. to E. of Palm Ave.	26	44	61.0	0.72	25	79	64.6	1.22	51	123	125.6	0.98
14B	Bayshore	1959–1960–1961	SM-101-D, MIP, RdwC Santa Clara County Line to Bronsten Rd.	11	25	39.5	0.63	12	34	38.4	0.89	23	59	77.9	0.76
15B	Ventura	1959–1960–1961	LA-101-LA Jct. Interstate 405 (San Diego Fwy) to Loúise Ave.	6	20	25.3	0.79	6	42	24.4	1.72	12	62	49.7	1.25
16B	Roseville	1959–1960–1961	Sac; Pla-160;160,80-B; A,A, Rsv Howe Ave, to Atlantic St.	23	23	41.2	0.56	21	27	37.0	0.73	44	50	78.2	0.64
17B	Escondido	1959–1960–1961	SD-395-SD Approx. 0.1 mile No. of Ash St. to Genesee Ave.	16	69	69.7	0.99	15	63	79.5	0.79	31	132	149.2	0.88
18B	Escondido	1959–1960–1961	SD-395-SD Genesee Ave. to Clairmont Mesa Blvd.	5	13	20.0	0.65	6	33	25.7	1.28	11	46	45.7	1.01
19B	San Diego	1959–1960–1961	LA-405-CIC, LA, A Approx. 0.2 mile No. of Venice Blvd. to Ovada Pl.	12	19	60.7	0.31	13	26	60.3	0.43	25	45	121.0	0.37
Totals Group "B" Ramps				232	425	664.6	0.64	229	637	678.6	0.94	461	1062	1343.2	0.79
Totals Group "A" Ramps				124	184	367.1	0.50	137	356	370.6	0.96	261	540	737.7	0.73
Collector - Distributor Road Accidents													41		
Grand Totals Group "A" and "B" Ramps				356	609	1031.7	0.59	366	993	1049.2	0.95	722	1643	2080.9	0.79

A Reevaluation of Group Driver Improvement Meetings

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•IN October 1961, the Research and Statistics Section issued a report titled "A Controlled Evaluation of Group Driver Improvement Meetings" (2), in which it was concluded that group driver improvement meetings as conducted in 1958 and 1959 were an effective means of post-licensing driver control. This group driver improvement meeting program is commonly referred to as the DIM program and throughout the remainder of the present report this terminology will be used.

During 1962, a second experimental evaluation of the DIM program was undertaken in a continuing effort to evaluate the effectiveness of driver control programs within the California Department of Motor Vehicles. The present report presents some findings of this second study.

Having a Driver Improvement Analyst (DIA) meet with several (usually 10 to 15) persons at once is a relatively inexpensive means of altering the driving behavior of persons in the negligent driver category. Since its inception in 1958, the basic outline of the group meeting has remained the same. In general, it is an attempt to "sell" safe driving to a group of negligent drivers with no action being taken against their licenses. This contrasts with the informal negligent operator hearing in which drivers are seen individually and which usually results in some action against the driving privilege. It was felt, however, that there were some changes over this period which could have influenced the effectiveness of the approach. The group meeting, at the time of the first study, was a tightly controlled experimental program, conducted by a small group of selected and specially trained analysts, whereas in 1962, it was a fully operative program and not immune to the pressures involved in the daily functioning of a statewide operation. Because of these factors it was decided that the program should be evaluated more comprehensively.

METHOD

The meeting and control subjects were persons selected for driver improvement meetings on the basis of their area of residence and driving record. The criteria were that they had accumulated a total of four negligent operator points in the last year and had not been previously contacted by DMV as part of the negligent operator control program. To be scheduled for a DIM during 1962, a person must have resided in one of 4 metropolitan areas: Fresno, Los Angeles, Oakland, or Sacramento. Convictions for traffic violations involving the unsafe operation of a motor vehicle and each accident for which the driver is deemed responsible counts one point. Convictions for major offenses, such as reckless driving, drunk driving, hit and run driving, and driving under suspension or revocation count double.

After selection, each driver was randomly assigned to the meeting or control group. Members of the meeting group were sent a notice of a driver improvement meeting while members of the control group were not contacted in any way. The date of the control assignment was recorded for each driver on his last abstract of conviction or accident report.

