DOT HS-805 099

TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS
Executive Summary

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Contract No. DOT HS-034-3-535
Contract Amt. $1,531,466

May 1979
FINAL REPORT

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

43120

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 805 099		

4. Title and Subtitle	5. Report Date
Tri-Level Study of the Causes of Traffic Accidents: Final Report - Executive Summary	May 30, 1979
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
J.R. Treat, N.S. Tumbas, S.T. McDonald, D. Shinar, R.D. Hume, R.E. Mayer, R.L. Stansifer, N.J. Castellan	DOT-HS-034-3-535-79-TAC(S)
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Institute for Research in Public Safety Indiana University 400 East Seventh Street Bloomington, Indiana 47401	11. Contract or Grant No. DOT-HS-034-3-535
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590	Final Report August 1972 - June 1977
	14. Sponsoring Agency Code

15. Supplementary Notes

This Executive Summary covers Volume I, Causal Factor Tabulations and Assessments; Volume II, Special Analyses; and six additional analysis reports under a contract modification. This summary was prepared by John R. Treat, project director.

16. Abstract

Technical Volume I reports causal factor tabulations from Phases II through V (1972-75). Volume II reports analysis tasks dealing with driver vision, knowledge, psychological make-up, etc. Additional analysis tasks conducted under a contract modification are reported in six separate volumes.

Data were collected on three levels. Police reports and other baseline data on the Monroe County, Indiana study area were collected on Level A. On Level B, teams of technicians responded to accidents at the time of their occurrence to conduct on-scene investigations; a total of 2,258 investigations were conducted during Phases II through V. Concurrently, 420 of these accidents were independently examined by a multidisciplinary team on Level C. General population surveys were also conducted.

Human factors were cited by the in-depth team as probable causes in 92.6% of accidents investigated in Phases II through V. Environmental factors were cited as probable causes in 33.8% of these accidents, while vehicular factors were identified as probable causes in 12.6%. The major human direct causes were improper lookout, excessive speed, inattention, improper evasive action, and internal distraction. Leading environmental causes were view obstructions and slick roads. The major vehicular causes were brake failure, inadequate tread depth, side-to-side brake imbalance, under-inflation, and vehicle-related vision obstructions. Vision (especially poor dynamic visual acuity) and personality (especially poor personal and social adjustment) were found related to accident-involvement. However, as measured in this study, knowledge of the driving task was not shown to be related.

17. Key Words	18. Distribution Statement
Traffic accident causes; driver errors; roadway design, maintenance and signing; vehicle defects, maintenance and inspection; driver vision; driver knowledge; multidisciplinary crash research.	Availability is unlimited. Documents may be released to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	78	

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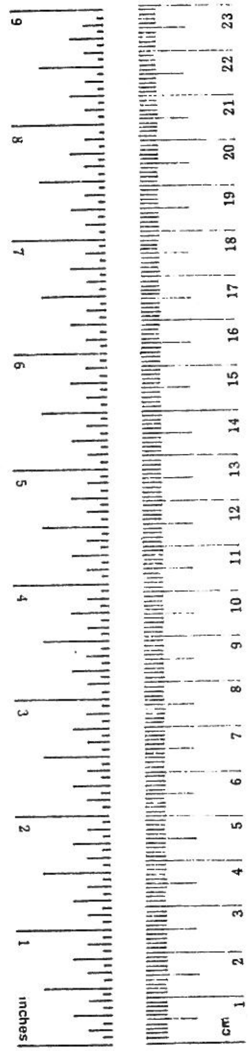
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

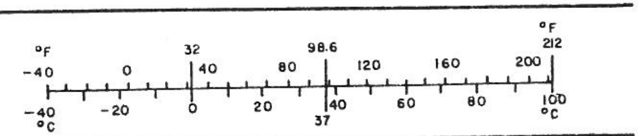
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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

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



Approximate Conversions from Metric Measures

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



TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS: FINAL REPORT

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[1] Mr. Kent B. Joscelyn served as co-principal investigator, along with Mr. Treat, from the project's inception in 1972 through mid-1975.

ACKNOWLEDGEMENTS

The project staff wish to acknowledge the support and guidance provided by the Director and staff of the National Highway Traffic Safety Administration's National Center for Statistics and Analysis, which was responsible for this research. We are particularly appreciative of the assistance provided by Mr. James C. Fell, the Contract Technical Manager, and Mr. J. Vernon Roberts, his predecessor. At yet an earlier stage in the project this role was filled by Mr. John M. Keryeski, now of the National Transportation Safety Board, who was also most helpful. Our thanks also to Mr. Kent B. Joscelyn, who served as co-principal investigator from 1972 to mid-1975.

Special thanks are extended to the Monroe County law enforcement agencies, whose daily cooperation was necessary in permitting our investigators to collect data at accident scenes, to utilize police radio frequencies, to acquire copies of police accident reports, and to acquire information from daily police activity logs. These include the Bloomington Police Department, under the direction of Chief Carl L. Chambers; the Monroe County Sheriff's Department, under the direction of Sheriff William H. Brown and his predecessor, Sheriff Clifford R. Thrasher; the Indiana State Police, under Superintendents Robert L. DeBard and Robert K. Konkle, and Post Commander Lt. Forest V. Cooper; and the Indiana University Safety Division, under George E. Huntington, Director.

Aside from access to accident scenes and vehicles, nothing was more critical than access to the persons involved in accidents, which brought our investigators in frequent contact with the Bloomington Hosptial and Indiana University Health Center, and in need of their support. Such cooperation was very willingly provided, and we are indebted to the doctors, nurses, and staffs of both of these facilities. At the Bloomington Hospital, special thanks go to Mr. Roland E. Kohr, Administrator; Dr. Robert M. Walker, M.D., head of the emergency room; and Mrs. Debra D. Jerden, R.N., emergency room supervisor.

This Executive Summary was prepared by John R. Treat, project director, with clerical assistance from Ms. Judy Deckard and Ms. Joni Shepherd. This summary was requested by NHTSA in 1979 to make information from the technical volumes more readily available. Its preparation was supported by the Indiana University School of Public and Environmental Affairs (SPEA). Authors of the Technical Volumes were John R. Treat, Nicholas S. Tumbas, Stephen T. McDonald, David Shinar, Rex D. Hume, Richard E. Mayer, Rickey L. Stansifer and N. John Castellan.

CAPSULE SUMMARY

1. Human Factors were cited most frequently as accident causes, followed by environmental and vehicle factors respectively (probable cause results: human factors, 93%; environmental factors, 34%; vehicle factors, 13%).

2. The leading human direct causes were: improper lookout (probable cause in 23% of accidents), excessive speed (17%), inattention (15%), improper evasive action (13%), and internal distraction (9%).

3. The leading environmental factors were: view obstructions (probable cause in 12% of accidents), slick roads (10%), transient hazards (5%), design problems (5%), and control hindrances (4%).

4. Brake systems and tires/wheels were probable causes in 5% and 4% of accidents, respectively; these were the most frequently involved vehicle systems. The specific factors most frequently involved were: gross brake failure (probable cause in 3% of accidents), inadequate tread depth (3%), side-to-side brake imbalance (2%), underinflation of tires (1%), vehicle-related vision obstructions (1%), excessive steering free play (<1%), inoperable lights and signals (<1%), and door came open pre-crash (<1%).

5. Driver vision (especially poor dynamic visual equity) and personality (especially poor personal and social adjustment) were shown to be related to accident involvement. However, knowledge of the driving task was not shown to be related.

6. Other topics dealt with in the report include: cluster and automatic interaction detector analyses of accident data, motorcycle accident analysis, driver characteristics as they relate to vehicle condition and causation, reliability of police-reported accident data, and representativeness of study data. An assessment of the benefits of radar and anti-lock braking was covered in a prior report (Interim Report II, Volume II).

TABLE OF CONTENTS

1.0 INTRODUCTION

This is the Executive Summary of the final report for the "Tri-Level Study of the Causes of Traffic Accidents," performed by the Institute for Research in Public Safety (IRPS) of the Indiana University School of Public and Environmental Affairs. The study was performed for the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation, under Contract No. DOT-HS-034-3-535. The period of performance was from 15 August 1972 to 30 June 1977,[1] which covers IRPS data collection Phases III, IV, and V. Phase II data, acquired under a previous NHTSA contract, are also reported. Phase I data appear in a previous report (see Section 1.2).

1.1 Research Objectives

The study was conducted to satisfy a broad range of NHTSA's needs for up-to-date data regarding traffic accident causation. Specific objectives included the following:

1. Identify those factors which are present and serve to initiate or influence the sequence of events resulting in a motor vehicle accident (Vol. I).

2. Determine the relative frequency of these factors and their causal contribution within a defined accident and driving population (Vol. I).

3. Assess the error/accident relationship as a function of driver age, driving knowledge, vision, driving experience, and vehicle familiarity (Vol. II).

4. Apply taxonomy development and group-identification concepts to the identification and definition of problem driver types, and from this to formulate recommendations for dealing with particular classes of drivers (Vol. II).

5. Assess the potential benefit of radar and anti-lock braking systems in reducing the incidence and severity of automobile accidents (See Interim Report II, Vol. II).

6. Develop new methodologies for assessing the role of human factors in accident causation (Vol. II).

1.2 Description of Project Reports

The final report is comprised of two technical volumes. Volume I reports causal factor tabulations and assessments, while Volume II reports several special analyses based on project data. Six additional analysis reports were subsequently prepared under a contract extension.

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[1] Phase V ended 30 September 1975. The contract was extended to June, 1977 for supplemental analysis tasks, which have been separately reported. The present Executive Summary has been prepared as a public service by Indiana University.

This Executive Summary capsulizes the following eight reports of the Tri-Level Study of the Causes of Traffic Accidents:

- Final Report Volume I: Causal Factor Tabulations and Assessments, 1977;
- 38024 Final Report Volume II: Special Analyses, 1977;
- Analysis Report 1: Analysis of Potential Benefits of Various Improvements in Vehicle Systems in Preventing Accidents or Reducing Their Severity, 1979;
- Analysis Report 2: Analysis of Driver and Vehicle Characteristics Related to Vehicle Condition and Causation; and an Assessment of Indiana PMVI Effectiveness in Reducing the Frequency and Severity of Accidents Caused by Vehicle-Related Malfunctions and Degradations, 1979; 43250
- 43251 Analysis Report 3: Analysis of the Validity of Police-Reported Accident Data, 1979;
- Analysis Report 4: Analysis of the Relationships Between Driver Characteristics and Accident Causation, 1979;
- Analysis Report 5: An Examination of the Characteristics and Collision-Producing Eerors of Accidents and Traffic Violation Repeaters, 1979; and,
- Analysis Report 6: Supplemental Causation Assessment Through Hypothesis Testing, 1979.

Several interim reports were also published; in chronological order, these included:

- *Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Vols. I & II.*

  Prepared under Contract No. DOT-HS-034-3-535, August 1973, DOT Report Nos. HS-801 and HS-801-335. This was a final report of the first year of activity under a planned three-year program. It provided causal factor tabulations for Phase III, as well as cumulative results for Phases II and III (2).

- *Tri-Level Study of the Causes of Traffic Accidents: Interim Report II, Volumes I & II.*

  Prepared under Contract No. DOT-HS-034-3-535. Volume I dated August, 1974; Volume II dated December, 1974 (Nos. HS-801-968 and HS-801-631). These were final reports of the second year of activity. Volume I provided a report of causal result tabulations and trends, while Volume II reported assessments of the potential payoff of radar warning, radar actuated, and anti-lock braking systems in preventing accidents or reducing their severity. Causal result data in Volume I included both Phase IV and cumulative Phase II, III, IV data (3).

Prior to the present study, IRPS was engaged in a related tri-level study under NHTSA sponsorship, entitled "A Study to Determine the Relationship Between Vehicle Defects and Crashes" (DOT-HS-034-2-263). In chronological order, relevant documents from that study were:

- *Interim Report of A Study to Determine the Relationship Between Vehicle Defects and Crashes: Methodology.*

  Prepared under Contract No. DOT-HS-034-2-263, November, 1971. DOT Report No. DOT-HS-800-661. Provides details of tri-level methodology. This document was produced during Phase I (4).

- *Results of a study to Determine the Relationship Between Vehicle Defects and Crashes, Vols. I & II.*

  Prepared under Contract No. DOT-HS-034-2-263, November, 1972. DOT Report Nos. DOT-HS-800-850 and 851. Provided results from data collection Phases I and II (1).

1.3 Status of Accident Investigation and Data Collection Activities

The tri-level methodology involved baseline data collection on Level A, on-site investigations by technicians on Level B, and in-depth investigations by a multidisciplinary team on Level C.

During Phase V IRPS continued to build both baseline and accident data files. Baseline data includes information describing Monroe County accidents reported to the state (location, date, etc.), drivers licensed in Monroe County (age, sex, vision as measured by the dynamic vision tester, etc.), vehicles registered in Monroe County (make, model, year, etc.), and Monroe County roadways (miles of surfaced and unsurfaced roads, etc.) (see Table 1-1).

Throughout Phase V, twenty-four hour per day coverage was maintained on Level B, permitting a sizeable increase in the accident data files. An additional 894 on-site (Level B) and 102 in-depth (Level C) investigations were conducted, bringing the total for the three-year period to 1,728 on-site and 269 in-depth. These data are generally compatible with those collected during Phase II (530 on-site, 151 in-depth) providing a total base of 2,258 on-site and 420 in-depth accidents readily available for analysis. Also during Phase V, information was acquired on all 3,068 Monroe County accidents reported to the state during this period, bringing the total number of state accident reports for the Phase II-V period to 13,568 (Table 1-2).

Procedures employed in collecting data and in making causation assessments are described in Appendix A of this volume.

Table 1-1

Summary of Baseline Data Collected by IRPS

Phase	File Name	File Description	Data Collection Period (source)	No. of Sampling Units	No. of Variables	Sampling Technique
PHASE II	PH2E30	Age and sex of Monroe Co. licensed drivers	May, 1972 (1971 driver's license applications)	1,061	3	Systematic sampling from a list
	ISP71	Monroe Co. Police reported accident data	April, 1972 (ISP)	3,914	56	Entire population
PHASE III	PH3E30	Age and sex of Monroe Co licensed drivers	May, 1973 (1972 driver's license applications)	1,000	3	Systematic sampling from a list
	PH3E31	Make & model year of Monroe Co. passenger vehicles	June, 1973 (1973 Monroe Co. passenger vehicle registrations)	2,000	2	Systematic sampling from a list
	PH3E09	Monroe Co. driver-vehicle characteristics	29 April, 1973 to 3 June, 1973 (Monroe Co. drivers)	300	43	Quota sampling (stratified by age and sex)
	ISP72	Monroe Co. police reported accident data	April, 1973 (ISP)	3,272	56	Entire population
PHASE IV	PH4E30	Age and sex of Monroe Co. licensed drivers	April, 1974 (1973 driver's license applications)	980	10	Systematic sampling from a list
	PH4E60	Monroe Co. licensed driver vision	8 April, 1974 to 8 July, 1974 (Monroe Co. licensed drivers)	149	70	Quota sampling (stratified by age and sex)
	PH4E61	Monroe Co. licensed driver vision test-retest	8 April, 1974 to 8 July, 1974 (Monroe Co licensed drivers)	51	112	Quota sampling (stratified by age and sex)
	PH4E62	Monroe Co. licensed drivers	August, 1974 (Indiana BMV)	63,000	16	Entire population
	PH4E63	Monroe Co. registered vehicles	June, 1974 (Indiana BMV)	33,921	35	Entire population
	ISP73	Monroe Co. police reported accident data	April, 1974 (ISP)	3,314	56	Entire population
PHASE V	PH5E30	Age and sex of Monroe Co. licensed drivers	July, 1975 (1974 driver's license applications)	2,081	18	Systematic sampling from a list
	ISP74	Monroe Co. police reported accident data	April, 1975 (ISP)	3,068	56	Entire population

Table 1-2

Summary of Accidents Investigated by IRPS Using Tri-Level Methodology

Data Collection Phases & Dates	Police Reports (Level A)	On-Site (Level B)	In-Depth (Level C)
I—10/70-5/71	3458 in 1970	469	68
II—6/71-5/72	3914 in 1971	530	151
III—6/72-5/73	3272 in 1972	306	64
IV—6/73-5/74	3314 in 1973	528	103
V—6/74-5/75	3068 in 1974	894	102
Combined Phases[1] II, III, IV, V	13,568	2258	420

[1] Phases II, III, IV, and V were assessed using the same causal assessment scheme, and are presented both separately and cumulatively. Phase I differed somewhat and, for the most part, is not reported herein.

2.0 CAUSAL RESULT TABULATIONS

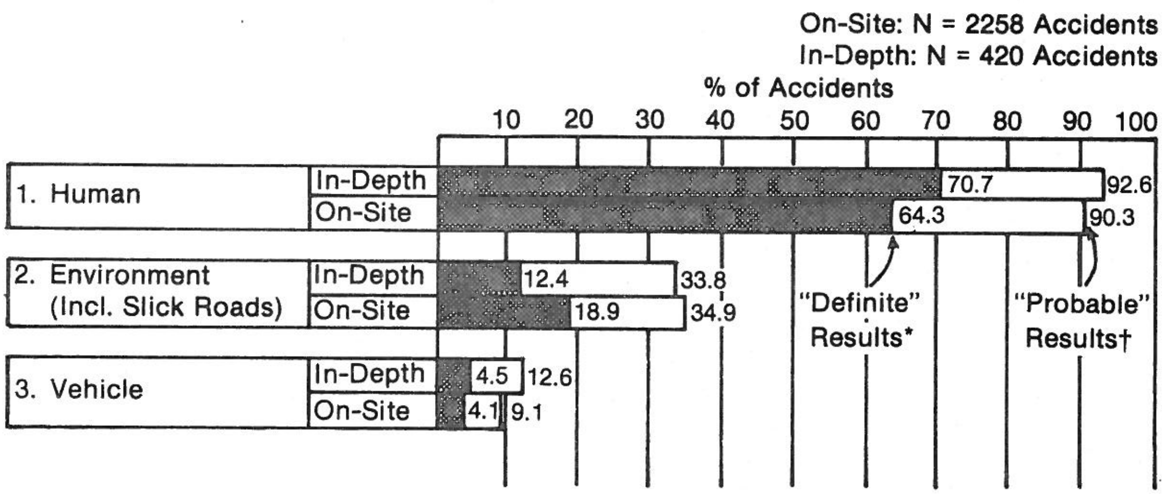
2.1 Overall Human, Environmental and Vehicular Results

Overall results of the study are shown in Figure 2-1. These data for Phases II-V are taken from the "detailed data tables" which comprise Appendix A of Volume I. Note that the darkened portions labeled "definite" results are taken from the "causal-certain" cells of the detailed data tables, while the "probable" results are taken from the "certain or probable, causal or severity-increasing" cells of the same tables. For each factor, the results from both the on-site/technician (Level B) and in-depth (Level C) investigation levels are shown.

Data from an additional certainty level, labeled the "possible" cause level, may also be obtained from Appendix A of Volume I, although not included in these figures.

