TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS: INTERIM REPORT I

VOLUME I Research Findings

Institute for Research in Public Safety
School of Public and Environmental Affairs
Indiana University
Poplars Research and Conference Center
400 East Seventh Street
Bloomington, Indiana 47401

August 31, 1973

Prepared for:
United States Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20591

Report No. DOT-HS-034-3-535-73-TAC

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16. Abstract

This is the final report of the first year of activity under a proposed three-year program entitled "Tri-Level Study of the Causes of Traffic Accidents." This study has been performed by the Indiana University Institute for Research in Public Safety (IRPS), under contract to the National Highway Traffic Safety Administration (Contract No. DOT-HS-034-3-535). The report covers the period August 15, 1972 to August 14, 1973.

Data were collected on three levels of detail. Police reports and other baseline data on the Monroe County, Indiana study area were collected on Level A. On Level B, teams of technicians responded to accidents at the time of their occurrence to conduct on-scene investigations. On Level C, a sample of 22% of these accidents were independently examined by a multidisciplinary team. A general population survey was also conducted.

The report is presented in nine major sections: 1.0, Introduction; 2.0, Methodology Overview; 3.0, Findings Regarding Accident Causes; 4.0, Accident and Control Sample Comparisons; 5.0, Cluster Analysis; 6.0, Problem Driver Identification; 7.0, Analysis of Study Sample Representativeness; 8.0, Conclusions; and 9.0, Recommendations (Volume I). Principal data collection forms are included in Appendices B and C (Volume II).

This is Volume I of a two-volume report, covering study findings. Appendices are presented in Volume II.

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Special thanks are due the doctors, nurses, and staff at both the Bloomington Hospital and the Indiana University Health Center who have cooperated to enable our investigators to obtain driver interviews and other needed information.

PROJECT MANAGEMENT STAFF

Kent B. Joscelyn, J.D., Institute Director, Co-Principal Investigator
John R. Treat, B.S.M.E., J.D., Project Director, Co-Principal Investigator
Nicholas S. Tumbas, M.P.A., Assistant Project Director

MULTIDISCIPLINARY TEAM MEMBERS

Jahanbakhsh Benham, Ph.D.
Daryl F. McCloskey, M.A.
Rickey L. Stansifer, B.S.M.E.
Nicholas S. Tumbas, M.P.A.
Daniel A. Nicolini, B.S.E.
John W. Prentice, B.S.M.E.
Ralph O. Wisco, B.S.
James C. Choate
Richard C. Crowle

ON-SITE INVESTIGATION TEAM MEMBERS

John P. Cornwell, B.S.
Roger V. Kelley
Keith R. Owens
Phillip G. Riley

DATA REDUCTION AND ANALYSIS STAFF

Donald M. Goldenbaum, Ph.D.
Albert R. Kaled, Ph.D.
Stephen T. McDonald, M.B.A.
Steven J. Polen, M.A.
Suzanne C. Pick-Grobe, A.B.
Paul E. Dawson, A.B.
Echo Cheng, A.B.
Arnold Lewin, A.B.
Roslyn Klein, A.B.
Mary Olgvin, A.B.
Ronald W. Drahos, B.S.
Diane Little
David E. Little
Janina Fitzgerald
Cheryl Sanderson

PUBLICATIONS STAFF

Benedict J. Dulaski II, M.A.
Linda Steele

CONSULTANTS

Roger P. Maickel, Ph.D.
John E. Pless, M.D.
Robert D. Robinson, M.D.
Joseph E. Zabik, Ph.D.

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List of Tables and Figures

1.0 Introduction

This is a final report of the first year of activity under a proposed three-year program entitled "Tri-Level Study of the Causes of Traffic Accidents." This study has been performed by the Indiana University Institute for Research in Public Safety (IRPS), under contract to the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation (Contract No. DOT-HS-034-3-535).

The period of performance for this initial year of activity was 15 August 1972 to 14 August 1973. During this period, approximately 3500 reported accidents occurred in the city of Bloomington and other parts of Monroe County, Indiana of which 356 were investigated immediately following their occurrence by teams of IRPS technicians. Of these 356, 78 were also independently examined by a multidisciplinary investigation team. Other data were collected during this period, including general population survey data, and baseline data describing the study county.

The report is presented in nine major sections: 1.0, Introduction; 2.0, Methodology Overview; 3.0, Findings Regarding Accident Causes; 4.0, Accident and Control Sample Comparisons; 5.0, Cluster Analysis; 6.0, Problem Driver Identification; 7.0, Analyses of Study Sample Representativeness; 8.0, Conclusions; and 9.0, Recommendations.

1.1 General Objective

This study is being conducted to satisfy a broad range of NHTSA's needs for up-to-date information about the factors which cause accidents (i.e., pre-crash phase factors). In order to help satisfy these needs, IRPS has worked in consultation with NHTSA to develop a three-year plan which proposes a series of interrelated objectives, and which also provides for the development of a flexible automated data file which will facilitate efficient handling of the questions and data needs which have not been foreseen in advance.

1.2 Specific Objectives

Specific objectives of the initial year of activity were to:

- Identify those factors which are present and serve to initiate or influence the sequence of events resulting in a motor vehicle accident.
- Determine the relative frequency of these factors and their causal contribution within a defined accident and driving population.
- Formulate and test countermeasures that will serve to eliminate the presence or influence of these factors.
- Assess the potential benefit of anti-skid braking systems in reducing the incidence and severity of automobile accidents.

- Assess the potential benefit of augmented braking systems in reducing the incidence and severity of automobile accidents.
- Apply the taxonomy concept to the identification and definition of problem driver types, and from this to formulate recommendations for dealing with particular classes of drivers.
- Apply the taxonomy concept in particular to the alcohol-impaired driver, in order to identify the type of driving performance mistakes particular types of alcohol-impaired drivers make under particular types of conditions.
- Develop an overall three-year program design that includes work performed under this current contract period and that will fill the needs of NHTSA for information on accident causation.

This report does not deal with all of these objectives. The three-year program design has been the subject of a separate report to NHTSA, and due to IRPS participation in two special investigations at the direction of NHTSA, it was not possible to complete the radar/anti-lock analyses in time for inclusion. These results will be the subject of a later report.

1.3 Background

The National Highway Traffic Safety Administration, in its complex task of reducing the incidence and severity of traffic accidents, is frequently in need of accident data more detailed than those which are available from police reports, insurance company statistics, and other mass data sources. An accident investigation system has therefore been developed by NHTSA, as illustrated in Figure 1-1(1). In large part the system is comprised of a network of contractors who, like IRPS, send their own investigators to the scene of accidents shortly following their occurrence (Figure 1-2).

Several of the largest teams, including IRPS, are of a tri-level structure, meaning that accident data are collected on three levels of detail. The three levels of the IRPS program (in order of increasing detail) are:

- The collection of baseline data on the study county from police reports, vehicle registration files, driver license files, roadway inventories, and local surveys (Level A).
- The on-site investigation of accidents immediately following their occurrence by teams of technicians (Level B).
- The independent, in-depth investigation of a sub-set of the accidents investigated on-site, by a multidisciplinary team (Level C).

Data collected on Level A enable the representativeness of study samples to be assessed. The

Figure 1-1

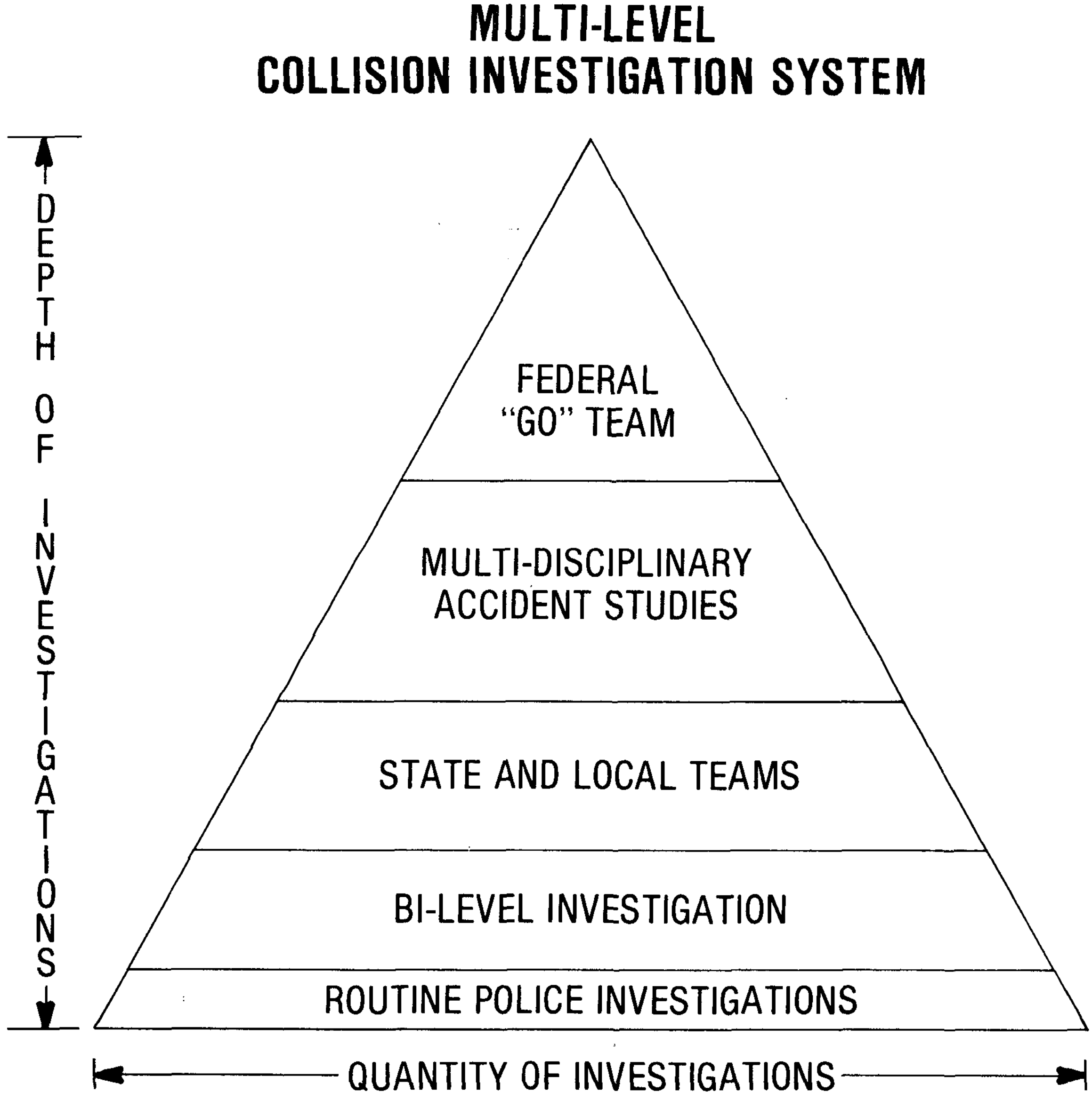
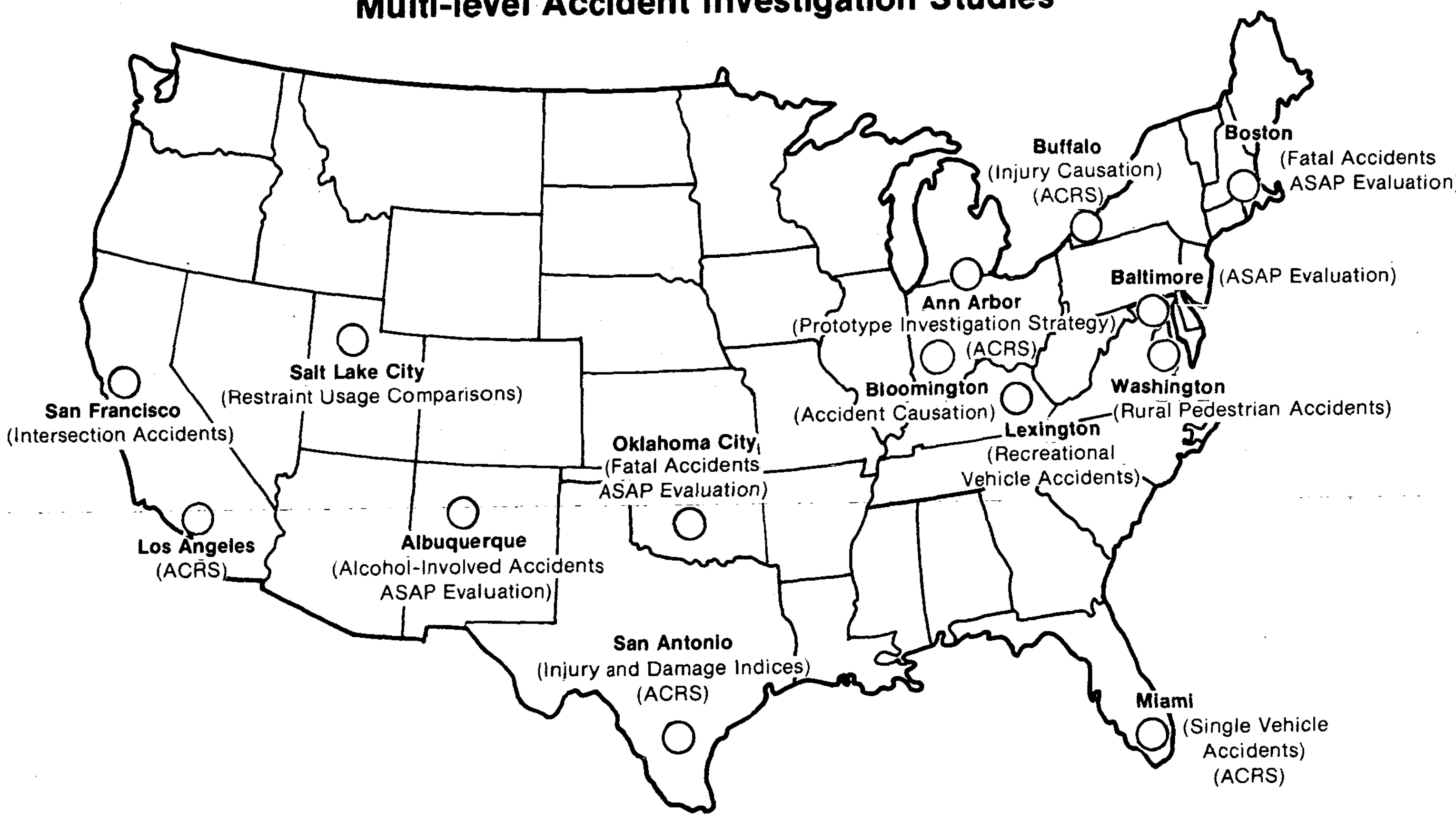


Figure 1-1. National Multi-Level Collision Investigation Systems, *(Reprinted by courtesy of the National Highway Traffic Safety Administration).*

Figure 1-2

Multi-level Accident Investigation Studies



ACRS—Air Cushion Restraint System Evaluation Regional Team

(Reprinted by courtesy of National Highway Traffic Safety Administration)

Level B (or on-site) investigations enable moderately detailed information to be collected from a relatively large number of accidents; accidents are investigated on this level at the rate of 300 to 1,000 per year, depending on the number of hours of coverage provided. Of the three levels, Level C provides the most thorough (and costly) type of investigation. On this level, highly detailed information is collected from about 75 to 150 accidents per year, depending on the number of professionals assigned to the team, the effort expended on each case, and the acquisition rate achieved on Level B.

In recent years, NHTSA has directed many of its contract teams to focus on particular problem areas. IRPS has been assigned responsibility for the examination of factors which cause accidents (i.e., pre-crash phase factors), rather than those which cause or affect crash damage and injury (crash phase factors), or which involve the treatment of injury and restoration of the highway system (post crash factors).

IRPS initiated its examination of pre-crash factors using a tri-level structure in July, 1970 in conjunction with *A Study to Determine the Relationship Between Vehicle Defects and Crashes,* under contract to NHTSA (Contract No. DOT-HS-034-2-263) (2). The present three-year program was then proposed to take a broader and more comprehensive look at accident causation, and activity was initiated in August, 1973 immediately following completion of the previous project. The present project has been able to make use of much of the data and many of the procedures and methods developed earlier. Data from the previous study is designated in this report as either Phase I or Phase II data, whereas data newly generated during the period reported (the first year of the proposed three-year program), is designated Phase III data.

1.4 Scope and Approach

Study objectives were approached through application of the tri-level data collection structure which has been described. Central features of the data collection approach were that an attempt was made to examine a representative sample of all motor vehicle accidents, and that unusually detailed and accurate information was obtained by having research investigators respond directly to the scene of accidents before vehicles were removed or evidence obscured, and before drivers and witnesses had departed.

Monroe County, Indiana served as the study universe. Upon receiving notification of an accident by radio monitoring of police frequencies, or by a direct *hot-line* telephone call from police agencies, an IRPS on-site (Level B) investigation team immediately responded to the scene in special investigation vehicles. At the scene, the team interviewed drivers, inspected involved vehicles and the driving environment, and measured skidmarks and other physical evidence. Later, based on information collected at the scene, the team reached conclusions as to factors which caused the accident. Conclusions and other data generated were then reduced for subsequent analysis. Twenty-two percent of these accidents were then sampled on a chance basis for an in-depth investigation by the multidisciplinary team. The in-depth investigation required additional driver interviews by a human factors specialist, required that involved vehicles be driven or towed to IRPS' garage facility for inspection by an automotive engineer and mechanic, required the inspection of the scene by a traffic engineer, and required reconstruction of the accident by a specialist. Based on this information, group conclusions were reached regarding accident causes, and a separate case report on each investigation was submitted to NHTSA.

Accidents investigated on both Levels B and C included accidents of all severities and model years, in about the same proportion in which they actually appear in the accident population. The only significant exclusions were accidents involving large trucks (over 8000 lbs. gvw), motorcycles, and vehicles pulling trailers.

Conclusions reached by Level B and C teams were tabulated, and results for each causal factor were expressed as the percentage of accidents in which causally implicated. Analyses were then conducted to assess such factors as the variance of accident severity as a function of causal factor, the model year distribution of vehicles having causative deficiencies, and whether there are particular driver, vehicle, or accident variables which uniquely cluster with individual causal factors.

Although a total of 356 accidents were investigated on Level B and 78 on Level C during the period reported (through 14 August 1973), only accidents acquired for investigation prior to 1 June 1973 were investigated and analyzed in time for inclusion in this report. New (Phase III) data reported thus includes 306 Level B and 64 Level C investigations.* However, many of the analyses in the report are based on combined Phase II and Phase III data, bringing the total number of accidents considered to 836 on Level B, and 215 on Level C.

In addition to investigating accidents on Levels B and C, IRPS also acquired baseline information from a variety of sources (Level A). For example, police report data were secured by acquiring a copy of the state police summary tape, data regarding driver age and sex distributions were acquired by manually sampling from local license files, and more detailed information about the local driving population was obtained by conducting field surveys. This information has been used primarily to assess the representativeness of study samples, and to aid in the identification of overrepresented drivers and vehicle age groups.

*Some tabulations are based on data from only 63 of these accidents.

2.0 Methodology Overview

Only an overview of study methodology will be provided here, since a detailed paper regarding IRPS accident investigation methodology is provided in Appendix A, and descriptions of specialized data collection and analysis methodologies accompany each of the topical sections. The principal data collection forms are provided in Appendices B and C.

The tri-level data collection structure developed in IRPS' earlier causation study has been largely retained in the current program, and many of the data collection forms and procedures have also been adapted for use with only minor changes. Methodology for this earlier study was extensively described in a report entitled *Interim Report of a Study to Determine the Relationship Between Vehicle Defects and Crashes: Methodology (1).*

2.1 Causation Assignment

Accident causes were assigned based on the clinical assessments of the Level B (on-site) and Level C (in-depth) investigation teams.

During the period reported, on-site teams have variously consisted of either two or three investigators. After completing their investigations at the scene, producing a sketch of the scene, and reducing data to the various collection forms, they jointly decided which causal factors should be cited. This discussion occurred with reference to an accident cause *dictionary* initially developed during IRPS' earlier causation study (See "Glossary"). Conclusions were then entered on a special form (Appendix B), coded, keypunched, and stored for later analysis. Procedures were much the same for the in-depth team, but involved more people, more formality, and were based on much more detailed data.

There were seven principal members of the in-depth team: a sociologist, a traffic engineer, a reconstruction specialist, an automotive engineer, a mechanic, and an engineering assistant/technical writer. Following the team's investigation of each accident and the reduction of data, an analysis and conclusion session was held. Information inputs to this session included color slides of the accident scene and vehicles, transcripts of driver interviews, computed speed estimates and time/distance evaluations (where feasible), scale drawings of the accident scene depicting vehicle trajectories through the collision sequence, inspection data regarding both accident vehicles and the accident environment, and completed human factors data forms indicating such factors as driving experience, vehicle familiarity, driver's trip plan and purpose of trip, etc. At this session representatives of each discipline presented their evidence, interacted, and then decided what causal factors should be cited using the same causal dictionary as the on-site team. These conclusions were then included in the individual case reports which were prepared on each in-depth investigation. These conclusions were coded directly from the case report copy, and then key-punched and stored for later analysis.

To facilitate the uncertainty and subjectivity inherent in clinical, case-by-case assessments of *cause*, a special classification system and nomenclature have been developed for use by both the on-site and in-depth teams, which permits investigators to express the assuredness of their conclusions as *certain, probable, or possible* (Figure 2-1). A *certain* rating is applied only when there is absolutely no doubt as to a factor's role, and is considered analogous to a 95 percent confidence level. A *probable* rating means *highly likely although not definite*, and is considered analogous to an 80 percent 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 inappropriate at the *possible* level.

Figure 2-1

Causal Factor Rating System

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

In addition, factors are designated as being of either *causal* or *severity-increasing* significance, according to the following definitions:

- Casual 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.
- 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 impact which resulted.

It should be noted that these definitions describe only pre-crash factors. Crash phase factors such as the performance of seatbelts, and post-crash factors such as the outbreak of fire are, thus, not intended to fall within either the "causal" or "severity-increasing" definitions. The following examples are intended to clarify the proper usage of these terms:

Example #1: A driver in heavy traffic suddenly notices that the vehicle ahead of him has stopped, and that he has no reasonable means of avoiding an accident other than staying in his lane and stopping. He hits his brakes and skids into the vehicle in front of him. Investigation reveals that due to a master cylinder problem, only his rear brakes were operative. It is calculated that even the poorest braking efficiency which could have been expected with all four wheels braking properly, would have brought his vehicle to a stop several feet short of impact.

Result: The brake system problem would be cited as a *causal factor*, (and other factors might be cited if identified).

Example #2: In this instance the situation is the same as above, except it is calculated that even with properly operating brakes, collision would not have been avoided, although the speed of impact would have been reduced.

Result: The brake system problem would be cited as a *severity-increasing* factor rather than as a *causal factor*.

It should also be noted that there is no limit to the number of factors of either significance which can be identified for a particular accident. Particularly in the second example, it is likely that there has been delay or failure on the part of the driver which has placed him in a situation where even properly operating brakes would not enable him to stop short of the vehicle in front of him. A human factor— possibly *inattention*- might thus also be identified as a *causal factor* in the same accident.

Sample results from the detailed causal data tables (which appear in Appendices D, E, and F) are shown in Figure 2-2. 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 2-2). Since results for both Levels B and C are shown in this same table, the end result is that for a given causal factor, there are a total of 18 cells of interest (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 information on 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 2-2's cells have been extracted for presentation in summary tables, and for use in many of the sub-analyses (e.g., the analysis of differences in Phase II and Phase III results). 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

Figure 2-2

Example of Detailed Causal Data Tables

	DEGREE OF CERTAINTY	LEVEL OF INVESTIGATION	CAUSAL N	CAUSAL 0/0	S/I N	S/I 0/0	CAUSAL OR S/I N	CAUSAL OR S/I 0/0
A. HUMAN FACTORS	CERTAIN	C	127	84.1	1	.7	128	84.8
		B	387	73.0	2	.4	389	73.4
	CERTAIN OR PROBABLE	C	146	96.7	0	0.0	146	96.7
		B	476	89.8	4	.8	480	90.6
	CERTAIN PROBABLE OR POSSIBLE	C	149	98.7	1	.7	150	99.3
		B	499	94.2	7	1.3	506	95.5
1. CRITICAL NON-PERFORMANCE	CERTAIN	C	2	1.3	0	0.0	2	1.3
		B	5	.9	0	0.0	5	.9
	CERTAIN OR PROBABLE	C	2	1.3	0	0.0	2	1.3
		B	6	1.1	0	0.0	6	1.1
	CERTAIN PROBABLE OR POSSIBLE	C	2	1.3	0	0.0	2	1.3
		B	6	1.1	0	0.0	6	1.1
A. BLACKOUT	CERTAIN	C	1	.7	0	0.0	1	.7
		B	4	.8	0	0.0	4	.8
	CERTAIN OR PROBABLE	C	1	.7	0	0.0	1	.7
		B	5	.9	0	0.0	5	.9
	CERTAIN PROBABLE OR POSSIBLE	C	1	.7	0	0.0	1	.7
		B	5	.9	0	0.0	5	.9
B. DOZING	CERTAIN	C	1	.7	0	0.0	1	.7
		B	1	.2	0	0.0	1	.2
	CERTAIN OR PROBABLE	C	1	.7	0	0.0	1	.7
		B	1	.2	0	0.0	1	.2
	CERTAIN PROBABLE OR POSSIBLE	C	1	.7	0	0.0	1	.7
		B	1	.2	0	0.0	1	.2

cell are termed *probable-level* results, or results *with probable findings included.*

Results obtained through the clinical assessment of cause on a case-by-case basis have the obvious difficulty of being impossible to directly validate on an experimental basis. However, viable alternatives have not been identified for many of the risk-identification problems addressed by the study. Conceptually, causal results should be viewed as establishing **minimum** involvement rates, and every effort has been to apply the *causal-certain* rating in a conservative manner so that it represents a reliable and defensible minimum.

As indicated earlier in this section, the *dictionary* of causal factors employed appears in a Glossary at the end of the report, and the assessment methodology is further described in Appendix A. The assessment methodology has also been the subject of exhaustive description in an earlier report (1). It should be noted that the causal hierarchy used, and many of the factor names, had their origin in earlier NHTSA-sponsored research, and particularly that of Cornell Aeronautical Laboratory (now Calspan, Inc.) (2).

2.2 Quantitative Analysis Procedure

Although many of the data processing forms and procedures were established during performance of *A Study to Determine the Relationship Between Vehicle Defects and Crashes,* (3) much of the analytical procedure was streamlined during the present study. Data editing and analysis programming procedures were completely redesigned, allowing for a greater degree of automation, thereby decreasing processing time and the probability of errors in the data. These changes reflect an intermediate stage in the construction of a fully automated File Management System (FMS) which when completed will edit and manipulate data without direct human intervention and will produce analytical reports, tables, and graphs with negligible turnaround time and minimal error.

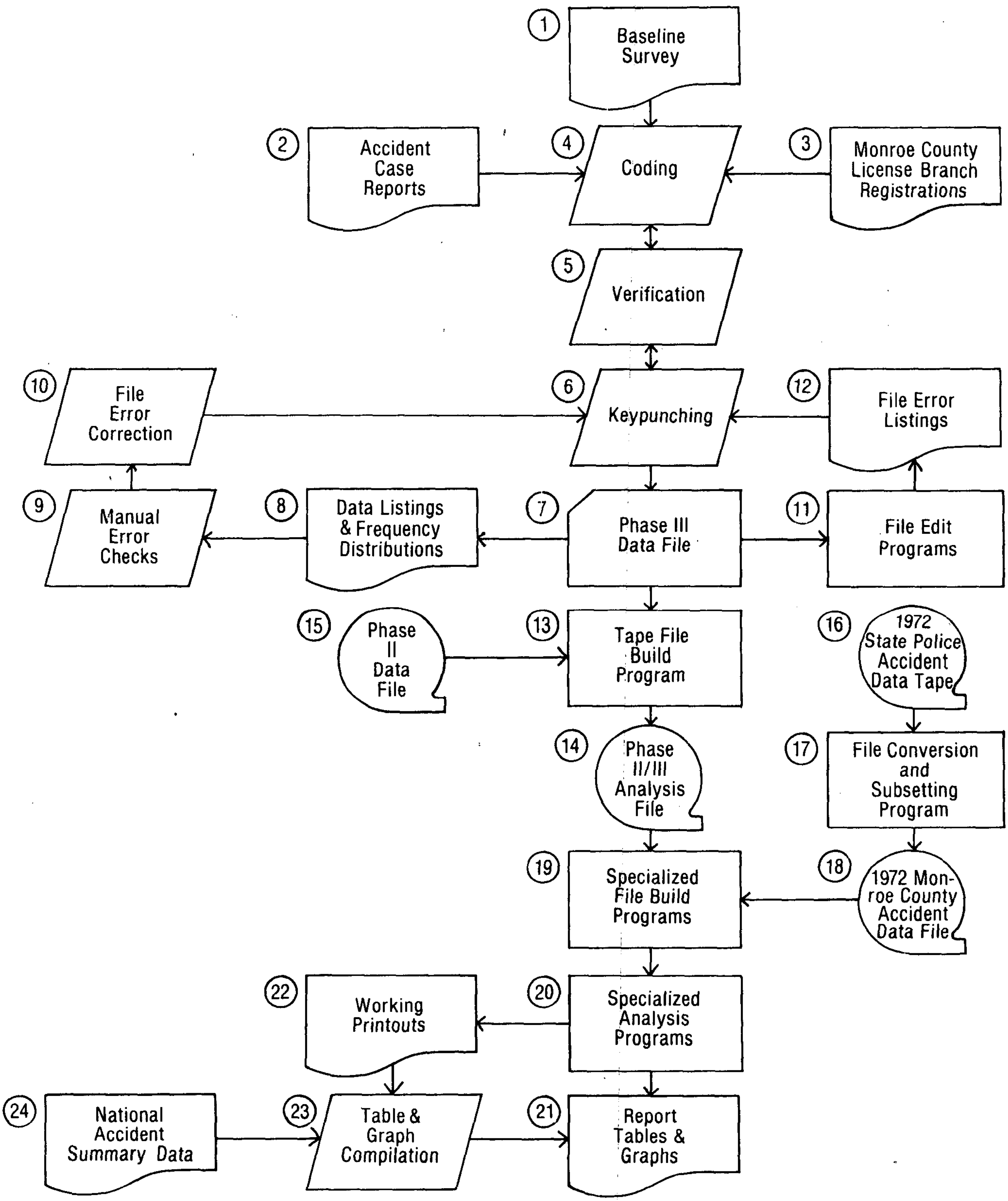
Figure 2-3 is a macroflowchart of the entire data reduction and analysis process. Circled numbers adjacent to each process, file, or document are used solely as reference aids in the discussion to follow. The chart shows the interfacing of data, processes, documents, and files, beginning with accident case report forms 2 * and baseline data surveys and samples, 1 3 and ending with completed report tables and graphs 21 presenting analyses of these data.

Figure 2-3 shows that there were three types of data requiring reduction from hard-copy to machine-readable medium. Baseline survey forms 1 used in parking lot survey of general population drivers and vehicles (Section 4.0) were self-coding. The form, shown in Figure G-3, required little preparation for keypunching. Coders 4 merely transferred codes marked by the field interviewers to column-numbered spaces on the form. This activity consumed little time relative to the large effort required to code data from the on-site and in-depth accident case

*Encircled numbers have reference to the flow chart which appears as Figure 2-3.

Figure 2-3

Data Reduction and Analysis Procedures



report forms(2). here, coding proceeded casewise, and all raw data forms pertaining to an individual accident were gathered together and referred to simultaneously in filling out coding forms for that accident. The coding forms themselves had been designed during performance of *A Study to Determine the Relationship Between Vehicle Defects and Crashes*, with the exception of three forms* which were added during the present study to enlarge the breadth of our accident data base. Coding forms for all data arrays† except the three new arrays had been printed and columns labelled to indicate the name of the variable assigned to that card column. Coders consulted a coding handbook to determine the appropriate code for each variable to be coded. The third coding effort comprised taking samples of **driver age, driver sex, vehicle make,** and **vehicle model year** from registrations on file at the Monroe County License Branch(3). The coding forms used at the License Branch are shown in Figures G-1 and G-2. All coding was verified (5) by an alternate coder, in order to reduce the possibility of human error in the coded data. For the baseline survey (1), data items were checked for consistency, and any discrepancies resolved where possible. When inconsistencies could not be resolved by examination of other data items on the form, the discrepant data items would be coded as missing data. For the accident data(2), the verification process was more extensive. An alternate coder verified each coded case by re-reading the case report, re-examining the codes on the case coding forms, and reconciling any inconsistencies noted. For the registration samples (3), data coded onto sampling sheets were verified by a second coder sent to the License Branch.

After coding forms were completed and verified, a keypunch operator punched 80-column data cards by referring to the code indicated for each card column on the coding form(6). Accident data were punched casewise, as coded cases became available. Baseline survey data and baseline sample data were punched *en masse*. After a number of cards had been punched, the deck was subjected to punch-verification(5), where the keypuncher repunched all card images from the coding sheets into a verifying machine which flagged any card columns potentially in error. Cards having punch errors were corrected on-line. The resultant card decks were then cataloged and stored for further editing.

The card decks comprising the preliminary Phase III data file(7) were subjected to several types of manual and computer-assisted edits. All card decks were input to computer programs which produced specially formatted listings of the card images(8). Other computer programs were used to produce tallies of the frequency of occurrence of each code for each variable(8). Coders conducted manual edit checks(9) on these printouts, inspecting the card image listings for missing and misfiled cards, and inspecting the frequency distributions for blank card columns and code values out of range. Coders reconciled any discrepancies and then took

*Data on on-site environmental factors, on-site human factors, and in-depth human factors were coded for phases I through III during the period of the study.

†An **array** is a homogeneous set of accident or baseline data coded from a single accident data form or other source.

actions necessary to correct the cards missing or in error (10). A final, automated edit check was then conducted on each data array (11) . The computer program used for this purpose was specially written to check for proper order of case numbers, traffic unit numbers, and card numbers for each array, and produced a listing (12) of all such cards in error. Where appropriate, decks were checked for proper number of cases. Using the error listings, coders amended the card deck files, referring to the original accident case reports where appropriate.

The card decks comprising the edited Phase III data file were written to 7-track magnetic tape by soft ware (13) which allowed read-back of any single array. All arrays comprising the Phase II data file* (15) were also written to this tape, thus creating a master Phase II/III Analysis File 14, organized by array. This file served as the primary of two working data files used for all computer-produced and computer-assisted analyses appearing in this report. Level A accident data were obtained from another source and maintained on a separate file. The original source of Level A data was the state police-supplied tape file containing data on all driver- and police-reported accidents occurring in Indiana during 1972 (16) . This four-reel tape file was converted from 9-track to 7-track for use on Indiana University's Control Data 6600 Computer System. The IRPS-written program which performed this transformation (17) also subsetted this file to include only accidents occurring in Monroe County, thus producing a 7-track Monroe County Accident Data File (18) . Both this Monroe County Accident File and the Phase II/III Analysis File were used as source files for creation of subfiles specially suited to individual analyses performed. For example, production of the causal factor tables presented in Appendices D, E, and F required analysis files having certain subsets of Phase II/III causal factor arrays merged on a casewise basis. The array selection, merging, and subsetting operations were performed by file-build programs (19) which produced analysis subfiles properly structured for each analysis to be performed. The analysis programs themselves (20) , written in Fortran IV, directly produced many of the tables (21) appearing in this report. The use of specially written, format-oriented programs is an improvement over the report table production techniques used during *A Study to Determine the Relationship Between Vehicle Defects and Crashes,* since these new programs eliminated the need for coders to compile report tables from numerous printouts, thereby substantially reducing the possibility of errors in the tables and saving a great deal of time. While this technique was used where feasible, programs to produce certain of the tables in this report would have required inordinate amounts of format-oriented programming time (e.g., tables in Section 6.0 on the Problem Driver). For analyses of this type, the programs written produced intermediate or *working* printouts (22) from which staff members compiled tables and drew graphs. These working printouts contained intermediate data such as one-way frequency distributions, cross-tabulations and chi-square statistics. These intermediate figures were used in manual

*This file consists of accident data collected during the second phase of performance of *A Study to Determine the Relationship Between Vehicle Defects and Crashes.*

computations and transformations, and then transcribed into tables appearing here. For the Representativeness Analysis (Section 7.0), documents showing national accident summary statistics (24) were used in conjunction with working printouts containing frequency distributions on Monroe County accidents to produce some of the tables shown in that section.

Although the table production process was partially automated during the course of this study, tables and graphs in future reports will be produced by increasingly automated processes, thereby reducing table and graph production time and minimizing errors. Likewise, data editing will be a completely automated process. Data reduction time will be further reduced by the use of several self-coding accident data collection forms during Phase IV.

3.0 Findings Regarding Accident Causes

3.1 Introduction

In this section the causal factors assessed by the on-site and in-depth investigation teams during the past year of the present program (Phase III), and during the previous phase of IRPS' earlier causation study (Phase II), are tabulated and analyzed in several different respects. Combined Phase II/III data are also presented.

The section is comprised of eight subsections, the last six of which each relate to different analyses or presentations of the causal factor results. The first of these six (Section 3.3) expresses the causal involvement of the human, vehicular, and environmental factor groups both alone, and in combination with each other (i.e., human only, human and environmental, etc.). However, results for more detailed factors, such as excessive speed and inattention, are not dealt with; these are covered later in Section 3.4. Section 3.3 is actually an alternative means of presenting the causal data from the following section (Section 3.4). In Section 3.4, results for individual factors (e.g., excessive speed) and factor groups (e.g., human direct causes) are expressed as the percentage of accidents in which implicated. The relationship between Sections 3.3 and 3.4 can be appreciated by noting that, if all of the involvement percentages containing human factors in Section 3.3 are added for any certainty level (e.g., human only; human and environmental; human and vehicular; and human, vehicular, and environmental) this will equal the involvement figure provided for all human factors in Section 3.4, at the same certainty level.

In Section 3.6, results obtained in Phase III are compared with those from Phase II, and significant differences noted. In Section 3.7, accident severity is examined as a function of causal factor. In Section 3.8, the model year distribution of vehicles involved in accidents as a result of their own system failures and deficiencies is compared to that of all vehicles registered in the county. Finally, in Section 3.9 results obtained by the on-site teams are compared with those resulting from in-depth investigation.

The causal results presented in this section were the principal inputs to the cluster analysis discussed subsequently in Section 5.0, and one of several inputs to the problem driver analysis in Section 6.0.

3.2 Methodology

Production of the accident cause tabulations did not require the application of quantitative analysis tools or other methodology beyond that described in Section 2.0 (Methodology Overview) and Appendix B of this report. However, special procedures were required to assess differences in Phase II and III results, determine accident severity as a function of causal factor, determine the model year distribution of vehicles involved in accidents as a result of vehicle deficiencies or failures, and assess the agreement and disagreement of results obtained for accidents investigated by both the on-site and in-depth teams.

In order to assess differences in causal findings in Phases II and III, results for each of the 136 causal factors and factor groups from each phase were compared (see Appendix D, E, or F for a list of these categories). The in-depth and on-site samples were examined separately, so that a total of 272 comparisons were involved. $\overline{X}^2$ tests with Yates correction were used to test the hypothesis that percentage differences for each factor were accounted for by chance alone.

In order to examine the propensity of different causal factors to influence accident severity, two separate sets of causal result tables were generated for accidents involving only property damage (PD), and for accidents involving either personal injuries or fatalities (PI/F). These were based on combined Phase II/III data. The relatively small number of accidents in the study sample which involved moderate to serious or fatal injuries (AIS 2 or over) prohibited further stratification by severity. It is estimated that about three-quarters of the accidents in the PI/F group involved only minor injury (AIS 1).

$\overline{X}^2$ tests were used to test the hypothesis that the distribution of accident severity (in terms of PD or PI/F) for accidents resulting from a particular causal factor is the same as the severity distribution for all accidents in the respective sample (on-site or in-depth).

In order to measure the relationship between vehicle age and the incidence with which vehicles were involved in accidents resulting from their own system failures and deficiencies, the model year distributions of registered county vehicles were compared to the model year distribution of vehicles having accident-causative or severity-increasing deficiencies in the on-site, Phase II/III accident sample. *Probable level* (i.e., certain or probable, causal or severity-increasing) results were used. In-depth results were not considered because the sample size was prohibitively small. One overall comparison and eight subfactor comparisons were made. $\overline{X}^2$ tests were used to test the hypothesis that model year distributions of these *culpable* vehicles are the same as registered county passenger vehicles. Yates corrections were applied for the subfactor tests (e.g., regarding the braking system) where data were reduced to 2 x 2 tables. Adjustments for the effects of changes in the vehicle population which occurred during the two-year period in which the accident sample was assessed were not attempted; such corrections would have been difficult and were not essential to the discovery of age-related involvement trends. Comparisons were tabulated via computer, and chi-square tests were then computed manually.

For the most part, percentage results obtained by the on-site and in-depth teams have simply been compared, and the largest differences noted and discussed. Tests of significance have not been applied to these differences since some of the accidents investigated by the on-site team were also examined by the in-depth team, and (in a sense) are thus not mutually exclusive. On the other hand, evaluation of differences in assessment practices between the two different types of investigation by examination of percentage differences only makes sense if it is assumed that the accidents in the two samples are about the same (i.e., were actually caused by the same kinds of factors in the same proportions). It is therefore not of concern that some of the accidents examined in fact **were** the same, when percentage results are compared.

However, percentage comparisons provide limited insight because disagreement on an accident-by-accident basis could have occurred frequently and yet **not** necessarily have affected the magnitude of factor percentage differences. For example, both teams could have reported involvement of a particular vehicle factor in 20 percent of accidents, and yet have never agreed as to the involvement of this factor in any of the accidents which both teams investigated. Therefore, an analysis was planned in which the 213 accidents investigated by **both** the on-site and in-depth teams during Phases II and III would be compared on a casewise basis, using agreement/disagreement criteria which were established. Results of this analysis for the top-level human, vehicular, and environmental factor groups are presented in Table 3-13. However, difficulties were experienced with the programs written to group results for the various more detailed categories (e.g., inattention and excessive speed) which were not able to be resolved in time for inclusion in this report. Such casewise comparisons for the detailed categories will be examined later.

3.3 Accidents Caused by Human Factors Only, Human and Environmental Factors, etc.

In this section, the proportion of accidents caused by various **kinds** of causal factors (e.g., human, vehicular, environmental), acting alone (e.g., human only) and in combination with other kinds of factors (e.g., human and environmental), is examined.

3.3.1 Results

Table 3-1 includes all resultant data on this subject and cumulative Phase II and III data are graphically displayed in Figure 3-1. Differences occurring in the cumulative data between certainty levels (e.g., certain, probable, possible) are clarified in Figures 3-2 (in-depth data) and 3-3 (on-site data).

Human factors acting alone were the predominant cause of accidents; human and environmental factors in combination generally ranked second. The rank of the remaining factors and combinations varied with the certainty level. At the highest certainty level (definite), the cumulative Phase II and III data showed two uncombined factors—environmental factors and vehicular factors—to rank third and fourth, respectively, followed by the combinations of human and vehicular (fifth), human, vehicular, and environmental (sixth), and vehicular and environmental (seventh) (Figure 3-1). At lower certainty levels (probable and possible) the combinations *human and vehicular* and *human, vehicular, and environmental,* increase substantially and rank ahead of the uncombined environmental and vehicular factors, which decline. These changes with certainty level held true on both the on-site and in-depth levels (Figures 3-2 and 3-3).

Table 3-1

Percent of Accidents Caused by Human, Vehicular, and Environmental Factors Alone and In Combination

	Definite Causes*						Probable Causes†						Possible Causes††					
CAUSAL FACTORS	Phase II		Phase III		Phase II & III		Phase II		Phase III		Phase II & III		Phase II		Phase III		Phase II & III	
	B	C	B	C	B	C	B	C	B	C	B	C	B	C	B	C	B	C
Human Only (H)	56.2	69.5	60.8	73.0	57.9	70.6	48.3	53.6	52.0	65.1	49.6	57.0	34.0	41.1	47.1	52.4	38.8	44.4
Environment Only (E)	7.4	5.3	4.2	4.8	6.2	5.1	5.1	0	2.0	3.2	3.9	.9	2.5	0	1.6	0	2.2	0
Vehicle Only (V)	3.6	3.3	2.3	0	3.1	2.3	2.6	2.6	2.3	0	2.5	1.9	1.3	0	1.3	0	1.3	0
H & E	13.8	11.9	20.3	7.9	16.1	10.7	31.1	28.5	35.6	28.6	32.8	28.5	40.4	31.8	38.6	34.9	39.7	32.7
H & V	2.5	2.0	.3	0	1.7	1.4	5.8	9.9	2.9	3.2	4.8	7.9	8.5	14.6	5.6	7.9	7.4	12.6
V & E	.4	0	.7	0	.5	0	.2	.7	.7	0	.4	.5	.8	.7	.7	0	.7	.5
H & V & E	.6	.7	.3	0	.5	.5	5.3	4.6	3.3	0	4.5	3.3	12.6	11.9	5.2	4.8	9.9	9.8
Not Affirmed	15.7	7.3	11.1	14.3	14.0	9.3	1.5	0	1.3	0	1.4	0	0	0	0	0	0	0

*Definite means "Causal-Certain" (See Section 2.1 for further explanation).
†Probable means "Causal or Severity-Increasing, Certain or Probable."
††Possible means "Causal or Severity-Increasing; Certain, Probable, or Possible."