At the time of the meeting, the driver's response to the DIM notice determined in which of the following categories he was placed:

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TABLE 1

AVERAGE NUMBER OF SUBSEQUENT ACCIDENTS AND CONVICTIONS BY TREATMENT GROUP

Group	Number of Subjects	Average Number of Accidents	Average Number of Convictions
Control	610	0.23	1.07
Meeting, total	1,440	0.24	0.95
Appeared	855	0.26	0.91
Did not appear	512	0.23	1.00
Notices returned	73	0.22	0.96

TABLE 2

AVERAGE NUMBER OF PRIOR ACCIDENTS AND CONVICTIONS BY TREATMENT GROUP

Treatment Group	Number of Subjects	Average Number of Accidents	Average Number of Convictions
Control	610	0.49	3.74
Meeting	1,440	0.36	3.58
Statistical tests		z = 5.13[a]	F = 13.44[a] (df: 1; 2,046)

[a]Significant probability of chance difference less than 1 in 1,000 ($P<0.001$).
Note: For large samples U is distributed as z.

1. Appeared category—subjects who attended the meeting.
2. Non-appeared category—subjects who did not attend and whose notices were not returned.
3. Notice returned category—subjects who did not attend and whose notices were returned by the Post Office, indicating possible change of address, etc.

Categories 1, 2 and 3 represented 59.4 percent, 35.6 percent and 5.1 percent of the meeting group, respectively. In this aspect the sample did not differ significantly from the expected values. Of the 3,666 persons scheduled for the 238 DIM's held during 1962, 59.7 percent attended with 35.0 percent falling in the non-appeared and 5.3 percent in the notice returned categories.

About 14 months after the meeting or control assignment dates, driver records were examined and the pertinent information was coded for analysis (Table 1). Limited clerical time permitted the coding of only random subsamples of 1,440 and 610 cases from the meeting and control samples, respectively. All cases had license number, birth year, sex and marital status coded from the latest application on file. For the meeting group, additional data (such as date and place of hearing) were coded from the group meeting card. In the case of the appeared subjects, these data also consisted of such information as occupation, number of dependents, mileage, use of vehicle and driving experience. For the non-appeared subjects, the additional personal data were unavailable and therefore could not be coded. Since the control group subjects had no group meeting card, their locale was determined and coded from the abstract of conviction containing their control assignment date.

Both number of accidents and countable convictions for the year prior and subsequent to the meeting or control date were recorded for each subject. The number of countable convictions was determined by the number of court abstracts of convictions on file at DMV headquarters that had at least one countable violation. For the prior year, failure to appear stops (FTA's) for countable violations were also coded as convictions; in the subsequent year, however, the FTA's and convictions were counted separately. In the event a subject fails to appear in court as promised at the time of his traffic citation, an FTA is attached to the subject's driver record. FTA citations have a high conviction rate on their eventual adjudication. The date of violation was used to place the conviction in time, but if the violation date was not available, the date 14 days prior to the court action was used. Accidents were measured by the number of accidents reported in the subjects' DMV files, and the accident dates were determined from the reports on file.

During a preliminary analysis of the data, it was determined that there was a difference between the age distributions for the meeting and control groups. (Throughout this study age is defined as the subject's age on his birthday in 1962.) The control group age distribution was then matched to the meeting group's. This was done separately for males and females. After matching, no difference was found between the meeting and control groups on age, sex, locale or marital status. Small but significant differences in the prior driving records of the meeting and control groups were found of using a treatment by sex analysis of variance for convictions, and a Mann-Whitney test for accidents (see Appendix). However, this was attributed to the difference in the starting dates of the prior and subsequent years for the two groups. The control's selection dates were used to determine the interval of the periods, while the meeting dates were used for the meeting group. Because of delays in holding meetings, these two dates could vary as much as 2 or 3 months for subjects selected for the meeting and control group on the same day. For the meeting group, this results in a shifting of the prior and subsequent period forward in time. While not affecting the length of the periods considered, it did allow the meeting groups' prior record to be affected more by regression toward the mean.