Figure 2-1

Percentage of Combined Phase II, III, IV, & V Accidents Caused by Human, Vehicular, and Environmental Factors



It may be seen from Figure 2-1 that human factors were more frequently involved as accident causes than either environmental or vehicular factors, which ranked second and third, respectively. In the cumulative Phase II/III/IV/V results, human factors were identified by the in-depth team as "definite causes" of 70.7% of accidents, and of 64.3% by the on-site team. At the "probable level," these figures become 92.6% (in-depth) and 90.3% (on-site). Thus, conservatively stated, the study indicates human errors and deficiencies were a cause in at least 64% of accidents, and were probably causes in about 90-93% of accidents investigated. In the detailed data tables (Appendices A and B of Volume I), results from a third and more speculative level, designated the "possible cause" level, may be obtained. These results, based on the "certain, probable, or possible--causal or severity-increasing" cell, indicate that human factors were possibly a cause in up to 97.9% of accidents investigated by the in-depth team, and 95.3% on-site (Appendix A, page A-1). Thus, the in-depth team was confident that drivers were totally non-responsible in only about 2% of accidents, and the on-site teams were similarly confident in about 5% of accidents.

Environmental factors of all kinds, including slick roads, are shown by Figure 2-1 to have been definite causes in 12.4% of accidents investigated by the in-depth team, and 18.9% of those investigated by on-site teams. Considering probable results, these figures become 33.8 and 34.9, respectively. "Possible" results were 46.0% in-depth and 44.2% on-site, indicating that environmental factors were possibly involved as causes in up to nearly one-half of accidents investigated (Appendix A, page A-32).

As shown by Figure 2-1, vehicular factors were identified as definite causes of 4.5% of accidents by the in-depth team, and 4.1% by the on-site team. Probable cause results were 12.6% and 9.1%, respectively. Possible cause results from the detailed data tables indicate that vehicular factors may have been causes in up to 25.2% of accidents in-depth and 14.7% on-site. Thus, both in-depth and on-site results are fairly consistent in indicating that vehicular failures and degradations definitely were causes of at least 4 to 5% of accidents, and may possibly have been causally-involved in 15-25% of accidents investigated.

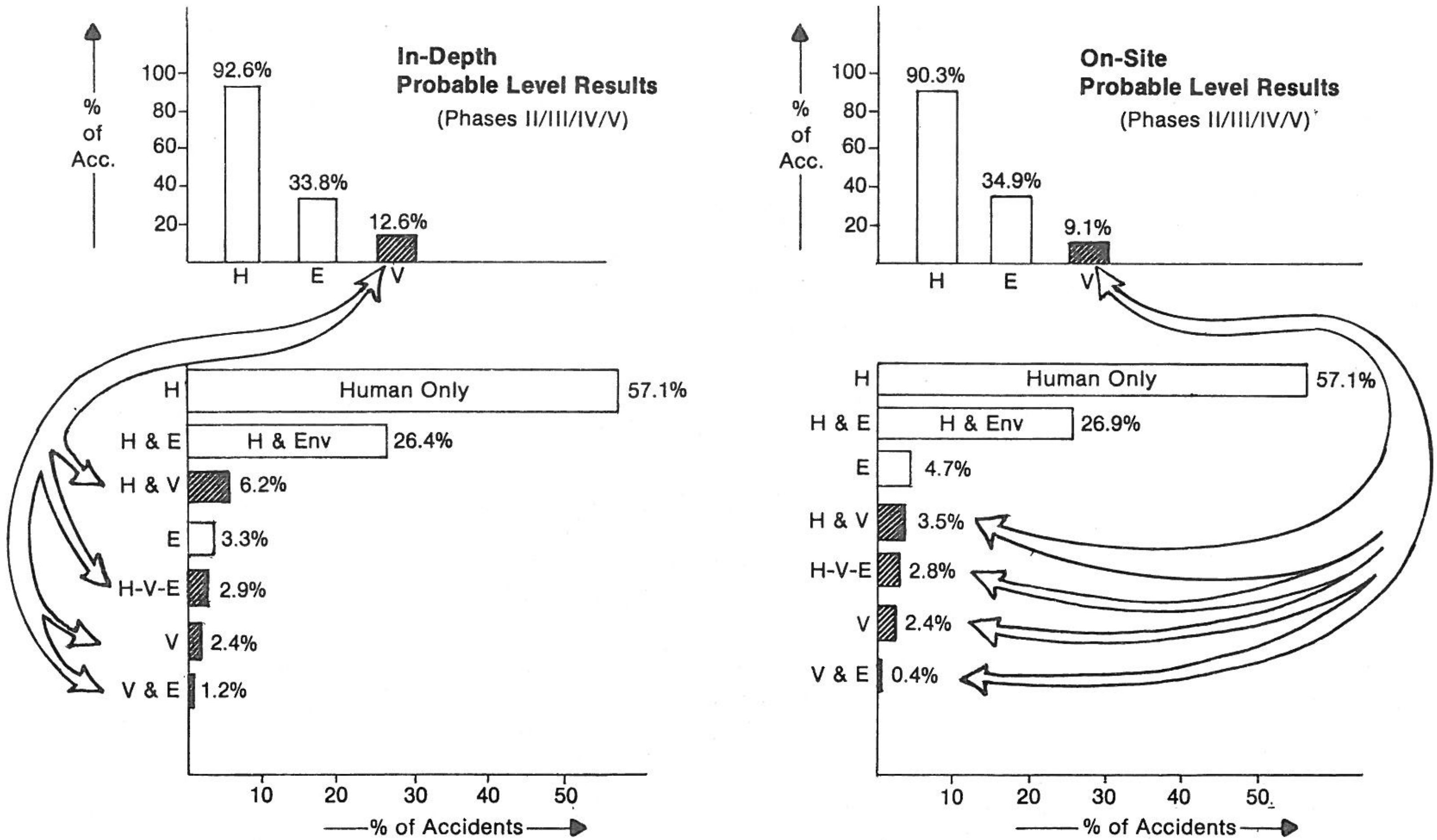
2.2 Causal Results: Alternate Format

Figure 2-2 shows the relationship between the portrayal in Figure 2-1 and the alternate presentation format of the present section. Note that as presented in Figure 2-1 the probable results for the human, environmental, and vehicular factors total in excess of 100% for both on-site and in-depth data. This is because, as shown in Figure 2-2, there was frequently more than one kind or type of factor involved as a cause in each accident. Thus, using probable level results for comparison, it may be seen from Figure 2-2 that human factors alone were identified as probable causes in 57.1% of accidents investigated by the in-depth team, which means no vehicular or environmental factors were identified as either definite or probable causes in these same accidents; i.e., in these accidents, environmental and vehicular factors were either not identified, or were identified only at the possible level. It may further be seen that both human and environmental factors were identified as definite or probable causes in 26.4% of these in-depth accidents. In these accidents, vehicular factors either were not identified, or were identified only as possible causes. Ranking next in the in-depth (probable level) results were human and vehicular factors, 6.2%; followed by environmental factors, 3.3%; human, vehicular and environmental factors, 2.9%; vehicular factors alone, 2.4%; and combinations of vehicular and environmental factors, 1.2%.

Note that if percentage results from the lower format for each bar containing a vehicular factor are totaled, the sum is the overall in-depth probable level result for vehicular factors of 12.6% of accidents. The same relationship pertains for both human and environmental factors.

Figure 2-2

Comparison of Result Presentation Formats

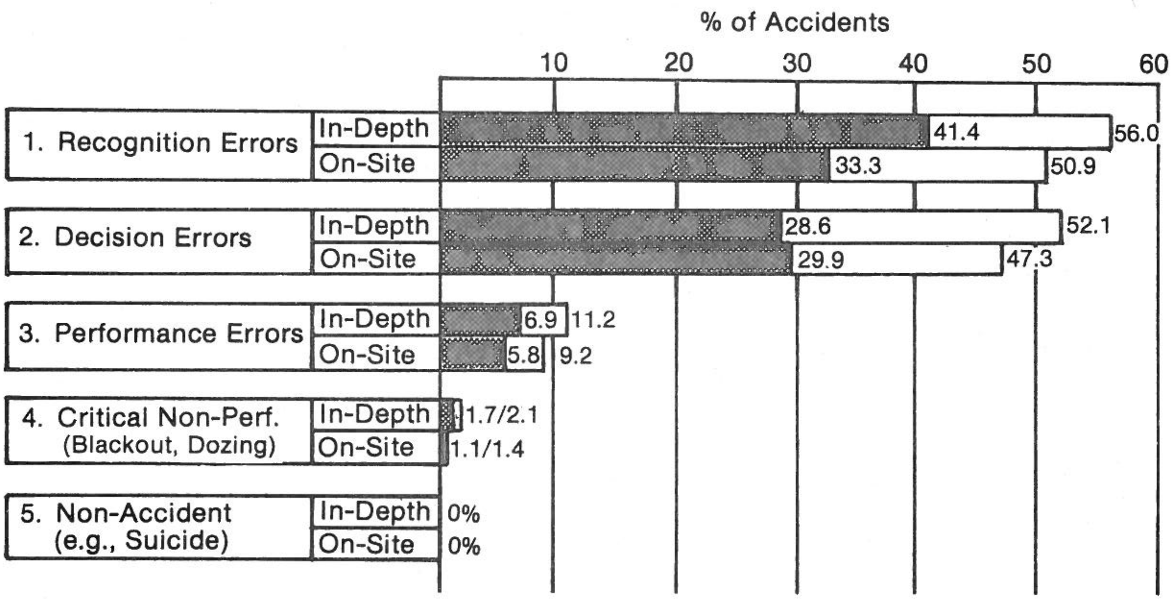


2.3 Human Factors - Direct Causes

Of the five major categories of human direct casues which were defined, recognition and decision errors predominated (Figure 2-3). These categories were ranked as follows: (1) recognition errors (in-depth team definite and probable results of 41.4 and 56.0%, respectively); (2) decision errors (28.6--52.1%); (3) performance errors (6.9--11.2%); (4) critical non-performances (1.7--2.1%); and, (5) non-accident/intentional involvements (none identified).

Figure 2-3

Percentage of Combined Phase II, III, IV, & V Accidents Caused by the Major Human Direct Cause Groups

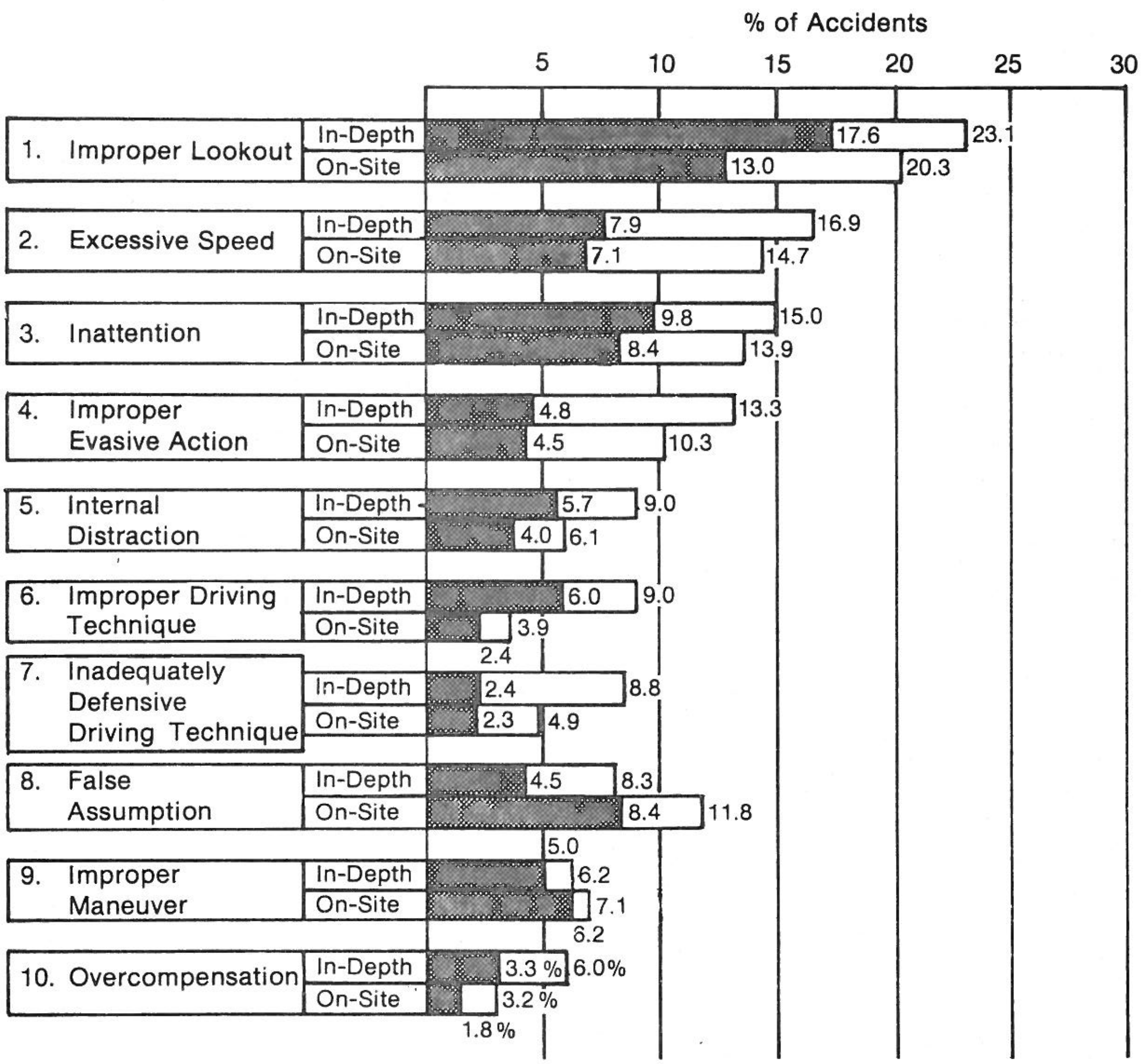


It may be summarized that the human errors and deficiencies which caused accidents primarily involved recognition errors (intended to include both perception and comprehension problems), and decision errors. Less frequently involved but still an important problem were instances where drivers had difficulty in executing actions which they correctly decided were appropriate (performance errors). Only a small portion (less than 3%) of the accidents investigated involved critical non-performances, such as the driver falling asleep or blacking out. Finally, there were no accidents among the 2,258 investigated (Phases II-V) which were identified as being intentionally caused, such as might result from anger or a suicide attempt.

Below the major categories of human direct causes mentioned in the preceding paragraph, a number of more specific human direct cause categories were defined (Figure 2-4). Among these, those most frequently cited as accident causes were: (1) improper lookout (17.6--23.1%); (2) excessive speed (7.9-16.9%); (3) inattention (9.8--15.0%); (4) improper evasive action (4.8--13.3%); and (5) internal distraction (5.7--9.0%).

Figure 2-4

Percentage of Combined Phase II, III, IV, & V Accidents Caused by Specific Human Direct Causes



"Improper lookout" was the leading accident cause identified; nearly one-fourth of all the accidents which IRPS investigated resulted when drivers changed lanes, passed, or pulled out from an intersecting alley, street, or driveway without looking carefully enough for oncoming traffic. More focused examinations indicated that about half of the individuals cited for "improper lookout" had totally failed to make any surveillance effort, while the remainder had looked but failed to see oncoming traffic which should have been visible. Further research is needed to identify the behavioral components and level of attention which comprise a "proper lookout," so that adequate training, licensing, and enforcement measures can be devised. More focused analyses of the interactions with environmental design features can be set to minimize the incidence of "improper lookout." It is significant that for the drivers who "looked but failed to see," approximately 40% faced a view obstruction which added to the difficulty of their surveillance task, even though it was assessed that this difficulty could and should have been easily overcome. Also of significance is the over-involvement of drivers 65 years of age and over in committing "improper lookout"; of drivers over 65 who caused accidents, approximately half had made errors of this kind. Future research should try to identify the relevant mechanisms (e.g., mechanical difficulties in turning the head, reduction in visual field or other visual skills, or changes in field dependence) in order to suggest appropriate countermeasures, such as specialized training programs.

Particularly relevant in considering countermeasures for the "excessive speed" category is the overrepresentation of males and females less than 20 years of age among those cited for this factor (18.1% of males under 20 years of age committed this error, compared to only 10.2% of accident males generally; 8.6% of females under 20 committed this error, compared to 5.2% for accident females, generally.) The interaction with roadway familiarity also merits attention. Most of the excessive speed errors occurred with reference to "road design," primarily in the sense of exceeding the critical speed for a curve and thereby losing control. The motivations underlying risk-taking behavior among young drivers (particularly males), as well as their skills in vehicle handling and judgment of roadway requirements, may require closer examination, and possibly a reevaluation of present driver training programs.

"Inattention" most frequently involved a delay in detecting that traffic ahead was either stopped or decelerating, and less frequently a failure to observe critical road signs and signals. Aside from informing drivers (through public information and driver education programs, etc.) of the importance of attentiveness to the driving task, possible areas of improvement include changes in the size, prominence, or placement of road signs and signals; other environmental changes to reduce the incidence of sudden stops; installation of in-vehicle communication systems, such as radar warning or actuation systems to avoid contact in the rear-end configuration mode; and installation of improved brake lights (e.g., with possible changes in intensity, color, or pulsation characteristics).

Many drivers were cited for "improper evasive action." The two major subcategories of this error involved either failure to attempt an appropriate (and often easily accomplishable) evasive steer, or negation of what would have been a successful evasive steer through over-braking, with a resultant lock-up of the front wheels (rendering the steering input ineffective). Again, a first action should be to inform drivers of the nature and attendant risks of these particular errors. However, further advances would require careful research to determine the most effective means of upgrading the evasive skills of drivers. Perhaps a classroom experience can be beneficial, but it is likely that simulator and actual in-vehicle practice would be required. Four wheel anti-lock braking systems are an effective vehicle-oriented countermeasure for front wheel lock-up through over-braking. Possibly, the relationship between braking pedal displacement and/or force and braking power on existing braking systems might also be improved.

2.4 Human Conditions and States

Human "Conditions and States" were defined as physical, physiological, and experiential factors which adversely affect the ability of a driver as an information processor and vehicle controller. These factors were viewed as "reasons for reasons," the roles of which are not easily identified through the clinical case-by-case assessment process. These categories, which include fatigue, driver experience, and alcohol-impairment, are sufficiently remote in their causal relationship that it is difficult to assess their involvement in an individual accident with any assuredness. However, unusual evidence sometimes does result in such factors being determined to be causally implicated, and in Figure 2-5, the ten most frequently identified conditions or states have been ranked. In addition, the "possible" cause results in the detailed data tables (Volume I, Appendix A), indicate those situations in which an investigator (based on being at the scene, conducting interviews, etc.) suspected that factors such as alcohol impairment or other conditions and states <u>might</u> have been involved.

The most frequently-implicated human condition or state was alcohol-impairment, which the in-depth team assessed as a cause in 0.5-3.1% (definite-probable involvement) of the combined Phase II-V accidents (Figure 2-5). Comparable results from the on-site team, examining a greater number of accidents and with less potential for bias through non-cooperation of impaired drivers, were 2.9--6.1%. Note that accidents investigated represented all severities of police-reported accidents, and are consequently comprised in large measure of either property damage or minor personal injury accidents (approximately 70% were property damage only). Results here should therefore not be confused with those cited for only serious or fatal accidents; alcohol is often cited as being involved in 40 to 50% of these serious accidents. Results for alcohol-impairment varied considerably from phase to phase and as a function of whether accidents were selected from all hours of the day or only from limited periods, and the reader is therefore cautioned to consult Volume I for further clarification.