Note: Total "N" is: Phase II—Level B—151, Level C—530; Phase III—Level B—63, Level C—306; Phase II/III—Level B—214, Level C—836. Not affirmed means that no causal factors were identified at the certainty level specified.

Human factors alone were identified as definite causes in 70.6 percent of the Phase II and III accidents investigated by the in-depth team, and in 57.9 percent investigated by the on-site team. In these accidents, although environmental and vehicular factors may have been identified at the possible or probable levels, only human factors appeared at the definite level. At lower certainty levels, the proportion of accidents in which only human factors are identified decreases; in 57.0 percent of accidents investigated by the in-depth team and 49.6 percent investigated on-site, human factors were identified as either definite or probable causes, although no environmental or vehicular factors exceeded the *possible* level in these cases. In 44.4 percent of accidents investigated in-depth, and 38.8 percent investigated on-site, human factors alone were identified as possible causes; in these accidents human factors were

Figure 3-1

Percentage of Accidents Caused by Human, Vehicular, and Environmental Factors Alone and In Combination—During Phases II/III (combined)

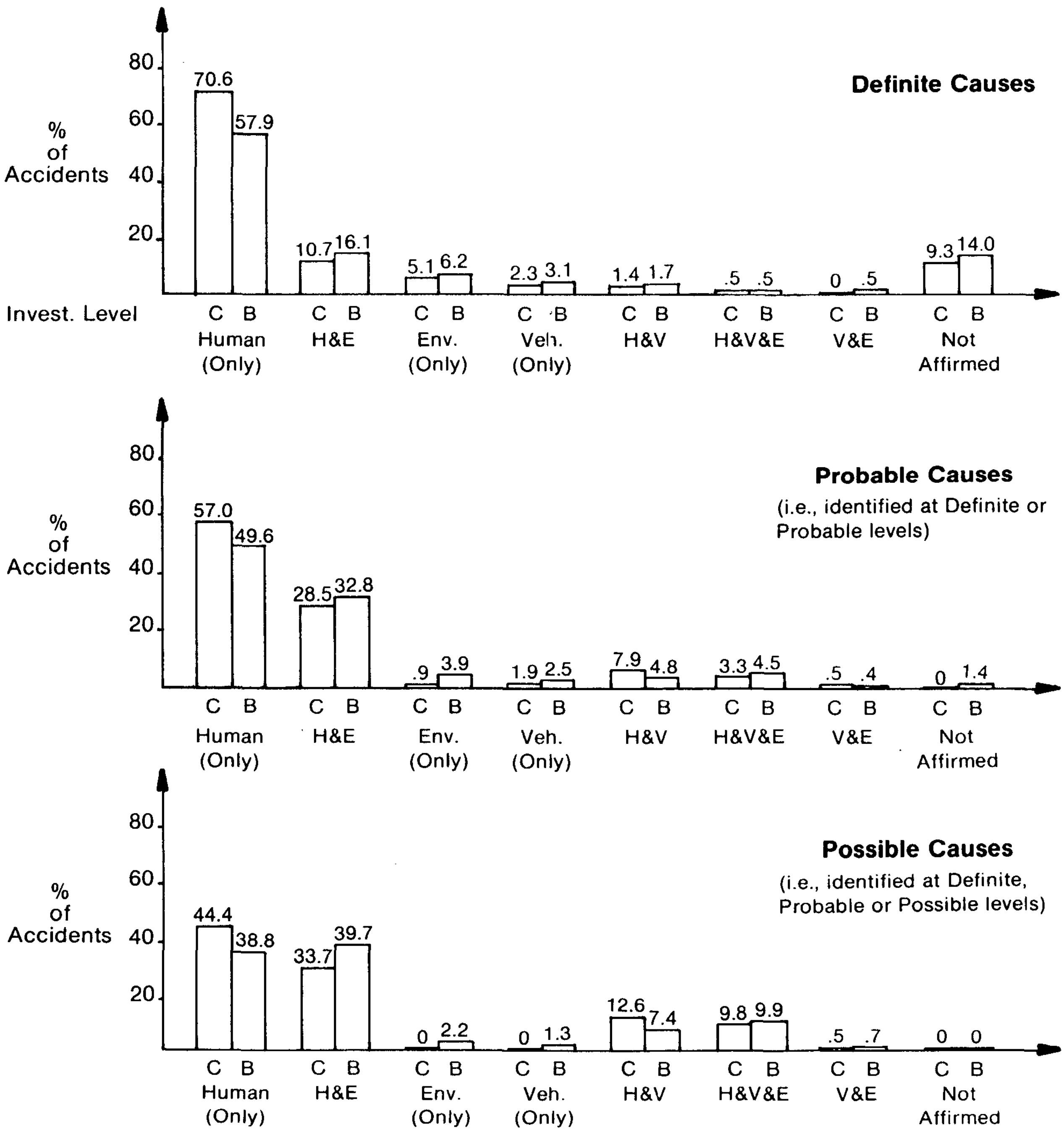
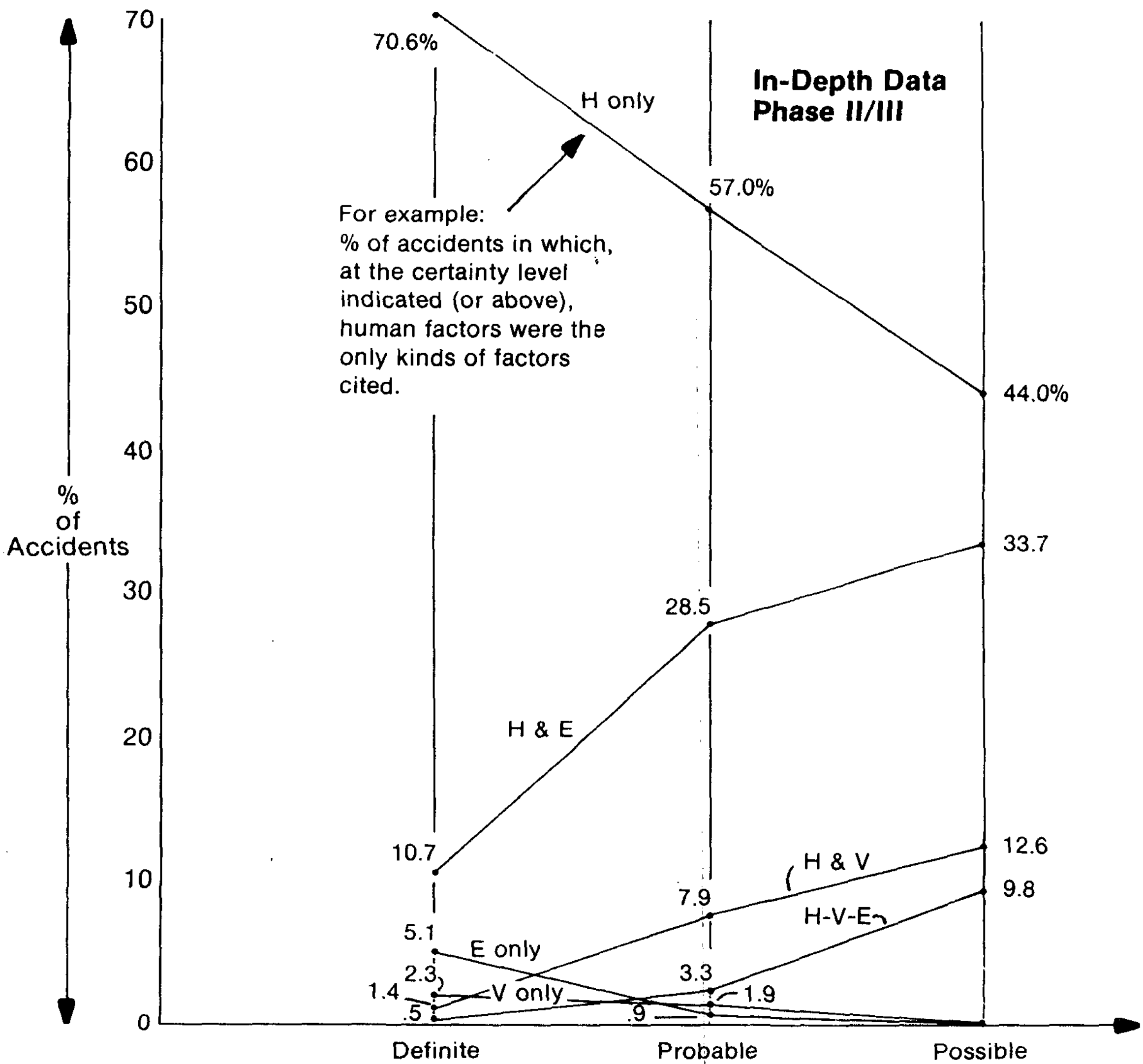


Figure 3-2

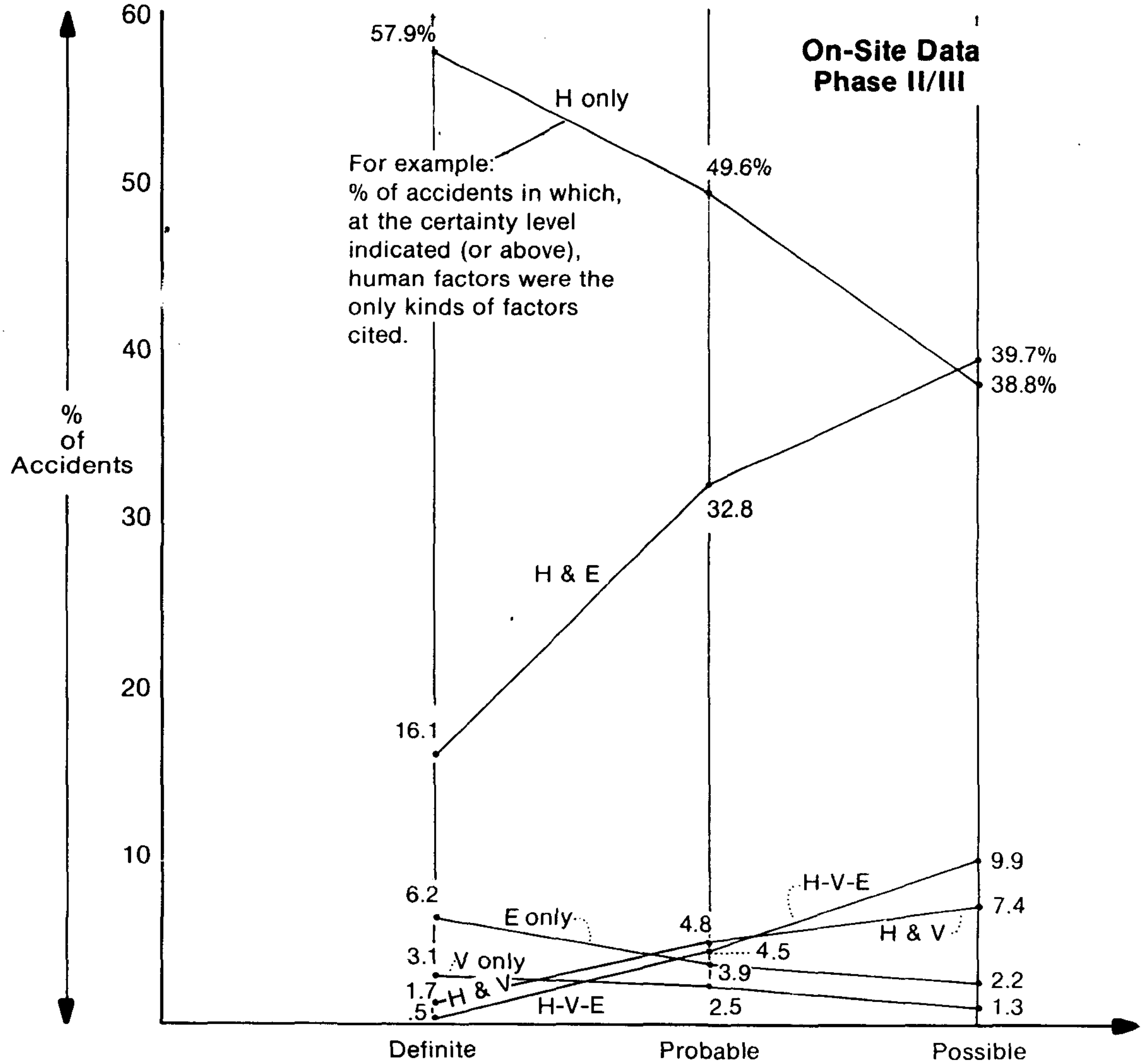
Percent of Accidents Caused by Human, Vehicular, and Environmental Factors Alone and in Combination (Phase II/III, In-Depth Team Data)



Note: Not shown are "V & E," and "Not Affirmed," since entries were minimal.

Figure 3-3

Percent of Accidents Caused by Human, Vehicular, and Environmental Factors Alone and in Combination (Phase II/III, On-Site Team Data)



Note: Not shown are "V & E" and "Not Affirmed," since entries were minimal.

identified as possible, probable, or definite causes, but no environmental or vehicular factors were considered to be even possible causes.

Both human and environmental factors were identified as definite causes in 10.7 percent of the Phase II and III accidents investigated by the in-depth team, and in 16.1 percent of the accidents investigated on-site. The proportion of accidents involving this combination increases as lower certainty levels are considered. Both human and environmental factors were identified at either the probable or definite level in 28.5 percent of the in-depth accidents, and 32.8 percent of those investigated on-site. Finally, in 33.7 percent of the in-depth and 39.7 percent of the on-site accidents, human and environmental factors were each identified as either possible, probable, or definite causes, and no vehicular factors were identified at any of these certainty levels (in these same accidents).

3.3.2 Discussion

These results underscore the overwhelming influence of human factors in automobile accident causation. Even where vehicular and environmental factors are causally involved, it is generally in combination with a human failure. When all the involvement percentages for human factors (alone and in combination with vehicular and environmental factors) are tallied, it is found that human factors were definite causes in 83.2 percent of the combined Phase II/III accidents investigated by the in-depth team, and in 76.2 percent of those investigated by the on-site team (Figure 3-4). A similar tabulation including the probable cause level totals 96.7 percent (in-depth) and 91.3 (on-site). (Results tabulated in this manner are presented in greater detail in Section 3.4.)

However, these results indicate that vehicular and/or environmental factors, were definite or probable causes in nearly one-half of the accidents investigated and thus are certainly not to be ignored. The large number of accidents involving combinations of human and environmental factors (about 30 percent at the probable level) indicates that it will be desirable in the future to see if there are combinations of particular human and environmental factors which tend to occur. An initial attempt has been made in this direction (Section 5.0), which generally indicated that strong correlations in the appearance of causal factors did not exist. It would be reasonable to expect, for example, that improper lookout (the most common human cause) might frequently occur in combination with view obstructions (the second most common environmental cause). This possibility needs to be further examined during the remaining period of the current program.

Figures 3-2 and 3-3 are interesting in their similarity, as well as in the relative constancy of the rate of change of each category as it progresses from definite, to probable, to possible. The similarity in the on-site and in-depth plots indicate that the teams have applied the causal categorization system in very much the same way, in spite of the great differences in both the staffing of the in-depth and on-site teams and the manner in which they operate (a limited number of professionals drawing on extensive data versus several different teams of technicians drawing only on data available at accident scenes).

It should be noted that results from the earliest project phase (Phase I) were not included in these tabulations. The decision not to include these earlier data was reached in consultation with NHTSA and was based on the fact that the Phase I causal categorization system differed from that of Phases II and III, and the investigation methodology in the earlier phase was generally less rigorous.

3.4 Involvement of Individual Factors and Subfactors

This section examines the frequency with which various individual factors were identified as accident causes. Combinations of factors are not examined. Results are expressed as the percent of accidents in which identified.

3.4.1 Results

Table 3-2 shows the location of the data tables which present Phase II, Phase III, and combined Phase II/III causal findings in detail. This table also indicates which individual (non-grouped) factors (e.g., improper lookout, inattention) were most frequently identified in each Phase. Tables 3-3 and 3-4 parallel Table 3-2, providing summaries of causal result data. Table 3-3 extracts percentages from the *causal-certain* cells of the detailed tables, and Table 3-4 extracts percentages from the *causal or severity-increasing, certain or probable* cells. In Figures 3-4 through 3-12, results from the combined Phase II/III data are graphically presented and ranked.

Table 3-2

Guide to Detailed Data Tables (With Indication of Most Frequently Implicated Factors)[1]

Causal Factors	Phase II	Phase III	Phases II & III
Major Groups:	(Appendix and page numbers)		
• Human—Direct Causes	D - 1	E - 1	F - 1
• Human—Conditions & States	D - 26	E - 26	F - 26
• Environmental	D - 31	E - 31	F - 31
• Vehicular	D - 50	E - 50	F - 50

Table 3-2 continued

Causal Factors	Phase II	Phase III	Phases II & III
Detailed Outline:			
Human Factors—Direct Causes	D - 1	E - 1	F - 1
1. Critical Non-Perf.	D - 1	E - 1	F - 1
a. Blackout	D - 1	E - 1	F - 1
b. Dozing	D - 1	E - 1	F - 1
2. Non-Accident (e.g., suicide)	D - 2	E - 2	F - 2
3. Recognition Errors	D - 2	E - 2	F - 2
a. Driver Failed to Observe Stop Sign	√ D - 2	E - 2	√ F - 2
b. Delays in Recognition—Reasons Identified	D - 2	E - 2	F - 2
(1) Inattention	√ D - 3	√ E - 3	√ F - 3
(2) Internal Distraction	√ D - 4	√ E - 4	√ F - 4
(3) External Distraction	D - 6	E - 6	F - 6
(4) Improper Lookout	√ D - 7	√ E - 7	√ F - 7
c. Delays in Perception for Other or Unknown Reasons	D - 9	E - 9	F - 9
d. Delays in Comprehension or Reaction—Other or Unknown	D - 10	E - 10	F - 10
4. Decision Errors	D - 11	E - 11	F - 11
a. Misjudgment	D - 11	E - 11	F - 11
b. False Assumption	√ D - 12	√ E - 12	√ F - 12
c. Improper Maneuver	√ D - 13	√ E - 13	√ F - 13
d. Improper Driving Technique	√ D - 15	√ E - 15	√ F - 15
e. Driving Technique was Inadequately Defensive	D - 17	√ E - 17	F - 17
f. Excessive Speed	√ D - 18	√ E - 18	√ F - 18
g. Tailgating	D - 19	E - 19	F - 19
h. Inadequate Signal	D - 20	E - 20	F - 20
i. Failure to Turn on Headlights	D - 21	E - 21	F - 21
j. Excessive Acceleration	D - 21	E - 21	F - 21

Table 3-2 continued

Causal Factors	Phase II	Phase III	Phases II & III
k. Pedestrian Ran into Traffic	D - 21	E - 21	F - 21
l. Improper Evasive Action	√ D - 21	√ E - 21	√ F - 21
5. Performance Errors	D - 23	E - 23	F - 23
a. Overcompensation	D - 23	√ E - 23	F - 23
b. Panic or Freezing	D - 23	E - 23	F - 23
c. Inadequate Directional Control	√ D - 23	E - 23	F - 23
Human—Conditions & States	D - 26	E - 26	F - 26
Physical/Physiological	D - 26	E - 26	F - 26
1. Alcohol-Impairment	D - 26	E - 26	F - 26
2. Other Drug Impairment	D - 26	E - 26	F - 26
3. Fatigue	D - 26	E - 26	F - 26
4. Physical	D - 27	E - 27	F - 27
5. Reduced Vision	D - 27	E - 27	F - 27
6. Chronic Illness	D - 27	E - 27	F - 27
Mental/Emotional	D - 27	E - 27	F - 27
1. Emotionally Upset	D - 28	E - 28	F - 28
2. Pressure from Other Drivers	D - 28	E - 28	F - 28
3. "In-Hurry"	D - 28	E - 28	F - 28
4. Mental Deficiency	D - 28	E - 28	F - 28
Experience/Exposure	D - 29	E - 29	F - 29
1. Driver Inexperience	D - 29	E - 29	F - 29
2. Vehicle Unfamiliarity	D - 29	E - 29	F - 29
3. Road Over-Familiarity	D - 29	E - 29	F - 29
4. Road/Area Unfamiliarity	D - 30	E - 30	F - 30
Environmental Factors—Including Slick Roads	D - 31	E - 31	F - 31
1. Slick Roads	√ D - 31	√ E - 31	√ F - 31
Environmental Factors—Excluding Slick Roads	D - 33	E - 33	F - 33

Table 3-2 continued

Causal Factors[1]	Phase II	Phase III	Phases II & III
1. Highway-Related	D - 33	E - 33	F - 33
a. Control Hindrances	D - 33	E - 33	F - 33
b. Inadequate Signs & Signals	D - 35	E - 35	F - 35
c. View Obstructions	√ D - 38	√ E - 38	√ F - 38
d. Design Problems	D - 40	E - 40	F - 40
e. Maintenance Problems	D - 41	E - 41	F - 41
2. Ambience-Related	D - 42	E - 42	F - 42
a. Special Hazards	D - 43	√ E - 43	F - 43
b. Ambient Vision Limitations	D - 44	E - 44	F - 44
c. Avoidance Obstructions	D - 46	E - 46	F - 46
d. Rapid Weather Change	D - 47	E - 47	F - 47
e. Camouflage Effect	D - 48	E - 48	F - 48
f. Environmental Overload	D - 49	E - 49	F - 49
Vehicular Factors	D - 50	E - 50	F - 50
1. Tires and Wheels	D - 50	E - 50	F - 50
2. Brake System	D - 52	E - 52	F - 52
3. Steering System	D - 56	E - 56	F - 56
4. Suspension Problems	D - 57	E - 57	F - 57
5. Power Train & Exhaust	D - 59	E - 59	F - 59
6. Communication Systems	D - 61	E - 61	F - 61
7. Driver Seating & Controls	D - 67	E - 67	F - 67
8. Body, Doors & Other	D - 70	E - 70	F - 70

[1]A check-mark (√) indicates that the factor exceeded 5% at definite level, or 10% at the probable level, for either investigation Level B or C. Only individual (non-grouped) categories are evaluated in this manner.

Table 3-3

Summary of Percentage of Accidents in Which Different Factors Were Definite Causes[1]

	Certainty Level: Definite					
	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
Human Factors—Direct Causes	73.0%	84.1%	81.7%	81.0%	76.2%	83.2%
1. Critical Non-Performance	.9	1.3	1.0	0	1.0	.9
a. Blackout	.8	.7	1.0	0	.8	.5
b. Dozing	.2	.7	0	0	.1	.5
2. Non-Accident (e.g., Suicide)	0	0	0	0	0	0
3. Recognition Errors	36.0	47.7	47.4	49.2	40.2	48.1
a. Driver Failed to Observe Stop Sign	4.3	9.9	2.9	3.2	3.8	7.9
b. Delays in Recognition—Reasons Identified	31.3	38.4	42.2	46.0	35.3	40.7
(1) Inattention	√13.2	√11.9	√13.1	√14.3	√13.2	√12.6
(2) Internal Distraction	3.4	5.3	3.3	7.9	3.3	6.1
(3) External Distraction	2.6	1.3	6.2	3.2	3.9	1.9
(4) Improper Lookout	√13.4	√√21.9	√√21.6	√√22.2	√16.4	√√22.0
c. Delays in Perception for Other or Unknown Reasons	2.1	6.0	5.6	1.6	3.3	4.7
d. Delays in Comprehension or Reaction—Other or Unknown	.8	1.3	.7	0	.7	.9
4. Decision Errors	40.6	39.1	43.1	28.6	41.5	36.0
a. Misjudgment	1.7	2.0	2.6	1.6	2.0	1.9
b. False Assumption	√13.8	4.6	7.5	7.9	√11.5	5.6
c. Improper Maneuver	7.2	8.6	7.5	3.2	7.3	7.0
d. Improper Driving Technique	4.2	7.9	6.2	0	4.9	5.6
e. Driving Technique was Inadequately defensive	2.1	2.6	3.9	6.3	2.8	3.7

Table 3-3 continued

Certainty Level: Definite

	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
f. Excessive Speed	8.7	9.3	√ 13.7	√ 11.1	√ 10.5	9.8
g. Tailgating	1.7	.7	1.0	0	1.4	.5
h. Inadequate Signal	.6	.7	1.3	1.6	.8	.9
i. Failure to Turn on Headlights	.4	0	0	0	.2	0
j. Excessive Acceleration	.2	0	1.0	1.6	.5	.5
k. Pedestrian Ran into Traffic	.4	2.0	.7	0	.5	1.4
l. Improper Evasive Action	7.5	11.9	5.9	1.6	6.9	8.9
5. Performance Errors	3.0	7.9	3.3	7.9	3.1	7.9
a. Overcompensation	1.5	4.0	2.3	6.3	1.8	4.7
b. Panic or Freezing	.9	0	0	0	.6	0
c. Inadequate Directional Control	1.1	5.3	1.0	1.6	1.1	4.2
Human Conditions & States						
Physical/Physiological	4.0	3.3	3.9	0	3.9	2.3
1. Alcohol Impairment	3.4	1.3	2.9	0	3.2	.9
2. Other Drug Impairment	.2	1.3	.7	0	.4	.9
3. Fatigue	0	0	0	0	0	0
4. Physical Handicap	0	0	.3	0	.1	0
5. Reduced Vision	1	1	0	0	.1	.5
6. Chronic Illness	1	0	0	0	.1	0
Mental/Emotional	.8	1.3	1.6	3.2	1.1	1.9
1. Emotionally Upset	.4	.7	1.0	0	.6	.5
2. Pressure from Other Drivers	.2	0	0	1.6	.1	.5
3. "In-Hurry"	.2	.7	.7	1.6	.4	.9
4. Mental Deficiency	0	0	0	0	0	0
Experience/Exposure	3.2	1.3	2.9	0	3.1	.9
1. Driver Inexperience	.8	.7	0	0	.5	.5
2. Vehicle Unfamiliarity	.4	.7	.3	0	.4	.5

Table 3-3 continued

Certainty Level: Definite

	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
3. Road Over-Familiarity	0	0	.3	0	.1	0
4. Road/Area Unfamiliarity	2.1	0	2.3	0	2.2	0
Environmental Factors						
Environmental Factors—Including Slick Roads	22.1	17.9	25.5	12.7	23.3	16.4
1. Slick Roads	7.0	4.0	5.6	6.3	6.5	4.7
Environmental Factors—Excluding Slick Roads	16.0	14.6	20.3	7.9	17.6	12.6
1. Highway-Related	13.0	11.9	13.7	7.9	13.3	10.7
a. Control Hindrances	2.1	2.6	2.3	0	2.2	1.9
b. Inadequate Signs and Signals	1.9	2.0	2.9	1.6	2.3	1.9
c. View Obstructions	7.2	5.3	7.5	6.3	7.3	5.6
d. Design Problems	2.1	3.3	2.6	0	2.3	2.3
e. Maintenance Problems	.2	0	0	0	.1	0
2. Ambience-Related	3.6	2.6	7.8	3.2	5.1	2.8
a. Special Hazards	2.5	2.0	6.9	3.2	4.1	2.3
b. Ambiend Vision Limitations	.6	.7	.7	0	.6	.5
c. Avoidance Obstructions	.4	0	0	0	.2	0
d. Rapid Weather Change	0	0	0	0	0	0
e. Camouflage Effect	0	0	.3	0	.1	0
f. Environmental Overload	0	0	0	0	0	0
Vehicular Factors	7.0	6.0	3.6	0	5.7	4.2
1. Tires and Wheels	1.3	0	.3	0	1.0	0
2. Brake System	2.5	4.0	2.0	0	2.3	2.8
3. Steering System	.2	.1	.3	0	.2	.5
4. Suspension Problems	0	0	0	0	0	0
5. Power Train & Exhaust	.4	0	0	0	.2	0

Table 3-3 continued

	Certainty Level: Definite					
	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
6. Communication Systems	1.3	0	.7	0	1.1	0
7. Driver Seating & Controls	.2	0	0	0	.1	0
8. Body, Doors, & Other	1.3	1.3	.3	0	1.0	.9

[1]Definite cause means "Causal-Certain." See Section 2.1 for additional explanation.

Notes: (1) Numbers which are encircled (e.g., 9.9) exceed 5%.
(2) One check-mark highlights factors implicated in 10.0%-19.9% of accidents.
(3) Two check-marks highlight factors implicated in 20% or more of accidents.

Table 3-4

Summary of Percentage of Accidents in Which Different Factors Were Probable Causes[1]

	Certainty Level: Probable					
	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
Human Factors—Direct Causes	90.6%	96.7%	93.8%	96.8%	91.7%	96.7%
1. Critical Non-Performance	1.1	1.3	1.0	0	1.1	.9
a. Blackout	.9	.7	1.0	0	1.0	.5
b. Dozing	.2	.7	0	0	.1	.5
2. Non-Accident (e.g., suicide)	0	0	0	0	0	0
3. Recognition Factors	50.6	60.9	56.5	55.6	52.8	59.3
a. Driver Failed to Observe Stop Sign	5.3	9.9	3.6	3.2	4.7	7.9
b. Delays in Recognition—Reasons Identified	45.1	51.0	51.3	52.4	47.4	51.4
(1) Inattention	20.6	19.2	18.3	19.0	19.7	19.2

Table 3-4 continued

	Certainty Level: Probable					
	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
(2) Internal Distraction	5.3	7.3	4.9	11.1	5.1	8.4
(3) External Distraction	2.8	2.6	7.2	4.8	4.4	3.3
(4) Improper Lookout	19.2	√25.8	√24.5	√23.8	√21.2	√25.2
c. Delays in Perception for Other or Unknown Reasons	3.2	9.9	5.9	1.6	4.2	7.5
d. Delays in Comprehension or Reaction—Other or Unknown	1.9	1.3	1.3	0	1.7	.9
4. Decision Errors	55.7	60.9	53.6	52.4	54.9	58.4
a. Misjudgment	2.1	2.6	3.3	4.8	2.5	3.3
b. False Assumption	17.4	8.6	9.8	14.3	14.6	10.3
c. Improper Maneuver	7.9	11.3	8.2	3.2	8.0	8.9
d. Improper Driving Technique	5.8	12.6	8.2	1.6	6.7	9.3
e. Driving Technique was Inadequately Defensive	2.5	9.3	6.5	15.9	3.9	11.2
f. Excessive Speed	15.8	√21.2	17.3	15.9	16.4	19.6
g. Tailgating	3.0	2.6	1.6	0	2.5	1.9
h. Inadequate Signal	1.9	2.6	2.3	6.3	2.0	3.7
i. Failure to Turn on Headlights	.4	.7	0	0	.2	.5
j. Excessive Acceleration	.4	0	1.0	1.6	.6	.5
k. Pedestrian Ran Into Traffic	.6	2.0	1.0	0	.7	1.4
l. Improper Evasive Action	15.5	22.5	11.4	7.9	14.0	18.2
5. Performance Errors	5.5	10.6	5.6	12.7	5.5	11.2
a. Overcompensation	2.3	4.6	3.3	11.1	2.6	6.5
b. Panic or Freezing	2.6	0	1.0	1.6	2.0	.5
c. Inadequate Directional Control	1.3	7.3	1.3	3.2	1.3	6.1
Human—Conditions & States						
Physical/Physiological	7.5	7.3	7.5	6.3	7.5	7.0

Table 3-4 continued

Certainty Level: Probable

	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
1. Alcohol-Impairment	5.5	2.6	5.2	6.3	5.4	3.7
2. Other Drug Impairment	.8	3.3	1.3	0	1.0	2.3
3. Fatigue	.6	.7	.3	0	.5	.5
4. Physical Handicap	0	0	.3	0	.1	0
5. Reduced Vision	.6	.7	0	0	.4	.5
6. Chronic Illness	.2	0	.3	0	.2	0
Mental/Emotional	2.1	4.6	3.6	3.2	2.6	4.2
1. Emotionally Upset	.6	2.6	1.0	0	.7	1.9
2. Pressure from Other Drivers	.2	1.3	.7	1.6	.4	1.4
3. "In-Hurry"	1.3	.7	2.0	1.6	1.6	.9
4. Mental Deficiencies	0	0	0	0	0	0
Experience/Exposure	9.2	1.3	5.9	4.8	8.0	2.3
1. Driver Inexperience	3.4	.7	1.3	1.6	2.6	.9
2. Vehicle Unfamiliarity	1.3	.7	.3	4.8	1.0	1.9
3. Road Over-Familiarity	.2	0	.7	0	.4	0
4. Road/Area Unfamiliarity	4.5	0	3.6	0	4.2	0
Environmental Factors						
Environmental Factors—Including Slick Roads	41.7	33.8	41.5	31.7	41.6	33.2
1. Slick Roads	16.2	7.3	13.7	11.1	15.3	8.4
Environmental Factors—Excluding Slick Roads	29.6	27.2	31.4	23.8	30.3	26.2
1. Highway-Related	24.0	21.9	22.5	22.2	23.4	22.0
a. Control Hindrances	4.5	4.6	3.6	1.6	4.2	3.7
b. Inadequate Signs & Signals	4.3	3.3	5.9	6.3	4.9	4.2
c. View Obstructions	13.0	11.3	12.7	12.7	12.9	11.7
d. Design Problems	4.3	6.0	4.2	3.2	4.3	5.1

Table 3-4 continued

	Certainty Level: Probable					
	Phase II		Phase III		Phases II & III	
	B	C	B	C	B	C
e. Maintenance Problems	.8	0	.7	0	.7	0
2. Ambience-Related	6.6	6.0	10.1	6.3	7.9	6.1
a. Special Hazards	4.3	3.3	8.2	6.3	5.7	4.2
b. Ambient Vision Limitations	1.3	.7	1.6	0	1.4	.5
c. Avoidable Obstructions	.8	.7	.3	0	.6	.5
d. Rapid Weather Change	0	0	0	0	0	0
e. Camouflage Effect	0	.7	.3	0	.1	.5
f. Environmental Overload	0	0	0	0	0	0
Vehicular Factors						
1. Tires and Wheels	14.0	17.9	9.2	3.2	12.2	13.6
2. Brake System	1.3	5.3	2.6	1.6	3.7	4.2
3. Steering System	1.7	2.0	2.0	1.6	1.8	1.9
4. Suspension Problems	.4	0	0	0	.2	0
5. Power Train & Exhaust	.6	0	.3	0	.5	0
6. Communication System	2.8	2.0	1.6	0	2.4	1.4
7. Driver Seating & Controls	.2	0	0	0	.1	0
8. Body, Doors, & Other	2.1	2.0	.3	0	1.4	1.4

[1]Probable Cause means "Causal or Severity-Increasing, Certain or Probable." See Section 2.1 for additional explanation.

Note: Numbers which are encircled (e.g., 20.6) exceed 10%.
A check-mark (√) highlights results of 20% or more.

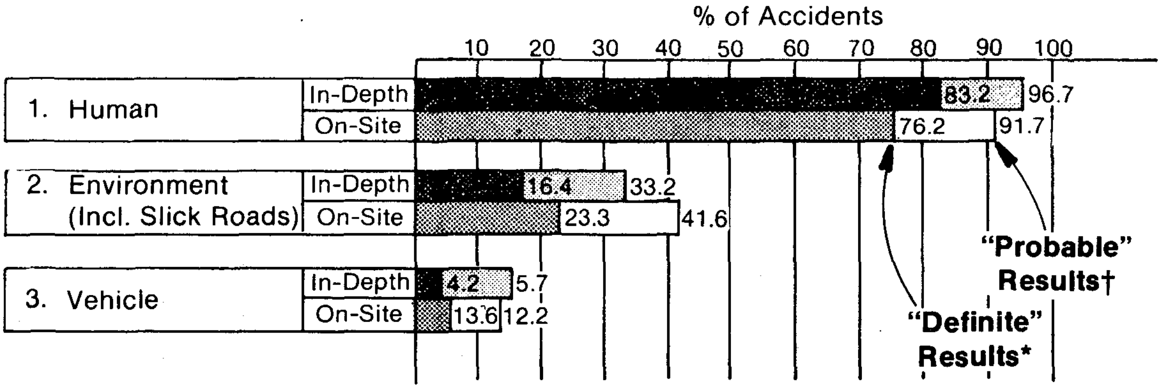
Human factors were found to be the most frequent accident causes. Environmental factors ranked second and vehicular factors, third (Figure 3-4). Human factors were identified by the in-depth team as definite causes of 83.2 percent of the Phase II/III accidents, and of 76.2 percent by the on-site team. When findings at the probable level are included, these figures become 96.7 percent (in-depth) and 91.3 percent (on-site).

Environmental factors were definite causes of 16.4 percent (in-depth) and 23.3 percent (on-site). With findings at the probable level included, these figures become 33.2 percent and 41.6 percent, respectively.

Vehicular factors were identified as definite causes of only 4.2 percent of accidents by the in-depth team, and of 5.7 percent by the on-site team. When findings at the probable level are included, these figures become 13.6 percent and 12.2 percent, respectively.

Figure 3-4

Percentage of Combined Phase II/III Accidents Caused by Human, Vehicular, and Environmental Factors



*Definite Means "Causal-Certain" (see Section 2.1 for further explanation).
†Probable means "Causal or Severity-Increasing, Certain or Probable."

3.4.1.1 Human Factors—Direct Causes

Figure 3-5 shows the rank of the categories immediately below Human/Direct Causes in the causal model hierarchy. Recognition errors were identified with about the same frequency as decision errors by both the on-site and in-depth teams. These groups were identified 5 to 10 times more frequently (depending on investigation level) than were performance errors, which ranked third. Critical nonperformances (e.g., falling asleep) ranked fourth, with probable involvements of only .9-1.1 percent. The nonaccident category, intended to include suicides and other intentional involvements, ranked last, with no entries at either the definite or probable levels (Appendix F, pages F-1 and F-2).

Figure 3-6 ranks factors from yet a lower level in the causal model. Factors which appear in the model under recognitions errors, decision errors, etc., have been put in a common pool and ranked, without regard to their original classification. It can be seen that improper lookout is the most frequent cause according to both the on-site and in-depth levels. Definite results here range 16.4-22.0 percent (B-C); with probable findings included, these figures become 21.2-25.2

range becomes 14.0-18.2 percent (B-C). Nearly all such errors involved failing to avoid the accident by steering. Such failures divide into two nearly equal categories. First, there were instances where drivers should have supplied an evasive steering input but did not (definite range 3.2-4.2 percent, probable range 7.0-7.3 percent of accidents). Second, there were instances where drivers supplied a steering input which would have been effective, but which was negated by their having locked the front wheels through heavy braking (definite range 1.9-3.3 percent, probable range 4.1-6.1 percent of accidents) (Appendix F, pages F-21 and F-22).

The remaining six categories of those ranked, with their probable involvement ranges, were: inadequately defensive driving technique (3.9-11.2 percent), false assumption (10.3-14.6 percent), improper driving technique (6.7-9.3 percent), improper maneuver (8.0-8.9 percent), internal distraction (5.1-8.4 percent), and overcompensation (2.6-6.5 percent).

3.4.1.2 Human Conditions and States

Conditions and states are factors which adversely affect the ability of a driver as an information processor. These are viewed as *reasons for reasons* which are not easily identified as causes through accident investigation and clinical assessment. Nevertheless, unusual evidence sometimes permits a condition or state to be causally implicated, and in Figure 3-7, the five most frequently identified conditions or states have been ranked. It can be seen that alcohol-impairment ranked first as the most frequently implicated condition or state (Appendix F, page F-26). It was identified by the in-depth team as a definite cause of .9 percent of the Phase II/III accidents, and by the on-site team as definite cause of 3.2 percent. When probable findings are included, these figures become 3.7 percent (in-depth) and 5.4 percent (on-site). These results are from a period in which only accidents occurring between 11:30 a.m. and 10:30 p.m., were investigated.

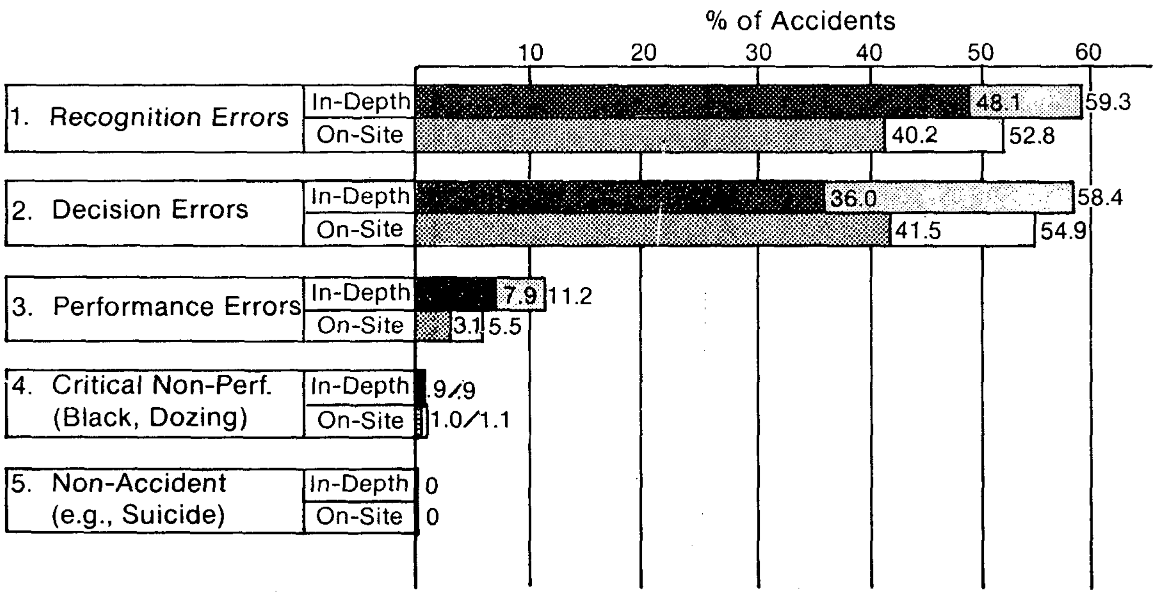
In Figure 3-8, results from an earlier period in which accidents were investigated around-the-clock (Phase I) are presented along with results from Phases II and III. Alcohol-impairment was more frequently implicated during Phase I (by both the on-site and in-depth teams) than in either Phase II or III. In Phase I, alcohol-impairment was a *prime cause* (analogous tc definite cause) of 7.4-9.0 percent (C to B) of accidents, and a *contributing cause* (analogous to definite or probable cause) of 12.8-16.2 percent (B to C) of accidents. In interpreting these results, it is important to remember that accidents investigated included a mix of property damage, personal injury, and fatal accidents in about the proportion in which they actually occur and are investigated by police agencies.*

Those ranking behind alcohol-impairment, with their probable involvement ranges are: other drug impairment (1.0-2.3 percent, B-C), vehicle unfamiliarity (1.0-1.9 percent, B-C), emotional upset (.7-1.9 percent, B-C), and pressure from other drivers (.4-1.4 percent, B-C).

*Phase III accidents investigated by IRPS on-site (Level B) teams were 73 percent property damage, 25 percent personal injury, and 2 percent fatality accidents. Corresponding national figures for 1972 were 63 percent, 36 percent, and 1 percent, respectively. See report Section 7.0 for further details.

Figure 3-5

Percentage of Combined Phase II/III Accidents Caused by the Major Human Direct Cause Subgroups



percent (B-C). Since there is no vehicular or environmental factor which ranks higher, improper lookout is the most frequent accident cause identified by this study. Most such errors occurred at intersections, rather than in changing lanes, passing, or pulling out from parking spaces (Appendix F, pages F-7 and F-8).

Using the in-depth (Level C) probable level findings as a criterion, excessive speed is the second ranking factor. Excessive speed was identified as a definite cause in 9.8-10.5 percent (C-B) of accidents, and as a definite or probable cause in 16.4-19.6 percent (B-C) of accidents. In the majority of instances in which excessive speed was cited, it was excessive with respect to road design, rather than weather or traffic conditions (Appendix F, pages F-18 and F-19).

Ranking a close third is inattention, which was identified as a definite cause in 12.6-13.2 percent (C-B) of accidents. With probable findings included, the range is 19.2-19.7 percent (C-B). Had definite cause figures (or on-site probable level figures) been used to establish ranking, inattention would have ranked second, ahead of excessive speed. In about 35-45 percent of the instances where inattention was cited, it was with respect to traffic ahead which had either stopped or was slowing down. Somewhat less frequently (22-32 percent of instances where cited), it was with respect to road signs or signals (Appendix F, pages F-3 and F-4).