What effect (if any) this time shift had on the subsequent driving record is unknown The average number of prior accidents and convictions for the meeting and control groups are given in Table 2.

Although there was considerable overlap, there was also a difference in the months in which the meeting and control groups were selected. It was found, however, that within the groups there were no significant differences in the prior or subsequent records of subjects selected in different months. Therefore, it was concluded the differences in months of selection did not bias the results of the study. A between-groups comparison was not made because of the noncomparability of the prior records for the meeting and control groups.

The major comparisons on each variable (convictions, accidents) are made between the control and the entire meeting group (appeared, non-appeared, and notice returned), rather than comparing persons in the appeared category to the control group. The reasons for this approach are readily apparent when we consider the composition of the control group, and the possible differences among the appeared and control groups other than treatment effects.

In the first place, we assume that if the control group had received a DIM notice, it would have the same proportion of subjects as the meeting group falling in the appeared, non-appeared, and notice returned categories. Also, even if the meetings had no effect, those persons who took the trouble to attend a meeting might differ from persons who did not, in respect to driving behavior. Since they cannot be identified in the control group, comparing only the appeared category from the meeting group to the entire control group might "stack the deck" against one of the groups. The same logic applies for the inclusion of the notice returned group (i.e., as a group, people who cannot be found by the Post Office might very well have different driving records than those who can).

From another standpoint, a comparison of the control group and the entire meeting group is not only scientifically correct but also very practical. If one were trying to

decide whether to continue or terminate the DIM program in its present form, it would be important to know the overall effect of the program. In other words, one would want to know whether the entire process of sending out notices and conducting meetings reduced accidents and violations[1]. It would not be enough to know that accidents and violations were reduced for those persons who attended the meetings, if accidents and violations actually increased among persons who received the invitations but did not attend. Because of the importance of this consideration, the primary approach of this study has been to evaluate the DIM program as a whole, rather than to investigate only the effects of the meeting on those who attended. It should be noted, however, that we have made supplementary comparisons of the appeared, non-appeared, and notice returned groups, as well as a comparison of males, females and age groups.

After tabulating the frequency distributions for each subgroup as well as the overall sample, the means (averages) were computed for each group and statistical tests were used to evaluate the significance of the differences found. All null hypotheses assumed no differences among the groups, with significance level at 0.05, unless otherwise noted.

RESULTS

Accidents

Regarding accidents, the only statistically significant difference among all the comparisons was found between the average number of prior accidents for the meeting and control group. However, this was dismissed as an artifact of the previously mentioned "time shift" (Table 2).

As for the subsequent driving performance comparisons, statistical tests indicated that all differences could be attributed to chance (Table 3). Thus, this study cannot provide any evidence that the program as presently conducted results in any overall reduction in accidents.

In order to explore the possibility of the DIM program exerting a differential effect (interaction) on various segments of the population, the samples were broken down by sex (Table 3) and age (Tables 4 and 5). No difference in the program's effectiveness was found between sexes. In fact, for females the mean of accidents for the meeting group, though not statistically significant, is in the wrong direction. In addition, there is no compelling evidence that the DIM program was more effective with one age segment than another (Tables 4 and 6 and Appendix).

An analysis of the meeting group by response categories (appeared, non-appeared, and no contact) only serves to reinforce suspicions as to the ineffectiveness of the program in reducing accidents (Tables 7, 8, and 9). Statistical tests (Kruskal-Wallis) of the differences among the 3 response categories did not detect any significant difference in the number of prior or subsequent accidents for males, females or both sexes combined. All other differences in prior accidents not related to the time shift were

TABLE 3

MEAN (AVERAGE) NUMBER OF SUBSEQUENT ACCIDENTS BY TREATMENT GROUP AND SEX

Sex	Control Group	Meeting Group	Test of Difference Between Groups	Probability of Difference
Total	0.23	0.24	z = 0.06	P > 0.50
Male	0.24	0.24	z = 0.49	P > 0.50
Female	0.17	0.28	z = 1.52	P > 0.10

[1]The authors acknowledge the fact that there may be other practical considerations in the evaluation of the DIM program, such as its fulfillment of a need for administrative justification of subsequent actions based on a series of progressively more forceful departmental contacts.