Possible cause results for the on-site data only are shown in Figure 2-6.

Figure 2-5

Percentage of Combined Phase II, III, IV, & V Accidents Caused by the Major Human Condition or State Subgroups

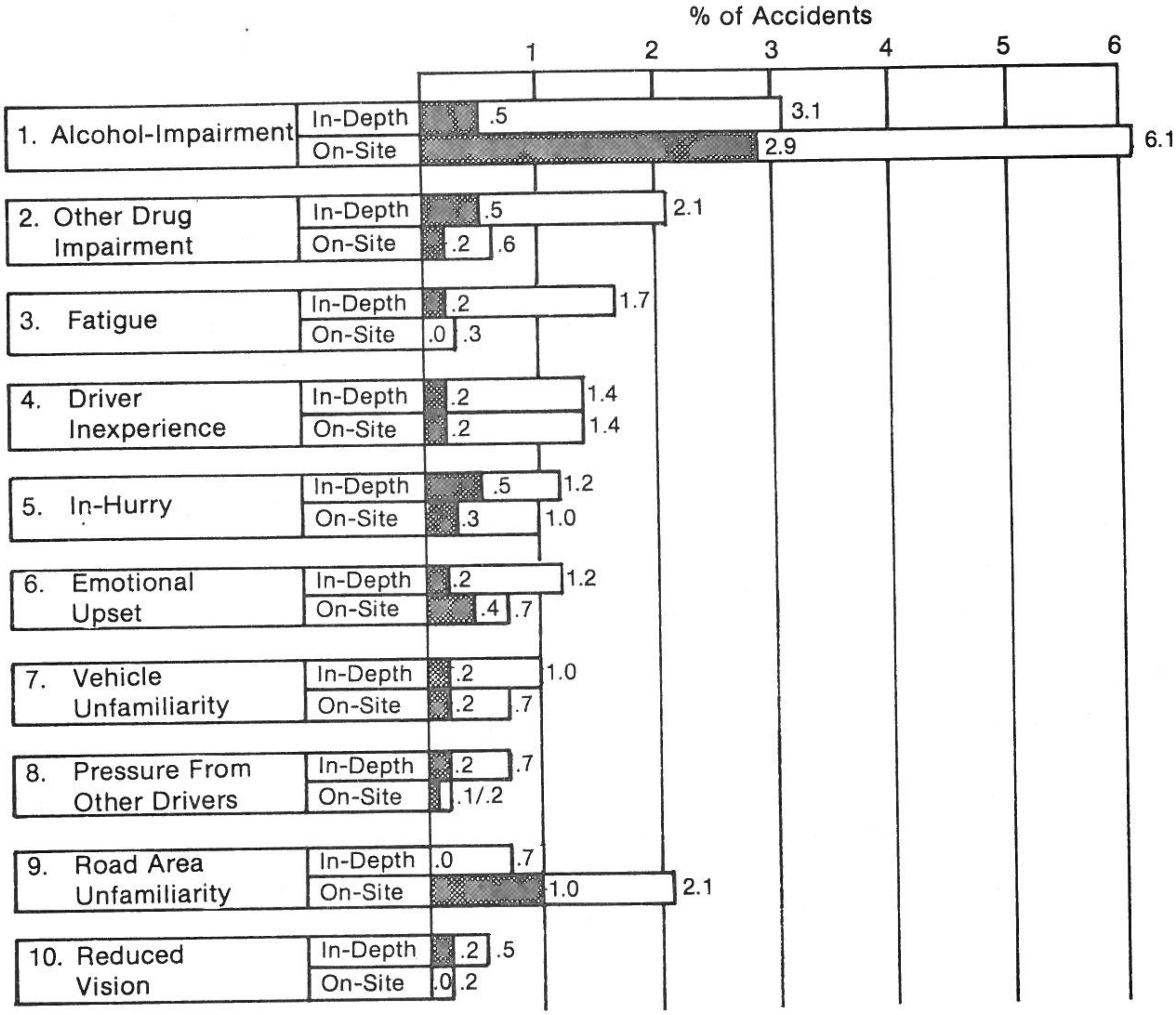
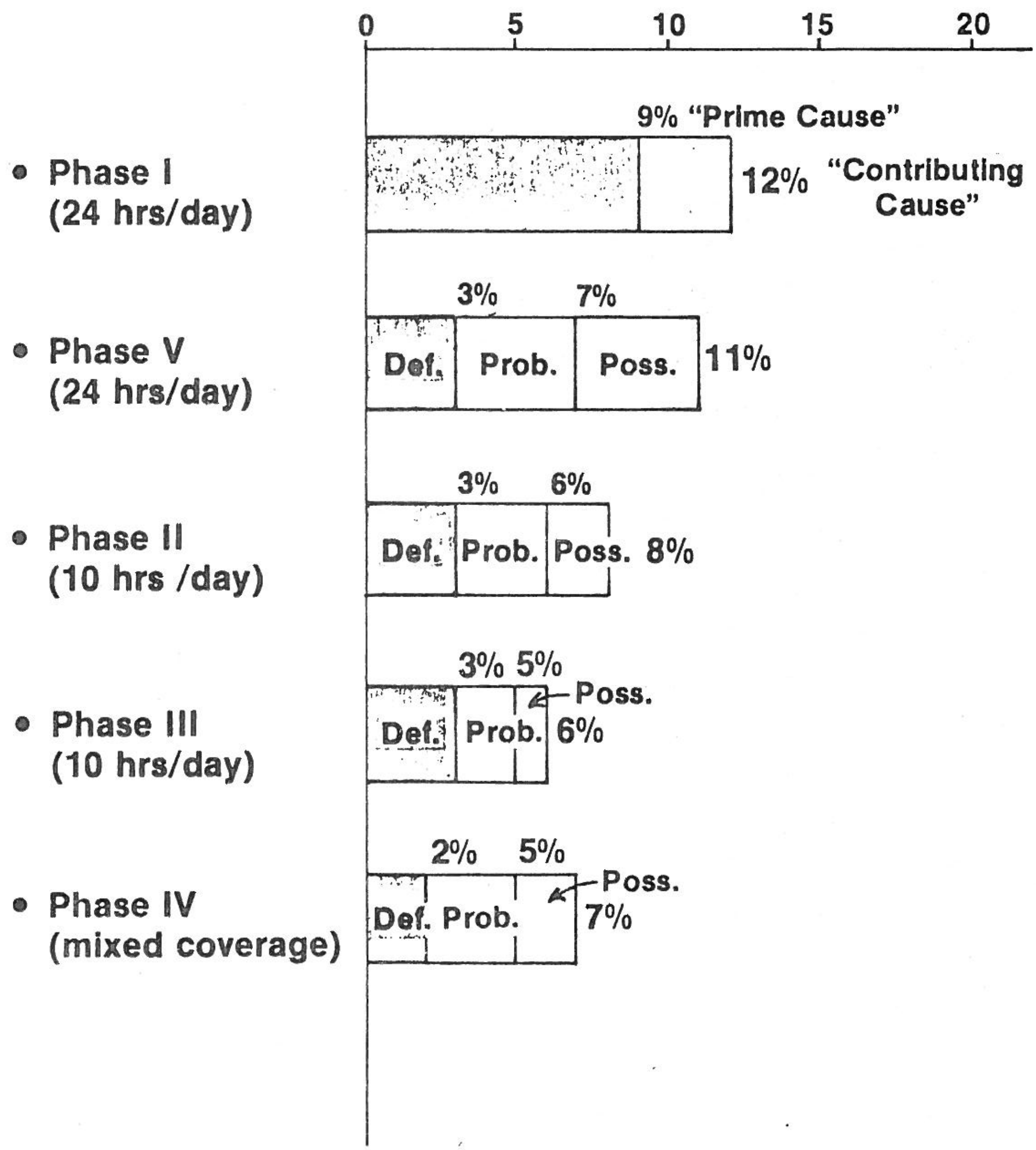


FIGURE 2-6

During Periods of Round-the-Clock Investigation, Alcohol Impairment was a Possible Cause in up to 11-12% of Accidents*



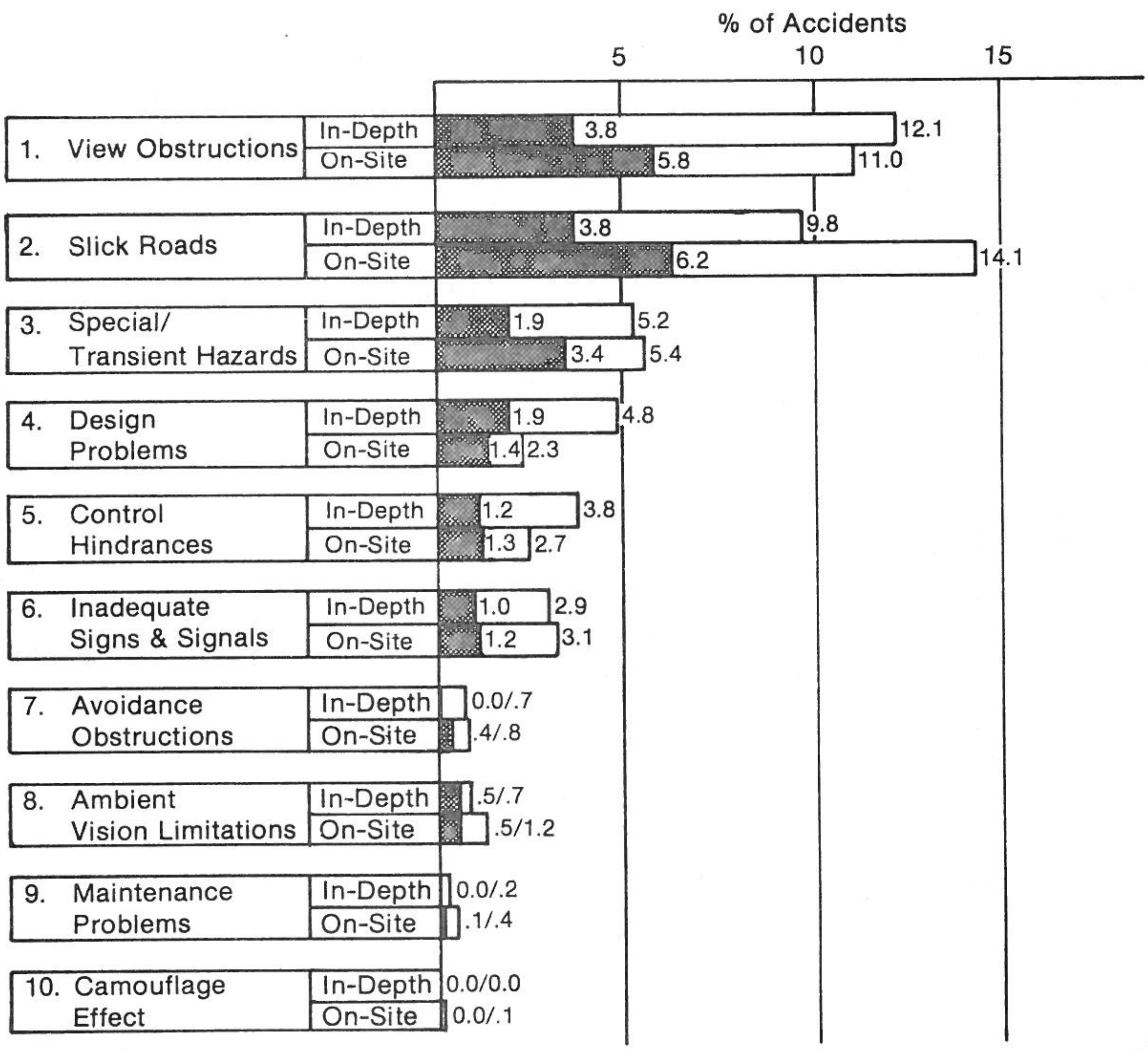
* The majority of these accidents were property damage only.

2.5 Environmental Factors

Roadway, visibility, and other non-driver or vehicle-related factors were defined as environmental factors. As shown in Figure 2-7, the leading environmental factors were: (1) view obstruction (in-depth definite and probable results of 3.8 and 12.1%, respectively); (2) slick roads (3.8--9.8%); (3) transient hazards (1.9--5.2%); (4) design problems (1.9--4.8%); and (5) control hindrances (1.2--3.8%).

Figure 2-7

Percentage of Combined Phase II, III, IV, & V Accidents Caused by Specific Environmental Causal Factors



Environmental improvements, including divided highways and elimination of at-grade intersections, have contributed heavily to the continuing reduction in fatality rates over the past 50 years. Yet the IRPS hierarchy was aimed at assessing the relative importance of various kinds of problems and deficiencies within the current highway system, rather than the benefits of improvements and upgrading beyond a currently acceptable status. In this sense, study results may be more informative to a highway maintenance manager than to a state or federal highway safety planner concerned with determining whether money could best be spent in dividing a highway or putting in an overpass rather than on other countermeasures.

Within this context, the major problems identified were view obstructions (such as trees, shrubbery, or parked cars restricting sight-distances at intersections), and slick roads (a factor which was tallied whenever it was judged that a particular accident would not have happened on dry pavement). Much less frequently involved were maintenance problems (such as missing signs or inoperable signals); control hindrances (such as pavement edge drop-offs); and inadequate signs and signals (e.g., curve warning sign needed but not provided).

Accidents in which "view obstructions" were involved most frequently occurred at regular road/road intersections, generally having stop signs on only two of the legs, and with the erring driver almost always on a controlled leg. The erring driver was often intent on going straight and sometimes on turning left, but was almost never attempting to turn to the right. While some of these view obstructions would be difficult to remove--such as buildings, legally-parked cars, and large embankments --the biggest share (more than half) consisted of trees and bushes, which might more easily be removed--particularly if removal efforts were focused only on intersections which accident records indicated to have high accident rates and/or frequencies. Countermeasures here include local surveys to identify view obstruction problems, and direct appeals to property owners to have such problems corrected. State and civic leaders can also work with business and property owners to assess their own property to ensure that they are not contributing to this important safety problem. Another large share of these view obstructions resulted from parked vehicles, nearly half of which were illegally parked. Hence, installation and enforcement of parking prohibitions serves an important safety function; it is important that law enforcement and the public alike perceive this importance.

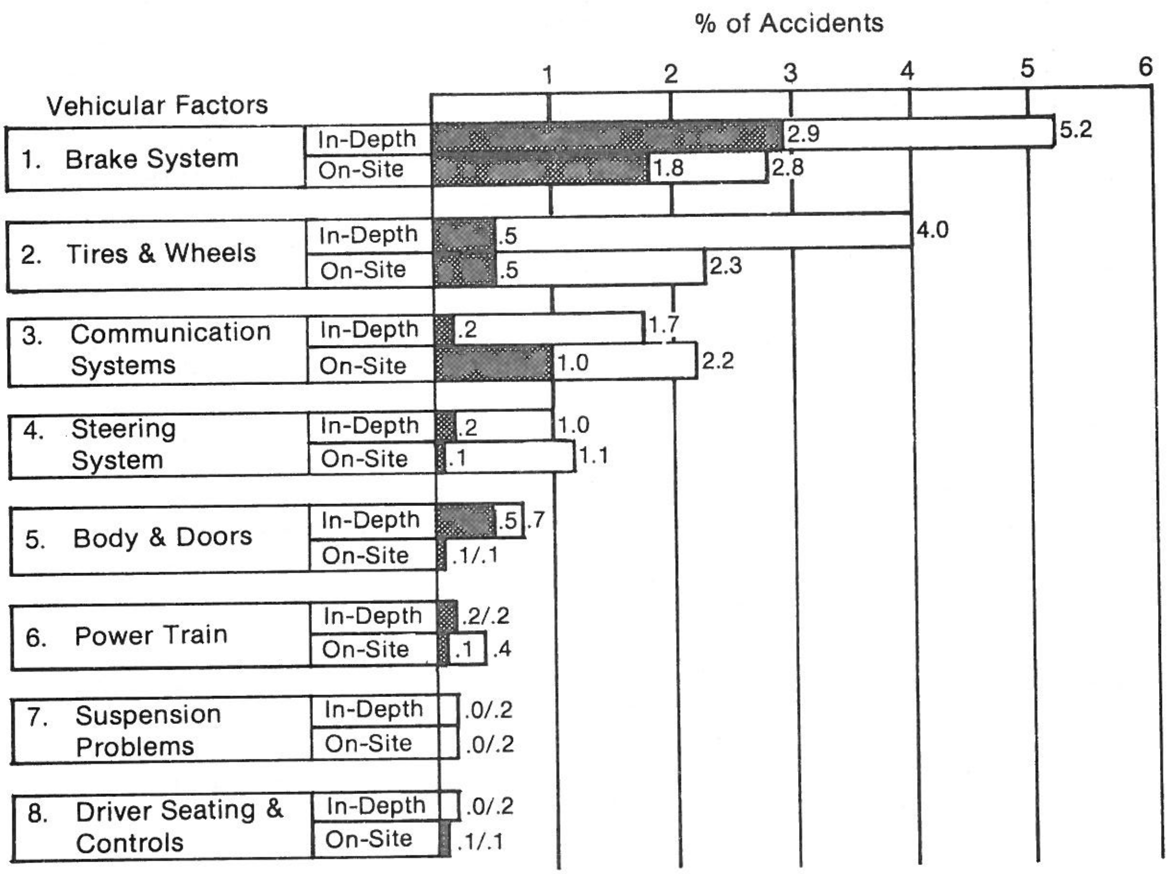
Under the "slick roads" category, rain-slickened roads predominated (possible causal factors in up to 10% of these accidents), while snow or ice covered roads were implicated as causally relevant in up to 4% of these accidents. Interactions with vehicular factors--especially tire tread depth--are evident; vehicle and tire problems were more frequently implicated when the road surface was damp or when precipitation was heavy, with control losses often occurring on curves. In addition to informing and better educating drivers in the safe negotiation of rain, snow and ice-slickened roadways, potential countermeasures lie in the areas of improved road design to eliminate such curves where possible; pavement grooving or other procedures to improve wet road traction, particularly at locations indicated to have a disproportionate number of accidents under wet road conditions; and improved tire design and inspection programs to improve traction on wet, snow, or ice-covered roads. Some research suggests that a major problem with slick roads is that they are not perceived as such by drivers; hence, variable signing systems that provide information on road slipperiness might also be of benefit.

2.6 Vehicular Factors

Vehicular factors were categorized first in terms of the major vehicular systems (Figure 2-8). According to this breakdown, the most frequently implicated categories were: (1) braking system (in-depth team definite and probable results of 2.9% and 5.2% respectively); (2) tires and wheels (0.5% - 4.0%); (3) communications systems (0.2% - 1.7%); (4) steering systems (0.2% - 1.0%); and (5) body and doors (0.5% - 0.7%).