Ranking fourth was improper evasive action. This factor was identified as a definite cause in 6.9-8.9 percent (B-C) of accidents investigated. With probable level findings included, the

Figure 3-6

Percentage of Combined Phase II/III Accidents Caused by Specific Human Direct Causes

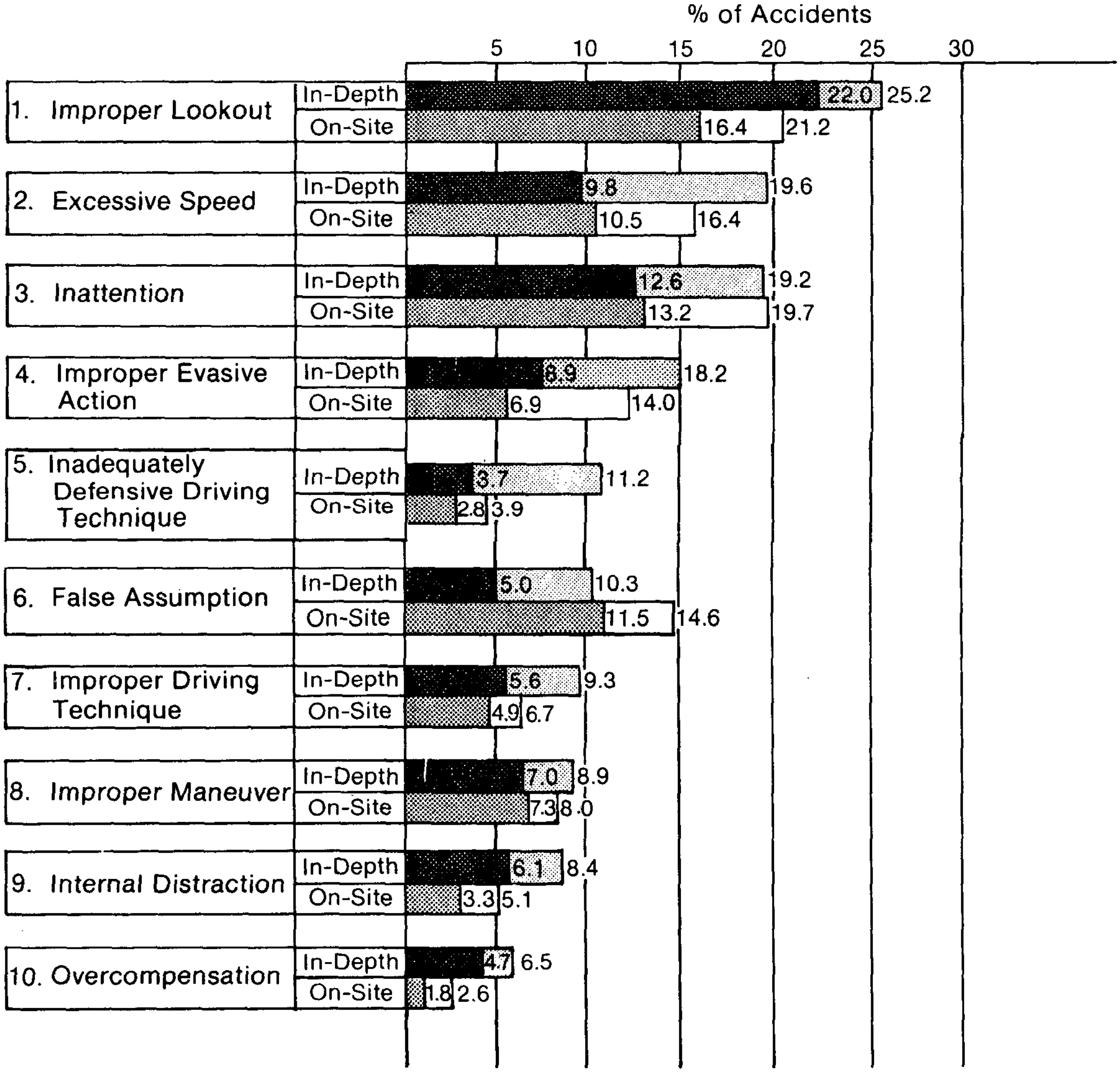
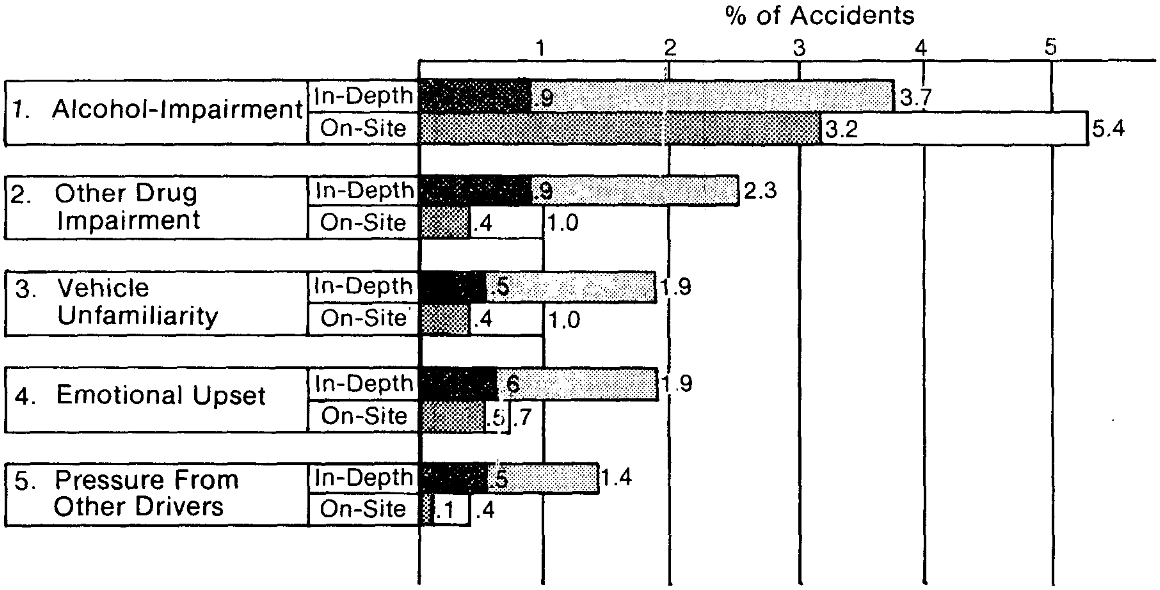


Figure 3-7

Percentage of Combined Phase II/III Accidents Caused by the Major Human Condition or State Subgroups



3.4.1.3 Environmental Factors

Environmental factors ranked between human and vehicular factors in frequency of involvement, and were identified as definite causes of 16.4-23.3 percent (C-B) of the Phase II/III accidents. With findings at the probable level included, these figures become 33.2-41.6 percent (C-B) (Appendix F, page F-31).

Figure 3-9 shows the involvement of environmental factors both including and excluding the slick roads category. Slick roads, including both those which were ice or snow covered and those which were merely rain-slickened, were identified as definite causes of 4.7-6.5 percent (C-B) of the Phase II/III accidents investigated. With probable findings included, these figures become 8.4-15.3 percent (C-B). With the slick roads category excluded, the remaining environmental factors were identified as definite causes of 12.6-17.6 percent (C-B) of accidents, and of definite or probable causes of 26.2-30.3 percent (C-B).

Also shown in Figure 3-9 is the rank of the two categories immediately below environmental factors (excluding slick roads) in the causal model hierarchy. Ranking first were highway-related factors, which were definite causes of 10.7-13.3 percent (C-B) of accidents, and definite or probable causes of 22.0-23.4 percent (C-B). With slick roads

Figure 3-8

Percentage of Accidents in Which Alcohol-Impairment was Judged to be Implicated as an Accident Cause

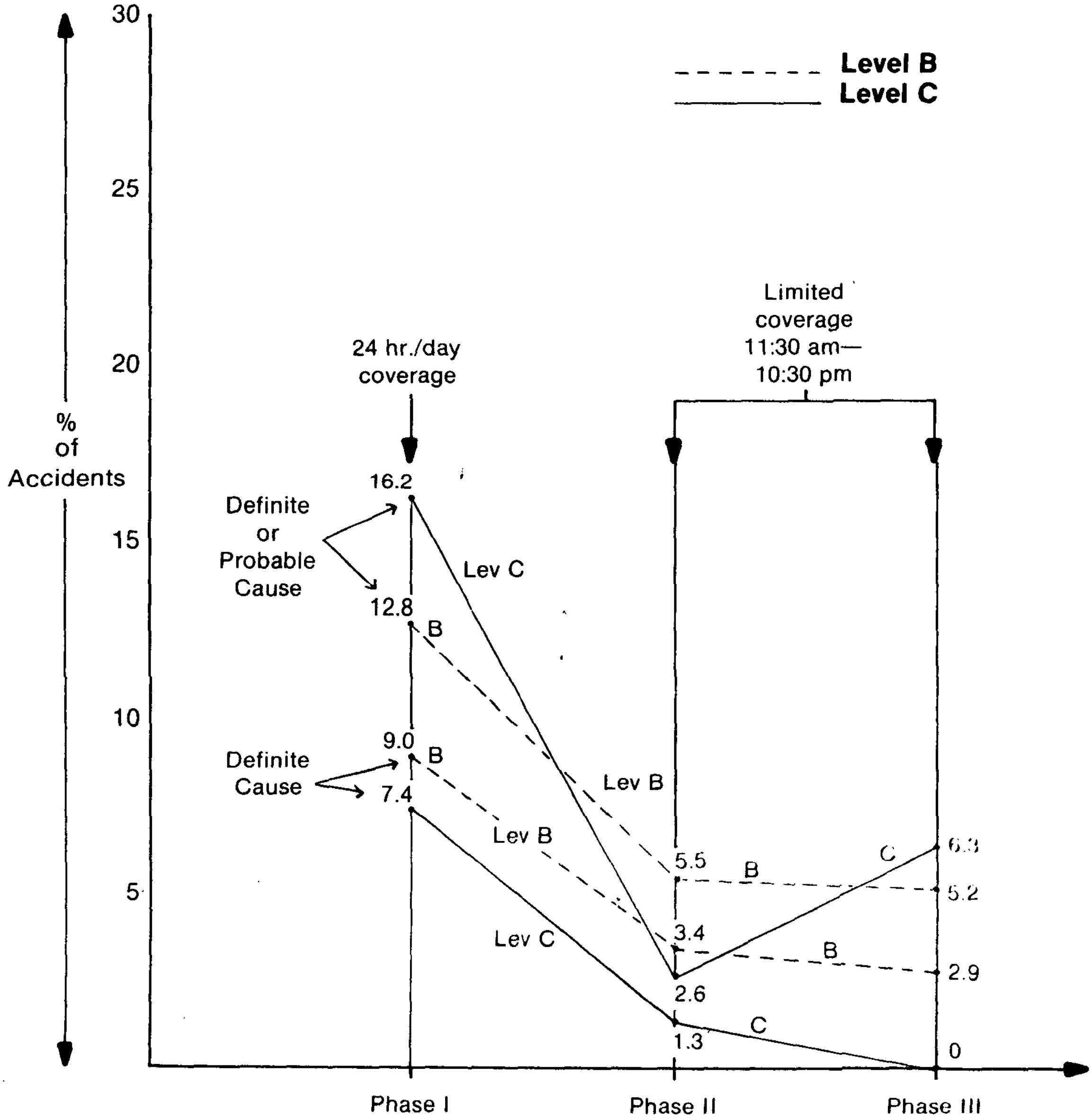
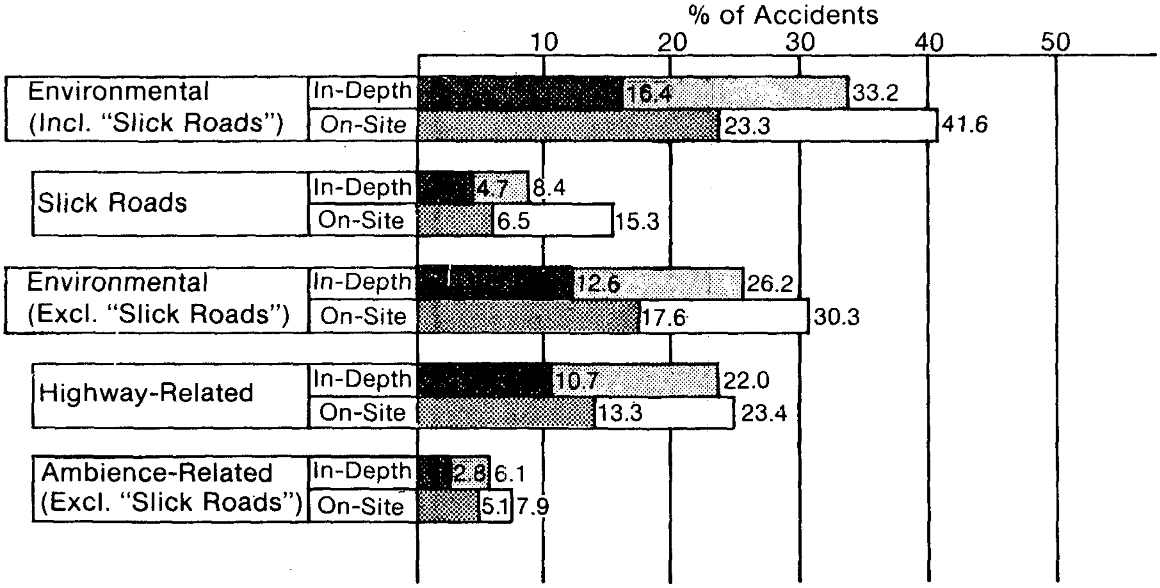


Figure 3-9

Percentage of Combined Phase II/III Accidents Caused by the Major Environmental Factor Subgroups



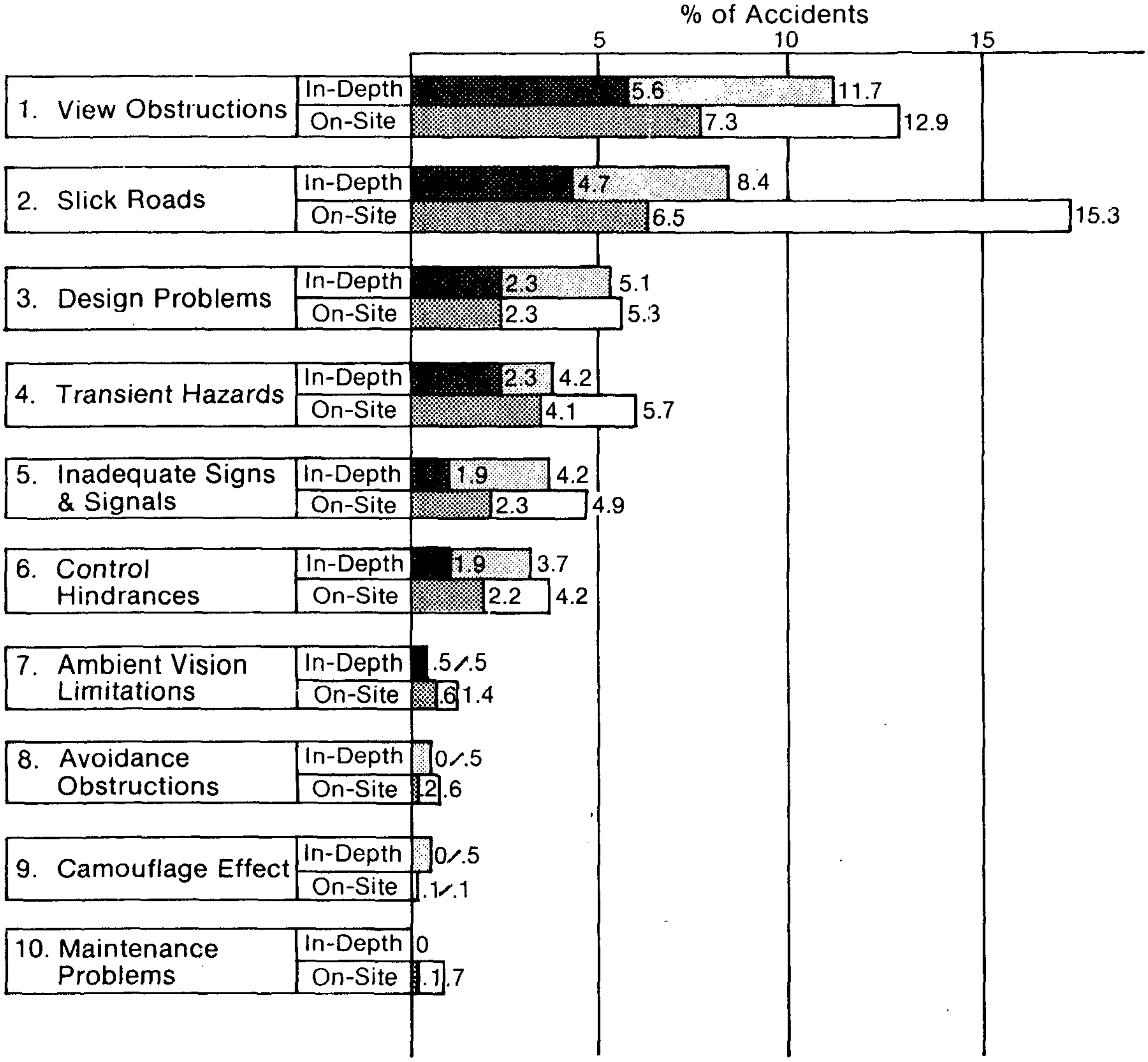
excluded, the ambience-related category ranked second; these factors were definite causes of 2.8-5.1 percent (C-B) of accidents, and definite or probable causes of 6.1-7.9 percent (C-B). Had slick roads been tallied under the ambience-related category (as in the original Phase II report), the highway- and ambience-related categories would have ranked approximately equal.

Figure 3-10 ranks factors from yet a lower level in the causal model. Factors which appear under the highway- and ambience-related heads, as well as slick roads, have been put in a common pool and ranked. It can be seen that according to the in-depth level, view obstructions are the most frequent environmental cause of accidents. They were definite causes of 5.6-7.3 percent (C-B) of the Phase II/III accidents, and definite or probable causes of 11.7-12.9 percent (C-B). Frequently (in about one-third of instances cited) these obstructions consisted of hedges, signs, or other roadside structures or vegetation. With about the same frequency these obstructions consisted of other vehicles; more than half the time, these vehicular obstructions were parked (Appendix F, pages F-38 and F-39).

Ranking second was slick roads, which were definite causes of 4.7-6.5 percent (C-B) of accidents, and definite or probable causes of 8.4-15.3 percent (C-B). Rain-slickened and snow or ice covered roads accounted for most of the entries under this category. In the combined

Figure 3-10

Percentage of Combined Phase II/III Accidents Caused by Specific Environmental Causal Factors



Phase II/III data the in-depth team cited the snow or ice covered category more often than rain-slickened, while the on-site teams reversed this tendency (Appendix F, pages F-31 and F-32).

Ranking third were design problems, which were definite causes of 2.3 percent of accidents on both the on-site and in-depth levels; with findings at the probable level included, results were 5.1 percent (in-depth) and 5.3 percent (on-site). No particular type of design problem stands out, although the largest number of entries was for road overly narrow or twisting (Appendix F, pages F-40 and F-41).

Ranking fourth were transient hazards. This category includes objects or animals in the road as well as errant (*phantom*) vehicles which cause accidents but are not themselves involved. Such factors were definite causes of 2.3-4.1 percent (C-B) of accidents investigated, and definite or probable causes of 4.2-5.7 percent (C-B). More than two-thirds of all entries under this category involved *noncontact vehicles causing problem*. Of course, the reason for the errant behavior of noncontact vehicles could not be determined since they invariably continued on their way, and were not available for investigation (Appendix F, pages F-43 and F-44).

The remaining six categories of those ranked, with their *definite or probable* involvement figures, are: inadequate signs and signals (4.2-4.9 percent C-B), control hindrances (3.7-4.2 percent, C-B), ambient vision limitations (.5-1.4 percent, C-B), avoidance obstructions (.5-.6 percent, C-B), camouflage effect (.1-.5 percent, B-C), and maintenance problems (0-.7 percent, C-B).

3.4.1.4 Vehicular Factors

Vehicular factors were identified as accident causes less frequently than either human or environmental factors. They were identified as definite causes of 4.2-5.7 percent (C-B) of the combined Phase II/III accidents. With probable findings included, resultant figures are 12.2-13.6 percent (B-C) (Appendix F, page F-50).

Vehicular factors were identified as accident causes significantly less frequently in Phase III than in Phase II (Table 3-5). Phase II identified them as definite causes in 6.0-7.0 percent (C-B) of accidents, and with probable findings included, in 14.0-17.0 percent (B-C). In Phase III, they were identified as definite causes of **none** of the in-depth (Level C) accidents, and of 3.9 percent of the on-site (Level B) accidents; with probable findings included resultant figures are 3.2-9.2 percent (C-B) (see Subsection 3.5 for discussion of differences between phases).

Figure 3-11 shows the rank of major vehicle cause categories. It can be seen that brake system problems are the most frequent vehicular cause according to the in-depth results. The on-site results are in agreement that brake systems are the most frequent **definite** cause, but with probable findings included would rank the tires and wheels category higher. Brake systems were identified as definite causes of 2.3-2.8 percent (B-C) of accidents, and with probable findings included as causes of 3.0-6.1 percent (B-C) of accidents.

The brake system problem which most frequently caused accidents was a gross failure of all or (in a split system) a part of the braking system. Gross failures of this kind were definite causes of 1.4-1.8 percent (C-B) of accidents, and with probable causes included were causes of 2.2-3.3 percent (B-C) of the Phase II/III accidents (Appendix F, pages F-52 to F-56). The infrequency of causative brake failures makes it difficult to accurately assess the importance (frequency) of various reasons for such failures. Based on present data, loss of pressure at the wheel cylinders (wheel cylinder failure) appears to predominate. Such failures have generally been associated with over-extension of wheel cylinder pistons where brake drums have been turned excessively during maintenance. Brake line failures were less frequently involved, but were identified by the on-site team as definite causes in .5 percent of the Phase II/III accidents (4 of 836).

Next among causative brake system problems were side-to-side imbalances, which were definite causes of 1.4 percent of the accidents investigated by the in-depth team, and definite or probable causes of 2.3 percent. The on-site results implicated side-to-side imbalances less frequently; they were cited as definite causes of only .1 percent, and as definite or probable causes of 2.3 percent of accidents investigated. Such imbalances appear to most frequently have resulted from contamination of linings by either brake fluid or wheel bearing grease.

Ranking second among the vehicle cause categories was tires and wheels. These were identified as definite causes in none of the in-depth investigations and 1.0 percent on-site, but with probable findings included were implicated in 3.7 percent (in-depth) and 4.2 percent (on-site). Underinflation and inadequate tread depth were the dominant entries under this category. The in-depth team cited underinflation slightly more often than inadequate tread depth (at the probable level), while to a much more marked degree the reverse was true for the on-site team (Appendix F, pages F-50 to F-52). It is interesting that neither tire nor wheel failures were cited as even possible causes of any of the 1305 accidents IRPS has investigated in Phases I, II, and III.

Ranking third among the vehicular categories was steering system problems, which were identified as definite causes of .2-.5 percent (B-C) of the Phase II/III accidents, and with probable findings included, as causes of 1.8-1.9 percent (B-C). Nearly all entries under this category were for excessive steering freeplay, which was a definite cause in .1-.5 percent (B-C) of accidents, and a definite or probable cause in 1.4-1.6 percent (C-B). No one source of such freeplay or looseness could be singled out as predominating. Sources were found to include gearbox lash, gearbox looseness, and excess play in tie-rod ends, idler arms, and ball joints (Appendix F, pages F-56 and F-57).

Ranking fourth among the vehicular categories was the communications systems category, which includes all problems with lights, signals, horns, glazed surfaces, etc. This category was not cited as a definite cause in any of the accidents investigated by the in-depth team during either Phase II or III (214 accidents), but was identified by the on-site team as definitely causing

1.1 percent (9 of 836). With probable level findings included, resultant figures are 1.4 percent (in-depth) and 2.4 percent (on-site). Most entries here were for inoperable lights and signals (predominated in-depth), or vehicle-related vision obstructions (predominated on-site). The lights and signals deficiencies were almost evenly divided among taillights, stoplamps, and turn signals, while more than half of the vision obstructions were for ice, snow, or similar obstructions on the windshield or windows (Appendix F, pages F-61 to F-66).

The remaining vehicle categories, power train and exhaust, suspension problems, and driver seating and controls, were not identified by the in-depth team as either definite or probable causes of any of the 214 Phase II and III accidents, and probable level findings by the on-site team did not exceed .5 percent (Figure 3-11).

Figure 3-11

Percentage of Combined Phase II/III Accidents Caused by Deficiencies in Major Vehicular Systems

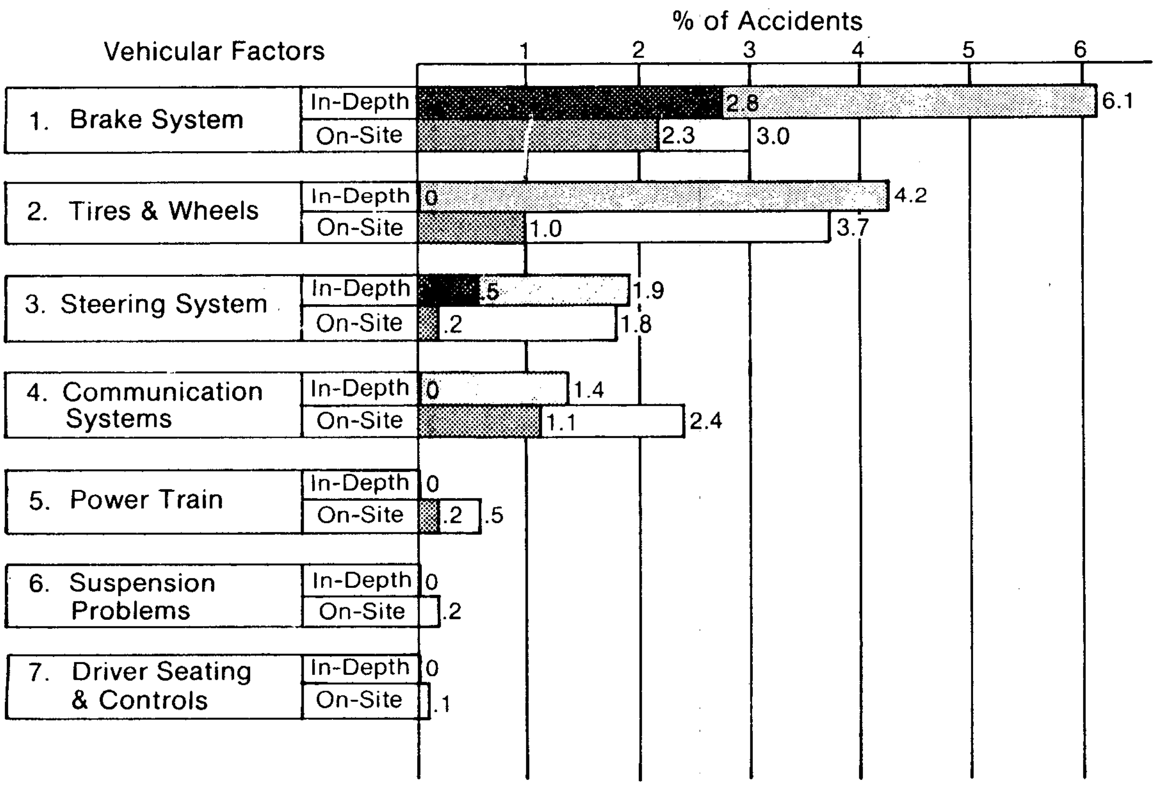
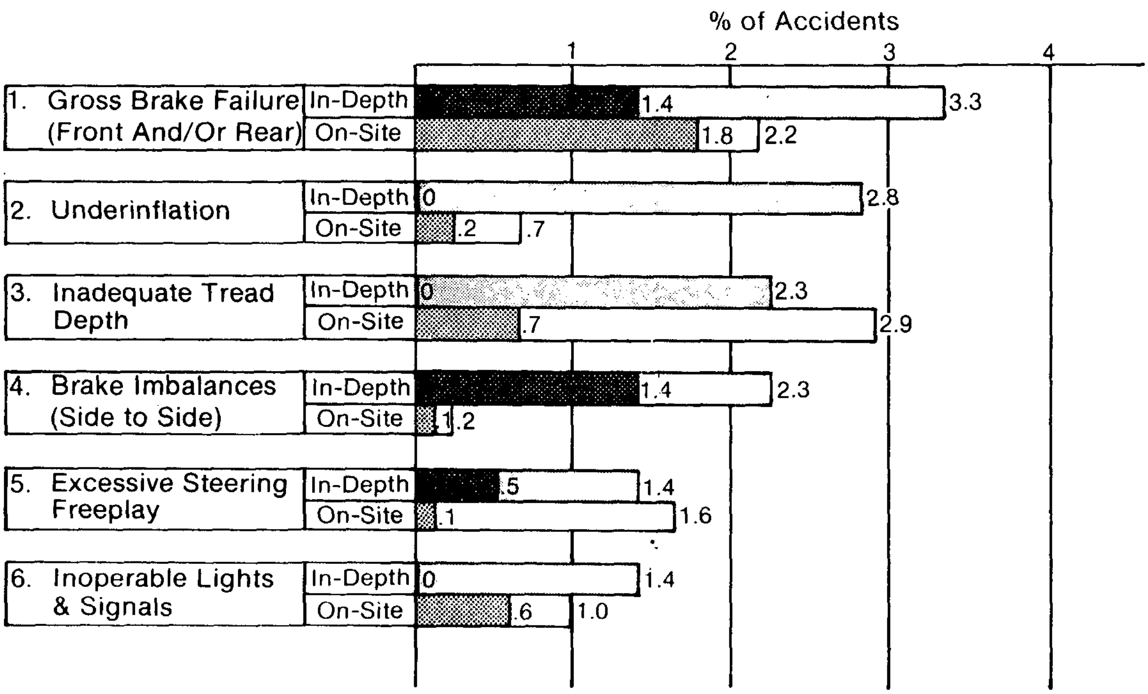


Figure 3-12 ranks factors from the next level in the causal hierarchy below those ranked in Figure 3-11. Factors which appear in the model under brake system, tires and wheels, etc., have been put in a common pool and ranked, without regard to their original classification. It can be seen that gross brake failure, with sudden loss of the front or rear brakes (in systems with split master cylinders) or of **both** front and rear brakes, is the vehicular factor which most frequently caused accidents. Ranking second is underinflation, followed by inadequate tread depth, brake imbalances (side-to-side), excessive steering freeplay, and inoperable lights and signals.

Figure 3-12

Percentage of Combined Phase II/III Accidents Caused by Specific Vehicular Deficiencies



3.4.2 Discussion

Human Direct Causes

Figure 3-5 shows that at least where a representative mix of all accident severities is considered, suicide cases are an extremely minimal problem. Similarly, the problems of blackout and falling asleep (critical nonperformances) are seen to play a small role, accounting for about 1 percent of accidents. Performance or action errors (where drivers were not able to control their vehicles in situations where a reasonably skillful driver could have) played a more significant role, but one which was only a small part (5 to 10 percent) of the accident causation picture.

Playing much larger and nearly equal roles were recognition and decision errors. The recognition errors category is intended to include all delays and errors in perception, comprehension, and reaction. In practice, it is often difficult for investigators to distinguish between these. However, it is believed that nearly all of the errors noted within this category involved delays in perception (i.e., actually sensing the danger cue), rather than in comprehension (i.e., realizing it was a danger cue), or reaction (i.e., delay in physically reacting to cue). The predominant decision error was excessive speed (i.e., an imprudent decision was made by a driver to drive at that speed under those conditions).

It can be seen in Figure 3-6 that of the five top-ranking human direct cause factors, two (improper lookout and inattention) are from the recognition errors category, while the remaining three (excessive speed, improper evasive action, and inadequately defensive driving technique) fall under the decision errors category. Not until the tenth-ranking item is reached (overcompensation) is a performance error encountered.

Since delays in perception are the most common accident causes identified by the study, it is appropriate that major efforts be devoted to either minimizing such delays or reducing their consequences. In turn, the two major subcategories of delayed perception (improper lookout and inattention) merit close examination. Instances of improper lookout generally occurred at intersections, and tended to divide into two categories. First, there were instances where drivers reported they *looked but did not see*. Secondly, and with about equal frequency, drivers reported that they simply failed to look, and generally could not account for their failure. With regard to the former mode, the dynamic vision testing equipment currently in use by IRPS' in-depth team may provide some information in the future as to whether there are visual deficiencies associated with such failures. Whether or not deficiencies are generally present in these situations, their solution would seem to require the instilling of a cautious attitude in drivers and the development of the habit of spending several seconds visually scanning for oncoming traffic at intersections. It is also possible that the trend towards reducing A-pillar thickness may help reduce this problem, although IRPS has not noticed A-pillars as being a significant factor where improper lookout is cited, and this possibility has not been analyzed.

The second aspect of improper lookout—a failure to look—may be more like inattention in terms of countermeasure requirements. In both cases, it appears that the countermeasure task, at least when a human factors approach is considered, is the seemingly difficult one of raising the overall level of driver concentration and attentiveness.

The major subcategory of inattention involved *traffic stopping or slowing ahead*. This suggests that improved rear-lighting systems which would attract an inattentive driver's attention might have a significant safety payoff, as might the augmented (radar) braking systems presently being considered. But until such changes are available to a large number of motorists, means must be sought to improve driver performance. The question of how to raise driver attentiveness is a difficult one and needs to be carefully examined. Part of this task may involve educating drivers to have an awareness and appreciation for the risk generated by removing their attention from vehicles they are following. One answer might be to have drivers periodically spend time on a driver simulator, where various emergency situations are generated, including vehicles ahead suddenly stopping unexpectedly. Repeated conditioning of this kind might cause drivers to be continuously apprehensive about the behavior of the vehicle ahead, and might at the same time improve their evasive skills. The latter payoff would also be highly beneficial, as indicated by the relatively high rank of the improper evasive action category.

The top-ranking decision error subcategory was excessive speed. Most instances of excessive speed were noted to involve drivers traveling too fast for the design of the road, rather than for existing traffic and weather conditions. Results elsewhere in this report (Section 6.0) indicate that this factor is uniquely associated with several distinct classes of drivers. For example, drivers involved in accidents as a result of excessive speed were generally male, and were generally less than 20 years old. Yet excessive speed was also found to correlate with the alcohol-impairment condition or state, and this in turn was primarily associated with older drivers. Hence, countermeasures for excessive speed may have to be carefully tailored to different groups. In the remaining period of the current program, IRPS will be attempting to identify the driver groups for each of these major causal factors in greater detail.

Conditions and States

In the conduct of this program, the driver has been viewed as serving an information-processing role. When information-processing errors or breakdowns occur, and these result in accidents, they have been termed human direct causes. Factors which adversely affect the ability of a driver to properly function as an information-processor, and which in turn may be reasons for failures which have occurred, have been termed *human conditions or states*. Because of their remoteness from the accident cause it is often difficult through the clinical accident investigation process to establish causation. The fact that a driver is unfamiliar with his vehicle might be easily detected. Yet the investigator's problem in analyzing the causative role of unfamiliarity is to determine whether the same accident would have occurred if the driver had been *familiar*. Nevertheless, where conditions or states can be causally implicated with reliability, their role has been assessed and tabulated (Appendix F, pages F-26 to F-30, and Figure 3-7).

Despite the relatively low involvement percentages cited (with most of these being at the probable rather than definite level), it is interesting to note from the detailed data tables that both the on-site and in-depth investigators have acknowledged physical/physiological abnormalities of all kinds to have played a definite causative role in 2.3-3.9 percent (C-B) of the combined Phase II/III accidents, and as either definite or probable causes in 7.0-7.5 percent of accidents (C-E). As a class, mental/emotional problems were implicated less frequently, and a definite causal involvement was established in 1.0 to 2.0 percent of the accidents (B-C). As to the role of experience/exposure factors, there was considerable difference between the in-depth and on-site results, with the latter reporting the higher percentages. Establishing causation is obviously difficult for this category, and it is suspected that the on-site technicians have been more liberal in their willingness to assume causation given the confirmed presence of driver inexperience, vehicle unfamiliarity, and similar factors.

Figure 3-8 shows that alcohol-impairment has been identified as a causative human condition or state less frequently during periods of limited coverage (11:30 a.m. to 10:30 p.m.) than during periods of 24 hour/day coverage. The probable explanation for this is that alcohol-impairment is more frequently encountered during the late night and early morning hours. During the remaining period of this study, IRPS plans to sample from all hours of the day, so that it should be able to validate both the presence and the causal role of alcohol use and impairment among drivers as a function of time of day.

The results cited for alcohol-impairment must not be confused with results from the many studies which have examined only serious and fatal accidents. Alcohol usage has been cited as involved in 50 percent and more of fatal accidents in numerous studies. Accidents considered in this study included a mix of property damage, personal injury, and fatal accidents in about the proportion in which they actually occur in the driving population. For example, 73 percent of accidents investigated on-site during Phase III were property damage only. During the same period, 78.8 percent of all Monroe County police-reported accidents involved only property damage (see discussion of representativeness, Section 7.0). It has been found that accidents resulting from alcohol-impairment tend to be more severe than accidents not caused by this factor (Section 3.6).

Environmental Factors

As with the vehicular results, environmental results are almost as interesting in what did not cause accidents as what did. For example, several local newspaper articles have highlighted the tremendous extent to which rural Monroe County stop signs become overgrown and obscured by foliage during the summer months. Yet obscured signs (which would have been tallied under maintenance problems) have not been identified as definite causes in any of the 836 accidents investigated during Phases II and III (Appendix F, page F-42).

Concern in the media has also focused on the danger of excessive drop-offs at road edges. Monroe County is no exception in having several major roads with soft gravel shoulders which frequently wash out, sometimes to the extent of several inches. Yet such dropoffs have been identified by both the on-site and in-depth teams as being definite causes of only about 1 percent of all the Phase II/III accidents investigated.

The slick-roads category, which was the top-ranking environmental causal factor (Figure 3-10), has had a controversial history. Especially among the professionals on the in-depth team, there has been disagreement as to whether roads which are rain-slickened or snow-covered should be evaluated as potential causal factors. It has been argued that when drivers fail to successfully cope with such conditions, the *cause* is entirely one of driver failure. To accommodate these diverse views, the results have been presented in the detailed tables in a special manner. Project rules have continued to require that where rain, snow, or ice have reduced the coefficient of friction of a road, a clinical assessment will be made as to whether the accident would have occurred if the road had been hypothetically restored to its normal (dry) coefficient of friction. However, results for environmental factors as a whole are now reported with the slick roads assessments both included and excluded. Study results indicate that many accidents occur on wet as well as snow or ice covered pavement which would not have occurred on dry pavement. Efforts currently underway to improve wet road traction, through improvement of both tires and pavement, are hence strongly supported by the results of this study, as are efforts to achieve more rapid control and removal of snow and ice.

View obstructions were the second-ranking environmental factor (Figure 3-10). The problem here is primarily one of parked traffic preventing one driver from seeing the other's vehicle. The parked vehicle problem is considered to be largely an urban one. The city of Bloomington has many city streets where traffic parked along both sides of the road and in close proximity to intersections makes safe negotiation of the intersections extremely difficult for even a very careful driver. Two of the highest accident frequency locations in this county are both city intersections where parked traffic severely limits a driver's sight distance of other traffic.

Vehicular Factors

In general, vehicular factors are indicated by the study to be a very real and significant problem in accident causation, although they cause accidents less frequently than either human or environmental factors.

Accidents caused by manufacturing defects and catastrophic mechanical failures have been found to be very infrequent occurrences. The top-ranking vehicle factors in Figure 3-12 generally resulted from improper maintenance. Gross brake failure was most frequently the result of pressure loss at wheel cylinders, usually as a result of brake drums having been turned beyond normal limits. Underinflation and inadequate tread depths are clearly factors within the realm of maintenance. Side-to-side brake imbalances could reflect manufacturing problems or design defects, since where such imbalances have been implicated, they have primarily resulted from lining contamination by brake fluid or bearing grease. While the responsibility for, or origin of such fluid losses has not been tabulated, it is clear that they are only a small part of the total vehicle causal picture. Of the remaining categories, excessive steering freeplay (as a causal factor) has been identified primarily in older vehicles with extensive use, while inoperable lights and signals are clearly susceptible to remedy by routine maintenance.

Based on these results, a conclusive case either for or against Periodic Motor Vehicle Inspection (PMVI) is not possible, and is ultimately a question of cost-effectiveness. It can be concluded, however, that the vehicular factors which are causing accidents are ones which could be detected and corrected through PMVI (excessively turned drums, inadequate tread depth, excessive steering wheel freeplay, inoperable lights and signals, etc.).

However, it is unfortunate that PMVI as currently practiced in Indiana is not likely to significantly reduce the incidence of gross brake failure (the number one vehicular cause identified). To do this would require pulling wheels and/or drums and this is not required. It appears that if PMVI is to be conducted, inspection and measurement of the brake mechanism for drum diameter, lining or pad thickness, lining contamination and proper operation of self-adjustment mechanisms, is worth incorporating.

Summary

In a sense, it is disappointing that more dramatic and easily pinpointed failures of the driver, vehicles, or the environment were not identified as the major accident causes, as these might have been both appealing and relatively easily addressed targets. For example, had falling asleep or tire failures turned out to be causes of large numbers of accidents, countermeasure programs could have included very specific public education and awareness targets, and could have aimed to solve the problems with specific technological improvements. Instead, several other general categories emphasizing human imperfection and carelessness have predominated, the countermeasures for which seem to call primarily for the relatively difficult task of altering behavior. These results indicate that we must ensure that drivers always look for traffic when entering intersections, and do so carefully enough that they will accurately detect oncoming trraffic. We must ensure that drivers monitor traffic ahead at a rate sufficient to ensure that sudden stops do not result in collision, and must also ensure that drivers monitor road signs and signals at an adequate rate. Finally, we must enable drivers to recognize the safe maximum travel speed for various road configurations, and induce them to be unwilling to accept the risk of traveling faster. In summary, we must ensure that drivers are aware of the *danger cues* in the driving environment, and can acquire and recognize these amidst all of the other information that is continually bombarding the driver.

In the environmental area, project results indicate that the most significant contribution to a reduction in accident frequency can be achieved by developing pavements with improved wet traction, emphasizing fast and thorough removal of snow and ice from road surfaces, and by reducing the incidence of non-signalized urban intersections with significant view obstructions generated by parked cars.

In the vehicular area, we should reduce the incidence of brake failure, enforce tread depth requirements, and educate the public to the dangers of both inadequate tread depth and underinflation. Improved inspection systems, designs which reduce the need for maintenance, and improved public education and information programs, might each contribute significantly to a reduction in the role of vehicular factors.

3.5 Differences Between Phase II and Phase III Results

In this section, causal result percentages from Phase III are compared with those from Phase II, and statistically significant differences are identified and discussed.

3.5.1 Results

Figure 3-13 compares the top level results graphically (e.g., for human, vehicular, and environmental factors), while Table 3-5 is a *check chart* indicating the individual factors (e.g., inattention, improper lookout) for which the largest differences were noted between Phases. Table 3-5 also indicates which differences were statistically significant; $\tilde{X}^2$ tests were run down to the lowest level of detail in the causal factor outline (e.g., to the level of *inattention—to traffic stopped or slowing ahead*).

In general, Phase III results were much like those for Phase II (Figure 3-13). Human factors were again the dominant cause of accidents, and environmental factors were again found to cause more accidents than vehicular factors. Three human factors—improper lookout, inattention, and excessive speed—were again among the most frequently identified specific causes (Figure 3-6). Yet there were several causal factors for which results differed by 5 percent or more, and several differences (not always the same ones) which were statistically significant.

The most notable difference was that vehicular factors were identified by the in-depth team much less frequently in Phase III than in Phase II (Figure 3-13). In Phase II, vehicular factors were definite causes in 6.0 percent of accidents, and definite or probable causes in 17.9 percent. In Phase III, there were **no** accidents in which the in-depth team identified vehicular factors as definite causes, and they were identified as probable causes in only 3.2 percent. This change was tested using results from the definite or probable level, and found statistically significant at the .01 level. The on-site teams also implicated vehicular factors in a smaller portion of accidents in Phase III than in Phase II, although this difference was not statistically significant.