TABLE 4

MEAN NUMBER OF SUBSEQUENT ACCIDENTS BY AGE AND SEX

Age	Meeting Group		Control Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Male, total	0.240	0.508	0.235	0.462
Under 26	0.271	0.548	0.215	0.442
26-40	0.240	0.493	0.213	0.448
41-60	0.203	0.480	0.313	0.520
Over 60	0.214	0.520	0.235	0.437
Female, total	0.278	0.526	0.171	0.416
Under 26	0.350	0.533	0.235	0.437
26-40	0.197	0.401	0.154	0.464
41-60	0.327	0.647	0.174	0.388
Over 60	0.222	0.667	—	—

TABLE 5

STATISTICAL TESTS OF THE DIFFERENCES IN THE NUMBER OF SUBSEQUENT ACCIDENTS AMONG AGE GROUPS BY SEX AND TREATMENT GROUP

Treatment Group	Male		Female	
	χ^2	Probability	χ^2	Probability
All cases	0.49	$P > 0.50$	4.49	$P > 0.20$
Meeting	2.91	$P > 0.40$	2.99	$P > 0.30$
Control	3.95	$P > 0.25$	1.73	$P > 0.50$

Note: H is distributed as χ^2 for large samples.

TABLE 6

MEAN NUMBER OF PRIOR ACCIDENTS BY AGE AND SEX

Age	Meeting Group		Control Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Male, total	0.354	0.556	0.491	0.592
Under 26	0.351	0.561	0.443	0.559
26-40	0.372	0.576	0.494	0.608
41-60	0.316	0.497	0.545	0.614
Over 60	0.357	0.577	0.529	0.514
Female, total	0.395	0.550	0.500	0.613
Under 26	0.600	0.591	0.412	0.618
26-40	0.262	0.513	0.615	0.637
41-60	0.365	0.525	0.391	0.583
Over 60	0.556	0.527	0.750	0.957

TABLE 7

MEAN NUMBER OF PRIOR ACCIDENTS BY SEX AND TREATMENT GROUP

Treatment Group	Total		Male		Female	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Control group	0.492	0.596	0.491	0.592	0.500	0.631
Meeting, total	0.358	0.555	0.354	0.556	0.395	0.550
Appeared	0.361	0.549	0.362	0.554	0.355	0.517
Non-appeared	0.350	0.550	0.332	0.539	0.533	0.625
Notice returned	0.384	0.659	0.409	0.679	0.143	0.378

TABLE 8

MEAN NUMBER OF SUBSEQUENT ACCIDENTS BY SEX AND TREATMENT GROUP

Treatment Group	Total		Male		Female	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Control group	0.228	0.457	0.235	0.462	0.171	0.416
Meeting, total	0.244	0.510	0.240	0.508	0.278	0.526
Appeared	0.256	0.515	0.248	0.509	0.309	0.554
Non-appeared	0.229	0.509	0.231	0.514	0.200	0.457
Notice returned	0.219	0.449	0.212	0.448	0.286	0.488

TABLE 9

STATISTICAL TESTS OF THE DIFFERENCES IN NUMBER OF ACCIDENTS AMONG RESPONSE CATEGORIES BY SEX

Sex	Prior		Subsequent	
	χ^2	Probability	χ^2	Probability
Total	0.26	$P > 0.50$	1.51	$P > 0.25$
Male	1.08	$P > 0.50$	0.68	$P > 0.50$
Female	4.22	$P > 0.10$	1.50	$P > 0.25$

Note: H is distributed as χ^2 for large samples. Each of the tests in this table has two degrees of freedom.

TABLE 10

MEAN (AVERAGE) NUMBER OF SUBSEQUENT CONVICTIONS BY TREATMENT GROUP

Sex	Total	Meeting	Control
Total	0.98	0.95	1.07
Male	1.02	0.99	1.10
Female	0.70	0.64	0.84

assumed to be random sampling variations. The subsequent accident performance of the appeared group is not significantly superior to the others and furthermore is not even in the proper direction.

Although both the response category and control-meeting comparisons are subject to certain limitations which will be explored in full later, together they present a disappointing picture of the accident-reducing power of the present group program.