Figure 2-8

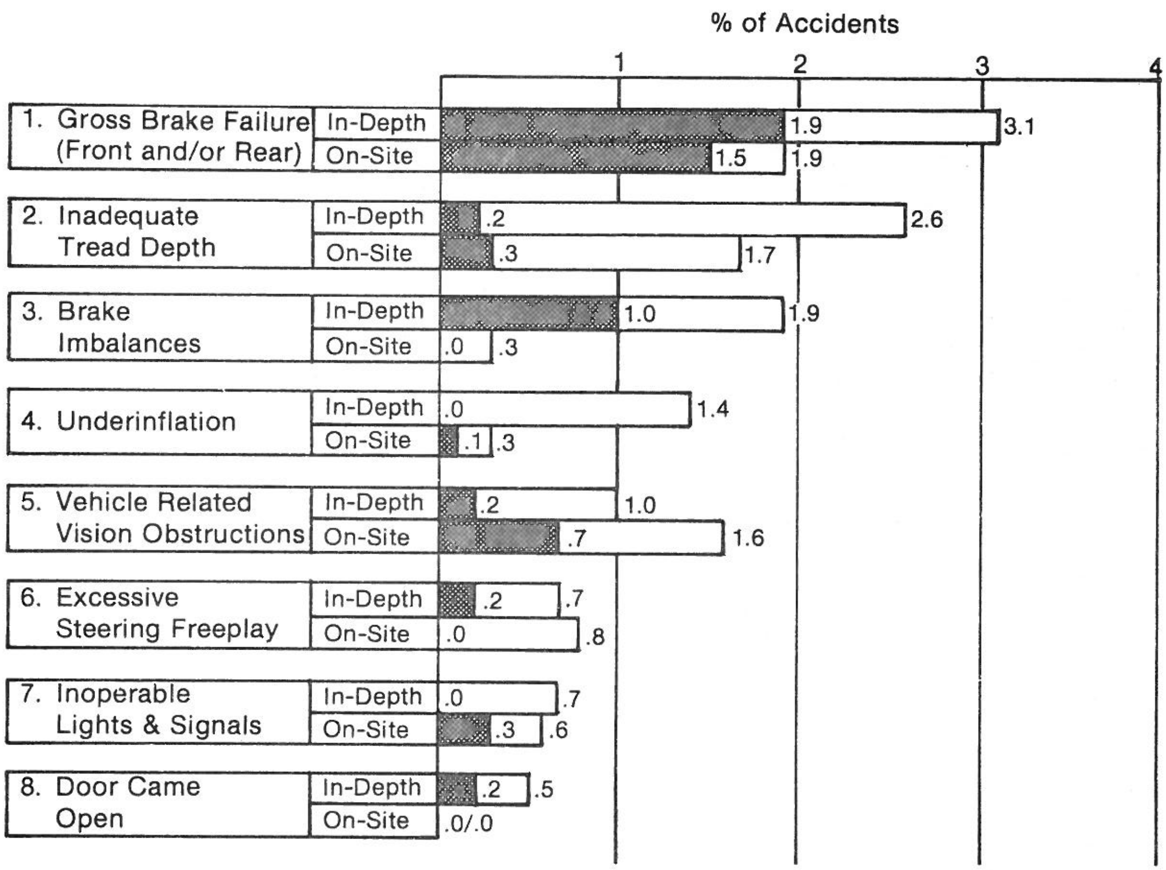
Percentage of Combined Phase II, III, IV, & V Accidents Caused by Deficiencies in Major Vehicular Systems



Assessments were also made for more specific kinds of problems within each major system (Figure 2-9). At this level, the most frequently-implicated vehicular causal factors were: (1) gross brake failure (1.9% - 3.1%); (2) inadequate tread depth (0.2% - 2.6%); (3) side-to-side brake imbalance (1.0% - 1.9%); (4) underinflation (0.0% - 1.4%); and (5) vehicle-related vision obstructions (0.2% - 1.0%).

Figure 2-9

Percentage of Combined Phase II, III, IV, & V Accidents Caused by Specific Vehicular Deficiencies



These vehicular factors were assessed with reference to the current "original equipment" state-of-the-art, and therefore do not directly indicate the safety benefits of possible future improvements, such as four wheel anti-lock braking systems or significantly improved handling characteristics (although Interim Report II, Volume II of this study did deal specifically with radar and anti-lock brakes). These results are, however, directly useful in designing vehicle inspection programs, and for focusing the attention of vehicle owners and others who play a role in vehicle maintenance on the safety critical components and problems.

Results indicate that brake failures, inadequate tread depth, and brake imbalances are the three leading vehicular accident causes. Consequently, these should be priority items in efforts to upgrade vehicle inspection and maintenance programs, and should be emphasized in consumer information/education programs aimed at making vehicle owners more active and knowledgeable participants in maintaining safe vehicle condition. Owners need to know what items are critical to inspect, how they can be checked, and which items require the attention of a qualified mechanic. Following the three priority items, the vehicular factors meriting greatest attention are underinflation, vehicle-related vision obstructions, excessive steering freeplay, inoperable lights and signals, and inoperable door latching mechanisms. (See also Table 2-1.)

Among accident-causing brake system problems, gross failures and side-to-side imbalances predominated. More than half of the components responsible for the causal brake problems observed were contained within the wheels. The failures encountered resulted from such factors as wear and adjustment permitting over-travel of wheel cylinder pistons, and dislodging of the star wheel assembly through improper assembly of self-adjustor mechanisms. Most of these failures occurred in older vehicles having only single chamber master cylinders. Side-to-side imbalances most frequently resulted from metal-to-metal contact, permitted by excessively worn linings, and less frequently from friction material contamination. In order to achieve their accident-reduction potential, inspection programs must be able to detect and objectively evaluate these problems. It is likely that a good visual inspection, such as could be accomplished through wheel pulling, would detect the vast majority of these problems. Alternatively, testing on a dynamic brake tester, or on-road testing from relatively high speeds, are probably superior means of detecting side-to-side imbalances, although they most likely would not detect and permit correction of those in-wheel problems which led to brake failure. Factors external to the wheel which accounted for brake failures included brake hose failures and problems in the master cylinder (e.g., sand in the compensator port, out-of-round primary piston seal).

It was found that 19% of the accident-involved vehicles IRPS inspected on Level C had at least one tire with less than 2/32" of tread, while 10% had at least two tires below this level, 3.5% had three, and 0.7% (five vehicles) had all four tires below this standard. This was true despite Indiana's annual vehicle inspection program, which incorporates a 2/32" tread depth standard. While problems with the inspection program may be partially responsible (it was estimated that 29% of a set of degraded components which IRPS found on accident-involved vehicles were present and should not have passed at the time of the vehicle's last state inspection), normal wear of tires between yearly inspection intervals is a major factor (i.e., a tire which passes today could be below the standard a month or two from now). An alternative would be to increase the inspection standard to some higher figure (perhaps 4/32"), although consumer opposition and increased enforcement difficulties can be anticipated. Alternatively, owners can be at least given a warning if they are below some higher standard (such as 4/32"), possibly with an estimate as to when the 2/32" level will be reached.

Table 2-1

Causal Involvement of Vehicle Factors in Phases II through V

Vehicular Problem	Highest Certainty Level* ("Certain") On-site n	%	In-depth n	%	Probable Level** (Includes "Certain" cases) On-site n	%	In-depth n	%	Possible*** (Includes "Certain" and "Probable") On-site n	%	In-depth n	%
A. All Vehicular Problems	92	4.1	19	4.5	205	9.1	53	12.6	333	14.7	106	25.2
B. Brake System	40	1.8	12	2.9	64	2.8	22	5.2	104	4.6	32	7.6
1. Gross Failure—front and/or rear	34	1.5	8	1.9	43	1.9	13	3.1	58	2.6	15	3.6
2. Delay—pumping required	2	0.1	0	0	9	0.4	1	0.2	15	0.7	2	0.5
3. Side-to-side imbalance	1	0.0	4	1.0	7	0.3	8	1.9	15	0.7	11	2.6
4. Premature lockup or grab	1	0.0	0	0	2	0.1	0	0	4	0.2	1	0.2
5. Performance degraded—other reasons	2	0.1	0	0	3	0.1	1	0.2	12	0.5	5	1.2
C. Tires & Wheels	11	0.5	2	0.5	51	2.3	17	4.0	85	3.8	37	8.8
1. Inflation	2	0.1	0	0	7	0.3	7	1.7	9	0.4	19	4.5
2. Inadequate tread depth	6	0.3	1	0.2	39	1.7	11	2.6	67	3.0	18	4.3
3. Blowout	1	0	0	0	2	0.1	0	0	3	0.1	0	0
4. Mismatch of tire types or sizes	0	0	0	0	0	0	0	0	3	0.1	2	0.5
5. Wheel loss or failure	1	0.0	1	0.2	1	0.0	1	0.2	1	0.0	1	0.2
6. Other problems	2	0.1	0	0	5	0.2	1	0.2	7	0.3	4	1.0
D. Communication Systems	22	1.0	1	0.2	49	2.2	7	1.7	78	3.5	22	5.2
1. Vehicle lights and signals	7	0.3	0	0	14	0.6	3	0.7	23	1.0	13	3.1
2. Vehicular view obstruction	15	0.7	1	0.2	36	1.6	4	1.0	54	2.4	9	2.1
3. Auditory (horn, ambient noise)	0	0	0	0	0	0	0	0	3	0.1	1	0.2
4. Other problems	0	0	0	0	0	0	0	0	0	0	0	0
E. Steering System	3	0.1	1	0.2	25	1.1	4	1.0	47	2.1	15	3.6
1. Excessive freeplay	1	0.0	1	0.2	19	0.8	3	0.7	37	1.6	10	2.4
2. Binding (undue effort required)	0	0	0	0	0	0	1	0.2	1	0.0	1	0.2
3. Freezing/locking	0	0	1	0.0	0	0	1	0.0	3	0.1	1	0.2
4. Other problems	2	0.1	0	0	5	0.2	1	0.2	6	0.3	5	1.2
F Body & Doors	2	0.1	2	0.5	2	0.1	3	0.7	5	0.2	3	0.7
1. Door came open (pre-crash)	1	0.0	1	0.2	1	0.0	2	0.5	3	0.1	2	0.5
2. Hood came open (pre-crash)	1	0.0	1	0.2	1	0.0	1	0.2	1	0.0	1	0.2
3. Other problems	0	0	0	0	0	0	0	0	1	0.0	0	0
G. Power Train & Exhaust	3	0.1	1	0.2	8	0.4	1	0.2	11	0.5	4	1.0
1. Power loss or hesitation	3	0.1	1	0.2	8	0.4	1	0.2	11	0.5	2	0.5
2. Exhaust system	0	0	0	0	0	0	0	0	0	0	2	0.5
3. Other problems	0	0	0	0	0	0	0	0	0	0	0	0
H. Suspension Problems	1	0.0	0	0	5	0.2	1	0.2	11	0.5	6	1.4
1. Shock absorber problems	1	0.0	0	0	4	0.2	0	0	7	0.3	1	0.2
2. Spring problems	0	0	0	0	0	0	0	0	3	0.1	2	0.5
3. Other problems	0	0	0	0	1	0.0	1	0.2	2	0.1	3	0.7
I. Driver Seating & Controls	3	0.1	0	0	3	0.1	1	0.2	11	0.5	3	0.7
1 Driver controls	3	0.1	0	0	3	0.1	1	0.2	10	0.4	3	0.7
2. Driver anthropometric	0	0	0	0	0	0	0	0	1	0.0	0	0
3. Other problems	0	0	0	0	0	0	0	0	0	0	0	0
J Other Vehicle Problems	8	0.4	0	0	13	0.6	0	0	20	0.9	2	0.5

* "Causal-certain"; means to a high degree of assuredness, but for this deficiency, there would have been no accident.

** "Certain or probable, causal or severity-increasing."

*** "Certain probable, or possible, causal or severity-increasing." Represents a fairly speculative judgment that a deficiency was present and *might* have influenced the accident's occurrence or severity.

NOTE: On-site N = 2,258; In-depth N = 420.

Underinflation was primarily implicated as a possible or probable factor contributing to poor vehicle handling in control loss situations. Based on the high incidence of improperly-inflated tires on vehicles IRPS inspected, it appears unlikely that the typical owner engages in routine checks on inflation, or is adequately concerned about the potential influence of improper inflation on vehicle control. In addition to better informing and educating drivers on this subject, vehicle inspection stations can be required to advise owners regarding tire pressure problems, major oil companies and service station operators can be encouraged to actively participate in checking pressures and advising motorists; and visible pressure warning indicators can be installed to inform drivers when inflation problems exist. In addition to safety, energy conservation and tire life benefits can also be stressed. While underinflation can also lead to tire failure, study results indicate that sudden failures (blow-outs) only rarely cause accidents (possibly involved as a cause in only 3 accidents of 2,258 investigated by the on-site teams).

Particular attention should be directed to providing adequate consumer information and education concerning vehicle maintenance. Contemporary concerns regarding consumer fraud may have created an atmosphere of skepticism which may sometimes result in desirable repairs and other maintenance practices not occurring. For example, it is possible that consumers may resist installation of new wheel cylinders and seals when having brakes relined, and mechanics may be reluctant to recommend it. In addition, mechanics may feel compelled to eliminate these items in a relining estimate, in order to assure that their bid is competitive. An informed consumer should be more able to distinguish unnecessary from valid preventative maintenance actions.

In the continued upgrading of vehicle inspection programs, it is necessary not only to key on those systems and components which are responsible for accidents, but to ensure that inspection procedures, and inspector skills and equipment are up to the task through adequate training, licensing, and program monitoring. For example, brake hose or line failure was responsible for several of the brake failures which caused accidents, yet a visual brake hose and line examination is not required in many programs. In some, at least, a high pedal force application is required, which might detect some incipient failures. However, it is believed that a visual examination could detect additional problem cases; those brake hose failures in the IRPS file which resulted from rubbing against an improperly-installed muffler, and from rubbing against a wheel rim during turns, are cited as examples. However, such a requirement implies a need for training as to likely failure points or sources of interference, and to assess degrees of deterioration in lines and hoses. It continues to be true that in many states inspection personnel receive no training whatever, and licensing requirements are often minimal. The inspection activity must also be adequately monitored to ensure that there is accountability on the part of inspectors and inspection stations for their performance. Too often, consumer complaints comprise the major source of information on station performance.

While most of the vehicular problems which caused accidents could have been prevented by "proper maintenance," the possibility of reducing the need for such maintenance through design innovations and improvements must not be overlooked. While failure to perform needed maintenance poses one set of problems (e.g., as when worn linings permit metal-to-metal contact, leading to a brake imbalance), maintenance carries with it the possibility of improper repair or assembly (e.g., as where an improperly-assembled self-adjuster leads to brake loss through over-extension of a wheel-cylinder piston, or where a new and slightly different muffler puts the tailpipe in contact with a brake hose). Desirable improvements might include seals which prevent friction material contamination over extended periods; longer-lasting brake linings and pads; driver warning/information systems to warn drivers and possibly encourage correction of degraded conditions; and component parts (such as brake adjuster mechanisms) which are designed to decrease the likelihood of improper assembly (especially by the growing number of amateur and owner-mechanics).

Based on both on-site and in-depth probable cause data from Phases II through V, it was found that at about the seventh or eighth year of vehicle age, an overinvolvement in accidents resulting from mechanical problems begins (Figure 2-10). The probability of an accident-involved vehicle 8 years of age or older being cited for a causative vehicular problem was more than 2 times greater than for accident-involved vehicles in general.

Vehicle causation problems should continue to be monitored in the future, since the continuous introduction of mechanical innovations will alter the relative involvement of the various problems and systems, requiring a periodic readjustment of inspection items and programs. The dual-chamber master cylinder, in particular, should cause a gradual reduction in the causal involvement of brake failures, which were the predominant vehicle problem in the IRPS data. The advent of disc brakes may also gradually alter these results, particularly as disc brake-equipped vehicles begin to make up a significant proportion of the high mileage/ older vehicle population--which was responsible for a disproportionately large share of vehicle problems in the IRPS data.

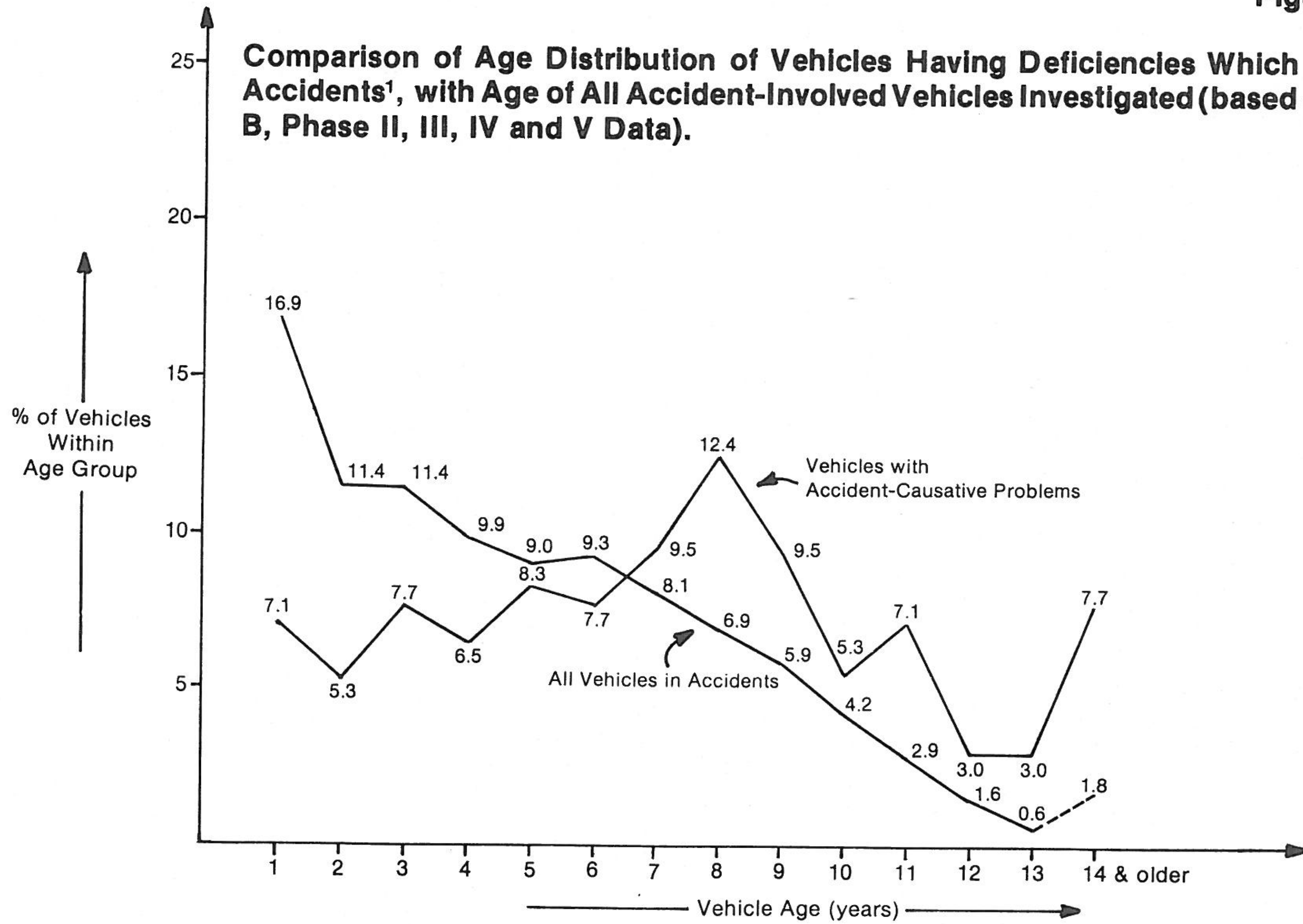
2.7 Accident Severity as a Function of Accident Causation

In this analysis, accidents involving individual causal factors were compared with all accidents investigated, in terms of the proportion involving either property damage (PD only), or personal injury/ fatality (PI/F). Only two causal factors of the many considered were found to be significantly more serious (in overrepresenting the PI/F class) in both the on-site and in-depth data; these were alcohol-impairment and excessive speed (Figure 2-11).