Other changes among the top-level categories (e.g., human factors) were smaller, and were not statistically significant. The on-site team identified human factors as definite causes of 8.7 percent more accidents in Phase III, although with probable findings included, the Phase III result was up only 3.2 percent over Phase II. The only other instance where top-level findings changed more than 5 percent was for in-depth findings regarding environmental factors,

Comparison of Causal Result Percentages for Phases II and III

Figure 3-13

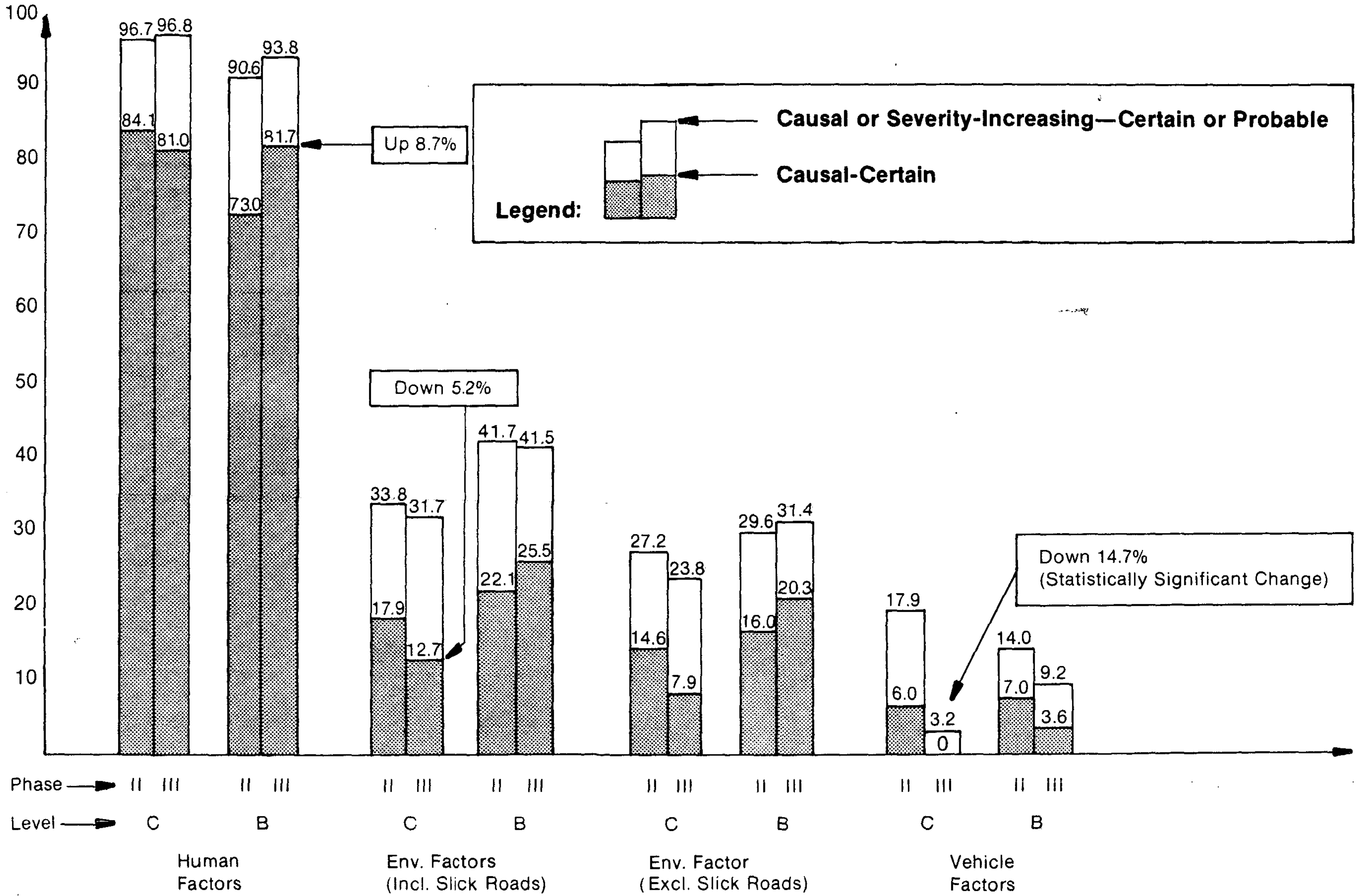


Table 3-5

Summary of Differences Between Phase II and III Causal Result Percentages (Which Were 5% or More, and/or Which Were Statistically Significant)

	On-Site				In-Depth			
	Phase III Up		Phase III Down		Phase III Up		Phase III Down	
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
Human Factors—Direct Causes	√							
1. Critical Non-Performance								
a. Blackout								
b. Dozing								
2. Non-Accident (e.g., suicide)								
3. Recognition Errors	√√	√						√
a. Driver Failed to Observe Stop Sign							√	√
b. Delays in Recognition—Reasons Identified	√√	√			√			
(1) Inattention								
(2) Internal Distraction								
(3) External Distraction		**						
••• Driver-Selected Outside Activity		(*)						
(4) Improper Lookout	√	√						
••• Enter From Street or Alley		√(*)						
c. Delays in Perception for Other or Unknown Reasons								√
d. Delays in Comprehension or Reaction—Other or Unknown								
4. Decision Errors							√√	√
a. Misjudgment								
b. False Assumption			√	√**				

Table 3-5 continued

	On-Site				In-Depth			
	Phase III	Up	Phase III	Down	Phase III	Up	Phase III	Down
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
••• Other or Unspecified				**				
c. Improper Maneuver							√	√
d. Improper Driving Technique							√	√√*
e. Driving Technique was Inadequately Defensive		**				√		
••• Should Have Adjusted Speed		***						
f. Excessive Speed	√							√
g. Tailgating								
h. Inadequate Signal								
i. Failure to Turn on Headlights								
j. Excessive Acceleration								
k. Pedestrian Ran Into Traffic								
l. Improper Evasive Action							√	√
••• Could Have Steered But Did Not				(*)				
5. Performance Errors								
a. Overcompensation						√		
b. Panic or Freezing								
c. Inadequate Directional Control								
Human Conditions & States								
Physical/Physiological								
1. Alcohol-Impairment								
2. Other Drug Impairment								
3. Fatigue								
4. Physical Handicap								
5. Reduced Vision								
6. Chronic Illness								

Table 3-5 continued

	On-Site				In-Depth			
	Phase III Up		Phase III Down		Phase III Up		Phase III Down	
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
Mental/Emotional								
1. Emotionally Upset								
2. Pressure From Other Drivers								
3. "In-Hurry"								
4. Mental Deficiency								
Experience/Exposure								
1. Driver Inexperience								
2. Vehicle Unfamiliarity								
3. Road Over-Familiarity								
4. Road/Area Unfamiliarity								
Environmental Factors—Including Slick Roads							√	
1. Slick Roads								
••• Road Wet						√(*)		
••• Road Snow/Ice Covered				**				
Environmental Factors — Excluding Slick Roads							√	
1. Highway-Related								
a. Control Hindrances								
b. Inadequate Signs & Signals								
••• Stop Sign Needed But Not Provided		(*)						
c. View Obstructions								
d. Design Problems								
e. Maintenance Problems								
2. Ambience-Related								
a. Special Hazards		*						
••• Non-Contact Vehicle Caused Problem		**						

Table 3-5 continued

	On-Site				In-Depth			
	Phase III Up		Phase III Down		Phase III Up		Phase III Down	
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
b. Ambient Vision Limitations								
c. Avoidance Obstructions								
d. Rapid Weather Change								
e. Camouflage Effect								
f. Environmental Overload								
Vehicular Factors							√	√√**
1. Tires and Wheels								
2. Brake System							(-4.0%)	√
3. Steering System								
4. Suspension Problems								
5. Power Train & Exhaust								
6. Communication Systems								
7. Driver Seating & Controls								
8. Body, Doors, & Other								

Note: Each check-mark (√) indicates a difference of 5%.
*—Indicates difference was significant at the .05 level.
**—Indicates difference was significant at the .01 level.
***—Indicates difference was significant at the .001 level.

including slick roads. Here, Phase III findings at the definite level dropped 5.2 percent, although with probable findings included, the drop was reduced to only 2.1 percent.

From Figure 3-13 and Table 3-5, it can be seen that there was an overall tendency for on-site results to increase in Phase III, and for in-depth team results to decrease. Vehicular findings are an exception, for while in-depth team findings dropped, on-site findings did as well. These differences were generally greater between definite cause percentages, than with probable findings included.

Table 3-5 indicates the individual causal factors (e.g., improper lookout) which changed more than 5 percent, and the changes which were statistically significant. Among the on-site team results, only for false assumption did Phase III results decrease by more than 5 percent; this decrease was statistically significant at the .01 level. A subcategory of false assumption—other or unspecified—also decreased significantly (.01 level). For two other categories, on-site results decreased significantly in Phase III, even though the percentage change was less than 5 percent. These were *improper evasive action/could have steered but did not* (.05 level), and *slick roads/snow or ice covered* (.01 level).

It has already been noted that overall on-site results for human factors increased by more than 5 percent at the definite level. However, the largest increases in on-site results (exceeding 10 percent at the definite level) were for *recognition errors,* and *delays in recognition/reasons noted.* Both of these are *grouped* categories, taking in numerous more specific human cause categories, including inattention and improper lookout. Despite their amount, these increases were not statistically significant.

No other increases exceeded 10 percent in either the on-site or in-depth results. Other factors for which on-site results increased at least 5 percent were improper lookout (exceeded 5 percent at both definite and probable levels but was not significant); improper lookout/entering traffic lane from street or alley (probable level only, significant at .05); and excessive speed (definite level only, not significant). For several additional factors, increases were noted in on-site results which were significant, even though the percentage differences were less than 5 percent. These were: external distraction (.01), external distraction/driver-selected outside activity (.05), driving technique was inadequately defensive (.01), driving technique was inadequately defensive/should have adjusted speed (.001), inadequate signs and signals/stop sign needed but not provided (.05), special (transitory) hazards (.05), and special hazards/noncontact vehicle caused problem (.01). In general, in the on-site results most of the large or significant differences between Phases were in the direction of Phase III results increasing; large or significant increases outnumbered decreases by a ratio of about four to one (whereas in the in-depth results the reverse was true).

For in-depth (Level C) results, Table 3-5 indicates that factors which increased more than 5 percent were: delays in recognition/reasons noted (exceeded 5 percent only at the definite level and difference at the probable level was not statistically significant), driving technique was inadequately defensive (at the probable level only, not significant), overcompensation (at the probable level only, not significant), and slick roads/road wet (exceeded 5 percent only at the probable level, significant at the .05 level).

With greater frequency, factors decreased notably in the Phase III in-depth results. For three categories, decreases exceeding 10 percent occurred in either definite or probable cause findings, and two of these three largest changes were statistically significant. The three factors were: decision errors (exceeded 10 percent at the definite level, 5 percent with probable findings, difference was not statistically significant), improper driving technique (exceeded 5 percent at definite level, 10 percent at probable, difference was significant at the .05 level), and the overall vehicular factors category (decrease exceeded 5 percent at definite level, 10 percent at probable, and was significant at the .01 level).

For several additional categories, decreases in the in-depth results exceeded 5 percent, although none of these differences was statistically significant. These categories were:

recognition errors (at the probable level only), driver failed to observe and stop for stop sign (both definite and probable levels), delays in perception for other or unknown reasons (probable level only), improper maneuver (definite and probable levels), excessive speed (probable level only), improper evasive action (definite and probable levels), environmental factors—including slick roads (definite level only), environmental factors—excluding slick roads (definite level only), and brake system (down 4.0 percent at definite level and more than 5 percent at the probable level). In general, most of the large differences occurring in the in-depth results between Phases were in the direction of the Phase III results decreasing; large or significant decreases outnumbered increases by a factor of about four to one.

3.5.2 *Discussion*

With all factors considered, Phase III results are considered to be quite similar to those of Phase II. The overall human, vehicular, and environmental factor categories are again ranked in the same order, and the specific causal factors which ranked high in Phase II generally have also ranked high in Phase III. Yet it does appear that there is an overall tendency for Phase III results to have decreased on the in-depth level, and to have increased on the on-site level. However, this tendency is stronger when only definite results are considered than when probable level findings are also considered. This in turn suggests that in Phase III, the on-site investigators have become more prone to apply a definite (causal-certain) rating, while the in-depth team members have become more conservative (i.e., less willing to attribute a definite level of certainty to their findings).

The most notable difference between Phases, and potentially the most important, is with respect to vehicular factors. There are several possible explanations for the change. First, it may be that the accident samples investigated have actually changed. This is supported to some extent by the fact that both the on-site and in-depth findings decreased. Secondly, it might be thought that the change in the in-depth results could reflect a change in in-depth team composition. In Phase III the participation of outside vehicle consultants was terminated, and a change in team automotive personnel occurred approximately midway through the year. However, there are several indications that these changes do not account for the decrease which occurred. First, results decreased on both the on-site and in-depth levels, despite the fact that comparable changes in the on-site team composition and procedures did not occur. Further, there were **no** accidents identified by the in-depth team as being definitely caused by vehicular factors. Yet catastrophic brake failure had been the number one vehicular factor identified in Phase II, and it is difficult to believe that any in-depth team of any composition would have failed to recognize a catastrophic brake failure, and to have rated it as a definite cause if it had been encountered. Further, the Phase II automotive engineer was present and participated in more than one-third of all the Phase III investigations. He was then replaced with individuals with mechanical and engineering expertise who had previously participated in the project during Phase II.

Finally, most of the procedures associated with in-depth vehicle inspection remained unchanged. All vehicles continued to be taken to a garage facility for inspection, where the same comprehensive inspection form and pass/fail criteria were utilized. In summary, changes in team composition might have altered findings to a small extent, but are not likely to have resulted in a change of the magnitude which was experienced. It is concluded that this decrease probably represents an actual change in the accident samples investigated. However, it cannot yet be concluded that vehicular factors have decreased in importance in the overall accident picture, since the in-depth sample consisted of only 63 accidents investigated over a period of eight months. However, results from remaining periods of this study will be viewed with extreme interest, as the reduction of future vehicular results to similar levels might well be construed as indicating a real decrease in the overall role of vehicular factors in automobile accident causation.

Several of the other significant differences which occurred were expected, and reasons for them are believed to be known. The significant decrease in false assumption on the on-site level is believed to reflect an improvement in categorizational skills. It was noted in last year's report that the on-site team was believed to be applying false assumption in instances where other categories (e.g., improper maneuver) would have more properly applied. Apparently, this tendency has been rectified.

The statistically significant decrease (on-site) in the percentage of accidents caused by snow or ice covered roads reflects the extremely mild and relatively snow-free winter which was experienced this past year in Indiana. Decreases in the in-depth results might have also been significant if the in-depth sample size had been larger; in general, smaller changes result in a finding of significance on the on-site level, due to the larger "N."

Finally, the significant increase in the proportion of accidents being caused by wet roads in the in-depth results probably reflects a change in categorizational practices. In last year's report a tendency for in-depth investigators to refrain from using the wet roads category was discussed. Several professionals on the team felt that wet roads were merely conditions which drivers had to cope with, and that their failure to do so could be properly classified only as a human factor. On the other hand, it was argued that accidents do occur on wet roads which would not have occurred on dry, and that there was no reason that a clinical assessment could not be made of this factor the same as for other deficiencies. In each case, the process is one of defining the deficient states which are of concern, and then assessing whether the outcome would have been changed (i.e., whether the accident would have been prevented or its severity reduced) if the deficiency had been hypothetically corrected. In Phase III, the method of grouping and reporting environmental factors was changed, so that a result was available both including and excluding the slick roads category.

Reasons for other differences noted are more difficult to reliably assess, but probably reflect minor changes in categorizational practices. Had large, consistent increases or decreases been noted on both the on-site and in-depth level, changes as a function of time in the kinds of factors which are causing accidents might have been suspected. However, with the exception of vehicular factors, consistent changes of this kind have not been noted, and more often the tendency has been toward an increase in findings on the on-site level, with decreases for the same factor in the in-depth results.

3.6 Analysis of Accident Severity as a Function of Causal Factor

3.6.1 Results

In Table 3-6, causal factors for which statistically significant differences in severity were observed are identified, together with the percentage by which the distribution varied from the expected value. These results are illustrated in Figure 3-14. In Table 3-7, the actual severity distribution for these same factors is shown, together with chi-square values obtained.

Table 3-6

Comparison of On-Site and In-Depth Human Factors by Severity of Accident (Statistically Significant Findings Only)

Comparison Variables	Percent PI/Fatal		Percent PD	
	Level C	Level B	Level C	Level B
Overall—All Accidents	33.7%	26.9%	66.3%	73.1%
Human Direct Causes—	N/A	N/A	N/A	N/A
Recognition Errors	(-)	(-)	3.1	4.8%*
Internal Distraction	31.0%*	14.6%	(-)	(-)
Internal Distraction—Event in Car; Loud Noise	16.3	31.4*	(-)	(-)
External Distraction			19.4	17.8*
Improper Lookout			12.1	7.8*
False Assumption			1.9	10.7*
Improper Maneuver—Passed at Improper Location		31.4*	.4	
Excessive Speed	11.3	18.6***		
Excessive Speed—for Road Design Regardless of Condition of Traffic	18.3	26.0***		

Table 3-6 continued

Comparison Variable	Percent PI/Fatal		Percent PD	
	Level C	Level B	Level C	Level B
Performance Errors	14.1	23.1**		
Overcompensation	9.2	23.1*		
Human Conditions & States	Level C	Level B	Level C	Level B
Physical/Physiological	26.3	29.0***		
Alcohol-Impairment	53.8 **	36.5 ***		
Environmental Factors— Excluding Slick Roads	Level C	Level B	Level C	Level B
Control Hindrances	28.8	26.2**		
Control Hindrance—Dropoff at Edge of Pavement		45.8**	.4	
Control Hindrances—Other or Unspecified	33.0	58.8 **		
Design Problem—Road Overly Narrow, Twisting, Etc.	9.2	39.8 **		

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

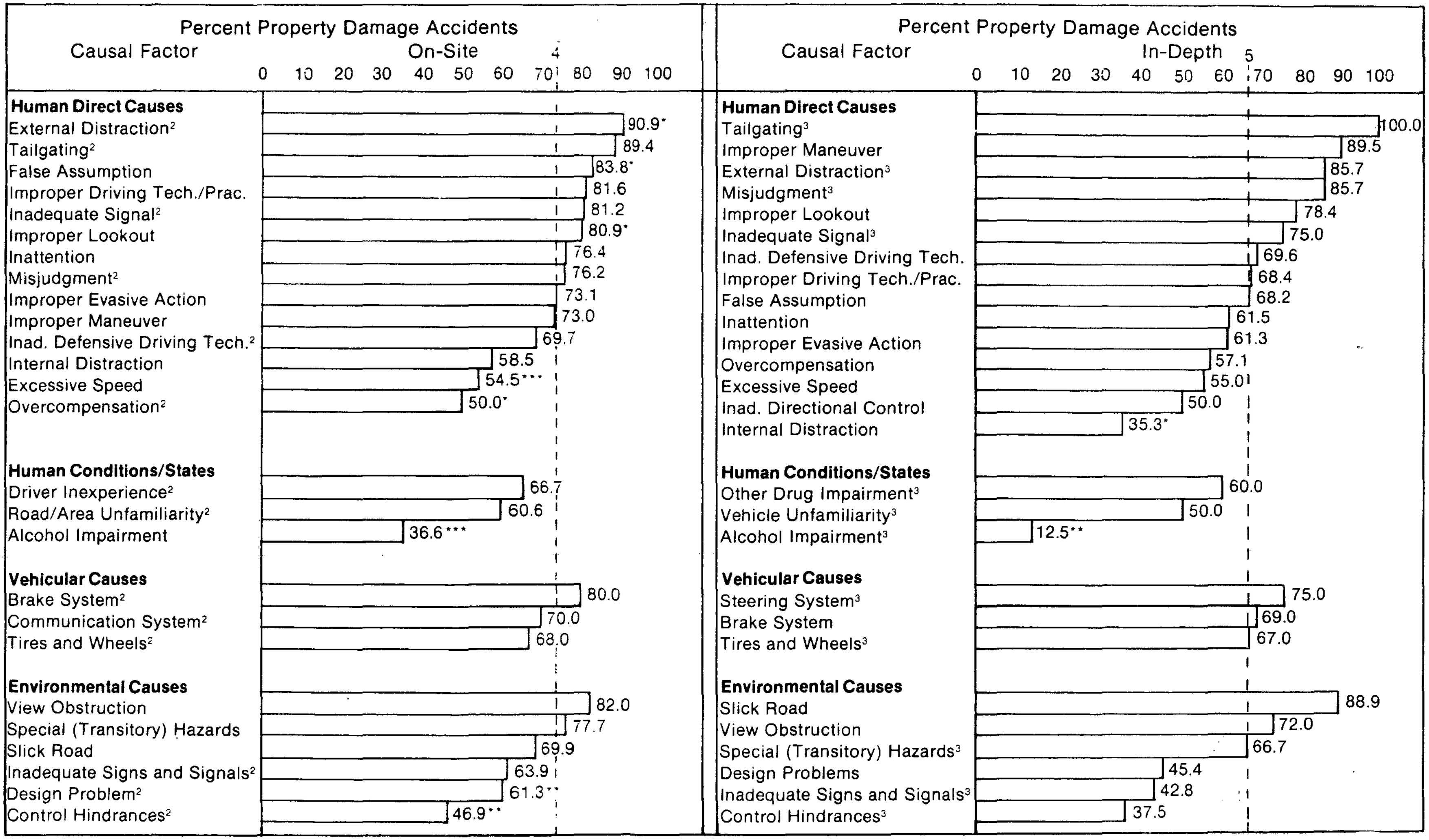
Overall, the in-depth sample was comprised of 66.3 percent property damage accidents (PD), and 33.7 percent personal injury or fatal accidents (PI/F).* The on-site sample was 73.1 percent PD, and 26.9 percent PI/F. These distributions were the expected values for each sample. The severity distributions of all accidents in each sample (on-site and in-depth) which involved a particular causal factor were compared with these values. Of the 544 total comparisons involved (one for each causal factor down to the lowest level of classification), only 17 were found to be statistically significant; the in-depth sample accounted for only two of these 17 (Table 3-6).

Only for alcohol-impairment was the accident-severity distribution different from the expected values to a statistically significant extent in **both** the on-site and in-depth samples; accidents caused by alcohol-impairment more frequently involved personal injuries or

*Since the distribution of severity for accidents not investigated by the Institute must be determined by police classification of the accidents, severity of accidents which were investigated by the Institute was also determined by the police classification of the same accident, for purposes of this comparison.

Percent Property Damage Accidents for "Frequently Occurring"[1] Causal Factors in Phase II and III Investigation

Figure 3-14



[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 Phase II, III on-site accident sample.
[5] Overall percentage of property damage accidents in Phase II/III in-depth accident sample.

*p≤.05
**p≤.01
***p≤.001

Table 3-7

Comparison of Accident Severity for Crashes Resulting from Different Causal Factors (With Shading Indicating Percentages Larger than Expected)

Human Factors, (Direct Causes)	Level of Investigation	Property Damage		Personal Injury, Fatality		Chi-Square[1]
		n	%	n	%	
Recognition Errors	C	84	69.4	37	30.6	$x^2 =$ .39 NS
	B	313	77.9	89	22.1	$x^2 =$ 4.43*
Internal Distraction	C	6	35.3	11	64.7	$x^2 =$ 6.01*
	B	24	58.5	17	41.5	$x^2 =$ 3.70 NS
Internal Distraction—Event in Car (Loud Noise, etc.)	C	2	50.0	2	50.0	$x^2 =$ .03 NS
	B	5	41.7	7	58.3	$x^2 =$ 4.53*
External Distraction	C	6	85.7	1	14.3	$x^2 =$ .47 NS
	B	30	90.9	3	9.1	$x^2 =$ 4.46*
Improper Lookout	C	40	78.4	11	21.6	$x^2 =$ 2.82 NS
	B	131	80.9	31	19.1	$x^2 =$ 4.60*
False Assumption	C	15	68.2	7	31.8	$x^2 =$ .00 NS
	B	98	83.8	19	16.2	$x^2 =$ 6.25*
Improper Maneuver—Passed at Improper Location	C	4	66.7	2	33.3	$x^2 =$ .17 NS
	B	5	41.7	7	58.3	$x^2 =$ 4.53*
Excessive Speed	C	22	55.0	18	45.0	$x^2 =$ 1.82 NS
	B	67	54.5	56	45.5	$x^2 =$ 20.71***
Excessive Speed—For Road Design Regardless of Conditions or Traffic	C	12	48.0	13	52.0	$x^2 =$ 2.99 NS
	B	33	47.1	37	62.9	$x^2 =$ 22.64***
Performance Errors	C	12	52.2	11	47.8	$x^2 =$ 1.48 NS
	B	21	50.0	21	50.0	$x^2 =$ 10.23**
Overcompensation	C	8	57.1	6	42.9	$x^2 =$ .20 NS
	B	10	50.0	10	50.0	$x^2 =$ 4.31**
Physical/Physiological	C	6	40.0	9	60.0	$x^2 =$ 3.56 NS
	B	26	44.1	33	55.9	$x^2 =$ 23.79***
Alcohol Impairment	C	1	12.5	7	87.5	$x^2 =$ 8.11**
	B	15	36.6	26	63.4	$x^2 =$ 25.93***

Table 3-7 continued

Human Factors, (Direct Causes)	Level of Investigation	Property Damage		Personal Injury, Fatality		Chi-Square
Environmental Factors (Excluding Slick Roads)	C	34	94.4	2	5.6	x^2 = 11.51***
	B	165	71.7	65	28.3	x^2 = .15 NS
Control Hindrances	C	3	37.5	5	62.5	x^2 = 1.83 NS
	B	15	46.9	17	53.1	x^2 = 9.88**
Control Hindrances Dropoff at Edge of Pavement	C	2	66.7	1	33.3	x^2 = .3€ NS
	B	3	27.3	8	72.7	x^2 = 9.52**
Control Hindrances Other or Unspecified	C	1	33.3	2	66.7	x^2 = .36 NS
	B	1	14.3	6	85.7	x^2 = 9.49**
Design Problem—Road Overly Narrow, Twisting, Etc.	C	4	57.1	3	42.9	x^2 = .01 NS
	B	4	33.3	8	66.7	x^2 = 7.72**

[1]Chi-Square is based on expected percentage severity distributions of 66.3% PD—33.7% PI/F and 73.1% PD—26.9% PI/F for Levels C and B, respectively.

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

fatalities than would have been expected. The percent of PI/F accidents in the in-depth sample exceeded the expected distribution by 53.8 percent, and in the on-site sample, by 36.5 percent (Table 3-6).

The remaining causal factor for which significant differences were observed in the in-depth sample (internal distraction) was in the direction of accidents more frequently being PI/F than expected. In the on-site sample, PI/F accidents were also overrepresented in accidents where internal distraction was a factor, although this difference was not statistically significant.

Primarily because of the larger sample size involved, significant differences were identified in the on-site sample for considerably more factors than in the in-depth sample (16 versus 2). Of the 16 for which significant differences were identified, 12 were in the direction of PI/F accidents being overrepresented, while for the remaining 4, PD accidents were overrepresented. In addition to alcohol-impairment (which was significant in both samples), causal factors for which PI/F accidents were significantly overrepresented in the on-site sample were: internal distraction—event in car, improper maneuver—passed at improper location, excessive speed—for road design, performance errors (overall), overcompensation, physical/physiological (top-level human condition and state category, which includes alcohol-impairment), control hindrances, control hindrance—drop-off at edge of pavement, control hindrances—other or unspecified, and design problem—road overly narrow or twisting.

The remaining four factors for which significant differences were identified in the on-site sample were in the direction of PD accidents being overrepresented. These factors were recognition errors (top-level human direct cause category), external distraction, improper lookout, and false assumption.

For most (14 out of 16) of the factors for which statistically significant differences in the on-site sample were observed in either direction, the in-depth sample differed in the same direction, although only for alcohol-impairment was the difference significant in both samples. The two causal factors which did not conform (i.e., were significant in the on-site sample in one direction, but differed insignificantly in the other direction in the in-depth sample) were *improper maneuver—passed at improper location* (PI/F significantly overrepresented on-site, PD slightly overrepresented in-depth), *and control hindrance—drop-off at edge of pavement* (PI/F significantly overrepresented on-site, PD slightly overrepresented in-depth).

No vehicular factors were found to be associated with accident severity to a statistically significant extent.

3.6.2 Discussion

Overall, there were more individual causal factors which were significantly associated with overrepresentation of PI/F accidents than of PD accidents.

It is interesting that of the 544 comparisons run, alcohol-impairment emerged as the only causal factor significantly associated with severity in both the on-site and in-depth samples, especially since it was identified as a definite or probable cause in only about 3.7 to 5.4 percent (in-depth and on-site) of the Phase II and III accidents.

IRPS has reasoned in the past that relatively low involvement figures were obtained for this factor because the sample investigated consisted largely of property damage accidents, and that these, in turn, less frequently involve alcohol-impairment. The present analysis confirms that this is a correct assessment—alcohol-impairment is more likely to have been a cause of a personal injury or fatal accident, than of a property damage accident.

Of the three causal factors most frequently identified by the study, two (excessive speed and improper lookout) were significantly associated with accident severity, while the third (inattention) was not. Of the two which were significant, excessive speed was associated with PI/F accidents, while PD accidents were overrepresented when improper lookout was cited. The result for excessive speed comes as no surprise; it is logical that an accident which results from traveling too fast is more likely to involve personal injury or death than an accident resulting from a factor which could apply in a static or low-speed situation.

Of particular interest is that **internal** distractions were associated with more serious accidents on both the on-site and in-depth levels, while **external** distractions were associated with less serious (PD) accidents. These results were not expected, and cannot be explained with confidence. It may be that external distractions involve primarily voluntary diversions of attention which the driver permits himself when speeds are low and he perceives the situation to be relatively free of risk. Internal distractions, on the other hand, may involve primarily compelling events, which induce the driver to involuntarily shift attention away from the driving task, without regard to speed or perception of risk. This explanation is supported by the particularly strong association with PI/F accidents for the internal distraction subcategory, *sudden event in car*. This category is intended to take into account distractions resulting from dropped cigarettes, loud noises, sick passengers, etc.

These results are also of interest in the similarity of results obtained by the on-site and in-depth teams. Despite the considerable difference in the makeup and operating characteristics of the teams, for the total of 17 factors or subfactors for which statistically significant severity differences were identified, on-site and in-depth severity distributions for those factors were in different directions on only two occasions, and in each of these, rather than being widely split in different directions, one or the other of the samples had an essentially normal severity distribution.

3.7 Analysis of Model Year Distribution of Vehicles Having Deficiencies Which Caused Accidents

In this section, the model year distribution of all vehicles which were involved in on-site investigated accidents as a result of vehicular deficiencies (e.g., gross brake failure), is compared with the distribution for all vehicles registered in the study county.

3.7.1 Results

Results are summarized in Table 3-8. Table 3-9 provides the overall model year distributions for all accident vehicles having causative deficiencies, and these are illustrated in Figure 3-15. Table 3-10 shows the model year distribution in terms of *old* (1967 and older) and *new* vehicles, for subcategories of vehicle deficiencies (e.g., for tires and wheels); these results are illustrated in Figure 3-16.

In general, older vehicles were overrepresented among those which caused accidents (i.e., among those which were involved in accidents as a result of their own vehicle malfunction or degradation) (Figure 3-15). This overrepresentation was statistically significant at the .001 level. As revealed by Figure 3-15, the overrepresentation actually begins with the 1965 model year, and appears in about the same degree for 1964 and 1963 models. However, a greater degree of overrepresentation occurs in 1962 and older vehicles.

Due to the limited number of accidents caused by particular deficiencies, analysis of the

Table 3-8

Summary of Results Regarding Model Year Distribution of Vehicles Having Deficiencies Which Caused Accidents[1] (Based on Phase II/III, Level B Data)

Comparison Variable	Table or Figure Number	Findings
All Vehicular Factors	Table 3-9 Figure 3-15	Vehicles 1965 and older overrepresented in accidents caused by vehicular factors
Tires and Wheels	Table 3-10 Figure 3-16	Vehicles 1967 and older overrepresented by 23.6 percent in accidents caused by tire or wheel problems
Brake System	Table 3-10 Figure 3-16	Vehicles 1967 and older overrepresented by 32.3 percent in accidents caused by brake system problems
Steering System	Table 3-10 Figure 3-16	Vehicles 1967 and older overrepresented by 33.2 percent in accidents caused by steering system problems
Suspension Problems	Table 3-10	[2]
Power Train and Exhaust	Table 3-10	[2]
Communication System	Table 3-10 Figure 3-16	No Significant findings
Driver Seating & Controls	Table 3-10	[2]
Body, Doors, and All Other Vehicle Factors	Table 3-10 Figure 3-16	Vehicles 1967 and older overrepresented by 33.2 percent in accidents caused by body, doors, and all other vehicle problems

[1]"Caused" means were "Causal or Severity-Increasing," "Certain or Probable)) factors, for purposes of this analysis.

[2]Chi-Square test could not be performed, due to prohibitively small sample size.

distribution for these specific deficiencies by individual model years was not meaningful. Instead, accident vehicles were classified as either *old* (1967 or earlier) or *new* (1967 is approximately the median model year for all registered vehicles in the county). Based on this analysis, older vehicles were overrepresented for each of the vehicular categories tested (tires and wheels; brake systems; steering system; communication systems; body, doors, and all

Table 3-9

Comparison of Model Year Distribution of Vehicles Having Deficiencies Which Caused Accidents,[1] with Model Year of all Registered Vehicles in Monroe County[2]

Vehicle Model Year	Phase II/III On-Site Sample		Monroe County Model Year Distribution	
1973	(0)[3]	(00.0)[2]	156	7.80
1972	(1)[3]	(1.14)[2]	250	12.50
1971	7	7.95	190	9.50
1970	7	7.95	187	9.35
1969	7	7.95	165	8.25
1968	8	9.09	217	10.85
1967	5	5.68	183	9.15
1966	7	7.95	171	8.55
1965	11	12.50	177	8.85
1964	9	10.23	91	4.55
1963	6	6.82	85	4.25
1962 Or Older	20	22.73	128	6.40
Totals	88	100.00	2000	100.00

[1]Chi-Square = 63.392 d.f. = 11 p<.001. "Caused" means were assessed as "Causal or Severity–Increasing, Certain or probable." Combined Phase II/III, Level B data are utilized.

[2]Based on a ten percent systematic sample of vehicle model year, taken from Monroe County, Indiana License Branch.

[3]1973 vehicles are non-existent in the Phase II accident sample. Because of the period of data collection, 1973 vehicles are underrepresented in Phase III; likewise, 1972 vehicles are underrepresented in Phase II.

Table 3-10

Comparison[1] of Incidence of Vehicular Causal Factors in Phase II/III On-Site-Investigation for "Older" vs. "Newer Model" Vehicles[2] (Based on Phase II/III, Level B, Causal or Severity-Increasing, Certain or Probable Findings)

Vehicular Factor	1968 or Newer		1967 or Older		Total	Chi-Square[3]
	N	%	N	%	N	
Tires and Wheels	9	34.6	17	65.4	26	5.01*
Brake System	7	25.9	20	74.1	27	10.27**
Steering System	3	25.0	9	75.0	12	4.16*
Suspension Problems	0	0.0	2	100.0	2	[4]
Power Train & Exhaust	4	100.0	0	0.0	4	[4]
Communication Systems	8	44.5	10	55.5	18	0.89
Driver Seating & Controls	0	0.0	1	100.0	1	[4]
Body, Doors, & All Other Vehicle Factors	3	25.0	9	75.0	12	4.16*
Monroe County Vehicle Sample	1165	58.2	835	41.8	2000	

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

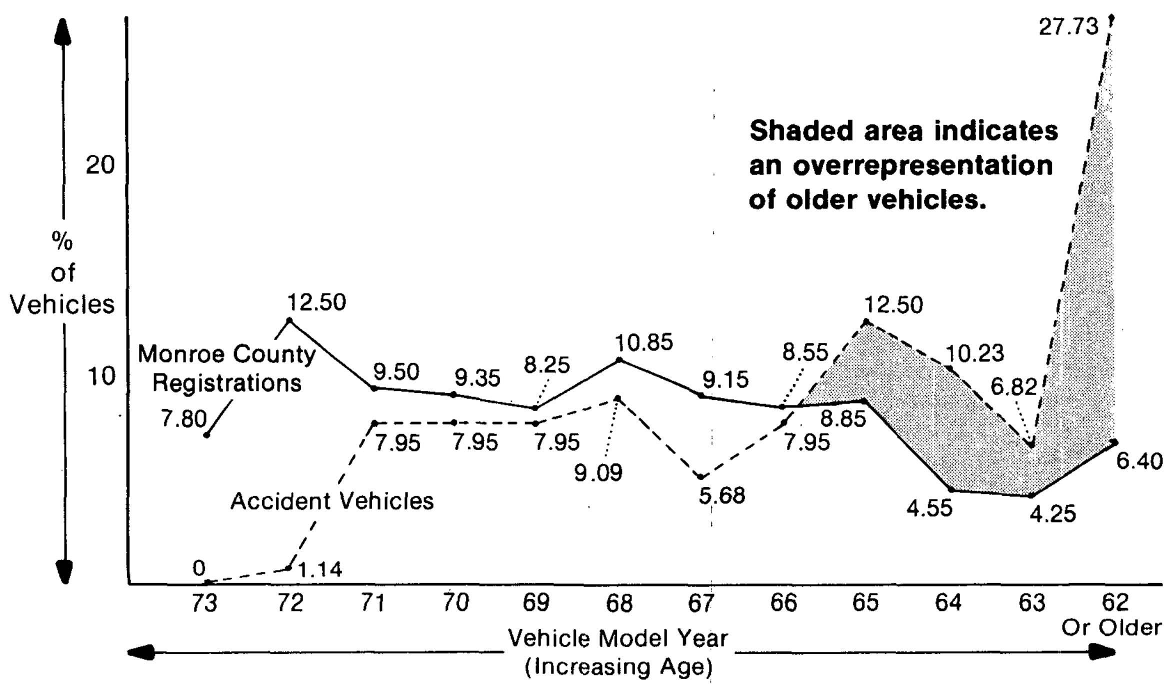
[1]Compared Against a Sample of 2000 Monroe County Vehicles
[2]"Older" Models are 1967 or Older
[3]For all Chi-Squares, d.f. = 1
[4]Chi-Square Test not Performed Due to Prohibitively Small Sample Size

other vehicular factors). Except for communications systems, each of these over-representations was statistically significant.

Statistical tests were not used for three comparisons (suspension problems, power train and exhaust, and driver seating and controls) since sample sizes were prohibitively small. However, both of the cases resulting from suspension problems, and the single case resulting from driver seating and controls, involved 1967 or older vehicles (Table 3-10). The four vehicles which had causative power train and exhaust problems reversed this trend, as all were 1968 or newer.

Figure 3-15

Graphical Comparison of Model Year Distribution of Vehicles Having Deficiencies Which Caused Accidents,[1] with Model Year of All Registered Vehicles in Monroe County [2]



[1]"Caused" means were "Causal or Severity-Increasing, Certain or Probable." Combined Phase II/III, Level B data are utilized.

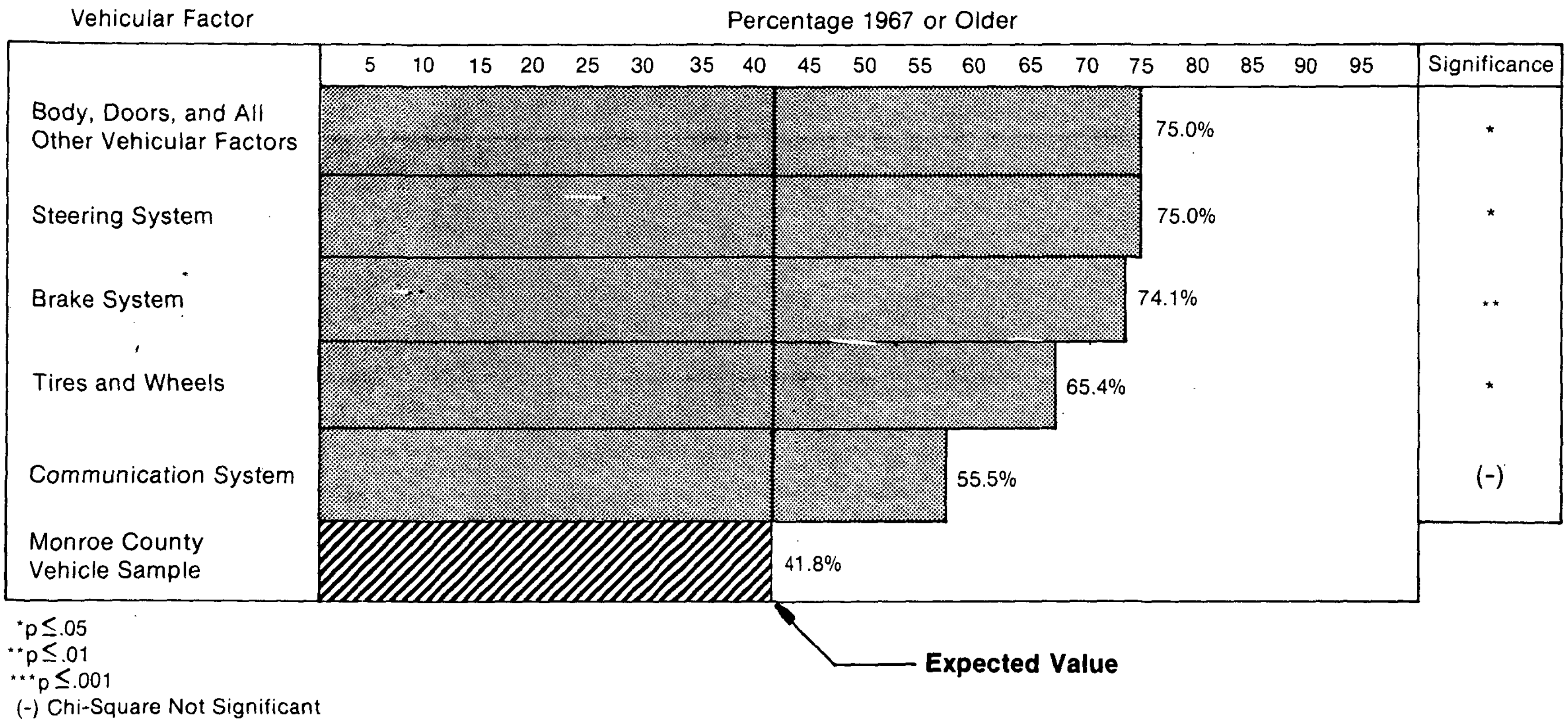
[2]Based on a ten percent, systematic sample of vehicle model year, taken from the Monroe County, Indiana License Branch.

3.7.2 Discussion

Numerous studies of general vehicle population outage rates, including one conducted for NHTSA in this same study county in 1971, have demonstrated that component outage rates generally increase with vehicle age or model year (1). Results reported above affirm that in addition, older vehicles are involved in accidents **because of** vehicle deficiencies and failures more frequently than would be expected (based on their number in the registered vehicle population). Other studies have shown that average yearly mileage per vehicle generally

Comparison of Incidence of Significant Vehicular Causal Factors in Phase II/III On-Site Investigation for Vehicles 1967 or Older (Based on Phase II/III, Level B, Causal or Severity-Increasing, Certain or Probable Findings)

Figure 3-16



decreases with vehicle age, indicating that the overrepresentation of older vehicles on a mileage basis (in accidents caused by vehicle deficiencies) is probably even more severe.

Further, the overrepresentation trend appears consistent when the major vehicle subsystems which have caused accidents are examined, including the two most frequently responsible among vehicle causes—brake systems and tires/wheels. Whether the responsible deficiency was in the brake system, tires and wheels, steering system, communications systems, or with respect to body, doors, and other vehicular factors, older vehicles were over-represented among vehicles involved in accidents resulting from such factors.

In results reported from an earlier Phase of IRPS' investigation program, it was noted that accident vehicles tended to have higher outage rates than general population vehicles, and that vehicles *most-at-fault* in accidents tended to have higher outage rates than those which were less culpable. Taken together, these results suggest that where mandatory inspection programs exist, vehicles involved in accidents should be either automatically required to be inspected or given a cursory inspection at the scene and referred for complete inspection if deficient; that this is particularly advisable for older, most-at-fault accident vehicles (whether or not a vehicle fault was involved); and that vehicles of 1962 model year and earlier should be examined especially carefully.

3.8 Comparison of On-Site and In-Depth Team Causal Results

3.8.1 Results

Table 3-11 indicates the causal factors for which the largest differences were noted between on-site and in-depth team results for both Phase III and the combined Phase II/III results. In Figure 3-17, accidents from Phases II and III which were investigated by both teams are analyzed as to their agreement or disagreement concerning the kinds of factors (human, vehicular, or environmental) which caused accidents. Figures 3-1 and 3-4 through 3-13 are also useful in illustrating result differences, while Tables 3-3 and 3-4 are a convenient summary of the actual percentages obtained for both levels. Detailed causal results appear in Appendices E, F, and G.