Convictions

In contrast to accidents, a significant difference in subsequent convictions was found between the meeting and control groups [meeting vs control (male and female): F = 5.1 (df: 1; 2,046), P < 0.05.]. The appropriate statistical analysis was performed on the conviction data to evaluate treatment effects (meeting vs control), and treatment by sex interaction (see Appendix).

It may be seen from the results of the statistical analysis of the data presented in Table 10 that the meeting group had significantly fewer convictions in the subsequent period than the control group. The treatment by sex interaction was not significant, however, indicating that the DIM program is equally effective with both sexes [sex by treatment interaction: F = 0.33 (df: 2; 2,046) P > 0.50]. The only significant sex difference occurred in the subsequent period and was in favor of the females. This fact, in combination with the lack of any treatment by sex interaction, indicates that females display a greater amount of natural regression than do males, but are affected by the meeting to about the same extent.

The question remained, however, as to whether the group program was differentially effective by age, and this was determined by testing for age by treatment interaction. The interaction was not significant [age by treatment interaction: Males - F = 0.48 (df: 3; 1,810), P > 0.50], indicating that the various male age groups were about equally affected by the group program (Table 11). A parallel analysis was performed for the female age groups, and again no significant age by treatment interaction was found in the subsequent period [age by treatment interaction: Females - F = 0.96 (df: 3; 224), P > 0.25]. The sexes were similar in that neither displayed a treatment by age inter-

TABLE 11

MEAN NUMBER OF SUBSEQUENT CONVICTIONS BY AGE AND SEX

Age	Meeting Group		Control Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Male, total	0.99	1.18	1.10	1.16
Under 26	1.11	1.31	1.20	1.22
26-40	1.03	1.19	1.13	1.16
41-60	0.77	0.97	0.90	1.12
Over 60	0.62	0.85	1.12	1.11
Female, total	0.64	0.91	0.84	0.96
Under 26	0.65	0.98	1.06	1.20
26-40	0.62	0.88	0.77	0.86
41-60	0.56	0.83	0.83	0.94
Over 60	1.11	1.27	0.50	0.56

action. Thus, there is no evidence that the effects of the meeting on convictions are not homogeneous over age. Appropriate tests showed that males over 40 in both the meeting and control groups had consistently fewer convictions than the younger men. Contrary to the males, the driving performance of the females was not differentially affected by age.

As was the case with accidents, an anlysis of the response categories (Tables 12, 13, and 14) indicates that the appeared, non-appeared and notice returned subjects do

TABLE 12

MEAN NUMBER OF PRIOR CONVICTIONS BY SEX AND TREATMENT GROUP

Treatment Group	Total		Male		Female	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Control group	3.74	0.78	3.76	0.78	3.60	0.69
Meeting, total	3.58	1.01	3.59	1.02	3.48	0.95
Appeared	3.57	0.98	3.59	0.98	3.45	0.98
Non-appeared	3.56	1.07	3.57	1.08	3.49	0.89
Notice returned	3.73	1.02	3.71	1.03	3.86	0.90

TABLE 13

MEAN NUMBER OF SUBSEQUENT CONVICTIONS BY SEX AND TREATMENT GROUP

Treatment Group	Total		Male		Female	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Control group	1.07	1.14	1.10	1.16	0.84	0.96
Meeting, total	0.95	1.16	0.99	1.18	0.64	0.91
Appeared	0.91	1.08	0.96	1.11	0.63	0.82
Non-appeared	1.00	1.27	1.03	1.36	0.71	1.14
Notice returned	0.96	1.24	1.03	1.28	0.29	0.49

TABLE 14

STATISTICAL TESTS OF DIFFERENCES IN NUMBER OF CONVICTIONS AMONG RESPONSE CATEGORIES BY SEX

Sex	Degrees of Freedom	Prior		Subsequent	
		F	Probability	F	Probability
Total	(2; 1,437)	0.85	P > 0.25	0.89	P > 0.25
Male	(2; 1,275)	0.55	P > 0.50	0.58	P > 0.50
Female	(2; 159)	0.59	P > 0.50	0.67	P > 0.25

not differ significantly in terms of the number of prior or subsequent convictions on their driving records. As with accidents, all other variation in prior convictions not related to the time shift was attributed to sampling fluctuation. The analysis was broken down by sex, as well as making an overall comparison, because it was felt that differences in the sex distributions might mask any difference within the sexes. It should also be noted that there were also differences in the age distributions among the response categories within sexes. Although subject to certain limitations, the data lead one to question the contribution of the group meeting process toward modifying subsequent driving performance.