In addition, in the on-site data only, accidents involving control hindrances (an environmental factor including such problems as pavement edge drop-offs) and tire/wheel problems, were significantly more serious. These factors therefore merit increased concern beyond that indicated merely by their frequency of involvement.

Figure 2-10

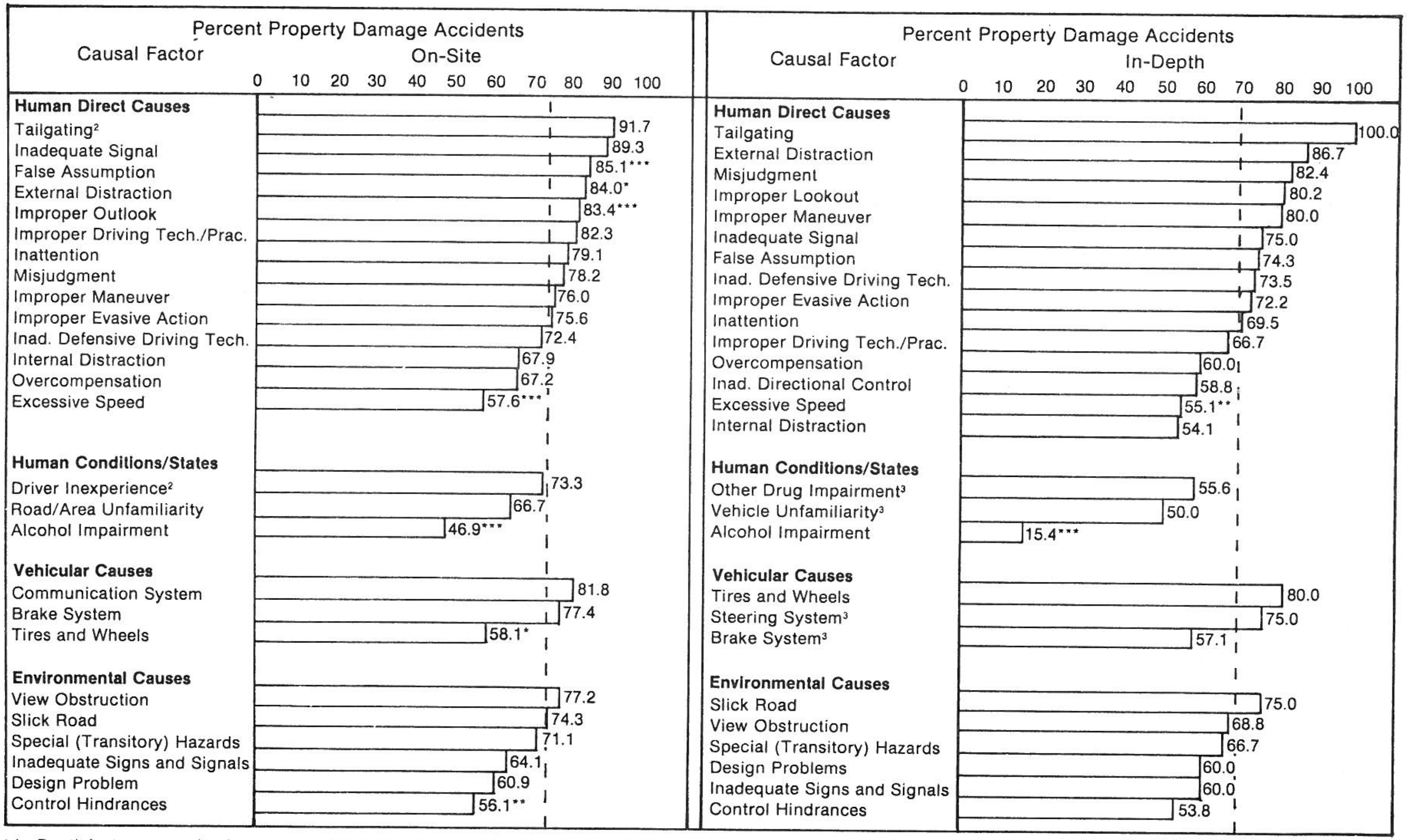
Comparison of Age Distribution of Vehicles Having Deficiencies Which Caused Accidents[1], with Age of All Accident-Involved Vehicles Investigated (based on Level B, Phase II, III, IV and V Data).



[1] "Caused" means that these were accidents in which, for the vehicle in question, vehicular factors were "certain or probable, causal or severity-increasing" factors.

Figure 2-11

Percent Property Damage Accidents for "Frequently Occurring"[1] Causal Factors in Phase II, III, IV and V Investigations



[1] In-Depth factors occurring four or more times in Phases II and III. On-Site factors occurring sixteen or more times in Phases II and III.
[2] N < 40 on On-Site level.
[3] N < 10 on In-Depth level.
[4] Overall percentage of property damage accidents in Phases II, III, IV, V on-site accident sample (73.8%)
[5] Overall percentage of property damage accidents in Phases II, III, IV, V in-depth accident sample (69.1%)

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

Factors associated with less than expected severity (in the sense of significantly underrepresenting the PI/F class of accidents) were false assumption, external distraction, and improper lookout.[1] Note that the last of these--improper lookout--was the study's most frequently implicated causal factor, according to both on-site and in-depth data. Its importance by virtue of frequency of involvement is offset somewhat by its lesser severity. In contrast, the increased severity associated with the second-ranking factor in prevalance--excessive speed--greatly increases its importance.

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[1] Based on on-site data. In the in-depth data, none of the factors significantly underrepresented the PI/F class.

3.0 DRIVER VISION TESTING

A Driver Vision Test (DVT) which is an integrated battery of 12 different driving-related tests, covering such visual skills as acuity for static and dynamic targets, visual field, and dynamic movement detection thresholds, was administered both to drivers who had been involved in accidents and a non-accident control group.

It was found that test/re-test correlations were statistically significant for most of these 12 separate tests, but were adequately high on only three tests: (1) static acuity in normal illumination; (2) static acuity in the presence of spot glare; and (3) dynamic visual acuity.

Given the 30 to 40 minute administration time, the DVT was found unduly time consuming for use in routine driver licensing, in its present configuration. However, investigations were made which suggest that for licensing purposes the DVT could be significantly shortened. For example, results show that all four tests of static foveal acuity correlated highly with most of the measures reflecting movement threshold acuity. Some of these tests may therefore be deleted.

Dynamic Visual Acuity (DVA) was found to be the test which best discriminated between accident at-fault drivers and a control group of non-accident drivers, once the effects of age were controlled for.

In another analysis, drivers who were judged to have committed accident-causing recognition errors were compared with those who had committed other errors, and with those who were involved in accidents but had committed no errors. The drivers who had committed recognition errors scored significantly poorer on the test of static acuity under low levels of illumination, than drivers who had committed no errors (20/88 vs. 20/75). Drivers who had committed "other errors" also scored more poorly than no-error drivers.

A separate analysis was performed examining measures hypothesized to have particular relevance to involvement in either right angle or rear-end collisions. As hypothesized, it was found that increased involvement in right angle collisions was associated with lower sensitivity to peripheral movement in-depth. Less clearly, it appeared that involvement in rear-end collisions increased as the ability to detect angular movement in the central visual field decreased. For those with poor dynamic visual acuity-which by far was the visual ability found to be most consistently related to accidents-there was increased involvement in both right angle and rear-end collisions, with the increase in the rear-end configuation being somewhat greater.

Of the more reliable measures provided by the DVT in its present form, dynamic visual acuity appears to be the only variable which is consistently and significantly related to accident involvement. Static acuity under normal illumination--presently the only visual screening criterion in most licensing tests--was not shown to be causally-related to accidents (with the particular device and procedures used in this study). The importance of most other measures of visual performance (e.g., static acuity under low levels of illumination and peripheral movement in-depth for large targets) cannot be adequately determined before the reliability of these measures is improved.

Results suggest that the DVT is adequate for testing foveal static acuity under normal and glare conditions, but is less than satisfactory in measuring static acuity under low levels of illumination--unless a sufficient dark adaptation period is provided. The DVT does, however, yield a stable measure of dynamic visual acuity and effective visual field.

The present administration and scoring procedures render measures of both central and peripheral movement detection too unreliable to be useful; accordingly, improvements are required in these areas.

For licensing purposes, the DVT requires too much time in its present configuation, and the equipment is excessively bulky as compared to devices presently in use. It is recommended that improvements can be made in both respects by retaining only tests found to be definitely related to driving ability, and which are independent of each other. The factor analysis and various validity analyses suggest that two candidate tests for a reduced battery are: (1) foveal static acuity (under low level illumination), and (2) dynamic visual acuity.

Before such recommendations are implemented, the unreliable tests must be improved. This is necessary before any definite conclusions about relevance to driving ability and accident avoidance can be reached. The pattern of results suggests that such improvements can be achieved by increasing the mechanical reliability of the DVT on one hand, and the objectivity of the scoring procedures on the other. Such methodological improvements in a modified and improved version of the DVT are currently being pursued under another NHTSA-sponsored contract.

4.0 DRIVER KNOWLEDGE TESTING

An analysis was undertaken to determine the usefulness of a particular driver knowledge test as an indicant of accident involvement or type of driving error. A 20-question driving knowledge test was constructed from a large pool of multiple choice items provided by NHTSA, along with nine supplementary questions provided by IRPS. The questionnaire was administered to 178 drivers from an accident group and 133 drivers from a control group.

Driver knowledge test scores varied significantly as a function of age. Drivers under 20 years of age scored relatively low. Drivers 20 to 34 scored the highest, but with a deterioration of scores beginning at age 35 and continuing, such that drivers 65 years of age and over scored the lowest.

Of the 20 questions, males performed significantly better on four questions, and marginally better on an additional two. Females performed marginally better on one of the questions. In terms of total test score, males scored significantly higher. The questions best answered by males appeared to concentrate on handling in emergencies and mechanical considerations, rather than on general driving style or laws.

As might have been expected, those who had received formal driver training scored significantly better than those who had not. The questions best answered by those who had had driver training emphasized general driving style and laws rather than emergency handling or mechanics.

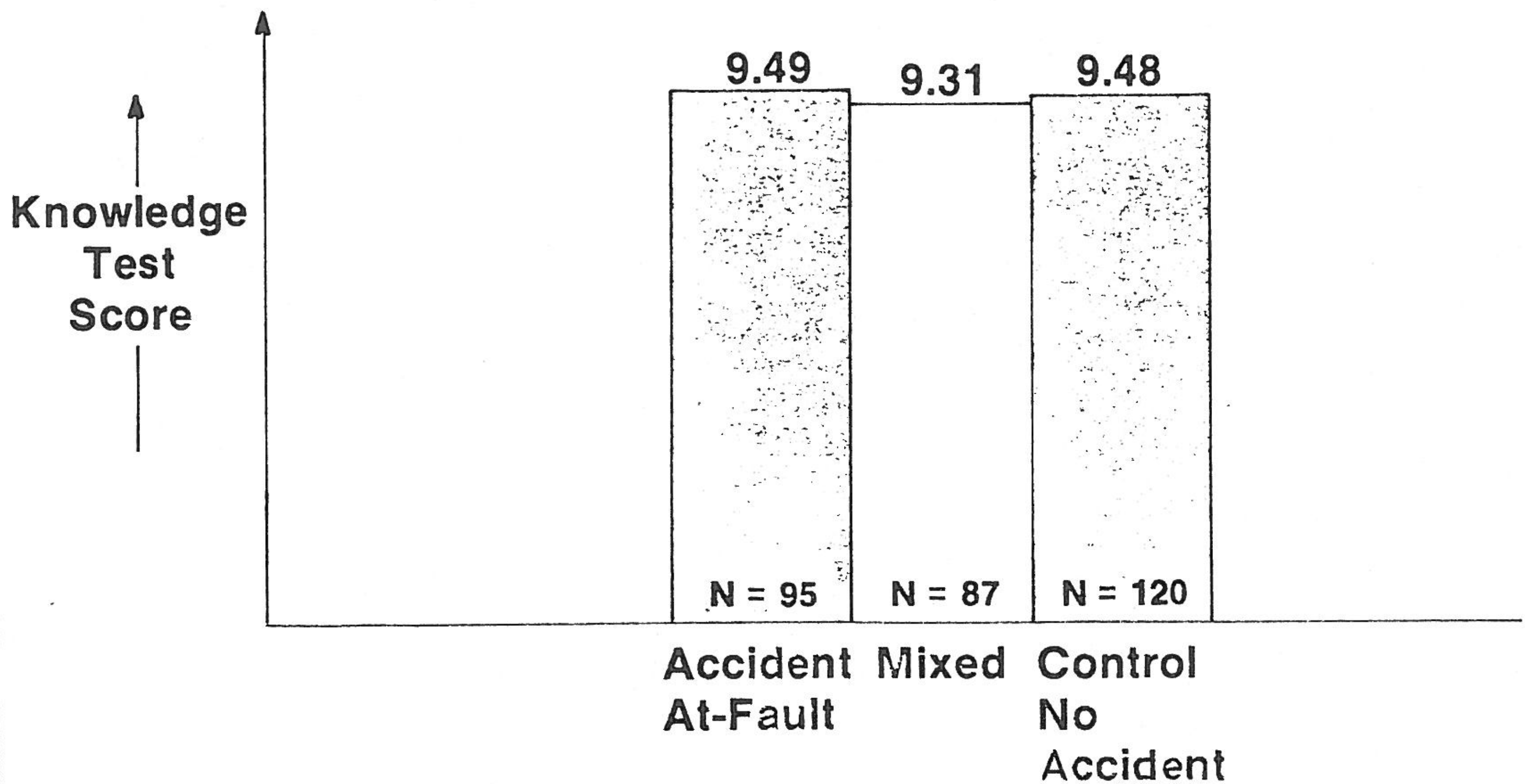
In a separate analysis, a comparison was made among the test scores of those judged at fault in accidents, those involved but not-at-fault, and a control group of non-accident drivers; no statistically significant differences were identified for any of the individual questions, or for total driver knowledge test score (Figure 4-1). Consequently, this analysis provides no support for the idea that driver knowledge (as measured by this test) is related to accident involvement. One problem with this evaluation, however, was that in the time which elapsed between the accident and the knowledge test, drivers committing certain errors may have learned through discussions of the accident with friends, parents, their insurance company, etc.

In yet another analysis, relationships were examined between particular questions and the incidence of accident-causing behaviors or problems which were hypothesized as being possibly related to them. Again, no statistically significant relationships were identified.

Despite the discouraging results obtained here, it is highly unlikely that all aspects of driving performance are unrelated to the content areas and driving skill requirements which have been previously identified. Apparently, when driving performance is measured by accident involvement, other skills and knowledge than that measured by this knowledge test is relevant. In the future, more specific and relevant definitions of driver knowledge should be tested.

FIGURE 4-1

- In a comparison of scores achieved by those at-fault in accidents, those involved but not-at-fault, and a control group of non-accident drivers, no significant difference was observed (scores based on the 15 questions having correct response rates of less than 90%).



Accordingly, one recommendation is that driver knowledge should be tested in the behavioral areas that have been determined to be the major causes of accidents, and that this testing should take place immediately following the accident-before any additional learning takes place. Questions that assess proper visual surveillance techniques, awareness of the risk of inattention, proper evasive maneuvers, etc., are possibly more directly relevant to accident avoidance than questions dealing with maintenance, driving style, or knowledge of traffic regulations.

In addition, driver knowledge of accident avoidance maneuvers should be tested under temporal stress. The drivers frequently reported that they "knew" that they had performed an inappropriate avoidance maneuver, but in the limited time available had responded "instinctively." When taking the knowledge test, these drivers often answered related questions appropriately. Hence the need to measure both whether drivers know the right answer, and how much time is needed to reach the correct decision. Perhaps testing could be conducted in an active simulation environment, in which the driver is required to actually perform the appropriate motor response.

5.0 METHODOLOGY DEVELOPMENT--NEW DRIVER MEASURES

This section built on previous research aimed at ascertaining distinguishable characteristics of the overinvolved or "problem driver." Driver characteristics and traits (independent variables) such as prior record, alcohol/drug usage, social adjustment, personal adjustment, and impulse control were examined in terms of their relationship to various on-road behaviors (dependent variables) characteristic of risk-taking, poor decision making, and poor perceptual-motor skill.

In a preliminary study, a group of young accident repeaters was compared with a matched group of non-accident drivers, in terms of alcohol/drug use, personal adjustment, social adjustment, impulsivity and clerical ability (Table 5-1). The high-accident group scored reliably higher on measures of alcohol/drug use, and on one or more measures of personal maladjustment, social maladjustment, impulsivity, and clerical speed/accuracy. The discriminant function was able to correctly assign 42 of the 46 matched subjects (i.e., over 90%).

In a second validation study comparing new groups of high and non-accident young drivers, the discriminant function from the original study correctly assigned 12 of 14 matched subjects (i.e., over 85%). This study substantiated the validity of these measures of social and personal adjustment, at least for the type of young licensed drivers studied.

Results of the original and validation studies were combined and further analyzed, providing a total N of 60 licensed college freshmen, ages 18 and 19. Results from these analyses are consistent with the idea that personal maladjustment (i.e., problems with one's self) and social maladjustment (i.e., problems with society) are related to accident involvement. To a lesser extent cognitive abilities (e.g., clerical abilities) and impulsivity are also related to accidents.

In a separate analysis, a comparison was made between drivers judged to have committed an error and those who were error-free. It was found that drivers who had committed errors tended to score higher in both personal and social maladjustment (i.e., were more maladjusted). In a subsequent analysis, scores were compared among drivers who had committed a recognition error, a non-recognition error, or were error-free. Marginally reliable differences were obtained, with the no-error group scoring best on personal and social adjustment, while the "other-error" group scored worse than the recognition error group. Thus, the scales tested were not able to predict type of error, but did appear related to accident causation.

A subsequent analysis was performed to better determine the relationship of these "driver profile scores" to specific types of driving errors. This analysis showed that:

- Drivers who were cited for any causative human factor, especially a human condition/state, alcohol-impairment, or inattention, were more personally maladjusted than the no-error controls. One hypothesis is that personal problems may preoccupy or distract the driver.