Table 3-11 indicates that results for **each** of the top-level human, vehicular, and environmental factor groups have differed between investigation levels by 5 percent or more in either the Phase III or combined Phase II/III results, at either the definite level or with probable results included. Nevertheless, similarities have outweighed the differences as to such top-level factors. As Figure 3-1 indicates, where results for human factors alone, human and environmental factors combined, etc., are considered, the rankings established by on-site and in-depth results are nearly the same. These similarities are especially apparent in comparing Figures 3-2 and 3-3. And as Figure 3-4 indicates, when the role of human, vehicular, and environmental factors are examined individually as a percentage of the combined Phase II/III accidents, the ranking established is the same (H-E-V), and the maximum percentage

Table 3-11

Summary of Causal Factors for Which the Largest Percentage Differences were Observed Between On-Site and In-Depth Results

	Phase III				Phase II & III			
	On-Site	Higher	In-Depth	Higher	On-Site	Higher	In-Depth	Higher
	Def.	Prob.	Def.	Frob.	Def.	Prob.	Def.	Prob.
Human Factors—Direct Causes							√	(5.0%) √
1. Critical Non-Performance								
a. Blackout								
b. Dozing								
2. Non-Accident (e.g., suicide)								
3. Recognition Errors							√	√
a. Driver Failed to Observe Stop Sign								
b. Delays in Recognition—Reasons Identified							√	
(1) Inattention								
(2) Internal Distraction				√				
(3) External Distraction								
(4) Improper Lookout							√	
c. Delays in Perception for Other or Unknown Reasons								
d. Delays in Comprehension or Reaction—Other or Unknown								
4. Decision Errors	√√				√			
a. Misjudgment								
b. False Assumption					√			
c. Improper Maneuver		(5.0%) √						

Table 3-11 continued

	Phase III				Phase II & III			
	On-Site	Higher	In-Depth	Higher	On-Site	Higher	In-Depth	Higher
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
d. Improper Driving Technique	√	√						
e. Driving Technique was Inadequately Defensive				√				√
f. Excessive Speed								
g. Tailgating								
h. Inadequate Signal								
i. Failure to Turn on Head-lights								
j. Excessive Acceleration								
k. Pedestrian Ran Into Traffic								
l. Improper Evasive Action								
5. Performance Errors								
a. Overcompensation				√				√
b. Panic or Freezing				√				
c. Inadequate Directional Control								
Human Conditions & States								
Physical/Physiological								
1. Alcohol-Impairment								
2. Other Drug Impairment								
3. Fatigue								
4. Physical Handicap								
5. Reduced Vision								
6. Chronic Illness								
Mental/Emotional								

Table 3-11 continued

	Phase III				Phase II & III			
	On-Site	Higher	In-Depth	Higher	On-Site	Higher	In-Depth	Higher
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
1. Emotionally Upset								
2. Pressure From Other Drivers								
3. "In-Hurry"								
4. Mental Deficiency								
Experience/Exposure						√		
1. Driver Inexperience								
2. Vehicle Unfamiliarity								
3. Road Over-Familiarity								
4. Road/Area Unfamiliarity								
Environmental Factors— Excluding Slick Roads	√√	√			√	√		
1. Slick Roads						√		
Environmental Factors— Including Slick Roads	√√	√			(5.0%) √			
1. Highway-Related	√							
a. Control Hindrances								
b. Inadequate Signs & Signals								
c. View Obstructions								
d. Design Problems								
e. Maintenance Problems								
2. Ambience-Related								
a. Special Hazards								
b. Ambient Vision Limitations								
c. Avoidance Obstructions								
d. Rapid Weather Change								
e. Camouflage Effect								
f. Environmental Overload								

Table 3-11 continued

	Phase III				Phase II & III			
	On-Site	Higher	In-Depth	Higher	On-Site	Higher	In-Depth	Higher
	Def.	Prob.	Def.	Prob.	Def.	Prob.	Def.	Prob.
Vehicular Factors		√						
1. Tires and Wheels								
2. Brake System								
3. Steering System								
4. Suspension Problems								
5. Power Train & Exhaust								
6. Communication Systems								
7. Driver Seating & Controls								
8. Body, Doors, & Other								

Note: One Check-mark (√) indicates a difference of 5.0—9.9%
Two check-marks (√√) indicates a difference of 10.0—19.9%
Three check-marks (√√√) indicate differences of 20% or more.

difference reported between investigation levels is only 8.4 percent (for environmental factors, definite or probable results).

With reference to Table 3-11, it is apparent that differences of 5 percent or more between in-depth and on-site results occur with about equal frequency in both the Phase III and combined Phase II/III results. In Phase II/III data, results of one level notably exceed those of the other with about the same frequency. However, in the latest data (Phase III), a tendency has developed for large differences (5 percent or more) to more frequently occur in the direction of on-site results exceeding those for in-depth, especially at the definite (causal-certain) level. In fact, in each of the five instances noted in Phase III where definite results from one investigation level exceeded those from the other, on-site results exceeded those from the in-depth team.

In the combined Phase II/III data, notable differences among human factors have generally been in the direction of in-depth results exceeding on-site, while for environmental factors the reverse has been true. When only Phase III is considered, the same tendency for on-site environmental results to be notably larger holds true, but for human factors the situation changes, and results from one investigation level notably exceed the other with about the same frequency. For vehicular factors, on-site results tended to exceed in-depth in Phase III, yet generally were less in Phase II. Differences are minimal (less than 2 percent) for vehicular factors in the combined Phase II/III results.

Within the human factors results, for Phase II/III, in-depth has tended to exceed on-site for recognition and performance errors, while on-site results have tended to notably exceed in-depth for decision errors. In Phase III the picture remained the same as to decision and performance errors, but changed as to recognition errors—with the exception of internal distraction, where differences of 5 percent were not experienced.

Based on combined Phase II/III data, the specific (non-grouped) human causal factors for which in-depth results notably (by 5 percent or more) exceeded on-site were: improper lookout (definite level), and inadequately defensive driving technique (probable level). The only factor for which the reverse was true (on-site notably exceeded in-depth) was false assumption. In Phase III, in-depth results were again greater with respect to inadequately defensive driving technique, but the differences with respect to both improper lookout and false assumption disappeared. However, additional factors appeared with large differences. In-depth results were now notably larger for internal distraction and overcompensation (both at only the probable level), while on-site results were larger for improper maneuver and improper driving technique.

With regard to human conditions and states, only for the grouped experience/exposure category in the combined Phase II/III results have differences of 5 percent or greater been identified. Here, on-site results exceed those for in-depth by 5.7 percent (probable level). This resulted primarily from a greater (on-site) tendency to assign causative significance to driver inexperience and road unfamiliarity.

Within the environmental factors results, for which on-site results have tended to exceed in-depth, it does not appear that there are particular subfactors responsible for the tendency. Instead, on-site results for each subcategory tend to exceed in-depth by a relatively small amount. Only for one specific environmental causal factor—slick roads— did the differences exceed 5 percent. Here, on-site results notably exceeded in-depth in the combined Phase II/III data. However, results for this factor differed by only 2.6 percent (at the probable level) in the more recent Phase III data.

In other respects, however, differences for environmental results were more pronounced in Phase III than previously. Again, there are no specific causal factors which can be pointed to as accounting for the differences. Instead, there is a distributed tendency across the environmental subcategories for on-site results to exceed in-depth.

For vehicular factors, the largest difference noted is that on-site results for the overall vehicular factor category exceeded in-depth results by 6.0 percent at the probable level during Phase III. Again, no particular subfactors appear responsible, as on-site results exceeded in-depth for tires and wheels, brake system, steering system, power train and exhaust, communication systems, and body, doors, and other vehicular factors, and were the same as in-depth (zero) for the remaining subcategories.

Agreement/Disagreement Analysis

Agreement/disagreement criteria are shown in Table 3-12. Results of this analysis are shown in Table 3-13 and Figure 3-17. Here, results from accidents which were examined by both the on-site and in-depth teams during Phases II and III are compared, and their agreements and disagreements tallied. It can be seen that for human factors, agreement was very high, and disagreement low (as defined in the methodology discussion in Section 3.2). Total disagreement as to the involvement of human factors occurred for only 3.8 percent of the accidents, while in an additional 5.2 percent, disagreements of certainty were involved (meaning that one team assessed human factors as being definitely involved, while the other rated this involvement as possible). For vehicular factors, disagreements of involvement were more frequent and disagreements of certainty less frequent, with a net result that the total disagreement level was about the same as for human factors. In 9.4 percent of accidents investigated by both teams, they disagreed as to whether vehicular factors were involved, while in an additional 1.4 percent of accidents, they disagreed as to the certainty which should be assigned. Disagreement was the greatest with respect to environmental factors. In 16.5 percent of the accidents investigated by both teams, they disagreed as to whether environmental factors were causally involved, and in an additional 3.3 percent of accidents, disagreed as to certainty of involvement.

From Table 3-13, more information may be discerned as to the direction of agreement or disagreement. This table shows that for human factors, all of the disagreements as to involvement were situations where the in-depth team identified a human factor, but the on-site team did not. Further, for most of the disagreements as to certainty (8 of 11), the in-depth team was the *more certain*. For vehicular factors, disagreements as to involvement were fairly evenly split between instances where in-depth identified a factor and on-site didn't (11 of 20 cases), and the reverse (9 cases), while disagreements of certainty had the in-depth team being more certain in two out of the three cases involved.

For environmental factors, most of the disagreements as to involvement resulted where the on-site team found involvement and the in-depth team did not (24 of 35 accidents), while the reverse was true in 11 accidents. Similarly, 6 of the 7 disagreements as to certainty involved the on-site team being more certain.

A similar analysis was attempted for the major human, vehicular, and environmental subfactors. However, technical difficulties were experienced with this effort which were not possible to resolve in time for inclusion in the present report. Such results will be reported at a later time.

3.8.2 Discussion

In considering these results, it should be borne in mind that in-depth accidents were selected from those investigated on-site, and that the combined Phase II/III results primarily

Table 3-12

Definitions of Level B/Level C Causal Factor Assessment Comparisons

	Agreement/Disagreement Classification	Conclusion Combination Type[1]	Level B Assessment	Level C Assessment
AGREEMENTS	Certain or Probable, Causal Agreement	A	Causal-Certain	Causal-Certain
		B	Causal-Certain	Causal-Probable
		C	Causal-Probable	Causal-Certain
		D	Causal-Probable	Causal-Probable
	Probable or Possible, Causal Agreement	E	Causal-Probable	Causal-Possible
		F	Causal-Possible	Causal-Probable
		G	Causal-Possible	Causal-Possible
		H	Causal-Possible	Not Identified
		I	Not Identified	Causal-Possible
	Not Identified by Either Team	J	Not Identified	Not Identified
DISAGREEMENTS	Level C More Certain (Disagreement of Certainty)	K	Causal-Possible	Causal-Certain
	Identified by Level C But Not by Level B (Disagreement of Involvement)	L	Not Identified	Causal-Certain
		M	Not Identified	Causal-Probable
	Level B More Certain (Disagreement of Certainty)	N	Causal-Certain	Causal-Possible
	Identified by Level B But Not by Level C (Disagreement of Involvement)	O	Causal-Certain	Not Identified

[1]These "types" are defined by the entries in the two right-hand columns.

reflect Phase II experience, since the Phase II sample (151 in-depth, 530 on-site) considerably exceeded that for Phase III (64 in-depth, 306 on-site). Tests for significance were not performed because the on-site and in-depth samples were not mutually exclusive. The samples were not separated so as to make them exclusive, since real differences might have existed in

Table 3-13

On-Site/In-Depth Agreement/Disagreement Results[1]

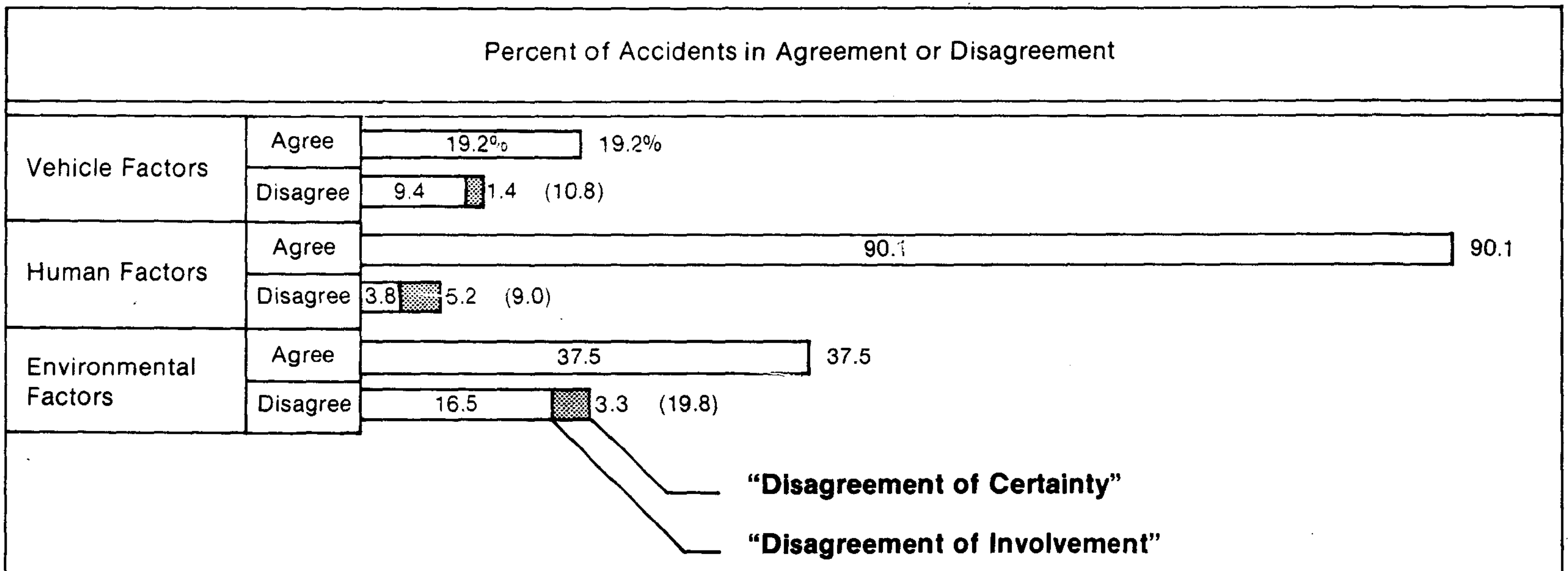
Differences In Assessment Of Degree Of Certainty For Causal Factors

	Agreements						Disagreements								Level Of Significance			
Factor	Certain And Probable		Probable And Possible		N/A		Level C More Certain		Identified By Level C But Not By Level B		Level B More Certain		Identified By Level B But Not By Level C		Factor Was Causal On Level B And S/I On Level C		Factor Was Causal On Level C And S/I On Level B	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Human	189	88.7	3	1.4	2	.9	8	3.8	8	3.8	3	1.4	—	—	—	—	4	1.9
Vehicular	12	5.6	29	13.6	49	70.0	2	.9	11	5.2	1	.5	9	4.2	—	—	3	1.4
Environmental	48	22.5	32	15.0	91	42.7	1	.5	11	5.2	6	2.8	24	11.3	2	.9	1	.5

[1]See Previous Table (Table 3-12) for Definition of "Agreement" and "Disagreement."

Figure 3-17

Disagreements Between On-Site and In-Depth Teams as to the Involvement of Human, Vehicular, or Environmental Factors[1]



[1]See Table 3-12 For Definitions of "Agreement" and "Disagreement."

the two samples, and this difference might have been measured rather than the assessment practices of the teams.

Assuming the accuracy of the in-depth team findings, large and consistent differences in the on-site findings are not identified to an extent which would indicate that there are serious limitations in the use of on-site (*technician*) teams as risk-identification tools. However, it is fair to say (assuming the accuracy of in-depth findings) that the on-site teams fail to identify a small number of causative human factors (but do not wrongly identify human factors which in fact were not involved), both wrongly identify (i.e., concluded vehicle factors were involved when in-depth concludes they weren't), and fail to identify some vehicular factors, and are prone to wrongly identify environmental factors as being involved which in fact are not.

Among the individual causal factors for which differences exceeding 5 percent were noted, several are thought to be understood. First, regarding *false assumption,* it was suspected after reviewing the initial results from Phase II that the on-site investigators were prone to apply this category in many situations which were not warranted. For example, if a driver crested a hill driving in the center of the road this would be termed a false assumption (i.e., assumed no one was coming) rather than where intended (and where generally placed by the in-depth team) under improper driving technique or practice. Investigators were counseled as to this problem, and with no other change, on-site results from Phase III for this factor are very similar to those obtained in-depth. However, both improper driving technique and improper maneuver are now notably greater in the on-site results (for Phase III) than in-depth, and there are no reasons for this change which can be assigned with confidence. For slick roads, the large Phase II/III difference was primarily the result of the reluctance of the in-depth team to view slickened roads as causal factors during Phase II. These professionals were strongly biased towards the view that such roads are only difficult conditions, so that failure to cope with such conditions was only classifiable as a human factor. However, the definitional framework developed for the study requires that if correction of a defined deficiency to its normal state would have prevented an accident from occurring, this deficiency must be designated a cause, and roads with reduced coefficients of friction are among such defined deficiencies. Therefore, subsequent to Phase II, in-depth team members were counseled as to the need to try to account for the causal role of such roads, and at the same time, the outline for recording and presenting causal results was altered to express involvement figures both including and excluding slick roads. With this change, everyone was convinced that results could be fairly dealt with and interpreted, and both conscious and unconscious obstacles to the use of the slick roads category were removed. On-site investigators were also reminded to be cautious of wrongly **assuming** a causal role for slick roads whenever accidents occurred under such conditions. In Phase III, differences between on-site and in-depth results for this factor were minimal.

The difference in results for vehicular factors which appeared in Phase III is particularly difficult to interpret, as is the tremendous (and statistically significant) decrease in in-depth vehicular results between Phases II and III. Overall, it is believed that the low involvement reported for the Phase III in-depth vehicular results is a result of a sampling abnormality, whereby the number of accidents in the sample of 64 considered which were caused by vehicular factors was unusually low. This being the case, it is unlikely that the notable difference in on-site and in-depth data for this factor (in Phase III) can be attributed to differences in the on-site and in-depth assessment practices.

Despite the general similarity of results, both Levels B and C continue to serve unique roles within IRPS' investigation program. For example, when the role of vehicular degradations (rather than failures) is examined, Level C results are favored since the Level B technicians cannot reasonably be expected to account for the subtle role that such factors might play in an accident, given the limited information which can be acquired on the scene of an accident. As would be expected, results from the on-site level have been considerably lower for such factors, when the aggregate of Phase II and III data are considered.

Similarly, in-depth team (Level C) data is uniquely useful when highly detailed information on individual accidents is required. For example, the dynamic vision testing currently being conducted on the in-depth level could not be incorporated as part of current on-site procedures.

In-depth team investigations have also been useful in providing well-documented examples of the involvement of different factors and phenomena, and this utility is enhanced by the current practice of providing a detailed case report to NHTSA on each such investigation. While the on-site process may accurately identify the involvement of a factor, much of the background documentation and collateral information which make such an example case useful may be absent.

On the other hand, Level B has continued to play an important role in the project. Initially, it is a source of in-depth accidents, and a means of preserving physical evidence and other information available at the scene, which probably would not be available later. Beyond this, the principle attribute of Level B is the relatively large sample size. For example, in the cluster and problem driver analysis portions of this report (Sections 5.0 and 6.0), Level B data was used since it provided a larger sample, and for this initial cluster analysis effort, the more detailed Level C information was not required. Eventually, as Level C sample sizes increase, it may be possible to introduce many new kinds of data from that level into the cluster analysis process, including knowledge test, vision test, impulse-expression test, vehicle inspection, and roadway deficiency data.

4.0 Accident Vs. Control Sample Comparisons

It is most meaningful to interpret distributions of descriptive variables for accident-involved drivers and vehicles after comparing them with corresponding distributions of general population drivers and vehicles.* In this way, exposure to risk is accounted (i.e., controlled) for. During Phase III, IRPS conducted a survey of general population drivers and vehicles, and collected samples from driver and vehicle registrations on file in Monroe County, in order to establish a control sample. Comparisons of accident and control samples allowed IRPS to obtain answers to the following questions:

1. Do accident-involved and general population drivers differ with respect to driver demographics, experience, training, and familiarity with the accident vehicle? Do accident-involved and general population vehicles differ with respect to vehicle make and model year?
2. Which drivers and vehicles tend to be overinvolved in accidents? Which drivers and vehicles tend to be underinvolved?

The survey included additional items related to driver accident history, percent of driving in certain locations and under certain conditions, knowledge of safe driving practices, and vehicle conditions. These items were tabulated and summarized graphically; however, space considerations prevent a detailed presentation here, permitting presentation of only the topics most relevant to relative involvement. These additional findings may be integrated into analysis and reporting activity during Phase IV.

4.2 Methodology

4.2.1 Overview

The analysis in this section quantifies the relationship between accident-involvement frequencies for various subgroups of drivers and vehicles relative to the existence of these subgroups in driver and vehicle populations as a whole. For the ten driver-related and two vehicle-related variables studied, accident and control data† were collected from accident and general populations within Monroe County. Information on the accident population was taken from Indiana State Police accident reports and case reports of accidents investigated by the IRPS on-site and in-depth teams. General population distributions for the two vehicular variables (*vehicle make* and *vehicle model year*) were extracted from 1973 passenger vehicle

*In this study, a *general population driver and vehicle* is defined as any driver/vehicle combination engaged in travel within the boundaries of Monroe County, Indiana.

†*Control* or *general population data* refer to data sampled from the general driving population of Monroe County, Indiana, during the period 9 April, 1973 through 6 June, 1973.

registrations on file at the Monroe County License Branch. At the time of sampling, 1972-1973 tag transfers were 95 percent complete. General population distributions for *driver sex* and *driver age* were taken from 1972 driver's license applications on file at the Monroe County License Branch. It was assumed that age and sex distributions of individuals applying for driver's licenses do not fluctuate significantly from one year to the next. Control data for the eight other comparison variables studied were collected in a parking lot survey of general population driver/vehicle combinations traversing the roadways of the study area.

Descriptions of accident and control sample sources are detailed in Table G-1. Each comparison variable is entered along with the parent population from which the sample was drawn, the data collection period, method of collection, collection agency, method of sample selection, sample size, and data collection level. (As mentioned in Section 4.1, variables in addition to the 12 listed in Table G-1 were recorded by control data interviewers, but these items were omitted from discussion because they do not directly address the question of relative involvement.) Control data collection instruments are presented in Figures G-1 through G-3.

4.2.2 Sampling Design and Sample Selection

As discussed earlier, comparison samples were of two types: *accident samples,* where only drivers and vehicles involved in crashes within Monroe County during the data collection period were considered for inclusion, and *control samples,* where drivers licensed in Monroe County, vehicles registered in Monroe County, and driver/vehicle combinations traversing the roads of Monroe County were considered for inclusion. Elementary or sample units for both samples were motor vehicles and motor vehicle operators.

A triple-phase* interpenetrating sampling plan was used for the collection of information about accident-involved drivers and vehicles. When sample units were duplicated or triplicated, samples from levels with the largest number of sample-units were chosen for comparison. For example, age and sex of accident-involved drivers were recorded on all three levels; information from Level A was used for comparison since proportions of populations sampled were as large as possible.

Control samples were drawn from three different sources:

1. **1972 Driver's License Applications**—Copies of all 1972 driver's license applications are filed in alphabetical order at the Monroe County License Branch. A three percent systematic sample was drawn from the approximately 33,000 applications on file. The only descriptors recorded were age and sex of the licensed driver. The sample was drawn 29 May, 1973.
2. **1973 Passenger Car Registration**—Copies of 1973 passenger car registrations

*Police-reported, on-site investigated, and in-depth investigated.

are filed by tag number at the Monroe County License Branch. A 10 percent systematic sample was drawn from the approximately 20,000 1973 registrations on file. The only descriptors recorded were make and model year of the registered vehicle. The sample was drawn 6 June, 1973.

3. **General Population Drivers and Vehicles**—In an attempt to obtain a control sample representative of general population drivers and vehicles, it is important that the sampling procedure assures that all driver/vehicle combinations are given an equal chance of being chosen. For this reason a proportional, stratified sampling plan was used. Two attributes, *age* and *sex* of licensed drivers, were used for stratification. These two variables were chosen because these attributes are relatively easy to spot in the field, thus facilitating the stratification process. Adequate age and sex information upon which to base the stratification was available from the three percent systematic sample of 1972 driver's license applications. The population was divided into 14 age/sex strata. Data collection quotas were then determined for each stratum, based upon the proportion of drivers in each stratum in the license application sample. Interviewers were instructed to fill each quota with respondents randomly selected from six public-access parking lots in Monroe County.

Three members of the IRPS tri-level staff served as interviewers. Training sessions were held before data collection began, in an effort to ensure efficiently collected and reliable data. Data collection began on 9 April, 1973, and ended 3 June, 1973. During this period, information on 300 driver/vehicle units was collected. On-line monitoring of the stratification process revealed that all quotas had been successfully filled.

4.2.3 Statistical Analysis and Computational Procedure

In this section chi-square one-sample tests (1) were used to test the hypothesis that accident-involved vehicle and driver distributions did not differ from general population vehicle and driver distributions. Control samples, drawn from general population Monroe County drivers and vehicles, were used to estimate expected accident-involvement frequency distributions. Expected and observed accident-involvement frequencies were then compared via manually computed chi-square one-sample tests and tabulated along with computer-tallied accident and control frequency distributions. In a similar study to examine the effects of vehicle aging on accident experience and severity (2) chi-square two-sample tests were used to measure differences between control and accident populations. This procedure was not replicated in this study because accident and control samples were not mutually exclusive. However, results of two-sample and one-sample tests appear to have given markedly similar results, showing no association between vehicle aging and accident experience.

After chi-square tests were run to examine for nonrandom differences between accident and control sample distributions, relative involvements for each driver or vehicle subgroup were manually calculated and graphically presented (See Figures H-1 through H-12). In this study, relative involvement (RI) for a particular driver- or vehicle-related variable with i subgroups is defined as:

$$RI_i = \frac{\text{Proportion of times subgroup i appears in the accident-involved sample}}{\text{Proportion of times subgroup i appears in the control sample}}$$

RI is consistent with the concept of relative involvement as documented in earlier studies by Thorpe (3), Carr (4), and Hall (5).

Numerators and denominators of RI's for a particular comparison variable are probability estimates of subgroup i, given accident- and general-population predictive probabilities (6) of subgroup i, respectively. From Bayes' Theorem, the probability of an accident given subgroup i of comparison variable E, for example, *driver experience* is expressed as:

$$\Pr\{\text{accident}|E_i\} = \frac{\Pr\{E_i|\text{accident}\} \times \Pr\{\text{accident}\}}{\Pr\{E_i\}}$$

Thus the probability of an accident given subgroup i of comparison variable E is equal to the prior probability of an accident, ($\Pr\{\text{accident}\}$), times the conditional probability of subgroup i given an accident ($\Pr\{E_i|\text{accident}\}$), divided by the general-population-predictive probability of subgroup i ($\Pr\{E_i\}$). The conditional probability of subgroup i, given an accident, is estimated from accident-involved sample distributions; and general-population-predictive probability of subgroup i is estimated from control sample distributions. Therefore, RI_i is an estimate of

$$\frac{\Pr\{E_i|\text{accident}\}}{\Pr\{E_i\}}$$

and is used to adjust our prior estimates of accident-involvement probabilities. An RI_i greater than 1.0 indicates that the additional information about comparison variable E shows increased probability of accident-involvement, while an RI_i less than 1.0 indicates a decreased probability of accident-involvement. An RI_i of 1.0 indicates no change.

4.3 Results

Summary Table 4-1 shows those comparisons which were performed, and serves as a directory of table and figure numbers for each comparison. The ten driver- and two vehicular-descriptive variables appearing in the left-hand column were used in two types of comparisons. First, Tables H-1 through H-12 compare for each variable indicated, the frequency distribution of various subgroups for the sample of accident-involved drivers with the distribution of subgroup frequencies for the control sample. Each of Tables H-1 through H-12 shows the accident and control sample distributions, the sources from which these

Summary Table 4-1

Accident and Control Sample Characteristics (Table and Figure Nos.)

Comparison Variable	Accident vs. Control Sample Comparison	Involvement Ratios
Driver Sex	Table H-1	Figure H-1
Driver Age	Table H-2	Figure H-2
Marital Status	Table H-3	Figure H-3
Education	Table H-4	Figure H-4
Annual Family Income	Table H-5	Figure H-5
Major Occupation	Table H-6	Figure H-6
Years Driving Experience	Table H-7	Figure H-7
Most Recent Yearly Mileage	Table H-8	Figure H-8
Vehicle Familiarity (Months Driving Accident Vehicle)	Table H-9	Figure H-9
Driver Training	Table H-10	Figure H-10
Vehicle Make	Table H-11	Figure H-11
Vehicle Model Year	Table H-12	Figure H-12

distributions were obtained, and a chi-square one-sample test. Second, Figures H-1 through H-12 show subgroup involvement ratios for each variable, comparing for each subgroup its proportion in the accident sample relative to its proportion in the control sample. The solid lines in Figures H-1 through H-12 connect the involvement ratios for all accident-involved drivers* (the overall accident sample); the dotted lines connect corresponding ratios for the subsample comprising only alcohol-impaired drivers.†

Summary Table 4-2 highlights the findings from each set of comparisons, reporting for each accident vs. control sample comparison the chi-square significance level and the largest subgroup difference between the accident and control samples. Only percentage differences equal to or greater than five percent are reported. Summary Table 4-2 also shows involvement ratio comparisons, reporting the most over-involved and the most under-involved subgroup

*Note the expanded ratio scale for *Marital Status* in Appendix H, Figure H-3.

†Discussion of these findings related to the alcohol-impaired driver is presented in Section 6.0.

Summary Table 4-2

Accident and Control Sample Characteristics[1] (Findings)

Comparison Variable	Accident vs. Control Sample Comparisons		Involvement Ratio Comparisons			
	Largest Subgroup% Difference[2]	x^2 Significance	Most Overinvolved Subgroup	Ratio Value	Most Underinvolved Subgroup	Ratio Value
Driver Sex	11.7% More Males Accident-Involved	***	Males	1.204	Females	.726
Driver Age	5.2% More 20-24 Year Olds Accident-Involved	***	20-24 Year Olds	1.222	55-64 Year Olds	.778
Marital Status	16.4% More Married in Control Sample	***	Divorced	4.700	Widowed	.583
Education	10.4% More Less-Than-High-School-Graduates Accident-Involved	***	Less-Than-High-School-Graduate	1.707	Graduate or Professional	.550
Annual Family Income	9.1% More $15-19,999 Incomes in Control Sample	***	$6-7,999 Income	1.591	$20-24,999 Income	.484

Summary Table 4-2 continued

Major Occupation	9.3% More Housewives in Control Sample	***	Laborers	2.134	Housewives	.443
Years Driving Experience	11.6% More Under-5-Years Accident-Involved	***	Less Than 5 Years	1.589	30-39 Years	.630
Most Recent Yearly Mileage	8.1% More Under-6,000-Miles in Control Sample	***	31,000+ Miles	1.580	Less Than 6,000 Miles	.653
Vehicle Familiarity (Mos. Driving Experience)	10.6% More 7-12 Month Experience in Control Sample	***	25-36 Months	1.568	7-12 Months	.651
Driver Training	6.4% More "Completed" Accident-Involved	*	Completed	1.114	Taken but Not Completed	.714
Vehicle Make	—	(NS)	"Other"	1.204	Lincoln	.500
Vehicle Model Year	—	(NS)	1970	1.319	1973	.628

[1]Only Comparisons for All Accident Drivers are Reported; Comparisons Involving Alcohol-Impaired Drivers are Omitted Here.
[2]Only Positive Percentage Differences of 5% or Greater Reported.

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

for each variable and the corresponding ratio value for each of these subgroups. When any subgroup is overrepresented in the accident sample, the involvement ratio is greater than 1.0. Likewise, any subgroup which is underrepresented in the accident sample (as compared with the control sample) will have an involvement ratio less than 1.0. An involvement ratio of 1.0, then, would indicate that a subgroup is no more under- or overrepresented in accidents than in the general driving population. It is important to note that for those variables where the accident sample did not differ to a statistically significant extent distributed from the control sample, involvement ratios may be misleading by implying that subgroup relationships exist when in fact they are spurious.

Summary Table 4-2 shows that for each variable except *vehicle make* and *vehicle model year,* the accident sample significantly differs from the control sample with respect to distribution of frequencies in the various subgroups. Of the comparisons which exhibited this statistical difference, all but one (*driver training*) exhibited a significance level of .001, meaning that it is highly improbable that the differences in the distributions are due to chance alone. The variable *driver training* exhibited a slightly lower significance level ($p < .05$) but the accident vs. control subgroup difference observed here too is not likely to be due to chance.

In general, Summary Table 4-2 shows that most of those over-involved in accidents are male drivers, (aged 20-24), divorced drivers, relatively uneducated drivers, low income drivers, drivers who are primarily employed as laborers, relatively inexperienced drivers, highly exposed drivers (high annual mileage), drivers having moderate familiarity with the accident vehicle, and perhaps unexpectedly, drivers who have completed a driver education course. In contrast, drivers underrepresented in accidents tend to be female drivers, older drivers (55-64 years old), widowed drivers, highly educated drivers, high income drivers, housewives, moderately experienced drivers (30-39 years experience), relatively unexposed drivers (<6,000 miles per year), and drivers with little or no formal driver training. These driver characteristics are underrepresented in the accident population. It is not necessarily the case, however, that any additive or multiplicative relationship exists between the ratios for under- and over-involved characteristics. For example, merely because males, 20-24 year olds, divorced, and less-than-high-school-educated subgroups are over-involved in accidents, does not **necessarily** mean that a driver having a combination of these characteristics would tend to be more accident-involved than a driver having only one of these. In fact, it is rare to find a driver who is male, 20-24 years old, divorced, less-than-high-school-educated, has $6,000-7,999 annual income, is a laborer by occupation, has less than five years driving experience, drives more than 31,000 miles per year, has 25-36 months familiarity with the accident vehicle, and has completed a driver education course.

With respect to vehicular variables, the involvement ratios shown for *vehicle make* and *vehicle model year* have no particular meaning because for these variables, the accident and control frequency distributions do not significantly differ. Chevrolets are probably no more involved in accidents than Oldsmobiles.

4.4 Discussion

It is important to note that the involvement ratios do not hold exposure constant. Therefore, these ratios are merely descriptive of the accident and control samples and should serve merely to indicate prevalent problem subgroups in the driving population. The presentation of accident rates (controlled for exposure) is of a different scope and answers a different question (i.e., *which are the most dangerous subgroups?* rather than *which are the most prevalent subgroups?*).

Perhaps the most striking finding in this portion of the study is that subgroup distributions differ between accident and control samples for driver-related variables, but not for vehicle-related variables. For *vehicle model year,* the absence of a dramatic accident/control difference is consistent with the finding of Hall (7), using induced exposure to obtain the control sample, and consistent with the finding of Little and Hall (8), using a control sample similar to that used here. It appears that safety features of newer model cars have not in fact reduced accident-involvement, and that degradation of older model vehicles (older age), as demonstrated in Section 3.7 on analysis of vehicular causal factors vs. vehicle model year, does not increase accident-involvement when accidents are viewed on an overall basis. Likewise, it appears that the *make* of vehicle does not have any relationship to the probability of its involvement in accidents. The involvement ratios have been computed and graphed for *vehicle model year* and *vehicle make* (Figures H-11 and H-12), but the reader is cautioned that the relative magnitudes of these ratios may be misleading. One would like to think that Lincolns are less likely to be involved in accidents than Chevrolets (Figure H-11), but because the accident and control distributions were not found to differ significantly, we cannot say that this is probably true.

It must be pointed out, however, that ultimate faith cannot be placed in the veracity of the above statement because of two potential methodological problems surrounding the procurement of a *control population* for comparison with the accident sample. First, the control sample is merely that—a sample. It must be **assumed** to be representative of the general driving (parent) population, but cannot be guaranteed so. Our real goal is to compare the accident *population* with the control or parent *population.* We are here comparing two samples, rather than two populations. In Section 7.0, we assess the representativeness of the accident sample with respect to all accidents occurring nationally (the accident *population*), and find our sample to be fairly representative of the population, although deviating in some respects. We have no information, however, on the control population. We have merely sampled from it, using stratification techniques on two easily controllable variables (*driver age* and *driver sex*), yet have no assurance that our control sample is representative or not representative of the control *population* with respect to perhaps more important variables, because we really have no conception of what the control population really comprises.

The second point to be made regarding methodological problems of observing the control population is that the control population was sampled at one instant in time—a static process—whereas the accident sample was created dynamically (i.e., over several years' time). The implications of this disparity are not clear. No attempts have been made here to correct for changing driver or vehicle components in the control population during the period of collection of the accident data. Here, then, we must assume that we have a control sample which is truly representative of the control population, and an accident population and sample which has in fact been drawn from the *control* population we have attempted to sample.

A detailed comparison of the involvement ratios for the alcohol-impaired driver vs. the *general* driver is presented in Section 6.0 on the Problem Driver. Here, however, it should be mentioned that Figures H-1 through H-12 show a much larger variability for the alcohol-related ratios than for the general-driver ratios. This difference in stability is probably due to the different sample sizes for the two classes of driver. The alcohol driver subset has such small numbers of observations for most of the subgroups that many of these ratios appear to be zero when in truth this is an artifact. Likewise, the ratio 30.333 for the alcohol-impaired *separated* driver (Figure H-3) is spuriously high. Though the stability of the alcohol-related ratios is affected by the small number of observations, the relative magnitudes are still probably close to their expected values. In other words, those subgroups which appear to be heavily over-involved probably are; likewise, those which appear to be quite under-involved probably are.

Of those driver-related variables whose subgroups comprise a continuum (e.g., *driver age*), several show trends across their scales. For *driver age,* the plot of involvement ratios (Figure H-2) appears to have a U-shaped function, such that both extremely young and extremely old drivers tend to be overrepresented in the accident sample. The slope of this curve is consistent with that found by Hall (9). For *education* of driver (Figure H-4), assuming that the subgroups as displayed form a sort of continuum, it seems clear that the greater the educational level attained, the smaller the probability of being involved in an accident. With respect to *annual family income* (Figure H-5), the picture is less clear. If one excludes the lowest and highest categories, the curve is shaped similar to that for *education*—that is, the greater the income, the smaller the representation in the accident sample. It appears that the extremely poor (under $3,000 annually), and the wealthy (greater than $25,000) reverse the trend a bit. At first glance, *years driving experience* (Figure H-7), shows no consistent pattern. Given that the ratio of 1.090 for the subgroup 20-29 years (1) "results from some identifiable component (such as the alcohol-impaired driver) whose effect when removed will reduce the ratio to about .669," or (2) "is by chance too high and is expected to be around .669," a clear trend then emerges. The curve again would be U-shaped, indicating that *very inexperienced* and very *highly experienced* drivers tend to be more accident-involved than drivers in the middle of the experience continuum.

At this point, we have identified two types of curves: the U-shaped curve exemplified by *driver age* and *years driving experience,* and the declining curve exemplified by *education* and *annual family income*. It is possible that these two types of curves point to two different types of processes, the former being a time-related process (warm-up/peak efficiency/decay), and the latter being a static process related to some sort of driver quality, this *quality* perhaps deeply tied to subtle psychological driver traits. In other words, those who are highly educated and have high income probably have some underlying traits which both caused them to attain this high level of accomplishment and also causes them to be good drivers. It is not likely that the education *per se* has fostered the *good driving* and therefore low accident involvement, since the ratios for *driver training* (Figure H-10) show that those who have had formal *driving education* and completed the course are more highly accident-involved than those who have not had this education directed at making good drivers. Therefore, education *per se* (even driving education) does not appear to make good drivers, but rather some underlying psychological and/or experiential characteristics (e.g., possibly intelligence, ambition, and opportunity).

For the yet undiscussed variables whose subgroups form some sort of continuum, there seems to be no clear picture. The curve for *most recent yearly mileage* (Figure H-8), seems to either have some rather complex and incomprehensible underlying process, or to have so much variability that a simple process (e.g., the more miles per year, the greater the likelihood of being accident-involved) is being obscured. This appears to be the same case for *vehicle familiarity* (months driving the accident vehicle), although here the curve seems to be even more variable.

The noncontinuous variables display interesting patterns also. *Marital status* is particularly revealing, in that divorced or separated drivers are overrepresented in the accident population. Married drivers and widowed drivers, on the other hand, are under-involved in accidents. Single drivers are slightly overrepresented in the accident population. It would seem that marital status is an excellent indicator of the probability that a driver will be involved in an accident. To a lesser extent, *occupation* also has some salient subgroups. Laborers, semi-skilled workers, and students are somewhat overrepresented in accidents, whereas housewives, white collar workers, and professionals are under-involved. The finding regarding housewives is related to the finding that females are under-involved, and it is not possible to examine the interaction between these two subgroups from the analysis presented here.

In conclusion, within the framework of the accident vs. control sample comparisons and the involvement ratios, it has been possible to identify disparities in representativeness between the accident and control samples. If one can legitimately assume that the control sample is representative of the control population and that the accident sample is reasonably representative of all accidents that happen (the accident population) and that our accident sample/population is a subset of the control population, we can then say that we have isolated various driving population subgroups which are under- or over-involved in accidents.

5.0 Cluster Analysis

5.1 Introduction

In making the study of traffic accidents more of a science—imposing rigor upon its terminologies, strengthening its explanatory and predictive power—and applying its tools to the problem of reducing highway-related deaths and injuries, it will be necessary to concentrate for a while upon the **descriptive** aspect of this science. Traffic accidents are truly modern natural phenomena, no less so than the moods of man or weather, or than the various types and categories of living plants and animals surrounding our complex, self-made environment.

There has to date been little emphasis upon the descriptive side of the study of traffic accidents. Certain aspects of such accidents are studied intently, usually in isolation from others. For example, much is known about accident frequencies during different times of the day, week, and year; about the ages of accident-involved drivers; about different ways to reconstruct the causes of specific accidents, and so on. What is needed at the outset is instead some idea of the natural characteristics of these phenomena, taking many possible characteristics simultaneously into account. We need to know, quite simply, what kinds of people have what kinds of traffic accidents in what kinds of vehicles, under what kinds of conditions, and for what kinds of reasons or causes.

In deriving a natural, empirically-based typology of accidents, it will not be sufficient to assume that characteristics known to occur frequently across all accidents therefore occur together in the same accidents. It is entirely possible that specific groups of high-frequency attributes (e.g., male driver, young driver, old car, weekend day) might not appear simultaneously in a majority of accidents, i.e., might not comprise **typical** accidents at all. Putting it another way, high-frequency attributes are not necessarily copresent attributes. Highway safety countermeasures should therefore not be aimed at types of drivers frequently involved in accidents on the assumption that they also have accidents for typical reasons, and under typical conditions.

This portion of the report describes an initial attempt undertaken at IRPS to identify copresent accident attributes, to determine the different natural categories or types of traffic accidents, and to begin to clear a path toward an empirically-based accident taxonomy.

In making this attempt, limitations both in available data and in available standard statistical analysis techniques have been dealt with. Due to design constraints on the current tri-level study, the more **interesting** a particular accident investigation variable, the fewer the number of cases for which observations were likely to be available on that variable. For example, most human factors variables of theoretical interest (e.g., driver income, education, occupation, and so on) were collected only during in-depth investigations (Level C), i.e., on only about one-fourth of all on-site cases investigated. In order to assure sufficient numbers of observations for development of an **initial** accident typology, descriptive and causal data were therefore drawn almost entirely from on-site (Level B) investigation forms. In subsequent phases and years of this study, cumulative in-depth (Level C) sample sizes should increase, permitting more interesting variables to be examined.

In addition, available data were for the most part comprised of nominal- or ordinal-scale variables; this placed constraints upon the types of analysis techniques which could feasibly be brought to bear upon the problem of identifying natural types of accidents, i.e., identifying attribute copresences among the many variables involved. Lastly, data currently available on the causes of the accidents investigated were based upon a particular typology of accident causes developed over the past few years. It was not possible to identify types of accident causes *in vacuo;* for purposes of developing the initial typology of accidents, causal categories examined were those drawn from the causal paradigm currently used in the project.

Most available statistical techniques failed either to measure up to the requirements of the analysis effort, or to meet the constraints on the available data, or both. For a variety of reasons, cross-tabulation, and AID and MCA approaches were found unsuitable, as were such standard, parametric multivariable techniques as factor analysis and multiple regression.

The statistical technique selected was that of *cluster analysis,* in particular, a variety developed for use by biologists and others in the field of numerical taxonomy (1, 2). The cluster analysis approach made it possible for the investigators to determine which values of which variables (*attributes*) tended to occur together in the same accidents, i.e., tended to be copresent in clusters. The approach used went further to assure that individual attributes (e.g., male driver, young driver, old car, weekend day) were allowed to cluster *naturally,* i.e., without bias, reflecting only the degree to which all were present in the same cases or *specimens,* and without having to select one or another of these attributes as a dependent variable. Cluster analysis was ideally suited to handling attribute-type (i.e., dichotomous or nominal-scale) data of the type comprising a majority of the data base. Finally, this approach made it convenient to examine large numbers of attributes simultaneously for copresence.

On the negative side, however, the approach used also required that large numbers of cases underlie the attributes being examined. In addition, it forced attributes into mutually exclusive groups—a characteristic ideal for developing *biological* taxonomies—but less helpful where there is a possibility that attributes overlap to some degree in individual cases, i.e., where no **firm** mutually exclusive and exhaustive types actually exist. This, it turns out, is what appears to be the case for traffic accidents. However, it was felt that if any statistical technique would identify natural types of traffic accidents, this was it.