CONCLUSIONS

Effectiveness of DIM Program

Any conclusions drawn from the differences between the subsequent records of the meeting and control groups rest on speculations about the nature of differences found in their prior records. The authors assumed that (a) the bias found in favor of the meeting group's prior record did not represent any real difference between the subjects, but was entirely due to the difference in the criteria for the assignment of the meeting and control dates; and (b) the resulting displacement of the subsequent period in time does not favor the meeting or control group. It is the authors' opinion that if the time shift had any effect on subsequent performance it would be very slight and would tend to reduce the number of accidents and convictions for the meeting group. Our reasons for this relate to aspects of the regression-toward-the-mean concept which are beyond the scope of the present discussion. It is also assumed there was no systematic difference in the reporting of accidents or maintenance of records related to the treatments.

In addition, one should use considerable caution in interpreting any of the results, since subsequent to the meeting or control assignment date neither the meeting nor control group received a pure treatment. In other words, since a "hands off" policy was not followed, members of both groups received departmental actions during the subsequent year. An action was imposed after an informal hearing, and it could range from a warning letter to revocation of the subject's license. It is known that the 1,440 members of the meeting group received 85 subsequent actions as compared to 79 for the 610 controls, resulting in 0.06 and 0.13 actions per subject, respectively, for the two groups. Because the controls' subsequent driving records were slightly worse than members of the meeting group, the control's rate should have been only slightly higher than the meeting group's, instead of over twice as high. This is attributable to the fact that, despite instructions to the contrary, the members of the meeting group were allowed to accumulate more negligent operator points before a subsequent informal hearing was scheduled. Collectively, the meeting group received 20.7 points per action, compared to 10.3 for the controls. If the DIM program is better than no treatment at all, this type of differential handling of cases could reduce its apparent effectiveness. Therefore, one cannot evaluate these results in any absolute framework, but only in regard to the DIM's value in the overall driver improvement program. Consequently, the control condition has been viewed by the authors as the treatment the subjects would have received under existing departmental procedures had there been no DIM program.

It was felt that within these assumptions and qualifications, the data support the following conclusions:

1. There is no indication that any reduction in accidents can be attributed to the DIM program.
2. The DIM program is an effective means of reducing traffic convictions among persons who are eligible for the program.
3. With regard to both accidents and convictions, there is no evidence that the DIM program is more effective for one sex or age than another.

The first conclusion is strengthened by the finding that the control group's sample mean for subsequent accidents was actually lower than the mean of the meeting group. A significant reversal of this trend by increased sampling is highly improbable, considering the size of the present sample.

Effects of Attending a Meeting

Although not subject to the previously mentioned time shift qualification, there is a much more serious limitation with respect to the interpretation of the data regarding the meeting group response categories (appeared, non-appeared, and no contact).

There is considerable evidence in the behavioral sciences that persons who voluntarily consent to an imposition tend to differ from persons who do not cooperate. In the present study, this is borne out by the fact that persons who attended the meeting differed significantly—in age, sex, and area of residence—from persons who did not attend. Among members of the appeared category there were proportionally more women, more men over 40, and more persons living in the Los Angeles area than in the rest of the meeting group. These differences tend to favor the appeared category's record, since women of all ages and men over 40, in both the meeting and control groups, had fewer convictions.

Because of this situation it is impossible to determine whether subsequent performance differences (or lack of) are a function of treatment (meeting) effects or pre-existing differences which determined the composition of the groups.