Table 5-1

Mean Score for High Accident and No Accident Groups on 22 Tests

Test	No Accident Group	High Accident Group	*t* Value (df=44)	*p* Value	Discriminant Function Coefficient
Alcohol-Drug Use (+)	3.74	5.26	-2.06	< .05	-.38
Personal Maladjustment					
Manifest Anxiety (+)	78	.83	- .13	ns	.24
Life Changes (+)	3.35	4.96	-2.16	< .05	04
Katz: General Psychopathology (+)	14.65	21.26	-3.24	< .01	.91
Katz: Withdrawal (+)	4.22	4.70	- .67	ns	-.43
Anxiety (+)	2.57	3.04	-1.14	ns	-.03
Social Maladjustment					
Citizenship (-)	9.04	7.83	.76	ns	-.53
Social Participation (-)	33.83	32.57	.14	ns	.08
Juvenile Delinquency (+)	.26	.91	-2.86	< .01	.27
School Socialization (-)	12.87	11.35	2.05	< .05	-.52
Katz: Negativism (+)	14.74	16.52	-2.17	< .05	.58
Pro-Religious Values (-)	4.09	3.74	.52	ns	.08
External Locus of Control (-)	3.26	2.26	2.05	< .05	-.57
Antisocial Tendencies (+)	6.74	9.13	-3.01	< .01	.64
Impulsivity					
Katz: Belligerence ( )	5.30	6.04	-1.60	< .12	-.41
Impulsivity (+)	3.87	5.17	-1 89	< .07	-.14
Pelz-Schuman: Risk Taking Attitudes (+)	3.17	4.04	-1.53	< .14	.24
Rommel: Unsafe Attitudes (+)	5.52	5.35	.29	ns	-.39
Goldstein: Pro-Competition Attitudes (+)	2.13	2.13	0	ns	.23
Goldstein: Pro-Speed Attitudes (+)	2.70	2.57	.44	ns	-.14
Clerical Speed Accuracy					
Finding A's (-)	42.13	38.09	1.32	< .20	07
Number Comparison (-)	28.30	20.30	2.87	< .01	-.59

Note. Plus (+) indicates prediction that High Accident score is higher than No Accident score; minus (-) indicates prediction that High Accident score is lower. Out of 22 tests, 19 scores occurred in the predicted direction, 1 tied, and 2 occurred in the reverse direction.

- Drivers committing almost any error, especially recognition and decision errors (and possibly those cited for alcohol-impairment), were more anti-social than controls. Possibly socially maladjusted drivers may make a conscious decision to drive more recklessly.

- Drivers cited for causally-relevant alcohol-impairment tended to lack impulse control. These three sets of findings suggest that personal maladjustment, social maladjustment and lack of impulse control may all be factors underlying accident involvement by reason of alcohol impairment. Further research is needed to clarify this point.

Results are highly encouraging for the idea that high accident drivers differ from no accident drivers, as a group, and are promising in their support of several theoretical notions concerning the differences. This is true despite the last three of these related studies being based on information which had been previously collected in the course of in-depth (Level C) investigations. (Existing questions on the in-depth human factors form were used to form ad-hoc scales for measures such as personal and social maladjustment). This leads to the recommendation that the five-step sequence as proposed in the text be pursued.

A recommended next step would be initiation of a prospective study in which an entire battery of questions specifically designed around these scales are given to a stratified, representative sample of the general driving population, for comparison with data on their previous crashes and violations. The fifth and concluding step would involve a major study in which the entire revised battery is administered to a representative sample of accident-involved drivers, in order to examine in detail the extent to which different types of accident causing behaviors are related to different basic human traits. A follow-up study would then monitor driver records for a future period to determine the predictive validity of the measures used.

6.0 DRIVER CHARACTERISTICS AND CULPABILITY

In this section, accident-involved drivers which IRPS investigators assessed as having committed errors (i.e., "culpable drivers"), were compared with non-culpable accident drivers in terms of their age, sex, driving experience, vehicle familiarity, annual mileage, and road/area familiarity.

Based on this analysis, it was found that for both men and women, culpable drivers had significantly less road/area familiarity than did non-culpable drivers.

Non-culpable men, in addition to having significantly more road/area familiarity, were characterized as having more familiarity with their vehicles than would be expected for their age, and as being between the ages of 35-54 (Table 6-1). Culpable men were characterized as having little road/area familiarity, having less familiarity with their vehicles than would be expected for their age, and as being either young (15 to 19) or old (over 64).

In addition to having significantly more road/area familiarity, non-culpable female drivers were characterized as having more driving experience than would be expected for their age, and as being either over 54 or between 35 and 44 years of age (Table 6-2). Culpable female drivers were characterized as having little road/area familiarity, an intermediate (moderate) level of driving experience for their age, and as being either under 25 or between the ages of 45 and 54.

This analysis has been conducted in such a manner that differences between drivers arising out of relatively uncontrollable risks (such as annual miles traveled by the different groups) have been controlled for, so that the differences which remain can be assumed to be accounted for primarily by "unsafe driving practices." It is therefore recommended that drivers be provided with information sufficient to let them know if and when they are falling into one of these unsafe, "high culpability" groups or situations, and that further research be conducted to determine exactly what kinds of driving behaviors or practices are involved, leading to the increased risk.[1]

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[1] Further analyses have been conducted regarding types of unsafe driving practices associated with these driver groups, as a part of the "Tri-Level Study of the Causes of Traffic Accidents, Modification for Special Data Analyses, Task 4."

Table 6-1

Comparison of Male, Culpable and Nonculpable Accident-Involved Driver Distributions Before and After Adjustment for Driver Age

Driver Characteristic	Before Age Adjustments				After Age Adjustments			
	Not Culpable Median	Culpable+ Median	Median Test	K-S° Test	Not Culpable Median	Culpable+ Median	Median Test	K-S Test
Driver Age	25.7	23.4	$x^2=14.27$ n=2208 p=.0002	Z=2.12 n=2208 p=.0002				
Driving Experience (months)	109.5	82.6	$x^2=17.67$ n=2010 $p\leq.0000$	Z=2.22 n=2010 p=.0001	168.0	167.9	$x^2=.36$ n=2006 p=.5495	Z=.93 n=2006 p=.3524
Vehicle Familiarity (months)	12.2	11.0	$x^2=14.98$ n=1982 p=.0001	Z=2.28 n=1982 p=.0001	14.4	12.7	$x^2=4.02$ n=1979 p=.0449	Z=1.59 n=1979 p=.0129
Annual Mileage in 100's of Miles	132.0	126.0	$x^2=.15$ n=1873 p=.6957	Z=1.09 n=1873 p=.1850	133.9	144.1	$x^2=.92$ n=1870 p=.3386	Z=.90 n=1870 p=.3942
Road Area Familiarity*	1.44	2.02	$x^2=30.09$ n=2013 $p\leq.0000$	Z=2.70 n=2013 $p\leq.0000$				

* **Larger median indicates less road area familiarity.**

° Kolmogorov-Smirnov 2-sample test.

+ At the certain or probable, causal or severity-increasing levels of certainty and significance.

Table 6-2

Comparison of Female, Culpable and Nonculpable Accident-Involved Driver Distributions Before and After Adjustment for Driver Age

Driver Characteristic	Before Age Adjustments: Not Culpable Median	Before Age Adjustments: Culpable+ Median	Before Age Adjustments: Median Test	Before Age Adjustments: K-S° Test	After Age Adjustments: Not Culpable Median	After Age Adjustments: Culpable Median	After Age Adjustments: Median Test	After Age Adjustments: K-S Test
Driver Age	27.5	25.7	χ^2=6.20 n=1037 p=.0128	Z=1.54 n=1126 p=.0173				
Driving Experience (months)	114.3	92.5	χ^2=5.26 n=1037 p=.0218	Z=1.68 n=1037 p=.0072	160.2	149.1	χ^2=6.88 n=1034 p=.0087	Z=1.82 n=1034 p=.0026
Vehicle Familiarity (months)	18.1	14.5	χ^2=.95 n=1031 p=.3287	Z=.71 n=1031 p=7009	18.8	18.2	χ^2=.02 n=1028 p=.8818	Z=.79 n=1028 p=.5596
Annual Mileage in 100's of Miles	98.7	98.3	χ^2=2.10 n=840 p=.1470	Z=.95 n=840 p=.3302	95.9	95.9	χ^2=.00 n=837 p=.9513	Z=.85 n=837 p=.4609
Road Area Familiarity*	1.38	2.24	χ^2=38.52 n=1047 p$\leq$.0000	Z=3.07 n=1047 p$\leq$.0000				

* Larger median indicates less road area familiarity.

° Kolmogorov-Smirnov 2-sample test.

\+ At the certain or probable, causal or severity-increasing levels of certainty and significance.

7.0 CLUSTER ANALYSIS

In this section, information regarding a sample of 353 of the drivers/vehicle units involved in accidents investigated in-depth (Phases II-V), were used as inputs to a cluster analysis. In this manner, the *drivers which were most similar on the basis of causation variables were* grouped together, and differences between groups in terms of other variables (such as driver knowledge, vision, and personal adjustment), were measured.

Results of the cluster analysis of the causal hierarchy indicate that the investigators used the hierarchy consistently, in that there were clear groupings or clusters of drivers/vehicles. These "natural" groupings tended to set apart drivers in terms of whether they had made decision errors, recognition errors, or were "not-at-fault," and in terms of whether environmental factors or human conditions and states had been assigned as causally-relevant to them (Table 7-1). This pattern is consistent with the causal factor hierarchy. While the initial groupings were produced using 353 drivers from the in-depth file, in 14 separate random samplings of 200 driver/vehicle units from the on-site file, a similar cluster structure consistently emerged (up to and including the five-cluster level).

Comparisons were made between a number of the clusters, in order to measure differences on additional descriptors which had not been used in the formation of the clusters. For example, the members of the largest cluster (n = 133), none of whom had committed any assignable error, were compared with combined members of the seven remaining at-fault clusters. Significant differences were identified for nine of the 29 variables compared; for example, members of the not-at-fault cluster scored significantly better in terms of both dynamic visual acuity and social adjustment. Differences were not significant with respect to driver knowledge test score, reaction time, socio-economic status, personal adjustment, alcohol usage, prior driving record, or age. On the other hand (as might be expected from the discussion on the confounding of age and vision in Section 2.1 of Volume II), the not-at-fault drivers scored more poorly on static acuity and, unexpectedly, on impulse control.

This and other inter-cluster comparisons demonstrated that the grouping of drivers into such clusters was informative in terms of additional driver attributes not used in the process of deriving the clusters.

N = 353

Table 7-1

Description of 8 Clusters in Terms of Causal Hierarchy

CLUSTER A (n = 133)

Not at Fault

CLUSTER B (n = 72)

Decision	.89
Environmental	.35

CLUSTER E (n = 43)

Environmental	1.00
Highway Related	.74
Ambience Related	.33
Recognition errors	.30

CLUSTER F (n = 7)

Conditions or States	1.00
Experience-Exposure	1.00
Decision	.71
Excessive Speed	.43
Performance Errors	.43
Environmental	.29
Non-Slick	.29

CLUSTER C (n = 69)

Recognition	1.00
Delays	1.00
Improper Lookout	.42
Internal Distraction	.25

CLUSTER G (n = 14)

Decision	1.00
False Assumption	1.00
Environmental	.64
Highway Related	.64

CLUSTER D (n = 12)

Conditions or States	1.00
Physical	1.00
Alcohol	.42
Decision	.42
Recognition	.33
Delays	.25

CLUSTER H (n = 3)

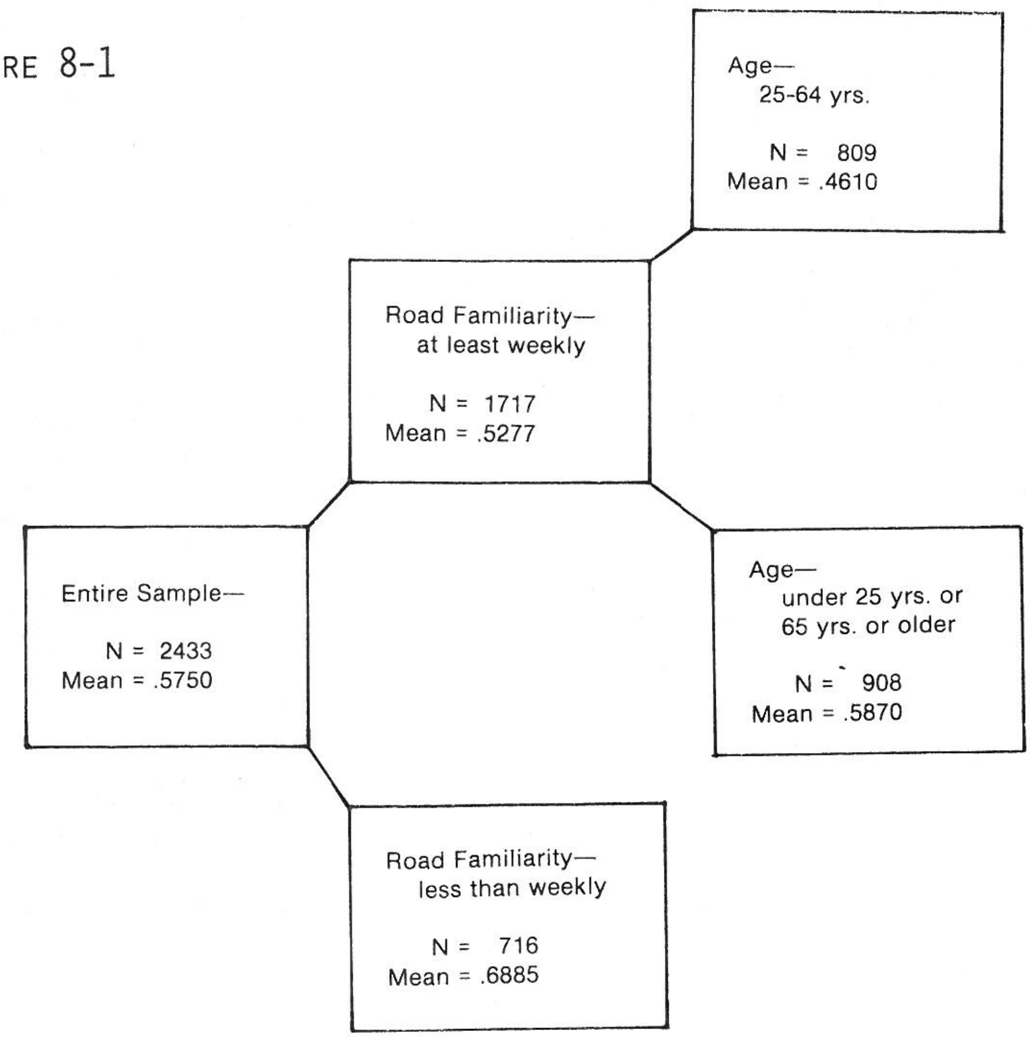
Conditions or States	1.00
Mental-Emotional	1.00
Decision	1.00
Improper Driving Technique	.67
Excessive Speed	.67
Environmental Factors	.33
Slick	.33
Non-Slick	.33
Highway Related	.33
Ambience Related	.33

8.0 AID ANALYSIS

In the automatic interaction detector (AID) analysis, the absence or presence of a variety of causal factors was the dependent variable, and the independent variables were 10 selected driver demographic and environmental characteristics.

Based on the AID analysis, road/area familiarity emerged as an extremely important variable; the human factors summary, a variable that indicates whether or not a particular driver was identified as having committed *any* attributable error, split first on the road familiarity descriptor, indicating that this was the most important descriptor in differentiating drivers who made errors from those who did not (Figure 8-1). One or more human causal factors was assigned for 69% of those who were unfamiliar with the road (i.e. drove it less than once per week), but for only 53% of those who drove the road once per week or more frequently. (Note that this is consistent with results in Section 6.0.)

FIGURE 8-1



The most frequently implicated human causal factors in the IRPS hierarchy were divided between either of two broad categories--recognition errors or decision errors. With *recognition errors* as the dependent variable, the sole split occurred (as for the human factors summary) on the road familiarity variable, with drivers who were more familiar with the road being less likely to have committed a recognition error. With *decision errors* as the dependent variable, however, an entirely different split occurred based on traffic volume at the time of the accident; decision errors were cited for 36% of the drivers who had accidents in "light traffic," but for only 27% in moderate or heavy traffic. However, as one might expect, decision errors were cited more frequently among drivers who were unfamiliar with the road. In addition, drivers between the ages of 25 and 64 were much less likely to be cited for decision errors than either young drivers or drivers 64 or over. Since the "excessive speed" category comprises a large proportion of all factors occurring under the decision errors heading, the rationale for the excessive speed split in large measure explains the decision error split (see below).

For the most frequently-implicated causal factor--improper lookout --road familiarity and driver age were close competitors to split the overall sample, with road familiarity actually producing the split. Drivers who were unfamiliar with the road, or who were 65 years of age or older, were substantially more likely than other drivers to have committed an improper lookout error.

For the second-ranking causal factor--excessive speed--the initial split occurred for traffic volume (as it did for the decision errors category of which it is the largest component), with excessive speed being cited for slightly under 5% of drivers in moderate or heavy traffic, but for nearly 14% of drivers in light traffic. This result could have been anticipated, since it is consistent with conditions which provide an opportunity to speed. In addition, young drivers were found nearly three times as likely as drivers 20 years or older to be cited for excessive speed; males were twice as likely as females; less experienced drivers (those with two years or less driving experience) were roughly two and one-half times as likely as more experienced drivers; and those who were relatively unfamiliar with their vehicle were roughly twice as likely as those who were more familiar.

For vehicular causal factors overall, the possible initial splits were pavement condition (dry, wet, snow, slush, or ice covered), precipitation intensity, driver age, and driving experience, with the split actually occurring for pavement condition; vehicular factors were cited as causes in 8.0% of accidents occurring on "wet" pavement, compared to 3.5% in accidents occurring on "dry, icy, or snowy" pavement. The high identification rates for wet pavement and precipitation are consistent with the fact that a majority of the vehicular factors were related to either tires or brakes--problems which would be greatly intensified by environmental factors that might increase stopping distances or reduce traction laterally.

Low road familiarity appeared related to the commission of a broad range of human causal errors, and further research is warranted to better identify reasons for this problem, as well as ways to alleviate it. For example, it might be possible to identify discrete components of familiarity in perceptual and behavioral terms leading to design of training programs which would teach drivers to learn more rapidly the relevant information from a new road. Equally, new signing and/or roadway design requirements might be desirable, to better "cue" drivers as to roadway alignment changes and related needs for speed adjustment. Other aspects of the problem may lie in either program management or funding. For example, it may be that an adequate system to identify locations needing warning signs, and to periodically check these locations and perform needed replacement or maintenance, has not been provided. In other cases, the need may be known, but funds may not be adequate to provide such signing.

Even with 2,433 accident driver/vehicle combinations (with no missing data) available from the IRPS on-site investigation level for this analysis, the decomposition of the sample into subparts quickly produced relatively small groups of interest that could not be adequately studied or further decomposed due to their small size. It is therefore important that future national data collection efforts incorporate an easily and consistently applied assessment scheme to aggregate additional cases and thereby increase the ability of researchers to analyze relatively large subgroups of these categories.

9.0 MOTORCYCLE ACCIDENTS AND CAUSES

In this section, three separate analyses were conducted: (1) an assessment of differences between accidents involving motorcycles and those involving other types of vehicles; (2) a comparison of the 52 motorcycle accidents investigated by IRPS as a part of the "Tri-Level Study" with those reported statewide by the Indiana State Police in 1973; and (3) an analysis of the 52 accidents investigated by IRPS in terms of causes assessed for both the motorcycles and the other involved vehicles.

It was found that:

- Motorcyclists were less frequently at fault, made fewer recognition errors, and had fewer accident-causing vehicle problems--than accident drivers generally.
- The other-involved (striking) motorists were more frequently culpable, made more recognition errors, made fewer decision errors, and were less likely to be cited for alcohol impairment--than accident drivers generally.
- A major problem appears to be that other motorists often fail to see on-coming motorcyclists, particularly at intersections.