5.2 Methodology

In order to determine what accident, driver, vehicle, environmental, and causal characteristics fell into *natural* groupings, it was necessary to carry out a number of highly interrelated programming and analysis steps. The cluster analysis procedure used was an interactive one, in that the analyst entered at key points to review outcomes and make decisions regarding the direction of subsequent steps in the analysis. This was to assure that cluster analysis would be conceptually neither irrelevant nor uninterpretable, on either a scientific or a practical basis. Attempts were made wherever possible to let the data "speak" to have resulting clusters reflect to the greatest possible extent **empirical** characteristics of the natural phenomena—traffic accidents—being studied.

Figure 5-1 summarizes the cluster analysis procedure in macroflowchart form. Circled numbers beside each program, file, output or activity are intended to serve as references in the brief description which follows.

Variables were selected for examination (1) in the cluster analysis according to several criteria: they were to be "basic" rather than esoteric, and there had to be sufficient numbers of observations from reliable data sources, to allow meaningful interpretation of resulting clusters. On this basis, variables selected for initial examination included those descriptive of accidents, drivers, vehicles and environmental circumstances as well as those indicating particular human, vehicular, or environmental causes for each accident. Data sources selected were the police investigation forms, on-site vehicular and environmental forms, and traffic unit forms for at-fault drivers. Data were drawn only from information on at-fault drivers and vehicles (traffic units); causal factors reflected only the *causal* rather than the *causal or severity-increasing* degree of significancy, identified at the *certain, probable, or possible* level of certainty.

Due to problems of relative infrequency, small sample sizes, or both, many specific variables had to be omitted that would otherwise have been of considerable interest in the program runs. These included a number of subcategory-level accident causative factors, (e.g., *tires underinflated; stop sign needed but not provided; failure to use horn to warn*) and human descriptive factors, (e.g., family income; occupation; driver education).

It is intended that subsequent work in development of the accident taxonomy will allow inclusion of these types of variables, once sufficient numbers of accident cases join the current automated file. A listing of variables used in this initial set of cluster analyses is given in Table 5-1 and 5-2. It should be noted that where certain variables could be considered logically to subsume others, especially in the case of causal factors, only those which could be considered logically independent and at the same level of specificity were included, in order to preserve computational independence.

Once variables had been selected for examination in the initial cluster analysis runs, they were pulled from master Phase II and Phase III data tapes (2), and merged and arrayed into a casewise subfile of all accidents (4) by a set of generalized subfile-creation programs (3) written specifically for this purpose. The resulting subfile (4) contained data for 773 accident cases on 40 basic variables, including 22 of the most frequently-occurring basic causal factor variables.

In order to determine how best to combine possible values of these variables into simple

Figure 5-1

Macroflowchart of Cluster Analysis Procedure

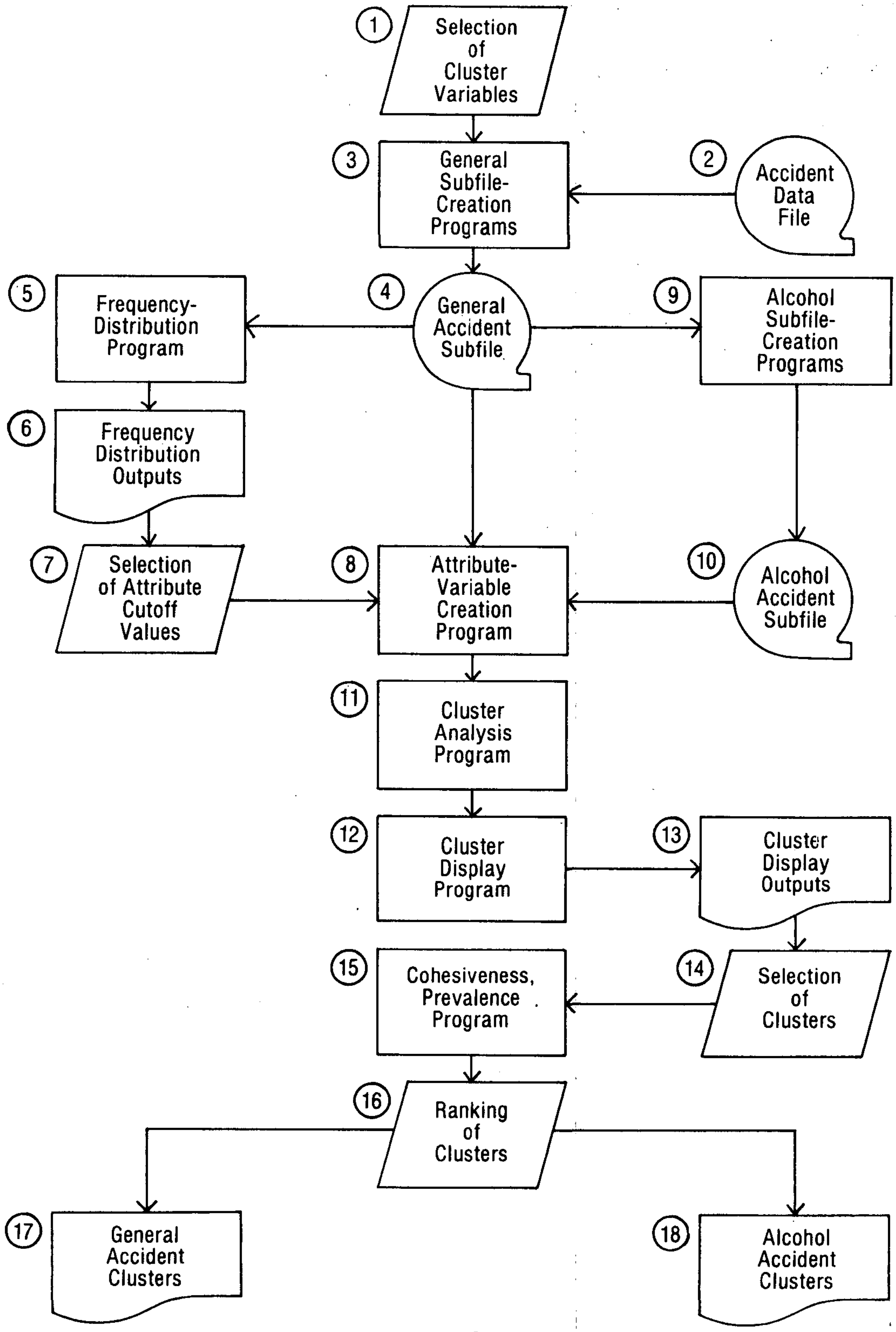


Table 5-1

Listing of Variables and Derived Cluster Analysis Attributes for General Accidents

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
Descriptive Human (DH)	Driver Age	16-24 Year Old Driver	52.7%	387
		Driver 25 Years or Older	47.3%	348
	Driver Sex	Male	68.6%	515
		Female	31.4%	236
	Most Recent Yearly Mileage	≤12K Mi. Most Recent Year	53.8%	300
		>12K Mi. Most Recent Year	46.2%	233
	Vehicle Familiarity (Mos. Driven)	≤12 Mos. In Acc. Veh.	61.0%	405
		>12 Mos. In Acc. Veh.	39.0%	260
	Physical Limitation (On License)	Driver Physical Limitation	40.8%	276
		No Physical Limitations	59.2%	401
	Route Familiarity (Frequency Driving Road)	Daily on Road	41.9%	283
		Not Daily on Road	58.1%	392
	Driving Experience (Months)	≤90 Mos. Driving Experience	52.0%	359
		>90 Mos. Driving Experience	48.0%	317
Descriptive Vehicular (DV)	Vehicle Model Year	Vehicle 1967 or Older	49.1%	334
		Vehicle 1968 or Newer	50.9%	340
	Odometer Mileage	≤42,911 Miles on Odometer	49.7%	340
		>42,911 Miles on Odometer	50.3%	344

Table 5-1 continued

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
Descriptive Environmental (DE)	Season of Year	Jan., Feb., Mar.	29.1%	201
		Apr., May, Jun.	17.3%	119
		Jul., Aug., Sep.	25.6%	177
		Oct., Nov., Dec.	28.0%	193
	Day of Week	Weekday (Mon.-Thurs.)	61.3%	424
		Weekend (Fri.-Sun.)	38.7%	266
	Light Condition	Daylight	77.6%	526
		Darkness/Dawn/Dusk	22.4%	152
	Visibility	Clear Visibility	82.2%	607
		Hazy or Foggy	17.8%	131
	Estimated Traffic Travel Speed	≤30 mph Traffic Speed	56.7%	264
		>30 mph Traffic Speed	43.3%	202
	Traffic Volume	Light Traffic	33.1%	251
		Moderate/Heavy Traffic	66.9%	508
	Road Surface Condition	Dry Pavement	73.3%	497
		Non-Dry Pavement	26.7%	181
Causal Factors (C)	Tires and Wheels	Tires and Wheels	3.0%	23
	Brake System	Brake System	3.8%	29
	Inattention	Inattention	18.6%	144
	Internal Distraction	Internal Distraction	4.9%	38
	External Distraction	External Distraction	3.9%	30
	Improper Lookout	Improper Lookout	16.2%	125
	False Assumption	False Assumption	11.4%	88
	Improper Maneuver	Improper Maneuver	6.1%	47

Table 5-1 continued

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
	Improper Driving Tech./Practice	Improper Driving Tech./Practice	4.0%	31
	Excessive Speed	Excessive Speed	13.6%	105
	Tailgating	Tailgating	3.1%	24
	Improper Evasive Action	Improper Evasive Action	10.5%	81
	Performance Error	Performance Error	4.8%	37
	Physical/ Physiological	Physical/ Physiological	8.3%	64
	Mental/Emotional	Mental/Emotional	3.9%	30
	Experience/ Exposure	Experience/ Exposure	8.7%	67
	Control Hindrances	Control Hindrances	3.6%	28
	Inadequate Signs and Signals	Inadequate Signs and Signals	6.5%	50
	View Obstructions	View Obstructions	14.5%	112
	Design Problems	Design Problems	4.1%	32
	Slick Roads	Slick Roads	9.2%	71
	Special Hazards	Special Hazards	4.8%	37
Accident Descriptive (A)	Accident Type	Side Impact	48.1%	365
		Rear End Collision	23.1%	175
		Ran Off Road	16.9%	128
	Accident Severity	PI/Fatal	25.9%	179
		Property Damage	74.1%	511

Table 5-2

Listing of Variables and Derived Cluster Analysis Attributes for Alcohol Accidents

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
Descriptive Human (DH)	Driver Age	16-24 Year Old Driver	26.1%	12
		Driver 25 Years or Older	74.9%	34
	Driver Sex	Male	89.4%	42
		Female	10.6%	5
	Most Recent Yearly Mileage	≤12K Mi. Most Recent Year	33.3%	7
		>12K Mi. Most Recent Year	66.7%	14
	Vehicle Familiarity (Mos. Driven)	≤12 Mos. In Acc. Veh.	70.4%	19
		>12 Mos. In Acc. Veh.	29.6%	8
	Physical Limitation (On License)	Driver Physical Limitation	48.3%	14
		No Physical Limitations	51.7%	15
	Route Familiarity (Frequency Driving Road)	Daily On Road	33.3%	9
		Not Daily On Road	66.7%	18
	Driving Experience (Months)	≤90 Mos. Driving Experience	33.4%	9
		>90 Mos. Driving Experience	66.6%	18
Descriptive Vehicular (DV)	Vehicle Model Year	Vehicle 1967 or Older	64.6%	31
		Vehicle 1968 or Newer	35.4%	17
	Odometer Mileage	≤42,911 Miles on Odometer	31.0%	13
		>42,911 Miles on Odometer	69.0%	29

Table 5-2 continued

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
Descriptive Environmental (DE)	Season of Year	Jan., Feb., Mar.	20.8%	10
		Apr., May, Jun.	12.6%	6
		Jul., Aug., Sep.	29.1%	14
		Oct., Nov., Dec.	37.5%	18
	Day of Week	Weekday (Mon.-Thurs.)	54.2%	26
		Weekend (Fri.-Sun.)	45.8%	22
	Light Condition	Daylight	41.3%	19
		Darkness/Dawn/Dusk	58.7%	27
	Visibility	Clear Visibility	87.8%	43
		Hazy or Foggy	12.2%	6
	Estimated Traffic Travel Speed	≤30 mph Traffic Speed	36.7%	17
		>30 mph Traffic Speed	63.3%	19
	Traffic Volume	Light Traffic	54.0%	27
		Moderate/Heavy Traffic	46.0%	23
	Road Surface Condition	Dry Pavement	80.9%	38
		Non-Dry Pavement	19.1%	9
Causal Factors (C)	Tires and Wheels	Tires and Wheels	3.9%	2
	Brake System	Brake System	2.0%	1
	Inattention	Inattention	11.8%	6
	Internal Distraction	Internal Distraction	9.8%	5
	External Distraction	External Distraction	2.0%	1
	Improper Lookout	Improper Lookout	3.9%	2
	False Assumption	False Assumption	2.0%	1
	Improper Maneuver	Improper Maneuver	3.9%	2

Table 5-2 continued

Variable Category	Original Variable	Derived Attributes	Relative Frequency	Total Cases Represented
	Improper Driving Tech./Practice	Improper Driving Tech./Practice	0%	0
	Excessive Speed	Excessive Speed	25.5%	13
	Tailgating	Tailgating	0%	0
	Improper Evasive Action	Improper Evasive Action	7.8%	4
	Performance Error	Performance Error	9.8%	5
	Physical/ Physiological	Physical/ Physiological	90.2%	46
	Mental/Emotional	Mental/Emotional	5.9%	3
	Experience/ Exposure	Experience/ Exposure	7.8%	4
	Control Hindrances	Control Hindrances	11.8%	6
	Inadequate Signs and Signals	Inadequate Signs and Signals	7.8%	4
	View Obstructions	View Obstructions	3.9%	2
	Design Problems	Design Problems	3.9%	2
	Slick Roads	Slick Roads	5.9%	3
	Special Hazards	Special Hazards	5.9%	3
Accident Descriptive (A)	Accident Type	Side Impact	30.6%	15
		Rear End Collision	18.4%	9
		Ran Off Road	36.7%	18
	Accident Severity	PI/Fatal	56.2%	27
		Property Damage	43.8%	21

attributes to be examined subsequently in the cluster analyses, it was necessary first to obtain frequency distributions for each variable. For example, defining *high mileage* and *moderate to low mileage* vehicles as being those, respectively, with odometer readings above or below an **arbitrary** value, might tend to bias the cluster analysis outcomes. If a vast majority of the accident-involved vehicles in the current sample happened to fall into one such arbitrary group rather than into the other, the low-frequency attribute would have less chance of clustering with other attributes, i.e., would be likely to be **overshadowed** by higher-frequency attributes. For this reason, when attribute groupings could be based entirely upon frequencies, they were split according to *median* values. In the case of our example, odometer mileage was broken into two attributes, *high mileage* being above 42,911 miles, and *low to moderate mileage* being less than or equal to that figure. Frequency distributions upon which such decisions were based (6) were obtained using SPSS *Codebook* and *Marginals* program subroutines (5), depending upon the raw number of variable values or categories to be examined, respectively.

Attribute cutoff values were thus selected in part upon examination of these SPSS printouts, and attributes were defined (7) as indicated in Tables 5-1 and 5-2. As indicated, the original 40 variables gave rise to a total of 61 individual attributes employed in the ensuing cluster analysis comparisons. Attribute definitions thus derived for the general accident file were applied to the alcohol subfile as well, in order to facilitate comparison of clusters obtained.

After several false starts, it was determined that the cluster analysis routine (11) worked best when all attributes had an incidence rate of at least 10 percent. For this reason, variable values were generally combined in such a fashion that the resulting attributes occurred in at least this proportion of the cases in the accident subfile (4). Exceptions were allowed among low-frequency accident causative factors, in order to assure that as many of them as possible would be examined in the cluster analysis program runs.

Once the attributes to be examined were defined (7), other subroutines of the SPSS program package were used (8) to convert attribute data into a presence-absence format, i.e., to create a 1-0 matrix indicating the presence or absence, respectively, of each attribute for each case in the accident subfile. When information on particular attributes was missing for particular cases, a value of 9 was entered in the matrix, and data in such cells were excluded from cluster analysis computations.

Parallel to this effort, a separate *alcohol* subfile was created, composed only of accidents in which alcohol was causally implicated. For this purpose, a special program (9) was written to select out such cases and array them according to the same format as that used in the general accident subfile (4). The resulting alcohol accident subfile (10), consisting of 51 such cases occurring over Phases II and III* of the study, was then subjected to the same attribute-

*Phase I causal factors were structured in a scheme incompatible with Phase II and III causal assessments. Phase I data were necessarily omitted from this analysis.

variable creation program (8) as was the general accident subfile, creating a parallel but separate 1-0 attribute matrix for alcohol cases. It should be noted that the two data files—general and alcohol-related—were not comprised of mutually exclusive sets of accident cases. The alcohol-related cases were left in the general accident subfile, in order to assure that this subfile reflected all types of accidents, as well as to maximize the number of cases represented.

Once the general and alcohol input matrices had been prepared, they were submitted separately as inputs into the cluster analysis program (11) , which was designed and written by an IRPS programmer/analyst. Details of the operation of this program are beyond the scope of this general description of the cluster analysis procedure. In general, however, the program employs adaptations of standard computational procedures used in numerical taxonomy, in which each separate attribute is forced into one and only one cluster, its *strongest,* per run. Clusters are identified through iterative reduction of a *similarity matrix,* according to a procedure conceptually analogous to that employed in stepwise multivariate regression. Attributes were allowed to group according to the degree to which they were copresent in the same cases, beginning with pairs of attributes, then higher numbers of attributes at successively lower levels of copresence or *similarity.*

5.3 Results

It is clear that the cluster analysis approach used has not yet dropped into the laps of the investigators the desired tidy, comprehensive *big picture* of accident and problem driver types. Findings to date are nevertheless both consistent and interesting. Cluster analysis results are presented in this section at successive levels of summarization and generality, emphasizing at final stages those groups of copresent attributes characterizing (and distinguishing) typical alcohol and non-alcohol-related traffic accidents.

First, Tables 5-3 and 5-4 describe the *top-level* attribute clusters found for general and alcohol-related accidents, respectively. These clusters were identified when **all** attributes were examined simultaneously by the cluster analysis program. As such, they may be considered to paint in broadest strokes the basic types of alcohol and non-alcohol accidents. Each cluster is described in terms of the specific attributes which comprise it, together with its *similarity, cohesiveness,* and *prevalence* values (see Appendix I). Clusters are listed on these tables according to *importance* value, i.e., the average of the other three measures for the cluster, and ranked according to the value of this final measure.

The first cluster described on each of the tables is thus the one to which greatest immediate attention should be directed. For general accidents (in Table 5-4) the most typical accident is a *property damage* accident occurring in *daylight* on *dry pavement* under *clear visibility* conditions, with *moderate to heavy traffic* travelling at *30 mph or less.* This six-attribute, top-

Table 5-3

Listing of General-Accident Clusters When All Attributes Were Examined Simultaneously

Cluster	"Similarity" Value	"Cohesiveness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Daylight Clear Visibility ≤30 mph. Traffic Speed Moderate/Heavy Traffic Dry Pavement Property Damage	.57	.17	.78	.507
16-24 Year Old Driver ≤90 Mos. Driving Experience >30 mph. Traffic Speed	.46	.24	.36	.353
>12 Mos. In Accident Vehicle Driver Physical Limitation Non-Dry Pavement Ran Off Road	.34	.20	.11	.217
False Assumption Excessive Speed PI/Fatal	.11	.15	.04	.100
Tires and Wheels Inattention Improper Lookout	.13	.12	.01	.087

level cluster has relatively high similarity (.57) and prevalence (.78) values, but a relatively low cohesiveness value (.17), indicating it is a widespread, yet relatively weak or *chain*-type cluster.

The same may be said of the first, or most typical alcohol-related accident in Table 5-4 which involves *male drivers* in *high-mileage, older vehicles* having *personal injury or fatal* accidents in *darkness, dawn or dusk* under conditions of *clear visibility* and *dry pavement*. Here too, similarity (.49) and prevalence (.89) values are relatively high, but cohesiveness (.13) is low. *Importance* values of these two clusters are roughly the same, .507 and .502, respectively.

The *importance* value of remaining clusters on these two tables drops off markedly,

Table 5-4

Listing of Alcohol-Accident Clusters Identified when all Attributes were Examined Simultaneously

Cluster	"Similarity" Value	"Cohesiveness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Male Vehicle, 1967 Or Older >42,911 Mi. Odometer Darkness/Dawn/Dusk Clear Visibility PI/Fatal	.49	.13	.89	.502
>12K Mi. Most Recent Year ≤ 12 Mos. In Accident Vehicle W/O Physical Limitations Not Daily On Road Ran Off Road	.47	.19	.52	.393
Weekday (Mon.-Thurs.) Property Damage	.28	.39	.29	.303

especially for the general-accident clusters. As mentioned earlier, this is to a certain extent attributable to the *masking* effect encountered during runs involving large numbers of attributes. A more representative picture of the various types of general and alcohol-related accidents could thus only be obtained from examination of the clusters presented in Tables 5-5 and 5-6, where clusters obtained under subgroup runs are similarly listed according to *importance* rank for general and alcohol-related accidents, respectively.

Note on these subgroup-run tables that the particular combinations of variables under which each cluster appeared are listed together with the attributes comprising the cluster. From Table 5-5 it may be seen that the most important general-accident cluster obtained among subgroup runs was one taking place under *daylight, clear visibility,* and *dry pavement* conditions in *moderate* or *heavy traffic*. Comparing this cluster, appearing in four separate subgroup program runs, with the first general-accident cluster described in Table 5-3, a high degree of consistency is apparent. Subsequent subgroup-run, general accident clusters listed in Table 5-5 tend to paint a somewhat different picture from that presented in Table 5-3, where all

Table 5-5

Listing of General Clusters Identified During Examinations of Attribute Subgroups and Combinations

Cluster	Attribute Subgroup Combinations Under Which Cluster Appeared	"Similarity" Value	"Cohesive-ness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Daylight Clear Visibility Moderate/ Heavy Traffic Dry Pavement	DE DE vs. DH DE vs. DV DE vs. DV vs. DH	.60	.25	.72	.523
Daylight Clear Visibility Moderate/ Heavy Traffic Dry Pavement Property Damage	DE vs. A	.60	.20	.74	.513
16-24 Year Old Driver ≤ 90 Mos. Driving Experience	DH DH vs. DE DH vs. C DH vs. DE or DV	.47	.28	.50	.417
Male No Physical Limitations	DH DH vs. C	.40	.43	.41	.413
Vehicle 1968 or Newer Property Damage	DV vs. A	.38	.43	.40	.403
16-24 Year Old Driver Male ≤ 90 Mos. Driving Experience Property Damage	DH vs. A	.46	.24	.48	.393

Table 5-5 continued

Cluster	Attribute Subgroup Combinations Under Which Cluster Appeared	"Similarity" Value	"Cohesive-ness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Improper Lookout Side Impact Property Damage	A	.36	.42	.39	.390
Driver 25 Years or Older >90 Mos. Driving Experience	DH DH vs. C DH vs. A DH vs. DV vs. DE	.42	.25	.44	.370
16-24 Year Old Driver No Physical Limitations ≤90 Mos. Driving Experience	DH vs. DV DH vs. C	.39	.24	.47	.367
Male Hazy or Foggy	DE vs. DH DE vs. DH vs. DV	.57	.37	.11	.350
Vehicle 1968 or Newer Darkness/ Dawn/Dusk	DE vs. DV	.44	.32	.10	.287
Female Daily on Road	DH vs. DE	.39	.30	.12	.270
Improper Lookout Side Impact Property Damage	C vs. A	.15	.28	.27	.233

Table 5-6

Listing of Alcohol Clusters Identified Under Examinations of Attribute Subgroups and Combinations

Cluster	Attribute Subgroup Under Which Cluster Appeared	"Similarity" Value	"Cohesive-ness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Driver 25 Years or Older Male $\geq$ 90 Mos. Driving Experience	DH DH vs. A	.32	.64	.67	.543
Male Darkness/ Dawn/Dusk Clear Visibility Dry Pavement	DH vs. DE	.55	.25	.81	.537
Darkness/Dusk Clear Visibility Dry Pavement Physical/ Physiological	DE vs. C	.54	.25	.82	.533
Driver 25 Years or Older Male > 90 Mos. Driving Experience Physical/ Physiological	DH vs. C	.64	.25	.70	.530
Male Vehicle 1967 or Older >42,911 Miles Odometer Clear Dry	DH vs. DV vs. DE	.57	.20	.82	.530

Table 5-6 continued

Cluster	Attribute Subgroup Under Which Cluster Appeared	"Similarity" Value	"Cohesive-ness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
Vehicle 1967 or Older >42,911 Miles on Odometer Clear Visibility Dry Pavement	DE vs. DV	.57	.25	.76	.527
Vehicle 1967 or Older >42,911 Miles on Odometer Physical/ Physiological	DV vs. C	.59	.33	.65	.523
Darkness/ Dawn/Dusk Clear Visibility Dry Pavement	DE DE vs. A	.54	.33	.65	.507
Driver 25 Years or Older Male 90 Mos. Driving Experience >42,911 Miles on Odometer	DH vs. DV	.55	.25	.70	.500
Vehicle 1967 or Older >42,911 Miles on Odometer	DV	.45	.42	.51	.460
>12K Miles Most Recent Year Not Daily on Road	DH DH vs. DV DH vs. C DH vs. A	.48	.45	.43	.453

Table 5-6 continued

Cluster	Attribute Subgroup Under Which Cluster Appeared	"Similarity" Value	"Cohesive-ness" Value	"Prevalence" Value	Mean of Measures or "Importance" Value
≤ 12 Mos. in Acc. Veh. Not Daily on Road	DH vs. DE	.57	.41	.33	.437
Vehicle 1967 or Older >42,911 Miles on Odometer PI/Fatal	DV vs. A	.44	.31	.51	.420
Physical/ Physiological Ran Off Road PI/Fatal	C vs. A	.44	.31	.48	.410
Ran Off Road PI/Fatal	A	.30	.34	.30	.313
Hazy or Foggy Light Traffic	DE DE vs. DH DE vs. DH vs. DV	.53	.32	.04	.297
Vehicle 1968 or Newer Moderate/ Heavy Traffic	DE vs. DV	.36	.32	.19	.290
Side Impact Property Damage	A	.19	.28	.21	.227
Excessive Speed Performance Error Physical/ Physiological	C	.11	.30	.18	.197

attributes were examined simultaneously. For example, the specific causal factors appearing in the fourth and fifth clusters listed in Table 5-3 (*false assumption, excessive speed, tires and wheels, inattention,* and *improper lookout*) may be seen to have occurred quite infrequently among the clusters appearing during corresponding subgroup runs (Table 5-5). The same may be seen to hold for alcohol-related accidents, in Tables 5-4 and 5-6, respectively.

In order to obtain a more representative picture of the relative role specific attributes played in comprising accident types of clusters, it was necessary to produce an intermediate set of tally sheets, Tables 5-7 and 5-8, for general and alcohol-involved subgroup runs, respectively. Here the number of times each attribute appeared with each other attribute in any cluster was tallied. Attributes were then ranked according to the total number of other attributes with which they appeared in these clusters.

Attribute rankings determined from Tables 5-7 and 5-8 are then summarized in Table 5-9 comparing general-accident and alcohol-accident attributes according to the frequency with which they appeared in subgroup clusters. For general accident runs, attributes occurring most frequently in clusters were *daylight, clear visibility, moderate to heavy traffic,* and *dry pavement,* each of which appeared sixteen times with other attributes. For alcohol accident runs, those in the first rank also included *clear visibility* and *dry pavement,* but added *male drivers* and dropped *moderate to heavy traffic*. It may be seen that causal factors held relatively low ranks for both types of accident, and that very few specific causal factors clustered with any other attributes, or with each other.

Carrying this last point further, it is clear that certain attributes tended to comprise clusters, i.e., to typify both types of accidents, while others did not. Table 5-10 lists attributes comprising vs. those not comprising clusters for general and alcohol accidents. In both types of accidents, for example, day of week, season, and most of the causal factors examined failed to appear in clusters at any point. These attributes simply did not associate with or typify accidents of either type, even though in the case of many such non-associating attributes, e.g., the four seasons, this failure certainly could not be attributed to attribute infrequency *per se.*

It is possible to summarize the similarities and differences between alcohol-related and general accidents on the basis of attributes appearing most frequently in subgroup run clusters. In Table 5-11 such a summarization is attempted, showing for each variable (e.g., driver age) in the analysis, the attribute or attributes found most frequently to cluster with other attributes (e.g., *16-24 year old drivers* in general accidents, *25 year old or older drivers* in alcohol-related accidents). Table 5-11 is thus is intended to characterize general and alcohol-related accidents according to attributes most likely to be copresent in particular accidents of each type. For certain variables, e.g., *most recent yearly mileage,* characteristic and copresent attributes were identified for one type of accident but not for the other; here alcohol-related accident clusters tended to include recent yearly mileage levels of *12,000 miles or higher* (4 appearances, rank 6),

Table 5-7

Copresence Tallies for General Cluster

	Attribute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1	16-24 Year Old Driver	0		3		2		7											1	13
2	Driver 25 Yrs. Or Older		0						4											4
3	Male	3		0		4		3						2					1	13
4	Female				0		1													1
5	No Physical Limitations	2		4		0		2												8
6	Daily On Road				1		0													1
7	≤90 Mos. Driving Experience	7		3		2		0											1	13
8	>90 Mos. Driving Experience		4						0											4
9	Vehicle 1968 Or Newer									0		2							1	3
10	Daylight										0		5		5	5			1	16
11	Darkness/Dawn/Dusk									2		0								2
12	Clear Visibility										5		0		5	5			1	16
13	Hazy Or Foggy			2										0						2
14	Moderate/Heavy Traffic										5		5		0	5			1	16
15	Dry Pavement										5		5		5	0			1	16
16	Improper Lookout																0	1	1	2
17	Side Impact																1	0	2	3
18	Property Damage	1		1				1		1	1		1		1	1	1	2	0	11

Table 5-8

Copresence Tallies for Alcohol Cluster Attributes

Attribute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
1 Driver 25 Yrs. Or Older	0	4				4			1									1					10
2 Male	4	0				4	1		2	1	2				2			1					17
3 >12K Mi. Most Recent Year			0		4																		4
4 ≤12 Mos. In Acc. Veh.				0	1																		1
5 Not Daily On Road			4	1	0																		5
6 >90 Mos. Driving Experience	4	4				0			1									1					10
7 Vehicle 1967 Or Older		1					0		5		2				2			1			1		12
8 Vehicle 1968 Or Newer								0						1									1
9 >42,911 Mi. Odometer	1	2				1	5		0		2				2			1			1		15
10 Darkness/Dawn/Dusk	1									0	4				4			1					10
11 Clear Visibility		2					2		2	4	0				6			1					17
12 Hazy Or Foggy												0	3										3
13 Light Traffic												3	0										3
14 Moderate/Heavy Traffic								1						0									1
15 Dry Pavement		2					2		2	4	6				0			1					17
16 Excessive Speed																0	1	1					2
17 Performance Error																1	0	1					2
18 Physical/Physiological	1	1				1	1		1	1	1				1	1	1	0		1	1		12
19 Side Impact																			0			1	1
20 Ran Off Road																		1		0	2		3
21 PI/Fatal							1		1									1		2	0		5
22 Property Damage																			1			0	1

Table 5-9

Rankings of Individual Attributes by Frequency of Appearance in Subgroup Run Clusters

General Accident Runs			Alcohol Accident Runs		
Attribute	Total Appearances	Rank	Attribute	Total Appearances	Rank
Daylight	16	1	Male	17	1
Clear Visibility	16		Clear Visibility	17	
Moderate/Heavy Traffic	16		Dry Pavement	17	
Dry Pavement	16				
16-24 Year Old Driver	13	2	>42,911 Odometer Miles	15	2
Male	13				
≤ 90 Mos. Driving Experience	13				
Property Damage	11	3	Vehicle 1967 or Older	12	3
			Physical/Physiological Impairment	12	
No Physical Limitations	8	4	Driver 25 Years or Older	10	.4
			> 90 Mos. Driving Experience	10	
			Darkness/Dawn/Dusk	10	
Driver 25 Years or Older	4	5	Not Daily on Road	5	5
>90 Mos. Driving Experience	4		PI/Fatal	5	
Vehicle1968 or Newer	3	6	>12,000 Miles Driven in Recent Year	4	6
Side Impact	3				
Darkness/Dawn/Duak	2	7	Hazy or Foggy	3	7
Hazy or Foggy	2		Light Traffic	3	
Improper Lookout	2		Ran Off Road	3	
Female	1	8	Excessive Speed	2	8
Daily on Road	1		Performance Error	2	
—	—	—	≤ 12 Mos. in Accident Vehicle	1	9
			Vehicle 1968 or Newer	1	
			Moderate/Heavy Traffic	1	
			Side Impact	1	
			Property Damage	1	

Table 5-10

Comparison of Attributes Typically Comprising vs. Not Comprising Clusters for General and Alcohol-Related Accidents

General Accidents		Alcohol-Related Accidents	
Attributes Comprising Clusters	Attributes Not Comprising Clusters	Attributes Comprising Clusters	Attributes Not Comprising Clusters
16-24 Year Old Driver	≤12K Mi. Most Recent Year	Driver 25 Yrs. Or Older	16-24 Year Old Driver
Driver 25 Yrs. Or Older	>12K Mi. Most Recent Year	Male	Female
Male	≤12 Mos. In Accident Vehicle	>12K Mi. Most Recent Year	≤12K Mi. Most Recent Year
Female	>12 Mos. In Accident Vehicle	≤12 Mos. In Accident Vehicle	>12 Mos. In Accident Vehicle
No Physical Limitations	Not Daily On Road	Not Daily On Road	Driver Physical Limitation
Daily On Road	Driver Physical Limitation	>90 Mos. Driving Experience	No Physical Limitations
≤90 Mos. Driving Experience	Vehicle, 1967 Or Older	Vehicle, 1967 Or Older	Daily On Road
>90 Mos. Driving Experience	≤42,911 Mi. Odometer	Vehicle, 1968 Or Newer	≤90 Mos. Driving Experience
Vehicle, 1968 Or Newer	>42,911 Mi. Odometer	>42,911 Mi. Odometer	≤42,911 Mi. Odometer
Daylight	Jan., Feb., Mar.	Darkness/Dawn/Dusk	Jan., Feb., Mar.
Darkness/Dawn/Dusk	Apr., May, Jun.	Clear Visibility	Apr., May, Jun.
Clear Visibility	Jul., Aug., Sep.	Hazy or Foggy	Jul., Aug., Sep.
Hazy or Foggy	Oct., Nov., Dec.	Light Traffic	Oct., Nov., Dec.
Moderate/Heavy Traffic	Weekday (Mon.-Thurs.)	Moderate/Heavy Traffic	Weekday (Mon.-Thurs.)
Dry Pavement	Weekend (Fri.-Sun.)	Dry Pavement	Weekend (Fri.-Sun.)
Improper Lookout	Light Traffic	Excessive Speed	Daylight
Side Impact	≤30 mph Traffic Speed	Performance Error	≤30 mph Traffic Speed
Property Damage	>30 mph Traffic Speed	Physical/Physiological	>30 mph Traffic Speed
	Non-Dry Pavement	Side Impact	Non-Dry Pavement
	Tires and Wheels	Ran Off Road	Tires and Wheels
	Inattention	PI/Fatal	Brake System
	Brake System	Property Damage	Inattention
	Internal Distraction		Internal Distraction
	External Distraction		External Distraction
	Improper Maneuver		Improper Lookout
	Improper Driving Tech./Prac.		False Assumption

Table 5-10 continued

General Accidents		Alcohol-Related Accidents	
Attributes Comprising Clusters	Attributes Not Comprising Clusters	Attributes Comprising Clusters	Attributes Not Comprising Clusters
	Improper Evasive Action		Improper Maneuver
	Performance Error		Improper Driving Tech./Prac.
	Physical/Physiological		Tailgating
	Mental/Emotional		Improper Evasive Action
	Control Hindrances		Mental/Emotional
	False Assumption		Experience/Exposure
	Excessive Speed		Control Hindrances
	Tailgating		Inadequate Signs and Signals
	Experience/Exposure		View Obstructions
	View Obstructions		Design Problems
	Inadequate Signs and Signals		Slick Roads
	Design Problems		Special Hazards
	Slick Roads		Rear End Collision
	Special Hazards		
	Rear End Collision		
	Ran Off Road		
	PI/Fatal		

Table 5-11

Attributes Most Likely to be Copresent in General and in Alcohol-Related Accidents

Variable	General Accident Attributes	Alcohol-Related Accident Attributes
Driver Age	16-24 Year Old Driver	Driver 25 Years or Older
Driver Sex	Male	Male
Most Recent Yearly Mileage	(-)	$>$12,000 Miles in Most Recent Year
Vehicle Familiarity	(-)	$\leq$12 Months in Accident Vehicle (??)
Driver Physical Limitation	No Physical Limitation	(-)
Route Familiarity	Daily on Road (??)	Not Daily on Road
Driving Experience	$\leq$90 Months Driving Experience	$>$90 Months Driving Experience
Vehicle Model Year	1968 or Newer	1967 or Older
Odometer Mileage	(-)	$>$42,911 Odometer Miles
Season of Year	(-)	(-)
Day of Week	(-)	(-)
Light Condition	Daylight	Darkness/Dawn/Dusk
Visibility	Clear	Clear
Estimated Traffic Speed	(-)	(-)
Traffic Volume	Moderate/Heavy Traffic	Light Traffic
Road Surface Condition	Dry Pavement	Dry Pavement
Accident Cause	Improper Lookout (?)	Excessive Speed (?) Performance Error (?)
Human Condition/State	(-)	Physical/Physiological Impairment
Accident Type	Side Impact	Ran Off Road
Accident Severity	Property Damage	PI/Fatal

(-) = No Attribute Clearly Copresent
(?) = Attribute Encountered in Only Two Subgroup Clusters
(??) = Attribute Encountered in Only One Subgroup Cluster

whereas no corresponding value of the same variable was strongly identified for general accidents.

Scanning the results reported in Table 5-11 indicates the typical *general* accident is one involving a young, male, inexperienced driver without physical limitations in a relatively new car, having a side impact collision resulting only in property damage. This same *typical* general accident is likely to take place on a dry road in daylight hours, under conditions of clear visibility and moderate to heavy traffic. Less certain, although to some extent characteristic of such accidents is the likelihood that he drives daily on the road in question, and that the cause of his accident was one of improper lookout.

As indicated on this same table, the typical *alcohol* accident instead involves an older, experienced male driver in a relatively old car, having an accident in which he ran off the road, resulting in personal injury or a fatality. This typical alcohol accident also differs in that it is likely to take place at night or during dawn or dusk hours, in light traffic. Like its general accident counterpart the alcohol accident occurs mostly under conditions of dry pavement and clear visibility. In addition, the typical alcohol-related accident is one in which the driver can be expected to have driven 12,000 miles or more during the previous year, to be driving a car with relatively high odometer mileage, and suffering impairment (as might be expected) from alcohol. Less certain, although again to some extent characteristic of such accidents is the likelihood that the driver is relatively inexperienced in the car he is driving, and that the cause of his accident was either excessive speed (a decision error), performance errors, or both.

5.4 Discussion

As was mentioned earlier, it is clear that the cluster analysis technique, applied to top-level descriptive and causal data on a reasonably large number of accidents, has not identified a *clean* set of mutually exclusive and exhaustive accident types, i.e., a taxonomy in the classic sense. The technique did **not** show, for example, that one distinct type of accident was *young male drivers in old cars, making judgmental errors on snowy nights,* or that another distinct type involved *older women drivers on slippery roads in cars with bad brakes.* In short, the initial cluster analysis outcomes do **not** indicate that particular kinds of people have particular kinds of accidents for particular kinds of reasons in particular kinds of vehicles under particular kinds of circumstances.

The technique nevertheless **has** been helpful to date in identifying those attributes or factors that tend to be found together in the same accidents, i.e., has been helpful in characterizing the typical general accident, and the typical alcohol-related accident, in terms of attributes most likely to be copresent in such accidents.

This outcome may be interpreted in at least two different ways, leading to different initial conclusions about the feasibility of developing and refining comprehensive traffic accident taxonomies.

A **first** possible interpretation would be that there really are no distinct types of traffic accidents, i.e., that there is only one basic type of general traffic accident, with minor variations (e.g., when alcohol is implicated as a cause of the accident). If this is the case, then it would follow that drivers have accidents for basically the same kinds of reasons, under arbitrary circumstances and in any kind of vehicle they happen to be driving. This would imply, as indeed the cluster analysis outcomes have shown to this point, that the *typical* accident is one which follows gross-level charactersitics only, i.e., that it occurs, as most do, during the day on dry roads under clear visibility conditions, and that it involves mostly male drivers having property-damage accidents.

Following this same line of interpretation, cluster analysis outcomes to date would indicate that there are no *problem driver* types, beyond the (by now prosaic) finding that young males with little driving experience have the most accidents. This would imply in turn that attributes of interest (e.g., specific types of drivers and accident causes) tend to mix arbitrarily in accidents, tend not to be related in identifiable patterns or relationships, and tend not to *cluster* in nature.

There are, however, several things that need to be kept in mind regarding the initial outcomes of the cluster analysis effort. Of primary importance are: (a) the limited number of variables or attributes examined in the initial runs, (b) the limited number of cases examined (particulary with regard to alcohol-related accidents), (c) the relative infrequency with which more *interesting* attributes (e.g., specific accident causes) occurred relative to such high-frequency attributes as the various pavement conditions, times of day, and so on, and (d) the restricted level of detail used in defining the specific attributes examined, e.g., *daylight* and *darkness, dawn or dusk* as opposed to specific hour of day, or actual illumination levels.

Assuming these limitations have had some effect upon initial cluster analysis outcomes, a **second** interpretation should also be considered: namely, that an accident typology may still emerge once accident characteristics are brought into finer focus, and sample sizes increase. With greater numbers of cases eventually investigated at the in-depth (Level C) level, it will be feasible to consider attributes concerning income, occupation, marital status, and so on. In addition, data will soon be available on dynamic vision and driver knowledge test results, and accidents will begin to be investigated again on a 24-hour basis. At some later point, current findings may thus be reversed; it may turn out that drivers' socioeconomic or behavioral characteristics are indeed associated in some simultaneous fashion with the reasons for their accidents, the types of vehicles they are driving, and the circumstances under which their accidents occur.

It is true at any rate that the cluster analysis/ taxonomy development effort has to this point produced, (a) a working tool (i.e., the cluster analysis program and related support software) of general usefulness in traffic accident research, and (b) initial, negative findings of considerable significance in their own right, provided subsequent inquiry bears them out.

6.0 Problem Driver Analysis

6.1 Introduction

There is a need to identify the characteristics of drivers involved disproportionately in accidents. Particularly, there is a need to identify the types of drivers who have accidents for particular reasons under particular circumstances, so that preventative and other countermeasures may be defined and brought to bear upon such drivers. This represents an initial effort by IRPS to discern problem driver types from the accidents thus far investigated as a part of the tri-level program.

The cluster analysis portion of this report, described in the previous Section 5.0, has provided initial findings in this direction, and has indicated that cluster analysis methodologies may aid in identifying problem driver types once sufficient in-depth and alcohol-accident data become available.

In the meantime, more traditional analysis tools should be applied to the problem of identifying *problem driver* types, and in addition, of identifying types of driver-cause-circumstance combinations found in general and in alcohol-implicated traffic accidents. Answers need to be provided immediately for the following questions: (a) who is the problem driver and is he a problem, and (b) does the alcohol-accident driver (a type of problem driver) differ from the general-accident driver in terms of his demographic characteristics, and in terms of the reasons for his accidents?

6.2 Methodology

The answer to the first question—"who is the problem driver?—may be answered through involvement ratio analyses. Findings presented in Section 4.0 are reanalyzed here so as to help identify driver subgroups over-involved in accidents, relative to the presence of these same driver subgroups in the general driving population.

These findings, presented originally in Figures H-1 through H-10, may also be used to help answer the second question—"does the alcohol-accident driver differ from the general-accident problem driver?" Note that the set of figures referenced in Section 4.0 displays involvement ratios both for general-accident and for alcohol-accident drivers. In that section, only general-accident ratios were discussed, as the interest at that point was in assessing differences between proportions of drivers and vehicles in the accident sample, and those in the general driving population. The present section concentrates instead upon drivers involved in general and alcohol-related accidents, looking for driver subgroups markedly over-involved or under-involved in accidents of either type, relative to their presence in the same general driving population.

The remainder of the second question—"does the alcohol-accident driver differ from the general-accident driver in terms of the reasons for his accidents?"—is approached through analysis of causal factor data reported originally in Tables 5-1 and 5-2 in Section 5.0. Tabulations and cross-tabulations of causal factor frequencies are generated both for general and for alcohol-involved accidents, in order to determine which kinds of causes pertain to the two types of accidents, and in order to identify driver subgroups having accidents most frequently for particular reasons within each of the two types of accidents.