The interpretation of the data is further complicated by the fact that the appeared category received more negligent operator points per subsquent action than the non-appeared and notice returned categories. On the average, persons who attended the meeting were allowed to accumulate 22.0 points, while those who did not attend were allowed to accumulate only 19.1 before an action was taken. Although the difference is not as dramatic as the one between the meeting and control groups, it could possibly suppress differences in subsequent accidents and convictions. This problem may be circumvented, however, through the use of qualifications similar to the ones employed for the previous conclusions, in that the investigators regarded the liberal criteria used for considering actions against people who attended the meeting as an integral part of the meeting-treatment itself. Therefore, our interpretation of the data is restricted by this definition. Considering the foregoing qualifications, and the absence of any significant differences among the response categories, the authors conclude that among persons being sent DIM notices, there is no evidence that attending the meeting results in a better subsequent accident or conviction record.

This conclusion is reinforced by the fact that, while not significantly different, the appeared category's sample means for accidents were consistently higher than those of the non-appeared, and even though the response bias tended to favor the appeared categories, no significant difference in convictions could be detected among the response categories. There is no existing evidence that the female appeared category was favored by a response bias.

Of course, some speculation is involved here because of the previously mentioned response bias factor. In other words, one could argue that the appeared subjects, as a group, are more difficult to rehabilitate than are those who refused to appear. To the authors, such an assertion does not appear tenable, especially in view of the fact that the age and sex breakdown of the groups favored the subjects who appeared.

Unresolved Issues

If the assumptions about the effects of the time lag and the response bias are inaccurate, the interpretation of the data could be changed in either direction. No doubt, the qualifications of the conclusions will leave many readers unsatisfied; some may feel the authors were too conservative and others will hold the opposite view. The investigators have tried to hold the middle ground and believe that they pursued the most fruitful lines in this regard, though it is by no means a closed question. Finally it must be stressed that these conclusions only apply to the DIM program as it was administered in California during 1962, and do not extend to all possible group driver improvment approaches.

If the authors' interpretation of the data is accepted, two pertinent questions are raised by this study:

1. Since there was no apparent difference between the effect of receiving a DIM

notice and attending the meeting, might not the same reduction in convictions result from a warning letter approach?

2. In view of the fact that the DIM program does not appear to reduce accidents, which is the primary goal of the driver improvement concept, should the department modify the present approach or adopt some alternative program(s) in an attempt to achieve this goal?

Recommendations

In order to answer the preceding questions and resolve some of the ambiguities of the present study, the authors recommend that:

1. Further research be conducted in order to determine what type(s) of program(s) might be effective in reducing accidents, as well as convictions, among those persons now scheduled for DIM's; and
2. The research be in the form of a tightly controlled, comprehensive study, comparing the DIM program, other established departmental programs, some new alternatives, and one or more control groups.

This type of research is a necessary adjunct to enlightened decisions regarding the retention and modification of current programs or the adoption of new ones.

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Appendix

SELECTION OF STATISTICAL TECHNIQUES

In view of the studies by Norton (reported by Lindquist, 4) and Boneau (1), it was decided that the use of the usual parametric analysis of variance (F statistic) was appropriate for testing differences in subsequent convictions, despite differences in variances and obviously non-normal (J shaped) distributions. In the case of accidents, however, it was felt that these problems together with the extremely restricted number of observed values recommended the use of non-parametric statistics. The Mann-Whitney and Kruskal-Wallis rank order statistics, corrected for ties, were used to evaluate differences in the number of accidents.

INTERACTION

Interaction is the variation in the relative effect of treatments at different levels of another variable. For example, if the difference between the meeting and control remained the same for males and females, the treatment by sex interaction would be zero. If there were a large change in the difference between the meeting and control groups resulting from the consideration of the males and females separately, the value of the treatment and sex interaction would be large. A 2 by 2 analysis of variance design, incidentally, was employed for the isolation of interactions and main effects. Unequal cell size and the time shift made a comprehensive treatment by sex by period analysis unfeasible.

AGE BY TREATMENT INTERACTION FOR SUBSEQUENT ACCIDENTS

Since nonparametric statistics provide no direct test of the age by treatment interaction, an indirect analysis was attempted, taking advantage of the fact that no overall age differences were found when the meeting and control groups were combined for the means and the results of the Kruskal-Wallis tests. It seemed safe then to assume that, if there were no significant age differences within the meeting and control groups, then no significant interaction existed. No age differences were found within the meeting or control group for either sex. This conclusion was supported by parametric analysis of variance (F test), which showed no significant age by treatment interactions for men or women.