As compared to reported accidents involving other types of vehicles, motorcycle accidents were more frequently single vehicle, rural, and non-intersection; occurred more frequently during the warmer months and on weekends; were more likely to occur during the afternoon and evening (rather than in the morning or early morning hours); more frequently occurred on dry road surfaces; and were more frequently injury-producing. The accident-involved motorcyclists were younger than drivers of other accident-involved vehicles, and were more frequently male. However, there was no recorded difference between motorcyclists and other accident-involved drivers with respect to the (police-recorded) presence of alcohol.

The 52 motorcycle accidents investigated by IRPS during the five yearly study phases were representative of all 1973 Indiana State Police-reported motorcycle accidents with respect to accident configuration, severity, place of occurrence, month, day of week, time of day, road surface condition, and light conditions. IRPS accident-involved motorcyclists were representative with respect to sex and presence of alcohol, but overrepresented the 20-34 year age group, and underrepresented motorcyclists less than 20.

Primary causes assessed for the 52 motorcyclists were human decision errors and environmental factors. The most frequent decision error was excessive speed, followed by false assumption and improper driving technique. The most frequent environmental factors for motorcyclists were view obstructions (e.g., hillcrests and sags), followed by slick roads and special hazards (primarily non-contact vehicles).

Other motorists in motorcycle accidents (i.e., drivers of other vehicles which collided with motorcycles), were most frequently assigned recognition errors (i.e., failure to recognize an oncoming motorcycle), decision errors, and environmental factors. Many recognition errors occurred when entering a travel lane from an intersecting street or alley. These involved inattention to other traffic, improper lookout, and "other delays in perception." Another frequent recognition error was internal distraction (e.g., conversation with a passenger). The most prevalent decision error was improper maneuver (e.g., turn from wrong lane), while view obstructions (e.g., other parked vehicles), were the most frequent environmental causes.

As compared to all other accident-involved drivers, motorcyclists in the IRPS sample were less frequently cited for human errors, made significantly fewer recognition errors, and had fewer accident-causing vehicle malfunctions.

On the other hand, as compared to accident-involved drivers generally, the drivers of vehicles striking motorcycles in the IRPS sample were more frequently culpable, made significantly more recognition errors, made significantly fewer decision errors, and were less likely to be affected by adverse physiological/psychological states (e.g., alcohol impairment was less frequently involved than for accident-involved drivers generally).

In review, a major problem appears to be that other motorists often fail to see oncoming motorcyclists, particularly at intersections. The striking "other vehicle" driver is less likely to be involved by reason of alcohol-impairment than are accident drivers generally, while for motorcyclists it appears that alcohol involvement is neither more or less frequent than for accident drivers generally.

A much larger data base than the 52 motorcycle accidents examined by IRPS would be required to confidently list the related problems and to provide adequate guidance to such countermeasures as driver education, vehicle inspection, or vehicle design. However, these results suggest the need to inform motorcyclists of the danger that other drivers will fail to see them, and underscore the importance of being seen (e.g., keeping the headlight on, wearing highly visible clothing), and decreasing speed at intersections.

10.0 MODIFICATION FOR ADDITIONAL ANALYSES

Under a modification to the "Tri-Level Study of the Causes of Traffic Accidents," six analysis tasks were defined which have been incorporated in separate analysis reports. A seventh task required the development of analysis files designed for convenient access and use by external sources. These analysis tasks and a brief summary of their major results, are as follows:

1. Analysis of Potential Benefits of Various Improvements in Vehicle Systems in Preventing Accidents or Reducing their Severity.

   Based on a review of the literature and in consultation with NHTSA, 11 potential improvements and variations of these were defined for assessment. Benefits were assessed by having four members of IRPS' engineering staff manually review individual in-depth case reports to extract additional information needed for these assessments, and to hypothetically assess the benefits derived from equipping one or more vehicles in each accident with each of these systems. A total of 420 in-depth investigation reports were available for review.

   "Possible" benefits recorded for the various systems ranged from a low of 0.5% (two accidents out of 420) for "standardization of driver controls," to a high of 8.8% (37 accidents) for "improved brake lights." The maximum "certain" benefit (eight accidents) was for "vehicle life-time brake components," which were also judged to be of "possible" benefit in up to 5.5% of these accidents (23 of 420). (See Figure 10-1.)

2. Analysis of driver and vehicle characteristics related to vehicle condition and causation; and an assessment of Indiana PMVI effectiveness in reducing the frequency and severity of accidents caused by vehicle-related malfunctions and degradations.

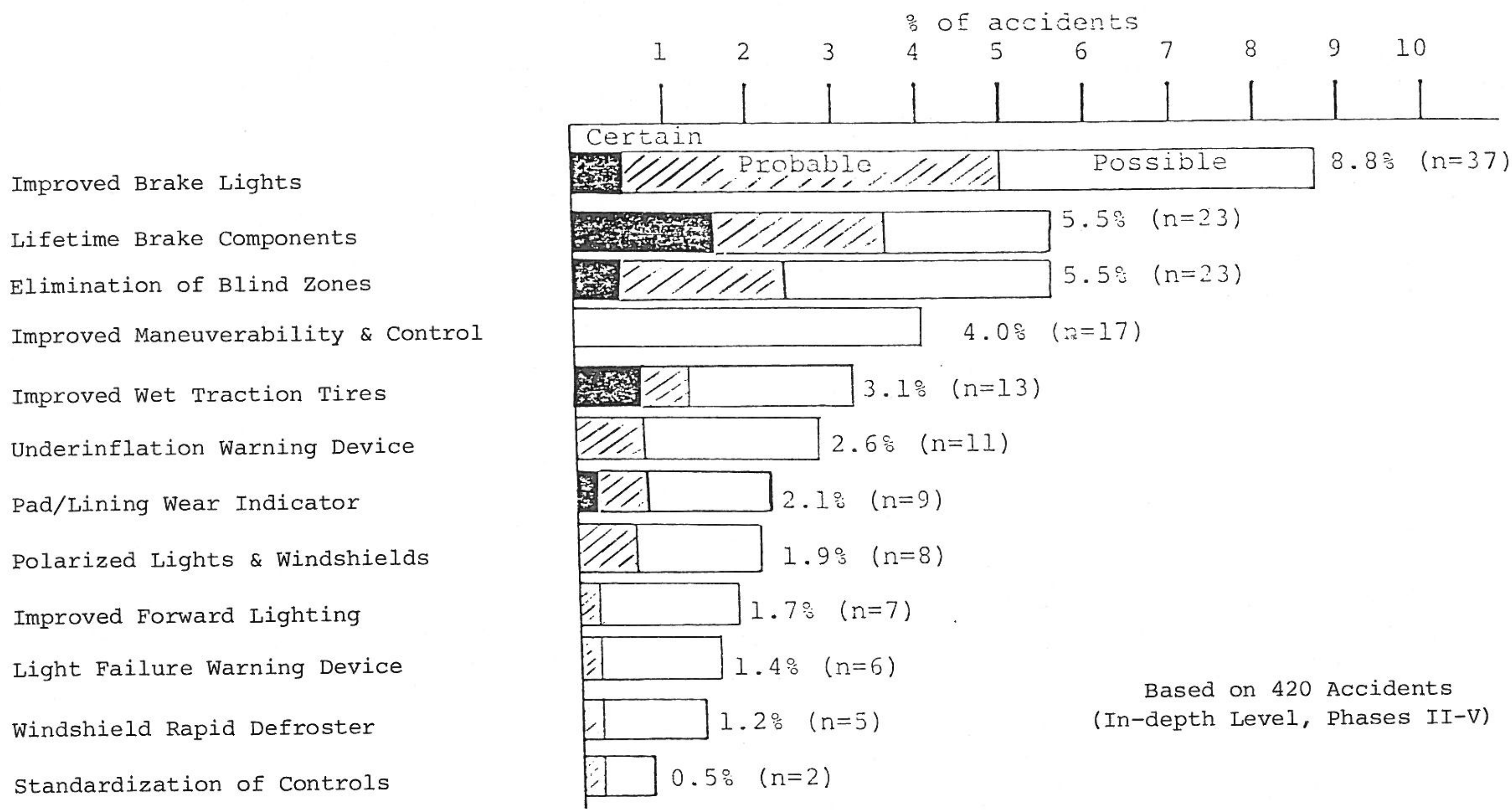
   This study was conducted to investigate the relationship of both driver and vehicle characteristics to the mechanical condition of vehicles and the involvement of vehicle factors in causing accidents. In addition, an investigation was conducted to evaluate the effectiveness of Indiana's Periodic Motor Vehicle Inspection program in achieving the objectives of (1) improving overall vehicle condition, and (2) inspecting and repairing those components which were judged to be of importance in causing or increasing the severity of traffic accidents.

   Results of this study indicate that vehicle condition was significantly related to driver age, education, marital status, occupation, family income, driver education, vehicle age, and vehicle manufacturer. The likelihood of vehicular causal involvement in accidents was significantly related to driver age, vehicle age, and vehicle body style. (See Table 10-1.)

   Concerning PMVI effectiveness, 51.7% of the components which were judged to be causally implicated in accidents were either not

FIGURE 10-1

Summary of Accident Prevention* Benefits for Vehicle System Improvements Considered (ranked according to "possible benefit" results)



*"Certain" means prevented certain. "Probable" means certain or probable, prevented or severity-reduced. "Possible" means certain, probable, or possible, prevented or severity-reduced.

TABLE 10-1

Effects of Driver Age on the Involvement of Vehicle Factors in Accidents (Certain or Probable Levels of Certainty)*

	Vehicle Involvement					
	Certain or Probable Involvement		Not Involved		Total	
Age	n	%	n	%	n	%
Less than 20	21	14.7	122	85.3	143	21.7
20-24	13	6.5	186	93.5	199	30.2
25-34	8	5.5	137	94.5	145	22.0
35-44	4	5.8	65	94.2	69	10.5
45-54	3	4.7	61	95.3	64	9.7
55-64	1	5.9	16	94.1	17	2.6
65 and Over	1	4.8	20	95.2	21	3.2
TOTAL	51	7.8	607	92.2	658	100.0

Chi-square = 12.60 with 6 d.f.; p = .0499

*Percentages refer to a proportion of traffic unit/drivers rather than a proportion of accidents. E.g., 51 of the 658 total accident-involved driver/vehicle units (7.8%) was cited as having a causally-relevant vehicle problem at the certain or probable level.

mandatorily inspected through Indiana PMVI, or if inspected, were later judged to be in a failing condition at the time of state inspection. Of all components checked which were defective at the time of the accident, 28.9% were judged to have been defective at the time of the state inspection. An analysis was also conducted which examined the effects of mileage since last inspection on the number of defective PMVI-inspected components; no statistically significant relationship was found.

3. Analysis of the validity of police-reported accident data.

Information theory and signal detection theory techniques were used to assess the reliability of police data by comparing it with Level II (technician) and Level III (multidisciplinary team) data collected during the Indiana Tri-Level Study.

The accident variables recorded by the police having the least reliability were vertical character of roadway, accident severity, and road surface composition. The data most reliably reported by the police were accident location, accident date, and numbers of drivers, passengers, and vehicles. The police data were found to provide little useful information with respect to driver and vehicle characteristics, with the exception of driver age, sex, and vehicle model for which the police were correct most of the time (but were not errorless). It was also found that police reports provided very little information regarding the presence of different human conditions and states, vehicle defects and environmental/roadway deficiencies.

The sensitivity of police investigators to all accident causes was found to be low. When causes were categorized as human direct, human indirect (i.e., driver physical and physiological conditions and states), vehicle, and environmental, the police were most reliable with respect to human direct causes. They were somewhat less reliable in accurately assessing vehicle and environmental causes, and were least reliable in attributing human indirect causes. In the assessment of alcohol presence and involvement, a strong and significant difference occurred in the reliability of reporting between male and female drivers, with a lower reliability associated with females (the presence and involvement of alcohol tended not to be reported by the police for accident-involved female drivers).

4. Analysis of the relationships between driver characteristics and accident causation.

This analysis was conducted to determine if driver characteristics were related to other factors which were judged to cause or increase the severity of accidents (20 different accident "causes" were considered). Statistical tests were employed to evaluate causation differences on the basis of driver trip plan, fatigue, number of passengers, age, driving experience, vehicle familiarity, and road area familiarity. Results indicate that driver fatigue, trip plan, road area familiarity, number of passengers and driver age were significantly related to factors which caused accidents. For males, vehicle familiarity was significantly related to accident causation; while for accident-involved female drivers, their amount of driving experience was significantly related.

5. An examination of the characteristics and collision-producing errors of accidents and traffic violation repeaters.

   This analysis was conducted to examine the characteristics and collision producing errors of accident and traffic violation repeaters, as compared to those drivers who had no recent record of accidents or violations. Statistical tests were employed to evaluate differences between accident/conviction repeaters and non-repeaters.

   Results of the study indicate that accident repeaters (as compared to non-repeaters) were more frequently young (20-24 years old), male, single, attended but didn't graduate from college and were more frequently implicated in accidents as a consequence of decision errors (and in particular, improper evasive actions).

   Drivers with prior convictions when compared to those with no prior convictions were more frequently between the ages of 20 and 24, male, single, had attended but not completed college, were white-collar workers (less frequently professionals or housewives), and tended to have their accidents as a consequence of excessive speed or alcohol impairment. It was also found that the accident and conviction repeaters experienced a greater degree of exposure to risk (e.g., more miles traveled annually), a factor which could account for the other effects found.

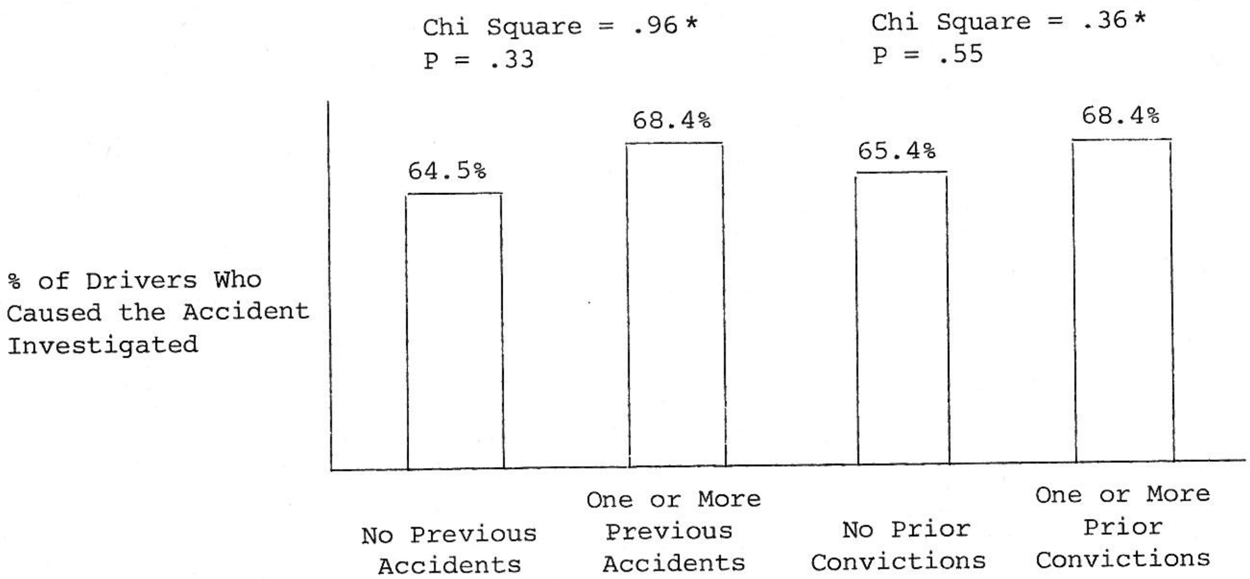
   In the accidents investigated, there was found to be no difference in the incidence with which culpability was attributed to repeaters and non-repeaters (where "culpability" is defined as the attribution of any human causal factor to a driver at the certain or probable level). (See Figure 10-2.)

6. Supplemental causation assessment through hypothesis testing.

   This analysis was conducted to statistically assess the causal involvement of selected vehicle factors. Accident situations in which the presence of component defects are considered to be a potential danger are identified and the condition of vehicles in these situations compared to the condition of vehicles in accident situations where the component defect was considered to be of less importance. Control variables which might themselves account for the differences found are identified and statistical methods used to control for their effects.

   Results of the study indicate that driver/vehicle combinations involved in control loss accidents were associated with the presence of a combination of human, vehicle and environmental factors, where

FIGURE 10-2



*Neither accident repeaters nor conviction repeaters differed significantly from their non-repeater counterparts on the basis of all types of human errors combined.

overall poor vehicle condition was indicated to be a contributing factor (i.e., in accidents involving a loss of vehicle control, vehicles experiencing such control losses tended to be in poorer mechanical condition than accident vehicles not experiencing control losses). Similarly, in accidents occurring on wet curves, under-inflated front tires were indicated to be a potential contributing factor (Table 10-2).

7. Construction of in-depth and on-site accident and traffic-unit based summary files.

   Under this task, special summary files designed for ease of access have been prepared. These four files summarize accident-based data from both the on-site (technician) and in-depth levels; and also summarize data from the same two levels, on a traffic unit (e.g., driver or vehicle) basis. For example, the accident file can provide data as a proportion of accidents investigated, whereas the traffic unit file can provide information as a proportion of driver/vehicle units involved. These files are to be made available by NHTSA through its various data bases and/or data base contractors.

TABLE 10-2

Effects of Potential Causation Factors on Driver/Vehicle Combinations Involved in Accidents on Wet Curves and Wet Straight Roads

Potential Causation Factor	Average Potential Causation Factor Series[1]: Dry and Straight	Dry and Curve	Wet and Straight	Wet and Curve	Total	F-Ratio	Significance
Initial Velocity (MPH)	21.244	31.690	21.032	29.156	23.236	13.38	.000***
% Underinflated Fronts	20.5	14.3	22.7	47.5	22.0	6.27	.000***
Vehicle Track	58.837	58.128	57.729	59.730	58.574	3.80	.010**
Road Grade	-.207	-1.748	.281	-1.270	-.403	6.51	.000***
% Front Tread Defects	22.3	15.1	18.5	38.5	21.5	3.30	.020*
Load/Weight Ratio	.075	.115	.072	.075	.081	4.84	.002**
Wheel Base	111.819	110.649	109.814	114.380	111.416	2.11	.098 NS
Vehicle Weight	3259.596	3102.866	3098.721	3429.700	3215.891	2.98	.031*
% Underinflated Rears	22.7	25.0	22.1	27.3	23.7	.18	.907 NS
% Rear Tread Defects	17.1	23.7	18.6	23.1	18.7	.89	.488 NS

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$
NS Not Significant

[1] Based on 400 driver/vehicle combinations which were involved in accidents on dry, straight roads; 97 - on dry curves; 131 - on wet, straight roads; and 40 - on wet curves; 668 driver/vehicle combinations total.

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2. Institute for Research in Public Safety, "Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Vols, I (Research Findings) and II (Appendices)," Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, prepared under Contract No. DOT-HS-034-3-535, NHTSA (DOT Report Nos. DOT-HS-801-334 and 335; NTIS PB-239 828/7Gl and PB-240 547/0Gl), August 31, 1973.