These involvement ratios, tabulational, and cross-tabulational comparisons do not identify *simultaneous* driver characteristics, i.e., characteristics pertaining simultaneously to particular drivers. (See the earlier discussion of this point in Section 5.1.) *Problem driver* characteristics mentioned in the present section will necessarily show up simultaneously in particular individuals. Furthermore, it is possible that drivers possessing such "worst" characteristics may not even pose the greatest danger, and may indeed not even exist. Only cluster analysis or some similar multivariate approach could be expected to yield such information, once sufficient data become available.

6.3 Results

Involvement ratio findings illustrated in Figures H-1 through H-10 are reorganized here as follows. Table 6-1 identifies comparison variables of greatest overall importance in the involvement ratio analyses. Table 6-2 then presents breakdowns of specific driver subgroups most over-involved, and subgroups most under-involved, in general and in alcohol-implicated accidents. Involvement ratio differences are then summarized for each subclass in Table 6-3. Finally, Figure 6-1 graphs subgroup involvement ratios, showing in each instance how particular subgroups involvement ratios differed between general and alcohol-implicated accidents.

Turning from the characteristics of problem drivers to the causes of general and of alcohol-involved accidents, Figure 6-2 shows the relative frequencies with which particular causes led to accidents of each type. *Involvement ratios* for each causal factor are then presented in Table 6-4, for alcohol-related accidents. Finally, cross-tabulation results (Tables 6-5 through 6-14) are summarized in Table 6-15, indicating which driver subgroups had accidents most frequently for specified reasons.

6.3.1 Driver Involvement Ratio Analysis

Regardless of the specific human, vehicular, or environmental causes of their accidents, one might ask: "What types of drivers have more than their share of general, and of alcohol-implicated accidents?" Table 6-1 shows involvement ratio values averaged over involvement ratio values for each category within each comparison variable. Thus, for *driver sex,* the average involvement value across males and females is .975, indicating that sex *per se* generally balances out to a position of relative unimportance insofar as over- or under-involvement in

Table 6-1

Average Subclass Involvement Ratios for Drivers in General vs. Alcohol-Implicated Accidents

Comparison Variable	Average Involvement Ratio In General Accidents	Rank	Average Involvement Ratio In Alcohol-Implicated Accidents	Rank
Sex	.965	9	.904	8
Age	.976	5	.960	6
Marital Status	2.160	1	6.320	1
Education	.968	7	1.084	5
Family Income	1.017	4	1.440	3
Major Occupation	.971	6	1.181	4
Years Driving Experience	.967	8	.929	7
Recent Yearly Mileage	1.075	3	.847	9
Vehicle Familiarity	1.084	2	1.745	2
Driver Training Exposure	.895	10	.706	10

accidents is concerned. The most "important" variable in general accidents is *marital status* (2.160, rank 1); *marital status* is also "important" for alcohol-implicated accidents (6.320, rank 1), to a greater extent. Similarly, the variable of least "importance" for both types of accidents is *driver training* (.895 and .706, respectively, rank 10). In general accidents, variables whose average involvement ratios exceed 1.000 for general accidents are *marital status, recent yearly mileage, vehicle familiarity,* and *occupation.* For alcohol-implicated accidents, variables whose average ratios exceed 1.000 are also *marital status, recent yearly mileage,* and *occupation,* and include *family income* and *education* as well.

Carrying forward the findings in Tables 6-1 and 6-2, one can identify specific subgroups most over-involved and most under-involved, within each comparison variable. Most over-involved and under-involved subgroups are presented separately for general and for alcohol-implicated accidents. Thus, for *marital status,* indicated to be the most important variable in terms of general over-involvement in Table 6-1, the most over-involved general-accident subgroup was *divorced* drivers (4.700); the most over-involved alcohol-accident subgroup was *separated* drivers (30.333). For *recent yearly mileage,* the second most important variable, the

Summary Table 6-2

Involvement Ratio Comparisons for Drivers in General vs. Alcohol-Implicated Accidents

Comparison Variable	General Accidents				Alcohol-Implicated Accidents			
	Most Over-involved Subgroup	Ratio Value	Most Under-involved Subgroup	Ratio Value	Most Over-involved Subgroup	Ratio Value	Most Under-involved Subgroup	Ratio Value
Sex	Males	1.204	Females	.726	Males	1.560	Females	.248
Age	20-24 Year Olds	1.222	55-64 Year Olds	.778	33-44 Year Olds	2.039	Less Than 20 Years Old	.414
Marital Status	Divorced	4.700	Widowed	.583	Separated	30.333	(Divorced and Remarried)	.000[1]
Education	Less Than H.S. Grad.	1.707	Graduate or Professional	.550	Voc. or Tech. High School	2.528	College Grad. Or Higher	.000[1]
Family Income	$6-7,999	1.591	$20-24,999	.484	$3-5,999	5.678	$8-11,999; $15,000	.000[1]
Major Occupation	Laborers	2.134	Housewives	.443	Laborers	6.791	Housewives, Farmers	.000[1]
Years Driving Experience	Less Than 5 Years	1.589	30-39 Years	.630	20-29 Years Years	1.850	50 Or More Years	.000[1]
Recent Yearly Mileage	31,000+ Miles	1.580	Less Than 6,000 Miles	.653	31,000+ Miles	4.760	Less Than 6,000 Miles	.402
Vehicle Familiarity	2-3 Years	1.568	½ - 1 Year	.651	2-3 Years	2.000	3-6 Years	.000[1]
Driver Training	Completed	1.114	Taken But Not Completed	.714	Not Taken	1.469	Taken But Not Completed	.000[1]

[1]None Observed in Alcohol Accident Sample.

Table 6-3

Driver Subclasses More Involved in Alcohol-Related Than in General Accidents

Rank	Driver Subclass	Difference in Involvement Ratios
1	Separated	26.333
2	Laborer	4.657
3	Divorced	4.400
4	$3-$5,999 Family Income	4.183
5	Widowed	3.209
6	Yearly Mileage 26-30,999	2.085
7	Vocational or Technical High School	1.750
8	Driver Age 45-54	1.513
9	40-49 Years' Driving Experience	1.168
10	Driver Age 35-44	1.133
11	High School Graduate	1.030
12	Occupation "Other"	.842
13	20-29 Years' Driving Experience	.760
14	Vehicle Familiarity Under 7 Months	.757
15	Drivers Training Not Taken	.612
16	Vehicle Familiarity 73+ Months	.600
17	Under $3,000 Family Income	.597
18	10-19 Years' Driving Experience	.588
19	Vehicle Familiarity 25-36 Months	.432
20	Semi-skilled Worker	.380
21	Male	.356
22	$6-$7,999 Family Income	.339
23	Driver Age 25-34	.222
24	Yearly Milegae 16-20,999	.120
25	30-39 Years' Driving Experience	.110
26	White Collar Worker	.070

Figure 6-1

Involvement Ratios for Alcohol-Impaired and General Driver Subgroups

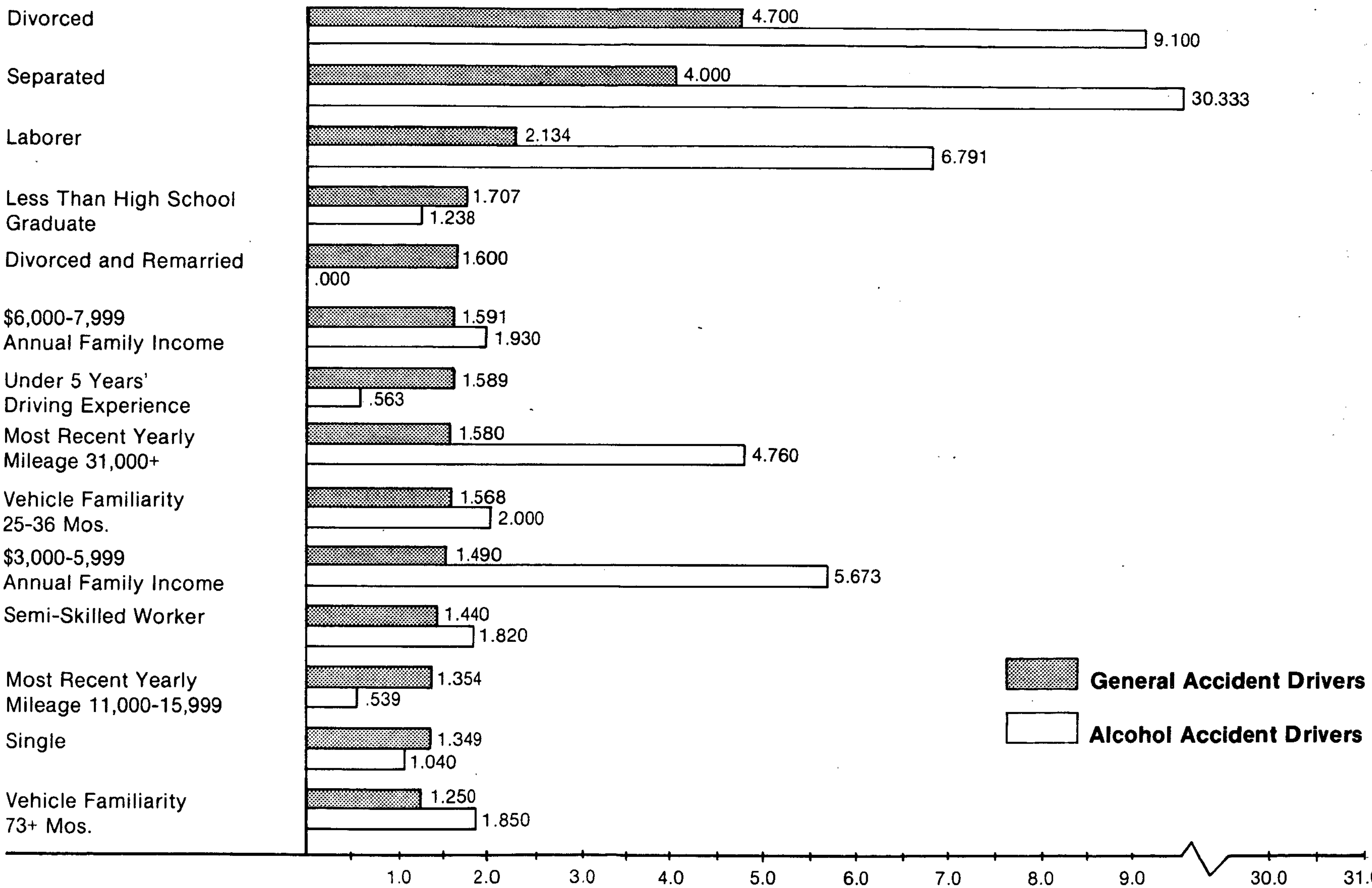


Figure 6-1 continued

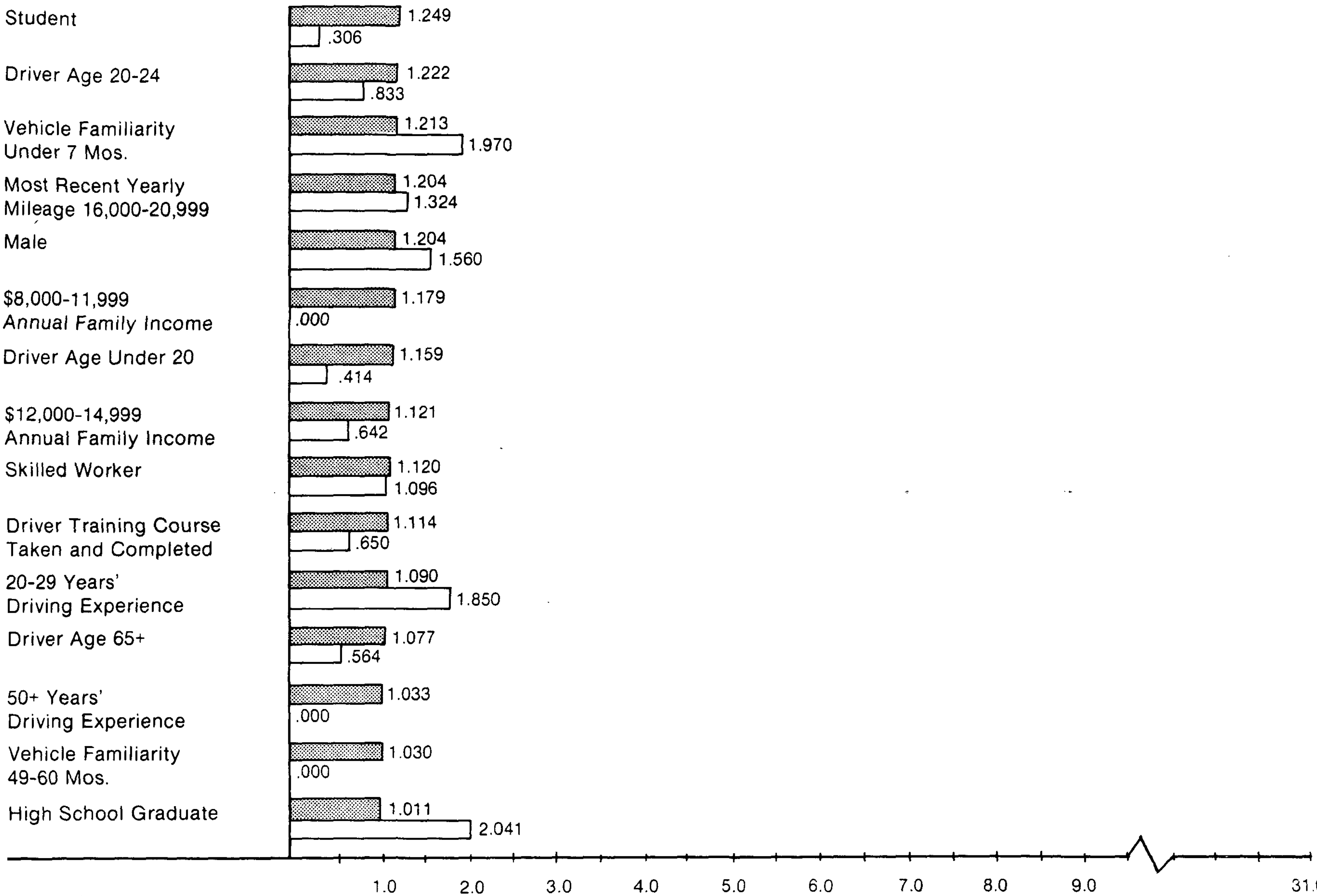


Figure 6-1 continued

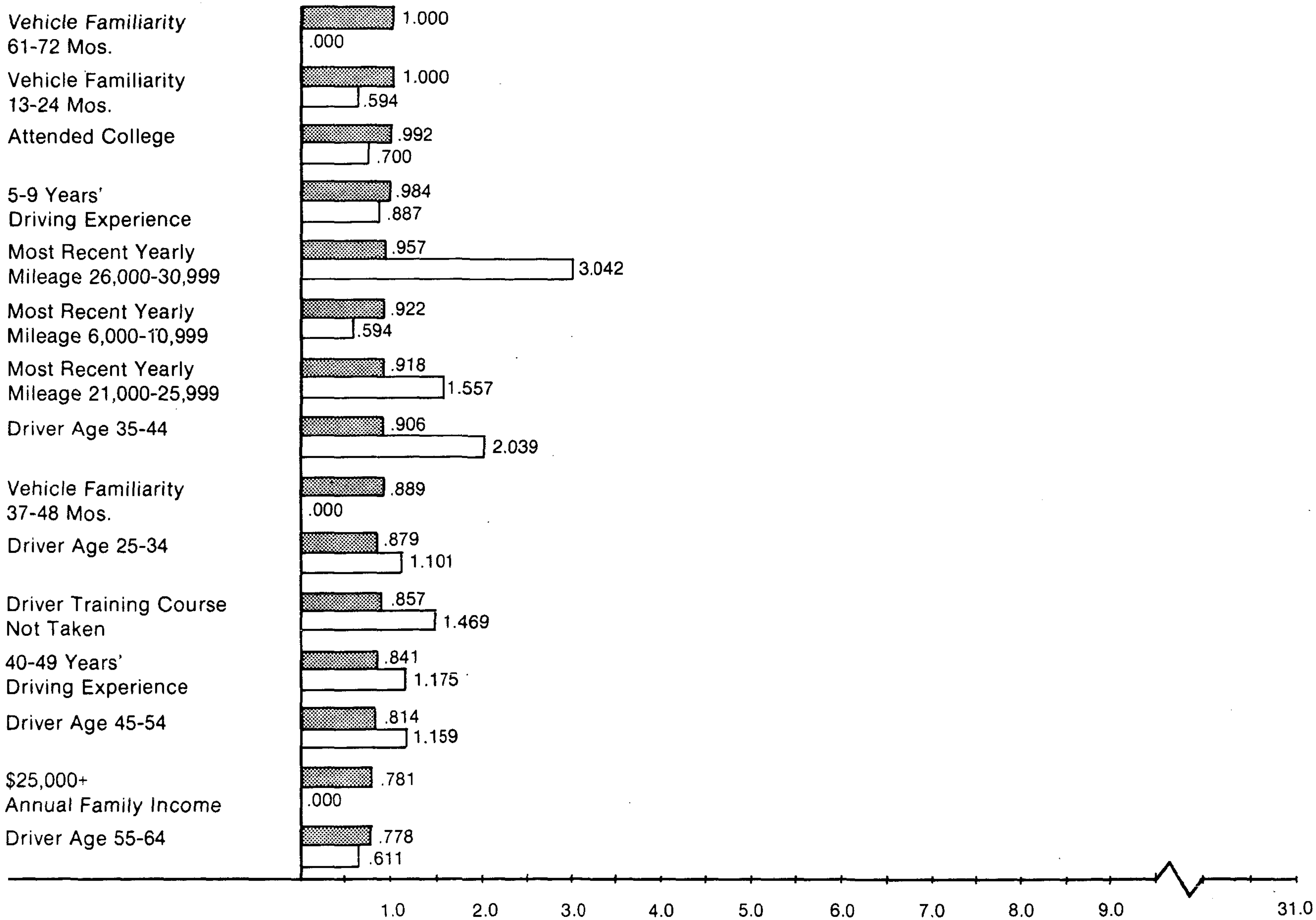


Figure 6-1 continued

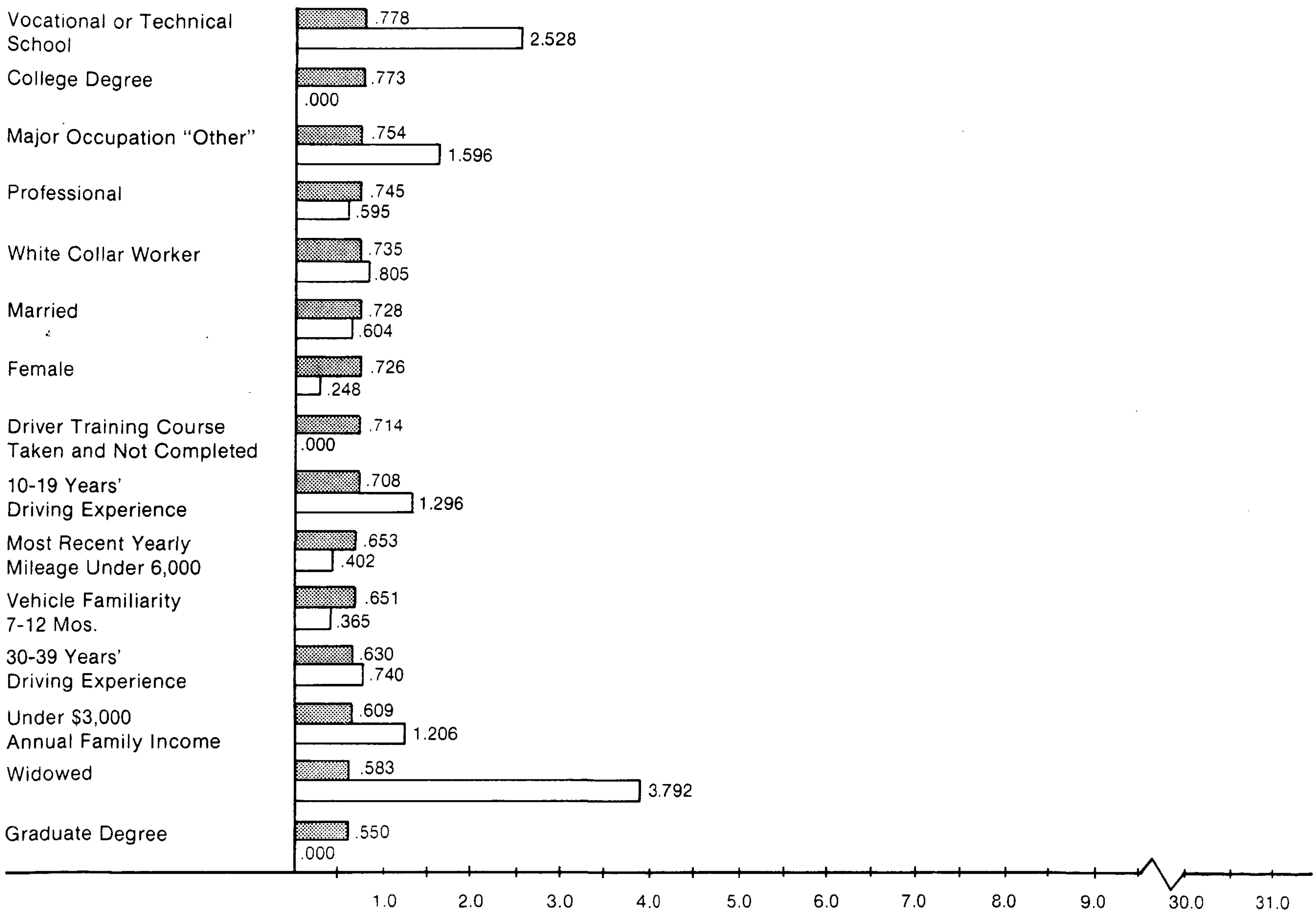


Figure 6-1 continued

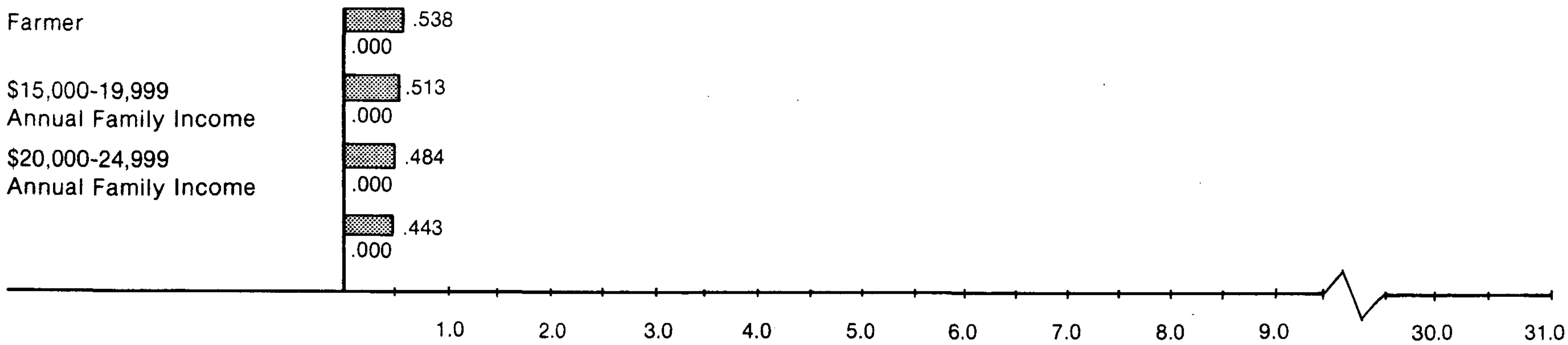


Figure 6-2

Comparison of Causal Factor Frequencies in General vs. Alcohol-Implicated Accidents

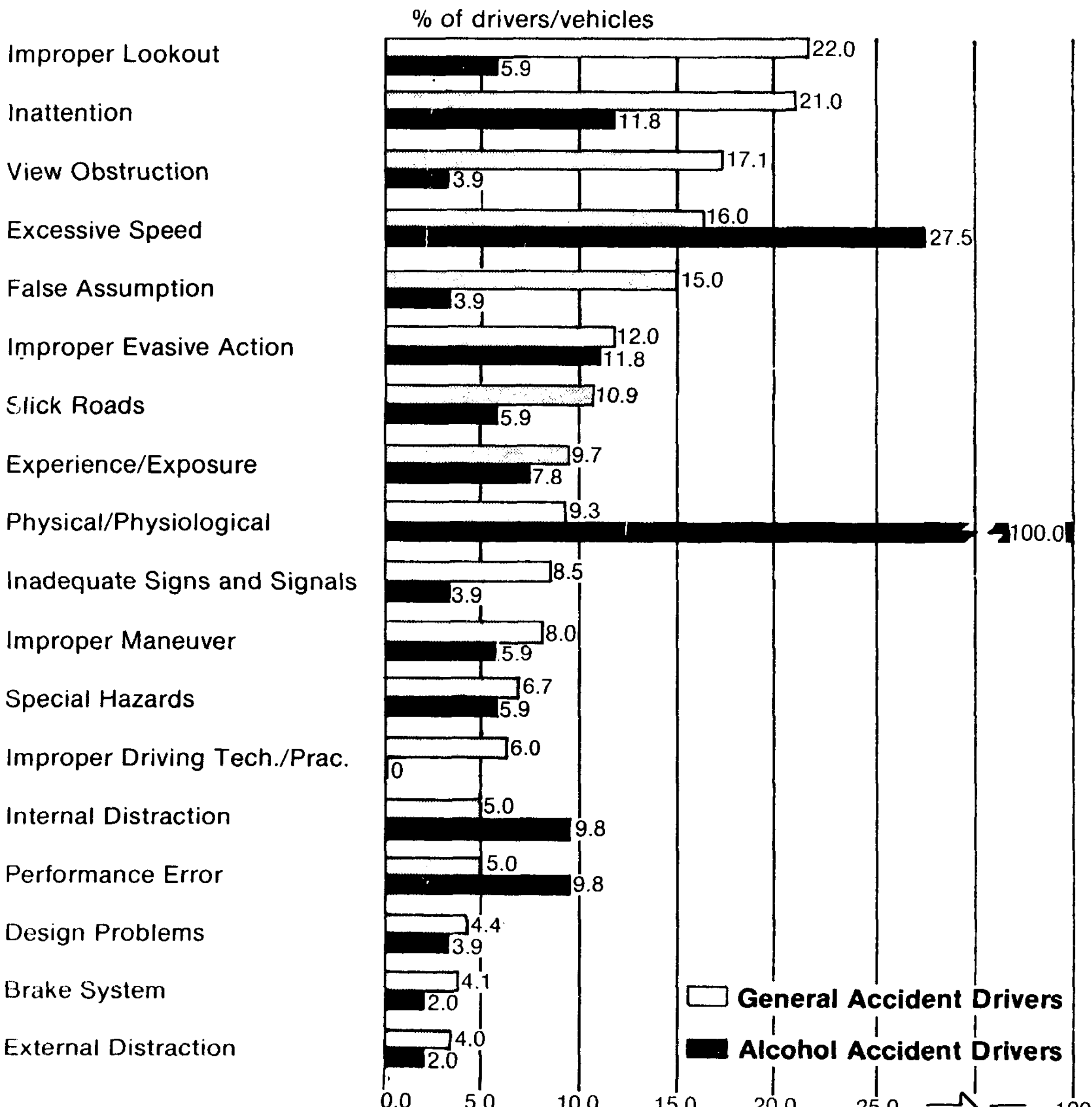


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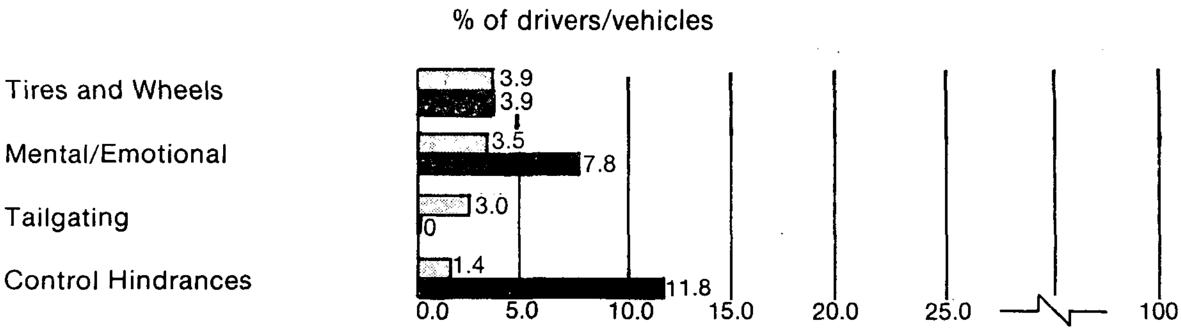
Figure 6-2 continued



most over-involved subgroup in both general and alcohol accidents was drivers with mileages of **31,000 or greater,** the highest mileage category.

For general accidents, Table 6-2 shows over-involved driver subgroups to be: *divorced, laborers, less than high school graduates, $6-7,999 family incomes, less than 5 years driving experience, at least 31,000 yearly mileage,* 2-3 years in accident vehicle, 20-24 year olds, males,* and drivers who have *completed driver training.* Again, each of these characteristics should be considered separately; this analysis is not intended to indicate that individuals possessing two or more such attributes are *more dangerous,* or that individuals possessing specific combinations of these attributes exist.

Comparing most over-involved subgroups for general and for alcohol-implicated accidents, Table 6-2 also shows that *problem drivers* in both kinds of accidents include *males, laborers,* 31,000+ *recent yearly mileages,* and *2-3 years experience in the accident vehicle.* In both types of accidents, over-involved subgroups include divorced or separated drivers (*broken marriages*), less-than-high-school graduates and vocational or technical high school graduates (*less-than-college educations*), $6-7,999 and $3-5,999 family incomes (*below median incomes*).

Over involved driver subgroups **differ** between general and alcohol-implicated accidents as follows: for general accidents, *problem driver* subgroups include younger drivers (20-24 years old), inexperienced drivers (less than 5 years driving experience), and drivers who have completed driver training. For alcohol-implicated accidents, over-involved subgroups include instead 33-44 year old drivers, experienced drivers (20-29 years driving experience), and drivers who have not taken driver training.

On the other hand, *under*-involved or *non-problem* driver subgroups in both general and alcohol-implicated accidents include females, housewives, drivers with low recent yearly mileages (less than 6,000 miles), and drivers who have taken but not completed driver training. They include those showing relatively more marital stability (widowed, or divorced and

*The credibility of drivers' annual mileage estimates may be questioned.

Table 6-4

Causal Factors Overinvolved vs. Underinvolved In Alcohol-Related Accidents

Rank	Causal Factor[1]	Involvement Ratio[2]	% Difference in Involvement Rate[3]
1	Control Hindrances	8.428	+10.4%
2	Mental/Emotional	2.229	+ 4.3%
(3)	Internal Distraction	1.960	+ 4.8%
(3)	Performance Error	1.960	+ 4.8%
4	Excessive Speed	1.719	+11.5%
5	Tires and Wheels	1.000	+ 0.0%
6	Improper Evasive Action	.983	- 0.2%
7	Design Problems	.886	- 0.5%
8	Special Hazards	.880	- 0.8%
9	Experience/Exposure	.804	- 1.9%
10	Improper Maneuver	.737	- 2.1%
11	Inattention	.562	- 9.1%
12	Slick Roads	.541	- 5.0%
13	External Distraction	.500	- 2.0%
14	Brake System	.488	- 2.1%
15	Inadequate Signs & Signals	.459	- 4.6%
16	Improper Lookout	.268	-16.1%
17	False Assumption	.260	-11.1%
18	View Obstruction	.228	-13.2%
(19)	Improper Driving Technique/Practice	.000[4]	- 6.0%
(19)	Tailgating	.000[4]	- 3.0%

[1]Physical/Physiological Excluded.
[2]Ratio of Frequency in Alcohol Accidents/Frequency in General Accidents: Ratios 1.000 Indicate Overinvolvement in Alcohol Accidents. Those ranked highest are the most over-involved in Alcohol Accidents.
[3]"+" Indicates Greater Involvement in Alcohol Accidents; "-" Indicates Greater Involvement in General Accidents.
[4]Frequency in Alcohol Accidents = 0%.

remarried), college graduates or higher, and those with considerable or extensive driving experience (30-39 years, 50 or more years).

Under-involved driver subgroups in general accidents also include 55-64 year olds, high family incomes ($20-24,999), and low vehicle familiarities (½-1 year). For alcohol-implicated accidents, under-involved subgroups include instead drivers less than 20 years old, family incomes of either intermediate ($8-11,999) or higher levels ($15,000 or greater), and moderate familiarity with the accident vehicle (3-6 years).

At the lowest level of detail, these same involvement ratio findings, originally presented in Figures H-1 through H-10, are re-portrayed graphically in Figure 6-1. Here involvement ratios are given for each driver subgroup, for both general and alcohol accidents. Driver subgroups (divorced, separated, laborer, and so on) are ranked from highest to lowest involvement ratios for *general* accidents; corresponding alcohol-accident involvement ratios are given for each subgroup immediately below. While agreement in involvement ratios is relatively close for most driver subgroups, there are certain subgroups for which they differ markedly.

Thus, Figure 6-1 illustrates that driver subclasses more involved in general than in alcohol accidents include less-than-high-school-graduates, divorced and remarried, under 5 years' driving experience, and so on. Subclasses more involved in alcohol than in general accidents instead include separated, laborers, divorced, $6-7,999 family income, and so on.

These same comparisons are presented again in summary fashion in Table 6-3, listing driver subclasses more involved in *alcohol-implicated* accidents than they were in general accidents. Subclasses meeting this criterion are ranked here according to the raw difference between their alcohol- and general-accident involvement ratios; for each such subclass, this difference was positive.

6.3.2 Driver Causal Factor Analysis

Regardless of the likelihood of their being involved in general or alcohol-implicated accidents, for what reasons do drivers have accidents of each type?

The answer to this question is given at the broadest level in Figure 6-2, illustrating frequencies with which each major causal factor was implicated at the "causal," "certain, possible, or probable" level. Causal factors are ranked here according to their frequency in general accidents; frequencies in alcohol-related accidents are presented alongside for each factor.

Improper lookout (22.0 percent), inattention (21.0 percent), view obstruction (17.1 percent), excessive speed (16.0 percent), false assumption (15.0 percent), and improper evasive action (12.0 percent) comprise the top six causal factors in *general* accidents. The top six factors in *alcohol-implicated* accidents also include inattention (11.8 percent), excessive speed (27.5 percent), and improper evasive action (11.8 percent); they differ in that the top six here also include control hindrances (11.8 percent), and internal distraction and performance error (both 9.8 percent). Note that for alcohol accidents, physical/physiological (100 percent) is excluded from consideration; the presence of this factor served as a basis for identifying alcohol-related accidents at the outset.

In terms of the relative magnitudes of these causal factor frequencies in general and alcohol-related accidents, a different story emerges. Table 6-4 ranks these same causal factors according to the degree to which their involvement in alcohol-related accidents exceeded that in general accidents. Here an *involvement ratio* is computed for each causal factor, as the ratio of its frequency in alcohol accidents to its frequency in general accidents. For any particular causal factor, an involvement ratio exceeding 1.000 thus indicates *over-involvement* of that factor in alcohol-related, as compared with general accidents.

On this relative basis, it is seen that raw percentage differences between alcohol-related and general accident frequencies (e.g., 11.5 percent for excessive speed) do not always agree with ranking according to the factor's involvement ratio. In terms of the latter, the five causal factors *over-involved* in alcohol-related accidents are control hindrances, mental/emotional, internal distraction and performance error, and excessive speed, in order of decreasing over-involvement. Tires and wheels were equally implicated as causal factors in both types of accident (involvement ratio was 1.000). Proceeding down the ranking, causal factors are seen to pertain less and less to alcohol-related accidents, and more and more to general accidents.

Turning from gross involvement to involvement levels for specific types of drivers, we may now consider what types of drivers have accidents for what types of reasons. Here the results of cross-tabulational analyses are presented in Tables 6-5 through 6-14, indicating which driver subgroups have accidents most frequently for particular reasons, i.e., showing frequencies for different causal factors for each driver subgroup. In these tables, only the six most-frequently-occurring causal factors are considered. For general accidents, these are inattention, improper lookout, view obstructions, excessive speed, false assumption, and improper evasive action. It was originally intended that cross-tabulation tables of these types should be produced both for general and for alcohol-involved accidents. This was not possible, due to limitations on the number of alcohol-involved accident cases; in many instances, comparable cross-tabulation tables were too sparse for interpretation, or simply not producible at all, due to the limited alcohol-accident sample size (51 cases). When 24 hour coverage is resumed, the alcohol sample size will increase significantly, thus, making it possible to again attempt cross-tabulations.

In Tables 6-5 through 6-14, four types of percentages are presented. Percentage **A** under the column headings is the percentage of accident-involved drivers represented by each driver subgroup in the accident sample. Thus, in Table 6-5, drivers 20 years old or younger comprised 24.1 percent of the 735 drivers in the sample examined. (Note that the number of drivers examined differs according to whether the driver characteristic was obtained during on-site or during in-depth investigations.)

Percentage **B** is the percentage of total accidents caused by the specified factor, occurring

Table 6-5

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Age (N = 735)

Causal Factor		Age Categories, Sample Percentages						
		≤ 20	20-24	25-34	35-44	45-54	55-64	65+
	A	24.1	28.6	17.4	10.9	8.0	4.8	6.3
Inattention	B	21.6	28.4	15.7	7.5	13.4	6.7	6.7
	C	16.4	18.1	16.4	12.5	30.5	25.7	19.6
	D	14.7	18.0†	14.8†	8.6	5.1	35.8*/†	20.8
Improper Lookout	B	18.5	29.4	13.4	12.6	11.8	2.5	11.8
	C	12.4	16.7	12.5	18.7	23.7	8.6	30.4
	D	9.5	17.2	9.6	21.6†	34.9†	4.5	56.9*/†
View Obstructions	B	19.4	17.1	15.7	10.2	7.4	6.5	7.4
	C	11.9	17.1	13.3	13.8	13.6	20.0	17.4
	D	9.6	10.2	12.0	12.9	12.5	27.1*	20.4
Excessive Speed	B	41.6	27.7	10.9	10.9	3.0	3.0	3.0
	C	23.7	13.3	8.8	13.8	5.1	8.6	6.5
	D	40.9*/†	12.9	5.4	13.8	19.1	5.4	3.1
False Assumption	B	20.7	28.7	18.4	12.6	9.2	5.7	4.6
	C	10.2	11.9	12.5	13.8	13.6	14.3	8.7
	D	8.8	11.9	13.2	15.9	15.6	17.0*	6.3
Improper Evasive Action	B	23.1	34.6	12.8	7.7	6.4	7.7	7.7
	C	10.2	12.9	7.8	7.5	8.5	17.1	13.0
	D	9.8	15.6	5.7	5.2	6.8	27.4*	15.9

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.

B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.

C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.

D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-6

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Sex (N = 751)

Causal Factor		Sex Categories, Sample Percentages	
		Male	Female
	A	68.6	31.4
Inattention	B	68.6	31.2
	C	18.8	18.6
	D	18.8*/†	18.5
Improper Lookout	B	62.6	37.4
	C	15.0	19.5
	D	13.7	23.2*/†
View Obstructions	B	63.3	36.7
	C	13.4	16.9
	D	12.4	19.7*
Excessive Speed	B	80.4	19.6
	C	15.9	8.5
	D	18.6*	5.3
False Assumption	B	60.9	39.1
	C	10.3	14.4
	D	9.1	17.9*
Improper Evasive Action	B	64.6	35.4
	C	9.9	11.9
	D	9.3	13.4*

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-7

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Marital Status (N = 187)

Causal Factor		Marital Status Categories, Sample Percentages		
		Single	Married	Separated, Divorced or Widowed
	A	51.3	42.2	6.4
Inattention	B	37.5	59.4	3.1
	C	12.5	24.1	8.3
	D	9.2	33.9*/†	4.0
Improper Lookout	B	56.0	40.0	4.0
	C	14.6	12.7	8.3
	D	15.9*	12.0	5.2
View Obstructions	B	48.0	48.0	4.0
	C	12.5	15.2	8.3
	D	11.7	17.3*	5.2
Excessive Speed	B	69.7	24.2	6.1
	C	24.0	10.1	16.7
	D	32.6*/†	5.8	15.9†
False Assumption	B	46.7	46.7	6.7
	C	7.3	8.9	8.3
	D	6.6	9.8*	8.7
Improper Evasive Action	B	55.6	44.4	0.0
	C	10.4	10.1	0.0
	D	11.3*	10.6	0.0

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-8

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Educational Level (N = 188)

Causal Factor		Educational Categories, Sample Percentages			
		Less Than High School Graduate	High School, Voc. or Tech. School Graduate	Attended College	College Graduate or Higher
	A	27.7	30.9	23.9	17.5
Inattention	B	24.2	24.2	27.3	24.2
	C	15.4	13.8	20.0	24.2
	D	13.4	10.8	22.8	33.4*
Improper Lookout	B	12.5	20.8	29.2	37.5
	C	5.8	8.6	15.6	27.2
	D	2.6	5.8	19.0	58.3*/†
View Obstructions	B	24.0	24.0	32.0	20.0
	C	11.5	10.3	17.8	15.1
	D	10.0	8.0	23.8*/†	17.2
Excessive Speed	B	41.2	29.4	23.5	5.9
	C	26.9	17.2	17.8	6.1
	D	40.0*/†	16.4†	17.5	2.1
False Assumption	B	40.0	13.3	13.3	35.3
	C	11.5	3.4	4.4	15.1
	D	16.6	1.5	2.4	28.7*
Improper Evasive Action	B	22.2	33.3	33.3	11.1
	C	7.7	10.3	13.3	6.1
	D	6.2	11.1	18.5*	3.9

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.

B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.

C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.

D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-9

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Family Income (N = 159)

Causal Factor		Income Categories, Sample Percentages		
		< $6,000	$6-14,999	≥$15,000
	A	22.6	61.7	15.7
Inattention	B	13.8	62.1	24.1
	C	11.1	18.4	28.0
	D	6.8	18.5	42.9*/†
Improper Lookout	B	26.3	52.6	21.0
	C	13.8	10.2	16.0
	D	16.1†	8.7	21.4*
View Obstructions	B	25.0	65.0	10.0
	C	13.8	13.3	8.0
	D	15.3*	14.0	5.1
Excessive Speed	B	14.3	71.4	14.3
	C	11.1	20.4	16.0
	D	7.0	23.6*/†	14.6
False Assumption	B	7.7	92.3	0.0
	C	2.8	12.2	0.0
	D	0.9	18.2*	0.0
Improper Evasive Action	B	14.3	64.3	21.4
	C	5.5	9.2	12.0
	D	3.5	9.6	16.4*

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-10

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Occupation (N = 181)

Causal Factor		Occupation Categories, Sample Percentages						
		Farmer or Laborer	Semi-Skilled	Skilled	White Collar	Profes sional	Student	House-wife
	A	17.7	7.7	8.8	9.4	10.5	38.7	7.1
Inattention	B	16.1	9.7	9.7	6.4	16.1	29.0	12.9
	C	15.6	21.4	18.7	11.8	26.3	12.9	30.8
	D	14.2	27.0	20.6†	8.0	40.3	9.7	56.0*/†
Improper Lookout	B	24.0	0.0	0.0	0.0	20.0	44.0	8.0
	C	18.7	0.0	0.0	0.0	26.3	15.7	15.4
	D	25.4†	0.0	0.0	0.0	50.1*/†	17.8	17.3
View Obstructions	B	20.8	8.3	0.0	12.5	4.2	45.8	8.3
	C	15.6	14.3	0.0	17.6	5.3	15.7	15.4
	D	18.3	15.4	0.0	23.4*/†	2.1	18.6	18.0
Excessive Speed	B	17.1	14.3	5.7	2.8	11.4	42.8	5.7
	C	18.7	35.7	12.5	5.9	21.1	21.4	12.4
	D	18.1	66.3*/†	8.1	17.6	22.9	23.7†	15.4
False Assumption	B	0.0	0.0	13.3	13.3	13.3	53.3	6.7
	C	0.0	0.0	12.5	11.8	16.5	11.4	7.7
	D	0.0	0.0	18.8*	16.7	13.3	15.7	7.3
Improper Evasive Action	B	10.5	5.3	10.5	10.5	10.5	47.4	5.3
	C	6.2	7.1	12.5	11.8	10.5	12.9	7.7
	D	3.6	4.9	14.9	13.2	10.5	15.8*	5.7

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-11

General-Accident Involvement Frequencies for Major Causal Factors, by Driving Experience Level in Years (N = 773)

Causal Factor		Experience Categories, Sample Percentages						
		<5	5-9	10-19	20-29	30-39	40-49	50+
	A	36.1	17.2	13.8	8.4	4.5	4.9	15.0
Inattention	B	34.2	25.6	22.2	9.4	4.3	0.9	3.4
	C	16.8	16.5	15.0	21.5	34.3	15.8	23.3
	D	15.9	24.6	24.1†	24.0	32.8*/†	2.9	5.3†
Improper Lookout	B	37.5	17.0	17.0	13.4	6.3	4.5	4.5
	C	16.8	9.8	19.6	32.3	2.9	10.5	15.5
	D	17.4	9.7	11.8	51.5*/†	4.1	9.6	4.6
View Obstructions	B	36.0	20.0	20.0	9.0	6.0	3.0	6.0
	C	13.6	15.8	13.1	18.5	14.3	21.1	12.1
	D	13.6	18.4	11.0	19.8*	19.1	12.9	4.8
Excessive Speed	B	45.7	28.4	18.5	2.5	2.5	1.2	1.2
	C	16.5	12.0	11.2	6.2	11.4	5.3	18.1
	D	20.9*/†	19.8	15.0	18.4	6.3	1.3	1.4
False Assumption	B	28.2	24.7	12.9	12.9	10.6	4.7	5.9
	C	9.7	18.0	11.2	21.5	5.7	15.8	2.6
	D	7.6	25.8†	10.5	33.0*	13.4	15.2†	1.0
Improper Evasive Action	B	40.3	20.8	12.5	15.3	5.6	4.2	1.4
	C	11.5	13.5	5.6	7.7	14.3	13.2	8.6
	D	12.8	16.3	5.1	14.0	17.8*	11.2	0.8

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-12

General-Accident Involvement Frequencies for Major Causal Factors, by Driver's Recent Yearly Mileage (N = 533)

Causal Factor		Mileage Categories, Sample Percentages						
		<6,000	6,000-10,999	11,000-15,999	16,000-20,999	21,000-25,999	26,000-30,999	31,000+
	A	18.0	29.3	21.0	13.7	6.9	3.4	7.7
Inattention	B	10.5	23.2	27.4	14.7	9.5	4.2	10.5
	C	10.4	14.1	23.2	19.2	24.3	22.2	24.4
	D	6.1	11.2	30.3†	20.6	3.3	27.4†	33.3*/†
Improper Lookout	B	18.4	43.7	20.7	6.9	5.7	0.0	4.6
	C	16.7	24.4	16.1	8.2	13.5	0.0	9.8
	D	17.1	36.4*/†	15.9	4.1	11.1	0.0	5.8
View Obstructions	B	18.7	37.3	16.0	9.3	8.0	4.0	6.7
	C	14.6	17.9	10.7	9.6	16.2	16.7	12.2
	D	15.2	22.8*	8.1	6.5	18.8	19.6	10.6
Excessive Speed	B	24.2	19.4	16.1	21.0	8.1	4.8	6.5
	C	15.6	7.7	8.9	17.8	13.5	16.7	9.8
	D	21.0†	6.2	6.8	27.3*/†	15.8	23.6	8.3
False Assumption	B	18.7	32.8	21.9	12.5	7.8	4.7	1.6
	C	12.5	13.5	12.5	11.0	13.5	16.7	2.4
	D	13.0	15.1	13.0	10.0	15.3	23.1*	0.5
Improper Evasive Action	B	12.3	29.8	29.8	10.5	12.3	1.8	3.5
	C	7.3	10.9	15.2	8.2	18.9	5.6	4.9
	D	5.0	11.9	21.6	6.3	33.7*/†	3.0	2.2

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.