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Note: Extensive reference is made to the research literature in the technical volumes. A complete reference section appears in both Volumes I and II.

APPENDIX A

Summary of Procedures

The study involved both the on-scene investigation of accidents by teams of technicians (on-site or Level B investigations), and the subsequent in-depth investigation of a subset of these accidents by a multidisciplinary team (in-depth or Level C investigations).

The approach was to acquire as much relevant information as possible regarding each accident's occurrence, and then make clinical case-by-case determinations of the causal factors involved. Factors were placed within a hierarchical structure for which major categories were expressly defined. Assessments occur with reference to an assessment system, permitting each causal factor to be evaluated as certainly, probably, or possibly involved and as being of either causal or severity-increasing significance. Each accident may have a number of causes, and by cause is meant a deficiency without which the accident would not have occurred.

It should be noted that while causal factors are classifed as being human, vehicular, or environmental, this in no way requires that the applicable countermeasures for a particular cause must be in the same area. For example, the best countermeasure for a human cause could well be one which involves changes in either the vehicle or the environment.

Data Collection

Data were collected on three levels. The collection of the baseline information on Level A involved several types of collection efforts. Comprehensive vehicle registration and driver license data were obtained from the Indiana Bureau of Motor Vehicles by having them produce a tape to IRPS' specification which extracts Monroe County information from that recorded for the State. A second type of collection required IRPS personnel to visit the local license branch to obtain license and vehicle registration data via a systematic sample of hard copy applications. A third type of collection involved general population surveys. During Phase IV, a sample of general population licensed drivers, stratified by age and sex, was surveyed as to driving knowledge and vision.

The Level B or on-site teams were staffed by technicians. These teams at various times were comprised of either one, two, or three individuals. Throughout Phases II and III, and prior to 4 February 1974 in Phase IV, coverage was limited to 10 hours per day, 7 days per week. The 10 hour period, which ran from 11:30 a.m. to 10:30 p.m. with one hour out for meals, took into account the periods of highest accident frequency. However, this alignment was obviously undesirable in providing non-representative data. By realigning the teams and with the support of additional funding from NHTSA, coverage was expanded to 24 hours per day, 7 days per week on 4 February 1974, with the result of more than doubling the accident acquisition rate in Phase V and the latter part of Phase IV.

Upon receiving notification of an accident by radio monitoring of police frequencies or by a direct hot-line telephone call from police agencies, the IRPS on-site investigation team immediately responded to the accident scene in an investigation vehicle. At the scene, the team interviewed drivers, inspected involved vehicles and the driving environment, took photographs, and measured skidmarks and other physical evidence. Later, based on information collected at the scene, the team made a structured assessment as to factors which "caused" the accident.

The in-depth (Level C) investigations involved the further examination of human, vehicular, and environmental factors in a subset of these same accidents by a multidisciplinary team. The in-depth driver interviews were conducted by psychologists or sociologists, and during Phase IV involved both dynamic vision testing and driver knowledge testing. The vehicle inspection was conducted at the IRPS garage facility by one of IRPS' automotive engineers, using an updated version of the inspection guide which was originally developed for the earlier "Vehicle Defects Project." Accident reconstruction personnel assisted in identifying, collecting, and interpreting accident-induced physical evidence, calculating speed estimates whenever possible, and making detailed scale drawings showing the accident scene and the pre-, at-, and post-impact trajectories of involved vehicles. Subsequent to the collection and analysis of information, the multidisciplinary group convened to review the evidence in an Analysis and Conclusion Session, reaching group conclusions as to accident causes. In addition to reducing this data for subsequent analysis, a separate case report on each investigation was prepared and submitted to NHTSA.[1]

Accidents investigated varied in severity in about the same proportion as in the population of police-reported Monroe County accidents. The 70% to 80% of accidents within IRPS' on-site sample which involved only property damage also corresponds closely to national figures for reported accidents. Non-police-investigated accidents were excluded. The only other significant exclusion was of accidents involving large trucks (over 8,000 lbs. gvw), and vehicles pulling trailers. The former were excluded because they could not be handled in the same manner as passenger cars with the tools and garage facilities available to IRPS,[2] and generate unusual complexities of braking and handling, especially where articulated vehicles are concerned. The same reason applied for vehicles pulling trailers, which constitute a very small percentage of the accident population, and which may present unusual difficulties of accident reconstruction. Motorcycles were included within Phases I, IV, and V of IRPS data, but were excluded during Phases II and III, again because it was thought that insufficient information was available regarding dynamic aspects of motorcycle handling to treat them with the same confidence as passenger cars. More recently, the need for information has overridden the concerns about the difficulty of reconstruction. Pedestrian accidents generally have been included, although

[1]The requirement for submission of case reports was suspended late in Phase V.

[2]For example, they could not be accommodated by the Clayton dynamic brake tester in use during early phases of the study.

during Phases IV and V it was decided these would be worked only by the on-site team, and would not be investigated by the in-depth team. Of the 205 Phase IV and V in-depth accidents, a representative sample of the pedestrian accident configuration would have consisted of only three accidents.

Causation Assignment

Accident causes were determined by the clinical assessments of the Level B (on-site) and Level C (in-depth) investigation teams. The on-site assessment occurred prior to and without knowledge of the in-depth data or conclusions. The in-depth team was permitted access to on-site data and opinions, but based their decisions primarily on the information gathered in the in-depth phase. On-site information was used only when the evidence was extremely transitory in nature, or when a driver's initial description of the accident differed significantly from his recollections later. Thus, the on-site data constituted a subset of the total data available to the in-depth team, although the latter reached its conclusions independently of the on-site teams' conclusions.

During the period reported, on-site teams were comprised of either one or two investigators, although during previous phases as many as three persons comprised an individual on-site team. After completing their investigations at the scene and reducing data to the various collection forms, these team members jointly decided which causal factors should be cited. Their discussion occurred with reference to an accident cause dictionary (see "glossary" in Volume I). Conclusions were then entered on a designated form, coded, keypunched, and stored for later analysis. Procedures were similar for the in-depth team, but were based on more detailed data, and were conducted by professionals within each of the relevant disciplines.

During Phase V, there were six principal members of the in-depth team: a human factors psychologist (team head), an automotive engineer, a reconstruction specialist, a draftsman/environmental data collection aide, and an engineering assistant/technical writer.[3] Following the team's investigation of each accident and reduction of data, a formal analysis and conclusion session was held. To optimize the team's decision process, i.e., reduce individual biases without incurring group pressures toward conformity, the following structure was developed for the A & C session. Each accident was analyzed by only four members: the technical writer chairing the session, the human factors specialist, the automotive engineer and the accident reconstruction specialist. The session was divided into three major functional phases:

1. Accident description, presented by each of the three specialists. It includes slides and scaled drawings of the accident scenes with reconstructed vehicle trajectories through the collision sequence, computed speed estimates, and ambient conditions (by the reconstruction specialist); inspection data of all vehicles involved and discussion of potential relevance (by the automotive engineer); and

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[3] A traffic engineer headed the team during Phase IV, the latter part of Phase III, and the early months of Phase V.

relevant human factors data including biographical background, interviews with the drivers, and results on driver knowledge, vision and reaction time tests (by the human factors specialist).

2. Causal factors identification. When all the information has been presented, the members independently identify the causal factors. For this purpose IRPS has developed a glossary of human, vehicular, and environmental factors of potential causal significance (see "glossary" in Volume I). The causal factors are then shared with the other team members and a common set of causal factors is identified. The writer coordinating the session verbally reviews the data and events relevant to each of the causal factors.

3. Probability assessment. An ordinal scale, developed in Phase II, permits the investigators to express their assuredness of the conclusion as certain, probable, or possible (Figure A-1). A certain rating is applied when there is absolutely no doubt as to a factor's role, and is considered analogous to a 95% confidence level. Thus, an assessment that a factor was a "certain cause" of the accident means that, assuming all else remains unchanged, there is no doubt but that if the deficient factor had been removed or corrected, the accident would not have occurred. This is not to say that there were not other factors present which also played a causal role, meaning that their correction might also have prevented the accident. The probable rating means "highly likely although not definite," and is considered analogous to an 80% confidence level. A possible rating is used to designate factors which are of potential relevance, although evidence does not substantially support their existence and/or involvement. Analogous confidence figures are considered somewhat tenuous for the "possible" level, but are estimated to represent a confidence of from 20% to 80%. Thus, the failure to tally a factor at the possible level represents the judgment that its involvement was highly unlikely.

Figure A-1

Causal Factor Rating System

Certainty of Investigator Assessment	Significance of Assessment	
	Causal	Severity-Increasing
Certain		
Probable		
Possible		

A more analytical procedure was developed in Phase V with a dual purpose in mind: (1) to be used in evaluating team members' use of the verbal categories certain, probable and possible, and (2) to improve the assessment methodology for future applications. The procedure requires each of the three voting team members (the writer does not vote) to assign a confidence level ranging from 0.00 to 1.00 to two independent events: (1) the probability of the existence (E) of the causal factor $[P(E)]$, and (2) its involvement (I)--the conditional probability that had the factor been removed the accident would have been prevented $[P(\overline{acc}|\overline{E})]$. The group average for each of the probability estimates is calculated, and the product of the two is then defined as the derived involvement (DI).

In order to compare the old methodology with the new, in Phase V, after all the accident information has been presented, the team members independently rated the causal factors both in categorical terms (certain, probable, and possible) for an overall assessment (OA), and numerically for determining E and I. Whenever the writer--after averaging the E and I ratings--noted great variance (difference of .4 or more between highest and lowest estimate), the factor was discussed and rated again, this time with the writer's rating included. Before the end of the A & C session, the members once again rated categorically each of the factors (OAR), as certain, probable or possible.

This recent modification to the assessment procedure is discussed in greater detail in Volume I, Section 7.0.

Under both the original and revised procedures just discussed, factors are designated as being of either causal or severity-increasing significance according to the following definitions:

- Causal Factor--a factor necessary or sufficient for the occurrence of the accident; had the factor not been present in the accident sequence, the accident would not have occurred.[4]

- Severity-Increasing Factor--a factor which was neither necessary nor sufficient for the accident's occurrence, but removal of which from the accident sequence would have lessened the speed of the initial impact which resulted.

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[4]The "or sufficient" aspect of this definition was intended for situations where there were multiple sufficient causes (i.e., more than one factor which, by itself, absent any other deficiency or failure, would have caused a particular accident). For example, it is conceivable (however improbable) that a heart attack could coincidentally occur at the same time as a mechanical failure, in a situation where either alone would have led to the same accident. In this instance the "but for" test fails (i.e., neither factor by itself is necessary), but the "or sufficient" aspect would serve to retain both factors as "causes." In practice, it is doubted that circumstances of this kind were encountered, so that the operational definition was one of "necessity." In other words, a factor was considered a cause if "but for" that factor, the accident would not have occurred.

These definitions describe only pre-crash factors. Crash phase factors such as the performance of seatbelts, and post-crash factors such as extrication and clean-up are not intended to fall within either the "causal" or "severity-increasing" definitions.

Note that the countermeasure for a particular kind of problem may be in a different area than the problem. For example, some human causes may imply a need to make changes in vehicles or the environment. Thus, remedies for inattention might include radar warning or brake activation systems, improved brake lights, etc.

Sample results from the detailed causal data tables (which appear in Appendices A and B of Volume I) are shown in Figure A-2. These illustrate the six main cells generated by the three certainty and two significance definitions just discussed. Note that the addition of a summary *causal or severity-increasing* column results in three additional cells, or a total of nine for each level (Figure A-2). Since results for both Levels B and C are shown in this same table, the result is that for a given causal factor, there are a total of 18 cells (each of which contains information regarding both *n* and *percent of accidents investigated)*.

While this method of presentation is well suited to a data user interested in details concerning a particular causal factor, it does not facilitate generalization as to the relative involvement of different factors. For this reason results from only a few of Figure A-2's cells have been extracted for presentation in summary tables, and for use in many of the analyses. These are:

- the causal-certain cell--results from this cell are termed *definite causes,* and

- the certain or probable-causal or severity-increasing cell--results from this cell are termed *probable level* results, or results *with probable findings included.*

The *dictionary* of causal factors employed appears in a Glossary at the end of Volume I, and the limitations and implications of the causal assessment methodology are discussed in Volume I, Section 2.3.

Figure A-2

Example of Detailed Causal Data Tables Found in Appendices A & B[1]

DETAILED HUMAN CAUSATION SUMMARY BY ACCIDENT FOR PHASES II, III, IV AND V

	DEGREE OF CERTAINTY	LEVEL OF STUDY	CAUSAL N	CAUSAL 0/0	S/I N	S/I 0/0	CAUSAL OR S/I N	CAUSAL OR S/I 0/0
II. HUMAN FACTORS	CERTAIN	C	[illegible]	[illegible]	2	.5	299	71.2
		B	[illegible]	[illegible]	5	.2	1456	64.5
	CERTAIN OR PROBABLE	C	388	92.4	1	.2	[illegible]	[illegible]
		B	2034	90.1	6	.3	[illegible]	[illegible]
	CERTAIN PROBABLE OR POSSIBLE	C	409	97.4	2	.5	411	97.9
		B	2144	95.0	9	.4	2153	95.3
II. A. DIRECT HUMAN CAUSES	CERTAIN	C	[illegible]	[illegible]	2	.5	298	71.0
		B	[illegible]	[illegible]	6	.3	1399	64.0
	CERTAIN OR PROBABLE	C	387	92.1	1	.2	[illegible]	[illegible]
		B	1976	87.5	10	.4	[illegible]	[illegible]
	CERTAIN PROBABLE OR POSSIBLE	C	407	96.9	2	.5	409	97.4
		B	2093	92.7	14	.6	2107	93.3
1.0 CRITICAL NON-PERFORMANCE	CERTAIN	C	[illegible]	[illegible]	0	0.0	7	1.7
		B	[illegible]	[illegible]	0	0.0	25	1.1
	CERTAIN OR PROBABLE	C	9	2.1	0	0.0	[illegible]	[illegible]
		B	30	1.3	1	.0	[illegible]	[illegible]
	CERTAIN PROBABLE OR POSSIBLE	C	11	2.6	0	0.0	11	2.6
		B	32	1.4	1	.0	33	1.5
1.1 BLACKOUT	CERTAIN	C	[illegible]	[illegible]	0	0.0	2	.5
		B	13	[illegible]	0	0.0	13	.6
	CERTAIN OR PROBABLE	C	2	.5	0	0.0	2	[illegible]
		B	16	.7	1	.0	17	[illegible]
	CERTAIN PROBABLE OR POSSIBLE	C	2	.5	0	0.0	2	.5
		B	17	.8	1	.0	18	.8

[1] Darkened boxes indicate source of "definite cause" and "probable level" causation data, frequently referred to in the text. Definite cause results are taken from the "causal-certain" cell, while "probable level" results are taken from the "certain or probable, causal or severity-increasing" cells.

APPENDIX B

Representativeness of Study Samples and Study Area

In this section, descriptors of Monroe County drivers, vehicles and roads were compared with available national statistics. In addition, Monroe County accident descriptors were compared with available national accident descriptors. Finally, the on-site and in-depth samples were compared with all police-reported accidents occurring in the county, and post hoc adjustments for non-uniform sampling were made to the on-site causation results.

The Monroe County study area--in terms of drivers, vehicles, and roadways--agreed particularly well with national data for vehicle model year, vehicle make and driver sex. It was found to differ from the nation principally with respect to driver age (younger drivers overrepresented), and road and street system mileage (proportion of municipal mileage correct, but state and U.S. highways underrepresented and county roads overrepresented). In addition, the proportion of surfaced roadways was also greater than for the nation as a whole (which is in conflict with any pre conceived notion that the Monroe County study area is more rural or primitive than the U.S. driving environment, generally). Note, however, that causation involvement rates were found to be relatively insensitive to the non-representativeness of these variables (Volume I, Table 9-6).

In the comparison of reported Monroe County *accidents* to available national accident descriptors, Monroe County was found to compare particularly well as to hour of accident and type of involved vehicle, but to differ somewhat with respect to accident driver sex (women overrepresented), place of accident occurrence (rural accidents overrepresented), accident light condition (daylight overrepresented), accident type (multi-vehicle collisions overrepresented; pedestrian, non-motor vehicle, and fixed object accidents underrepresented), road surface condition (wet roads overrepresented), accident driver age (young drivers overrepresented), and accident severity (property damage accidents overrepresented). Again, it should be noted that for each of these variables, causation involvement rates were found to be relatively insensitive to the degree of non-representativeness experienced (Volume I, Table 9-6).

The Phase II-V on-site sample is representative of 1972-1974 reported Monroe County accidents (i.e., does not vary to a statistically significant extent) in terms of place of occurrence (urban or rural), driver sex, and driver age. The most non-representative characteristics are light conditions (on-site sample overrepresented daylight accidents); road surface condition (overrepresented accidents which occurred on dry road surfaces); weather conditions (overrepresented clear conditions); hour of accident (overrepresented accidents occurring between noon and 3:59 p.m.); character of location (underrepresented open road, non-intersection accidents); investigation source (underrepresented non-police reported accidents--expected since only police-investigated accidents met the criteria for investigation); and arrest status (overrepresented drivers who were not arrested). Note that with the exception of investigation source, the effects of non-representativeness of each of these variables has been examined and found to be extremely insignificant in terms of overall involvement of human, vehicular, and environmental factors.

The Phase II-V in-depth sample was found to be representative of the 1972-1974 reported Monroe County accidents (again, in the sense of not varying to a statistically significant extent) with respect to weather conditions, character of location, road surface condition, driver license status, and driver sex. The most non-representative characteristics of the Phase II-V in-depth accidents are light conditions (in-depth sample overrepresented daylight accidents); hour of accident (overrepresented accidents occurring from noon to 3:59 p.m.); accident type (overrepresented non-collision/running off road accidents); investigation source (underrepresented accidents not investigated by police agencies--again, an artifact of the selection criteria that only police-investigated accidents were considered); and arrest status (overrepresented drivers who were not arrested). Again, these differences have been found to have only a minor or insignificant effect on the aggregate causal result percentages (Volume I, Table 9-6).

While the effects of non-representativeness on the specific, detail level causal factors were not examined, from the data presented in Volume I, Section 3.2.3, it is evident that results regarding the involvement of alcohol-impairment as an accident cause varied as a function of the extent of coverage provided (i.e., according to whether accidents were selected from all hours of the day or only from limited periods). The overall effects of hours of coverage on alcohol-impairment are not clear (Volume I, Figure 3-5). However, for on-site team results (which are probably less influenced by selection biases arising from non-cooperation of drinking drivers), more frequent involvement was consistently recorded during 24-hour per day coverage than during periods of limited coverage (from 11:30 a.m. to 10:30 p.m.). This would indicate a greater involvement of alcohol-impairment in late night and early morning accidents. Overall, since 24-hour per day coverage was not provided continually throughout Phases II-V, this would indicate that the aggregate results for alcohol-impairment in Phases II-V are understated.

Overall, considering the degree of representativeness of Monroe County and the IRPS accident samples, as well as the effects of non-uniform sampling on estimates of causal involvement, it is concluded that the study area and samples are adequate to provide reasonable and useful estimates of the relative involvement of the kinds of human, vehicular, and environmental factors assessed.

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