B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.

C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.

D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-13

General-Accident Involvement Frequencies for Major Causal Factors, by Vehicle Familiarity in Years (N = 665)

Causal Factor		Vehicle Familiarity (Years)						
		<1/2	1/2 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+
	A	39.7	21.2	17.7	9.8	4.4	3.5	3.8
Inattention	B	34.2	25.6	22.2	9.4	4.3	0.9	3.4
	C	15.2	21.3	22.0	16.9	17.2	4.3	16.0
	D	13.1	25.7†	27.6*/†	16.2	16.8	1.1	14.3
Improper Lookout	B	37.5	17.0	17.0	13.4	6.3	4.5	4.3
	C	15.9	13.5	16.1	23.1	24.1	21.7	20.0
	D	15.0	10.8	15.5	31.6†	34.5*	27.9†	22.6
View Obstructions	B	36.0	20.0	20.0	9.0	6.0	3.0	6.0
	C	13.6	14.2	16.9	13.8	20.7	13.0	24.0
	D	12.3	13.4	19.1	12.7	28.2	11.1	38.0*/†
Excessive Speed	B	45.7	28.4	18.5	2.5	2.5	1.2	0.8
	C	14.0	16.3	12.7	3.1	6.9	4.3	4.0
	D	16.1†	21.8*	13.3	0.8	3.9	1.5	0.8
False Assumption	B	28.2	24.7	12.9	12.9	10.6	4.7	4.3
	C	9.1	14.9	9.3	16.9	31.0	17.4	20.0
	D	6.5	17.4	6.8	22.2	34.7*/†	23.4	22.6
Improper Evasive Action	B	40.3	20.8	12.5	15.3	5.6	4.2	0.8
	C	11.0	10.6	7.6	16.9	13.8	13.0	4.0
	D	11.2	10.4	5.4	26.4*	17.5	15.6	0.8

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

Table 6-14

General-Accident Involvement Frequencies for Major Causal Factors, by Driver Training Exposure (N = 188)

Causal Factor		Exposure Categories, Sample Percentages	
		Driver Training Taken (a)	Driver Training NOT Taken
	A	62.2	37.8
Inattention	B	57.6	42.4
	C	16.4	19.7
	D	15.2†	22.0*/†
Improper Lookout	B	60.0	40.0
	C	12.9	14.1
	D	12.4	14.9*
View Obstructions	B	60.0	40.0
	C	12.9	14.1
	D	12.4	14.9*
Excessive Speed	B	57.6	42.4
	C	16.4	19.7
	D	15.2†	22.0*/†
False Assumption	B	66.7	33.3
	C	8.6	7.0
	D	9.2*	6.2
Improper Evasive Action	B	76.5	23.5
	C	11.2	5.6
	D	13.8*	3.5

A = % of Accident-Involved Drivers Represented by Driver Subgroup; e.g., 24.1% of Drivers were 20 yrs. old or younger.
B = % of Total Accidents Caused by Specified Factor, Occurring Within Specified Driver Subgroup; e.g., 21.6% of All "Inattention" Accidents were Caused by Drivers 20 years or younger.
C = % of Driver Subgroup's Accidents Caused by Specified Factor; e.g., 16.4% of all 20 yr. old or younger Drivers' Accidents were caused by Inattention.
D = Adjusted % of Driver Subgroup's Accidents Caused by Specified Factor (= BC/A); e.g., 14.7% of 20 yr. old or younger Drivers' Accidents were caused by Inattention, Taking into Account the % of Inattention Accidents which the Size of this Subgroup Warrants.

*Indicates Highest "D" Figure for the Causal Factor in that row.
†Indicates Highest "D" Figure for the Driver Subgroup in that column.

within the specified driver subgroup. Thus, in the same table, 21.6 percent of all *inattention* accidents were caused by drivers 20 years old or younger.

Percentage **C** is the percentage of the driver subgroup's accidents caused by the specified factor. Thus, in Table 6-5, 16.4 percent of all 20-year-old-or-younger drivers' accidents were caused by inattention.

Percentage **D,** finally, is an adjusted percentage C, in which C is weighted by the ratio of B to A, an *involvement ratio* indicating the degree to which the driver subgroup had accidents for that reason in proportion to the percentage of accident-involved drivers actually in that subgroup. Thus, in the same table, C changes from 16.4 percent to 14.7 percent when multiplied by B/A, (21.6 percent/24.1 percent), or 0.896. Here the ratio B/A, being less than 1.000, indicates that drivers 20 years old and under had slightly less than their **share** of the total inattention-caused accidents, considering the proportion of such drivers in the total accident sample. The result, D, is weighted so as to reflect the degree to which this driver subgroup-causal factor combination is actually a problem worthy of consideration in the *problem driver* analysis.

Findings in these ten tables are summarized in Table 6-15, identifying from each such table the driver subgroup (e.g., male) within each driver characteristic (e.g., sex) showing highest adjusted causal factor frequencies **(D)** for each causal factor. For example, 55-64 year old drivers had a higher adjusted percentage of their accidents caused by inattention (35.8 percent), than did any of the other age subgroups examined.

Examined row-wise, Table 6-15 identifies driver subgroups most involved in accidents caused by each of the six major causal factors, i.e., identifies driver subgroups to which greatest attention should be paid with regard to each causal factor. From this point of view, the subgroup constituting the greatest *problem* in inattention-caused accidents was housewives, whose adjusted causal-factor involvement frequency is 56.0 percent. Similarly, the greatest *problem group* for improper lookout was drivers 65 years old or older (56.9 percent); for view obstructions, drivers with considerable vehicle familiarity—5 years or more in the accident vehicle (38.0 percent); for excessive speed, drivers in semi-skilled occupations (66.3 percent); for false assumption, drivers with 3-4 years' vehicle familiarity (74.7 percent); and for improper evasive action, drivers with recent yearly mileages of 21,000-25,999 miles.

Viewed columnwise, the same table gives a picture of particular driver subgroups within each characteristic (age, sex, and so on) showing up most frequently as *problematic* across the six major accident causes. With regard to age, 55-64 year old drivers presented the greatest *problem* for four out of the six causal factors; this age subgroup may thus be worthy of considerable attention in human-factor accidents. Note also that the age subgroup most problematic with regard to the fifth factor, improper lookout, was drivers 65 and over, who also had the highest adjusted frequency for any age group with regard to that causal factor (56.9 percent). As might be anticipated, the age group most involved in accidents caused by

Table 6-15

Summary of Driver Subgroups Showing Highest Adjusted Causal Factor Frequencies, for General Accidents

Causal Factor	Driver Characteristic									
	Age	Sex	Marital Status	Educational Level	Family Income	Occupation	Driving Exper. (Years)	Recent Yearly Mileage	Vehicle Familiarity(Years)	Driver Training
Inattention	55-64 (35.8)	Male (18.8)	Married (33.9)	College Grad.+ (33.4)	$15,000+ (42.9)	Housewife (56.0)	30-39 (32.8)	31,000+ (33.3)	1-2 (27.6)	Not Taken (22.0)
Improper Lookout	65+ (56.9)	Female (23.2)	Single (15.9)	College Grad.+ (58.3)	$15,000+ (21.4)	Professional (50.1)	20-29 (51.5)	6-10,999 (36.4)	3-4 (34.5)	Not Taken (14.9)
View Obstructions	55-64 (27.1)	Female (19.7)	Married (17.3)	Attended College (23.8)	Under $6,000 (15.3)	White Collar (23.4)	20-29 (19.8)	6-10,999 (22.8)	5+ (38.0)	Not Taken (14.9)
Excessive Speed	Under 20 (40.9)	Male (18.6)	Single (32.6)	Less Than H.S. Grad. (40.0)	$6-14,999 (23.6)	Semi-Skilled (66.3)	Under 5 (20.9)	16-20,999 (27.3)	½ - 1 (21.8)	Not Taken (22.0)
False Assumption	55-64 (17.0)	Female (17.9)	Married (9.8)	College Grad.+ (28.7)	$6-14,999 (18.2)	Skilled (18.8)	20-29 (33.0)	26-30,999 (23.1)	3-4 (74.7)	Taken (9.2)
Improper Evasive Action	55-64 (27.4)	Female (13.4)	Single (11.3)	Attended College (18.5)	$15,000+ (16.4)	Skilled (18.8)	30-39 (17.8)	21-25,999 (33.7)	2-3 (26.4)	Taken (13.8)

excessive speed was instead those 20 or younger, with the next-highest involvement frequency (40.9 percent).

Continuing through the table columnwise, *problematic* driver subgroups include females, those who have attended or graduated from college, and those who have not taken driver training. No subgroup stands out clearly (across all causal factors) for marital status, family income, occupation, recent yearly mileage, and vehicle familiarity. With regard to driving experience in years, those driving 20-29 years stood out for three of the six causal factors, 30-39 years for two factors, and under 5 years for one factor (excessive speed).

Considering the table as a whole, the most *problematic* driver subgroup-causal factor combinations were those with 3-4 years' vehicle familiarity in false assumption accidents (74.7 percent), those in semi-skilled occupations in excessive speed accidents (66.3 percent), those with college or higher educations in improper lookout accidents (58.3 percent), and so on. At the lower end of the *problematic* scale were, for example, single drivers in improper evasive action accidents (11.3 percent), married drivers in false assumption accidents (9.8 percent), and finally, drivers who had taken driver training in false assumption accidents (9.2 percent).

6.4 Discussion

The large number of individual findings presented in this section, together with the cluster analysis findings presented in Section 5.3, are intended to provide complementary glimpses at the answers to a now-familiar set of questions. Is there a *problem driver?* Who is the *problem driver?* How does the alcohol-accident driver differ from the general-accident driver and the non-alcohol driver? At the broadest level, what kinds of drivers have what kinds of accidents in what kinds of vehicles under what kinds of circumstances, and for what kinds of reasons?

It is of little use to reiterate in detail at this point the many (and predictable) problems of design, sample size, analysis techniques, etc., encountered in IRPS' initial efforts to answer these questions. What is needed instead is some attempt to pull together the findings resulting from these different analysis techniques into some reasonably coherent picture. In this way, initial, tentative answers may be gleaned, and needed countermeasures identified where it is possible to do so.

Table 6-16 presents such an attempt. It summarizes *problem* human, vehicular, environmental, and causal characteristics of general and of alcohol-implicated accidents, comparing top-level findings of the cluster analysis and of the involvement-ratio analysis sections of the present report. Under each of the *cluster analysis* columns, characteristics listed are those most likely to be copresent within individual accidents (see discussion in Section 5.1). Under the *involvement-ratio analysis* columns of the table, characteristics listed are not known to be copresent; instead, they are known to occur with inordinate frequency, and to be overrepresented in accidents, whether or not they actually are copresent in particular, individual accidents.

Table 6-16

Summary of "Problem" Human, Vehicular, Environmental and Causal Characteristics in General- and Alcohol-Implicated Accidents

Comparison Variable	General Accidents		Alcohol-Implicated Accidents	
	Cluster Analysis	Involvement-Ratio Analysis	Cluster Analysis	Involvement-Ratio Analysis
Driver Age	16-24	20-24	25+	33-44
Driver Sex	Male	Male	Male	Male
Most Recent Yearly Mileage	([1])	31,000+	>12,000	31,000+
Vehicle Familiarity	([1])	2-3 Years	≤1 Year (??)	2-3 Years
Driver Physical Limitation	None	(-)	([1])	(-)
Route Familiarity	Daily On Road (??)	(-)	Not Daily On Road	(-)
Driving Experience	≤7½ Years	≤5 Years	>7½ Years	20-29 Years
Vehicle Model Year	1968 Or Newer	1970	1967 Or Older	1962 Or Older
Odometer Mileage	([1])	(-)	> 42,911	(-)
Light Condition	Daylight	(-)	Darkness/Dawn/ Dusk	(-)
Visibility	Clear	(-)	Clear	(-)
Traffic Volume	Moderate/Heavy	(-)	Light	(-)
Road Surface Condition	Dry	(-)	Dry	(-)
Accident Cause	Improper Lookout	Improper Lookout([2])	Excessive Speed (??) Performance Error (??)	Excessive Speed ([2])
Accident Type	Side Impact	(-)	Ran Off Road	(-)
Accident Severity	Property Damage	(-)	PI/Fatal	(-)
Marital Status	(-)	Divorced	(-)	Separated

Table 6-16 continued

Comparison Variable	General Accidents		Alcohol-Implicated Accidents	
	Cluster Analysis	Involvement-Ratio Analysis	Cluster Analysis	Involvement-Ratio Analysis
Education	(-)	<High School Graduate	(-)	Voc./Tech. H.S. Graduate
Family Income	(-)	$6-7,999	(-)	$3-5,999
Major Occupation	(-)	Laborer	(-)	Laborer
Driver Training	(-)	Completed	(-)	Completed

(-) = Comparison Not Possible
(¹) = No Characteristic Clearly Identified
(²) = Based Upon Involvement Frequency, Rather Than Involvement Ratio

Nevertheless, Table 6-16 shows that top-level findings under both analysis techniques are highly similar; that insofar as comparisons of findings are possible, a similar *portrait* emerges. Clearly, the *problem driver* in *general* accidents may be a young male with relatively little driving experience and no license restrictions, driving a relatively new vehicle under clear, dry, daylight conditions in moderate to heavy traffic. He may have driven this vehicle from two to three years, and may drive it quite a lot, with high yearly mileage. This same *problem driver* may also be divorced, and in the lower educational and socioeconomic strata. His accident is likely to be one involving side impact, resulting in property damage only, and caused by improper lookout.

If there is a *problem driver* in *alcohol-implicated* accidents, he is an older male with much driving experience, driving an older vehicle under clear, dry, nighttime conditions in light traffic. He may have driven his vehicle from one to three years, may also have high yearly mileage, and his vehicle may have high odometer mileage. This same alcohol-accident *problem driver* may also be separated from his spouse, and in the lower educational and socioeconomic strata. His accident is likely to be one in which he ran off the road, resulting in a personal injury or fatality, and caused by excessive speed or performance error. Like his general-accident counterpart, he is likely to have completed a driver training course. Unlike the other, he is likely to be relatively unfamiliar with the road upon which he had the accident.

These two portraits—of the general-accident and of the alcohol-accident *problem driver*—may also be considered portraits of two types of *problem accident*. If substantiated through further study and analysis, they may well serve as a basis for targeting two types of driver-vehicle-circumstance-cause configurations worthy of independent sets of safety countermeasures.

7.0 Assessment of the Representativeness of Study Samples

7.1 Introduction

Throughout the study, emphasis was placed on obtaining representative study samples. In this section, the accidents investigated on Levels B (on-site) and C (in-depth) during Phase III are compared with all driver- and police-reported accidents (i.e., Level A or baseline accidents) occurring in Monroe County, Indiana, during the same period. Also, data on the Monroe County study area are compared with national data, thus permitting an assessment of the extent to which study findings can be generalized to the nation.

In determining the representativeness of the driver, accident, vehicle, and roadway samples obtained during Phase III, it is necessary to answer four types of questions. Each question set below uses common variables to compare the on-site and in-depth accident samples with Monroe County accidents, Monroe County accidents with accidents in the nation, and Monroe County drivers, vehicles, and environmental conditions with those of the nation. These four sets of related questions are:

1. Were drivers, vehicles, and roadways in Monroe County generally representative of those in the nation? (Tables 7-3 to 7-7)
2. Were *accident-involved* drivers and vehicles, accident types, conditions, and locations in *Monroe County* representative of those in the nation? (Tables 7-8 to 7-15)
3. Were *accident-involved* drivers and vehicles, accident types, conditions and locations, sampled for *on-site* investigation representative of those in Monroe County? (Tables 7-16 to 7-23)
4. Were *accident-involved* drivers and vehicles, accident types, conditions and locations sampled for *in-depth* investigation representative of those in Monroe County? (Tables 7-16 to 7-23)

7.2 Methodology

Figures for 1972 national driver, accident, vehicle, and roadway characteristics were drawn from U.S. government publications, R.L. Polk and Company, and the National Accident Summary File. These same characteristics for Monroe County, Indiana, were taken from the Indiana State Highway Commission, R.L. Polk and Company, a sample of age and sex of drivers registered at the Monroe County License Branch, and statistics extracted by IRPS from the 1972 Indiana State Police computer tape of accident reports. Statistics pertaining to the IRPS on-site and in-depth accident samples were extracted by specially written computer programs from the Phase III data files.

In comparisons of the representativeness of on-site and in-depth accidents with those in Monroe County (Tables 7-16 to 7-23), a chi-square statistic was used. For each table, a theoretical (baseline) distribution for Monroe County was extracted from data on all 1972 driver- and police-reported Monroe County accidents, as represented on the 1972 Indiana State Police computer tape of accident reports. The number of on-site or in-depth investigated accidents falling into each category was compared with the number of accidents falling into that category in the baseline distribution. Differences between *observed* (on-site or in-depth) *frequencies* and *expected* (baseline) *frequencies* were summed across all categories to produce the chi-square statistic.

7.3 Results

Summary Table 7-1 shows the table numbers encompassing the representativeness comparisons, and Summary Table 7-2 summarizes corresponding findings drawn from these tables, highlighting only those percentage differences found to be equal to or greater than five percent. It can be seen from this table that some of the comparisons are not applicable, and that for others data were not available for performing certain of the comparisons.

7.3.1 General County Representativeness

With respect to *driver sex,* Table 7-3 shows little difference between Monroe County and U.S. drivers. There were 0.8 percent fewer female drivers in Monroe County than in the national driving population.

With respect to *driver age,* it can be seen from Table 7-4 that Monroe County differed in several age categories from those in the nation as a whole. This difference is most notable for drivers in the 20-24 year old age bracket, which accounted for 23.4 percent of county drivers, but only 11.3 percent of U.S. drivers. The next most notable difference is in the 45-54 year old age category, in which the county was underrepresented, having 11.3 percent of the licensed drivers, as opposed to 18.5 percent in the nation. This underrepresentation of the county occurred for all the higher age brackets, beginning with the bracket for drivers 35-44 years old, and probably results from the overrepresentation of younger drivers.

With respect to *vehicle make,* Table 7-5 shows fairly close agreement between county and national distributions. The largest difference observed is 3.6 percent more Chevrolets in the U.S. vehicle population than in Monroe County.

With respect to *vehicle model year,* Table 7-6 illustrates close agreement between county and national vehicle populations, with a maximum difference of only 1.0 percent in the 1972 category.

With respect to street mileage by *systems and type of road surface,* Table 7-7 shows fairly close agreement between percentages of urban vs. rural roads in the county vs. the nation. A large difference occurred, however, with respect to surfaced rural roads; 20.1 percent (difference obtained by subtraction) more county rural roads were surfaced than were rural roads in the nation. Accordingly, Monroe County is underrepresented with respect to

Summary Table 7-1

Comparisons of Accident Sample, Local, and National Sampling Population Characteristics (Table Nos.)

Comparison Variable	County vs. National (Non-Accident Data)	County vs. National (Accidents)	On-Site and In-Depth vs. County (Accidents)
Driver Sex	Table 7-3	Table 7-8	Table 7-16
Driver Age	Table 7-4	Table 7-9	Table 7-17
Vehicle Make	Table 7-5	1	1
Vehicle Model Year	Table 7-6	1	1
Vehicle Type	1	Table 7-10	Table 7-18
System and Type of Road Surface	Table 7-7	3	3
Road Surface Condition	2	Table 7-11	Table 7-19
Urban vs. Rural Accident Location	2	Table 7-12	Table 7-20
Accident Light Condition	2	Table 7-13	Table 7-21
Type of Accident	2	Table 7-14	Table 7-22
Accident Severity	2	Table 7-15	Table 7-23

1 = Data not Available

2 = Not Applicable

3 = Units of Measurement not Compatible

Summary Table 7-2

Comparisons of Accident Sample, Local, and National Sampling Population Characteristics (Findings)

Comparison Variable	County vs. National (Non-Accident Data)	County vs. National (Accidents)	On-Site and In-Depth vs. County (Accidents)
	Largest Subgroup % Difference[1]		
Driver Sex	(-)	(-)	5.97% More Accidents with Female Drivers in On-Site Sample than in County**
Driver Age	12.1% More Drivers Age 20-24 in County	11.0% More Drivers Age 20-24 in County	(-)
Vehicle Make	(-)	1	1
Vehicle Model Year	(-)	1	1
Vehicle Type	1	(-)	2.1% More Passenger Vehicle Accidents in On-Site Sample Than in County*
System and Type of Road Surface	20.1% More Miles Rural Surfaced Road in County	3	3
Road Surface Condition	2	(-)	11.1% More Accidents on Dry Roads in On-Site Sample Than in County***
Urban vs. Rural Accident Location	2	(-)	(-)
Accident Light Condition	2	5.6% More Daylight Accidents in County	16.9% More Daylight Accidents in In-Depth Sample Than in County*
Type of Accident	2	9.7% More Collisions with Other Motor Vehicles in County	16.3% More "Ran Off Road" Accidents in In-Depth Sample Than in County**

Summary Table 7-2 continued

Comparison Variable	Largest Subgroup % Difference[1]: County vs. National (Non-Accident Data)	County vs. National (Accidents)	On-Site and In-Depth vs. County Accidents
Accident Severity	2	16.0% More Property Damage Accidents in County	16.9% More Property Damage Accidents in County Than in In-Depth Sample***

1 = Data Not Available

2 = Not Applicable

3 = Unit of Measurement Not Compatible

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

[1]Only Percentage Differences of 5% or Greater Reported; Where x^2 Test Performed, Only Largest Statistically Significant Percentage Difference Reported.

nonsurfaced rural roads, the nation having 17.7 percent more nonsurfaced rural roads than Monroe County. Another difference worth noting, though not apparent from Table 7-7, is that during the period of the study, Monroe County had no Interstate Highways or expressways.

7.3.2 Representativeness of Monroe County Accidents

With respect to *driver sex,* Table 7-8 shows little difference between Monroe County accident-involved drivers and those in the nation. There were only about 3.6 percent more female accident-involved drivers in Monroe County than in the nation.

With respect to *driver age,* it can be seen from Table 7-9 that there were 11.0 percent more accident-involved drivers aged 20-24 in Monroe County than in the nation. It is also clear that for each age bracket above 25-34 years old, there tended to be more accident-involved drivers in the U.S. than in Monroe County.

With respect to *vehicle type,* (Table 7-10), there is quite close agreement between Monroe County and U.S. accident-involved vehicles, with a maximum difference of 1.1 percent more *other vehicles* accident-involved in the nation than in the county.

With respect to *road surface condition,* Table 7-11 demonstrates fairly close agreement between Monroe County and U.S. accident conditions, with a maximum difference of 4.6 percent more accidents occurring under wet road surface conditions locally than nationally.

Table 7-3

Comparison of Monroe County with National Licensed Drivers by Driver Sex

Sex	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Male	573	57.3	64,400,000	56.5
Female	427	42.7	49,600,000	43.5
Total	1,000	100.0	114,000,000	100.0

Sources: Monroe County—Sample taken from Monroe County License Branch, 1972 Applications; U. S.—*Accident Facts, 1972 Edition.*

With respect to *urban versus rural accident location,* Table 7-12 shows that only 2.6 percent more accidents occurred in rural areas in Monroe County than in rural areas in the nation as a whole.

With respect to *accident light condition,* Table 7-13 indicates moderate agreement between categories, with 5.6 percent more daylight accidents occurring locally than nationally.

With respect to *type of accident,* Table 7-14 shows that collisions with other motor vehicles were 9.7 percent higher locally, and collisions with nonmotor vehicles 4.0 percent lower locally than nationally. Monroe County was also 3.0 percent underrepresented in collisions with fixed objects, and 2.0 percent underrepresented in collisions involving objects or animals. Other categories show close agreement between types of accidents happening locally and nationally.

With respect to *accident severity,* Table 7-15 shows a fairly large discrepancy between personal injury and property damage accidents locally versus nationally. Monroe County was overrepresented by 16.0 percent with respect to property damage accidents, and underrepresented by 15.7 percent on personal injury accidents when compared to accidents in the nation. The proportion of fatal accidents was comparable in the county and the nation.

7.3.3 Representativeness of On-Site and In-Depth Accidents

With respect to *driver sex,* the proportion of female drivers in the accidents investigated by the on-site team (36.9 percent) exceeds that of the county baseline for female drivers in accidents (31.0 percent). This difference, 5.9 percent, is statistically significant. The disparity in proportion of female drivers is much less (0.5 percent) in the in-depth sample, and this difference is not statistically significant. These distributions are shown in Table 7-16.

With respect to *driver age* (Table 7-17), although both the on-site and the in-depth

Table 7-4

Comparison of Monroe County with National Licensed Drivers by Age

Age	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
< 20	157	15.7	11,700,000	10.3
20—24	234	23.4	12,900,000	11.3
25—34	257	25.7	22,500,000	19.7
35—44	128	12.8	22,200,000	19.5
45—54	113	11.3	21,100,000	18.5
55—64	72	7.2	13,800,000	12.1
65 and Over	39	3.9	9,800,000	8.6
Total	1000	100.0	114,000,000	100.0

Sources: Monroe County—Sample taken from Monroe County License Branch, 1972 Applications; U. S.—*Accident Facts, 1972 Edition.*

distributions show minor deviations from the corresponding baseline categories, the differences are not statistically significant.

Regarding *vehicle type,* Table 7-18 shows that the on-site sample significantly differs from the Monroe County baseline, whereas the in-depth sample does not. The on-site sample contains 2.1 percent more passenger vehicle accidents than the Monroe County baseline distribution, 0.9 percent fewer truck accidents, and 1.1 percent fewer motorcycle accidents.*

With respect to *road surface condition,* Table 7-19 indicates that the on-site sample differs significantly from the Monroe County distribution of accidents by road surface condition, while the in-depth sample does not. In the on-site sample, there were 11.1 percent more accidents occurring on dry roads than in the county, 3.9 percent fewer accidents occurring on wet roads, and 7.2 percent fewer accidents occurring on snowy or icy roads.

Regarding *urban versus rural accident location,* Table 7-20 shows no statistically significant differences between the on-site or in-depth sample and the Monroe County baseline, despite the fact that there were 6.1 percent more rural accidents in the in-depth sample than in the county.

*Contract requirements excluded accidents involving motorcycles, vehicles weighing over 8000 lbs. GVW, and vehicles pulling trailers.

Table 7-5

Comparison of Monroe County with National Vehicle Populations by Make (1972)[1]

Make	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Chevrolet	6,093	21.0	21,113,066	24.4
Ford	5,541	19.1	17,417,398	20.1
Oldsmobile	2,797	9.6	5.519,811	6.4
Buick	2,175	7.5	5,594,806	6.5
Pontiac	2,032	7.0	6,746,178	7.8
Plymouth	1,607	5.5	5,795,058	6.7
Mercury	1,575	5.4	3,182,538	3.7
Dodge	1,574	5.4	4,717,514	5.5
American Motors	546	1.9	2,795,503	3.2
Cadillac	477	1.6	2,077,677	2.4
Chrysler	420	1.5	1,765,585	2.0
Lincoln	172	.6	499,405	.6
Imperial	45	.2	153,608	.2
Studebaker	43	.2	159,930	.2
Desoto	8	.0	39,958	.0
Miscellaneous	3,917	13.5	8,860,922	10.3
Total	29,022	100.0	86,438,957	100.0

Source: Monroe County—R. L. Polk and Company; U. S.—R. L. Polk and Company.

[1]Passenger Cars in Operation as of July 1, 1972.

Table 7-6

Comparison of Monroe County with National Vehicle Populations by Model Year (1972)[1]

Model Year	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
1972	2,683	9.3	7,168,762	8.3
1971	3,114	10.7	8,914,629	10.3
1970	2,914	10.0	8,850,619	10.2
1969	3,123	10.8	9,122,040	10.6
1968	3,038	10.5	8,595,562	9.9
1967	2,730	9.4	7,498,740	8.7
1966	2,789	9.6	7,930,415	9.2
1965	2,558	8.8	7,583,223	8.8
1964	2,033	7.0	5,920,108	6.9
1963	1,601	5.5	4,713,426	5.5
1962	963	3.3	3,343,015	3.9
1961	469	1.6	1,823,892	2.1
1960	343	1.2	1,413,196	1.6
1959	162	0.6	805,358	0.9
1958	64	0.2	389,291	0.4
1957	93	0.3	526,483	0.6
Prior to 1957	345	1.2	1,813,062	2.1
Total	29,022	100.0	86,411,821	100.0

Source: Monroe County—R. L. and Company; U. S.—R. L. Polk and Company.

[1]Passenger cars in operation as of July 1, 1972.

Table 7-7

Comparison of Monroe County with National Road and Street Mileage by System and Type of Surface

System and Type of Surface	Monroe County (1968)		U. S. (1971)	
	Mileage	% of Total	Mileage	% of Total
A. Rural	750.2	86.6	3,165,895	84.2
1. Non-Surfaced	19.6	2.3	750,017	20.0
2. Surfaced	730.6	84.3	2,415,878	64.2
B. Municipal	116.4	13.4	593,047	15.8
1. Non-Surfaced	5.2	0.6	25,853	0.7
2. Surfaced	111.2	12.8	567,194	15.1
Total	866.6	100.0	3,758,942	100.0

Sources: Monroe County—Indiana State Highway Commission (Planning Division), 1968 Road Inventory; U. S.—Highway Statistics, 1971.

Table 7-8

Comparison of Monroe County with National Accident-Involved Driver Populations, by Driver Sex

Sex	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Male	3,977	69.0	1,921,624	72.6
Female	1,790	31.0	726,743	27.4
Total	5,767	100.0	2,648,367	100.0

Sources: Monroe County—Indiana State Police Statistics, 1972; U.S.—National Accident Summary File, 1972 Statistics.

Table 7-9

Comparison of Monroe County with National Accident-Involved Driver Populations, by Driver Age (1972)

Age of Driver	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Under 20	979	18.2	529,271	19.9
20—24	1,534	28.6	466,650	17.6
25—34	1,215	22.6	556,294	21.0
35—44	623	11.6	375,346	14.1
45—54	496	9.2	331,457	12.5
55—64	298	5.6	219,046	8.3
Over 64	225	4.2	175,897	6.6
Total	5,370	100.0	2,653,961	100.0

Age: The age of individual concerned is the number of whole years between birth and the accident. Age is often not shown in the source documents but derived by subtracting the reported date of birth from the date of the accident. Exceptions are pedestrians, pedalcyclists, and other cases in which the age is obtained from the individual or by estimation.

Sources: Monroe County—Indiana State Police Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

Table 7-10

Comparison of Monroe County with National Accident-Involved Vehicle Populations by Vehicle Type (1972)

Vehicle Type	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Passenger Vehicle	5,301	87.6	2,365,049	87.2
Truck	652	10.8	269,356	9.9
Bus	19	0.3	14,172	0.5
Motorcycle	68	1.1	28,910	1.1
Other Vehicle	10	0.2	34,913	1.3
Total	6,050	100.0	2,712,400	100.0

Passenger Vehicle: Any motor vehicle primarily intended for the transport of passengers but generally having no more than nine (9) seats, commonly referred to as a passenger car. Passenger vehicles include: Station wagon, taxicab, hearse, ambulance, and police patrol car. Over-the-road recreational vehicles such as campers or motor homes (as distinguished from off-road, e.g., snowmobiles, swamp buggies, or all-terrain-vehicles) are predominantly registered as passenger vehicles, although many are built on truck chassis, or represent bus or van-type truck conversions. Over-the-road recreational vehicles should be coded as passenger vehicles.

Truck: A motor vehicle primarily intended for the transport of cargo or special equipment, and will generally be so defined by applicable motor vehicle registration laws. Truck includes truck tractors with or without trailer, and motorized fire apparatus.

Bus: A motor vehicle built for the transport of usually at least ten (10) persons, including the driver. All school buses are included in this category as are electric trolley buses which do not operate on rolls.

Motorcycle: A two-wheeled motor vehicle having one or more riding saddles, and sometimes a third wheel for the support of a sidecar. The sidecar is considered a part of the motorcycle. Motorcycle includes motorized bicycle, scooter, or bicycle.

Other Vehicle: Any road vehicle not defined as passenger vehicle, truck, bus or motorcycle, other motor vehicles, and, nonroad vehicles such as railway trains or vehicles but not aircraft or watercraft.

Sources: Monroe County—Indiana State Police Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

Table 7-11

Comparison of Monroe County with National Accidents by Road Surface Condition (1972)

Condition of Road Surface	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Dry	2,029	62.0	943,620	61.3
Wet	853	26.1	331,498	21.5
Snowy or Icy	236	7.2	128,163	8.3
Other Condition or Not Stated	154	4.7	136,354	8.9
Total	3,272	100.0	1,539,635	100.0

Dry: A road free of water or any other form of precipitation (maximum adhesion for a given tire).

Wet: A road has water on its surface, but is neither snowy nor icy.

Snowy or Icy: A road has snowfall precipitation or slush, or ice from freezing dew or rain, melting and refreezing snow (including hail), or both, on its surface.

Other Condition or Not Stated: Includes oily, muddy, slippery surfaces, and new road surfaces that have not hardened.

Sources: Monroe County—Indiana State Police Accident Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

Table 7-12

Comparison of Monroe County with National Accidents by Urban and Rural Places (1972)

Place of Occurrence	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Urban Area	2,068	63.2	1,013,653	65.8
Rural Area	1,204	36.8	525,982	34.2
Total	3,272	100.0	1,539,635	100.0

Urban Area: An area including and adjacent to a municipality or other known place of 5,000 or more population, as shown by the latest Federal census, whose boundaries shall be those fixed by the state highway departments, subject to approval of the U. S. Department of Transportation.

Rural Area: Any area that does not meet the specifications for an urban area.

Sources: Monroe County—Indiana State Police Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

With respect to *accident light condition*, it can be seen in Table 7-21 that both the on-site and in-depth samples are significantly different from the Monroe County baseline. The on-site sample had 12.4 percent more daylight accidents than occurred in the county, and the in-depth sample 16.9 percent more. The on-site sample had 2.5 percent fewer and the in-depth sample 3.0 percent fewer dawn or dusk accidents than the county. Also, the on-site sample is underrepresented by 9.9 percent and the in-depth sample by 13.9 percent with respect to accidents occurring in darkness. In general, it can be observed that the percentage discrepancies from the baseline distribution are greater for the in-depth sample, although the level of statistical difference is greater for the on-site sample. This situation is an artifact of relative sample size.

With respect to *type of accident*, Table 7-22 shows that both the on-site and in-depth samples differed significantly from the baseline distribution of type of accident. For the on-site sample the largest discrepancy is a 5.0 percent underrepresentation of collisions involving another object or animal, whereas for the in-depth sample, the largest disparity is a 16.3 percent overrepresentation of *ran off the road* accidents as compared to the Monroe County baseline. Other minor differences appear in both samples. It is worth noting that the in-depth sample contains no cases of collision with a pedestrian.

Table 7-13

Comparison of Monroe County with National Accidents by Light Conditions (1972)

Light Conditions	Monroe County		U. S. (1972)	
	N	%	N	%
Daylight	2,161	68.8	956,803	63.2
Dawn or Dusk	144	4.6	68,924	4.6
Darkness	835	26.6	487,889	32.2
Total	3,140	100.0	1,513,616	100.0

Daylight: The light level between sunrise and sunset. Accidents on roadways with permanent illumination at levels such that headlights need not be used, as in many urban tunnels, should be coded as "daylight" accidents..

Dawn or Dusk: The ambient light level for the hour before sunrise, and the hour after sunset, respectively.

Darkness: The ambient light level between dusk and dawn. Roads may or may not be illuminated by streetlights. Headlights are normally required for visibility during darkness.

Sources: Monroe County—Indiana State Police Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

With respect to *accident severity*, Table 7-23 indicated that both accident samples differ significantly from the distribution of accident severity in Monroe County. The in-depth sample contains 5.8 percent more fatal accidents than the Monroe County baseline, and both the on-site and in-depth samples are overrepresented on personal injury accidents (4.5 and 10.9 percent, respectively). Property damage accidents were 5.8 percent underrepresented in the on-site sample, and 16.9 percent underrepresented in the in-depth sample.

7.4 Discussion

The *sex* distribution for both general and accident population Monroe County drivers, and for drivers in the in-depth accident sample, differed only slightly from corresponding national distribution. However, female drivers were significantly overrepresented in the on-site sample (see Table 7-24). This finding is similar to last year's, except that last year, there was a slight

Table 7-14

Comparison of Monroe County with National Accidents by Type of Accident (1972)

Type of Accident	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Collision with Pedestrian	30	0.9	44,474	2.9
Collision with Non-Motor Vehicle	26	0.8	74,410	4.8
Collision with Fixed Object	199	6.1	140,019	9.1
Other Noncollision Running Off Road	351	10.7	137,921	9.0
Noncollision, Overturning	21	0.7	17,620	1.1
Collision Involving Other Object or Animal	243	7.4	145,098	9.4
Collision with Other Motor Vehicle(s)	2,402	73.4	980,093	63.7
Total	3,272	100.0	1,539,635	100.0

Collision with Pedestrian: Any accident involving a motor vehicle in transport and a pedestrian.

Collision with Nonmotor Vehicle(s): Any accident involving a motor vehicle in transport and a nonmotor vehicle.

Collision with Fixed Object: Any accident involving a motor vehicle in transport and a fixed object.

Other Noncollision Accident: Any accident involving motor vehicle in transport, other than running off road, overturning, and collision.

Running Off Road: A motor vehicle in transport leaves the roadway without colliding with any person, object, or vehicle on the roadway, but in such a way as to produce injury or damage.

Noncollision, Overturning: Any accident in which a motor vehicle in transport overturns for any reason except where overturning is result of collision.

Collision Involving Other Object or Animal: Any accident involving a motor vehicle in transport and any other object which is moveable or moving, but not fixed, or an animal herded or unattended.

Collision with Other Motor Vehicle(s): Any accident involving at least two motor vehicles upon the same roadway or upon roadways within an intersection.

Sources: Monroe County—Indiana State Police Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

Table 7-15

Comparison of Monroe County with National Accidents by Severity of Accident

Severity	Monroe County (1972)		U. S. (1972)	
	N	%	N	%
Fatality	15	0.5	12,146	0.8
Personal Injury	679	20.7	559,820	36.4
Property Damage	2,578	78.8	967,669	62.8
Total	3,272	100.0	1,539,635	100.0

Fatal Accident: Any motor vehicle or other road vehicle accident that results in fatal injuries to one or more persons.

Nonfatal Injury Accident: Any motor vehicle or other road vehicle accident, other than a fatal accident, that results in injuries, other than fatal, to one or more persons.

Property Damage (Noninjury) Accident: Any motor vehicle accident in which there is no injury to any person, but only reported damage to a motor vehicle or other road vehicle or to other property, including injury to domestic animals. (The legal requirements for reporting of property damage (noninjury) accidents vary among States from necessity for towing one vehicle from the scene to damage amounts ranging from $500 to $25.)

Sources: Monroe County—Indiana State Police Accident Statistics, 1972; U. S.—National Accident Summary File, 1972 Statistics.

Table 7-16

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Driver Sex

Sex	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Male	333	63.1	73	69.5	3977	69.0
Female	195	36.9	32	30.5	1790	31.0
Total	528	100.0	105	100.0	5767	100.0
d.f. = 1 Chi-Square	8.57**		.02 NS			

* = p≤.05
** = p≤.01
*** = p≤.001
NS Not Significant

(though statistically nonsignificant) tendency for females to also be overrepresented in the in-depth sample. Again this year, it is reasoned that females might be more susceptible to providing the cooperation required by the accident investigation process.

As in the past, Monroe County continues to have more younger drivers (and proportionally fewer older drivers) in both its general and accident populations than does the nation. However, Monroe County young drivers are overrepresented less in the accident population than are young drivers nationally (especially in the under 20 year old age bracket), so that the disparity is much more apparent in the general than in the accident populations. Age distributions in both the on-site and in-depth samples are similar to those for all county accidents, and hence overrepresent young drivers as compared to the nation. The over-representation of young drivers is for the most part believed to reflect the presence of Indiana University, with a student enrollment of about 30,000.

Both *vehicle model year* and *make* distributions are about as close to national distributions as could be hoped for, so that vehicle cause findings can be generalized to the nation with a high level of confidence.

With regard to *vehicle type*, the county, national, on-site, and in-depth accident distributions are quite similar. This is despite the fact that study criteria have excluded vehicles pulling trailers and those weighing in excess of 8000 lbs. GVW. The percentage of trucks in the on-site and in-depth samples is only slightly (less than 1 percent) below that for the county,

Table 7-17

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Driver Age

Driver Age	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Under 20	97	18.5	25	24.0	979	18.2
20—24	155	29.6	25	24.0	1534	28.6
25—34	104	19.8	24	23.1	1215	22.6
35—44	59	11.3	5	4.8	623	11.6
45—54	43	8.2	13	12.5	496	9.2
55—64	33	6.3	6	5.8	298	5.5
Over 64	33	6.3	6	5.8	225	4.2
Total	524	100.0	104	100.0	5370	100.0
d.f. = 6 Chi-Square	8.74 NS		8.64 NS			

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

Table 7-18

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Vehicle Type

Vehicle Type	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Passenger Vehicle	479	89.7	94	88.7	5301	87.6
Truck	53	9.9	11	10.4	652	10.8
Bus	0	0.0	0	0.0	19	.3
Motorcycle	0	0.0	0	0.0	68	1.1
Other Vehicle	2	.4	1	.9	10	.2
Total	534	100.0	106	100.0	6050	100.0
d.f. = 4 Chi-Square	9.72*		5.44 NS			

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

indicating that trucks which are involved in accidents generally weigh less than 8000 lbs. GVW, and hence generally fall within study criteria. Vehicle type criteria thus probably do not prevent the generalization of study findings to all accidents, and a reasonable estimate of the distribution of causal factors uniquely associated with trucks (if any) would be possible if a significant number of these accidents could be selected. The altering of project criteria to include large trucks, etc., does not appear necessary to this study, given its general focus.

With regard to urban/rural breakdowns for both road system and accident location, Monroe County differs only slightly from national distributions, which is very much a positive factor in the use of Monroe County as an accident laboratory. However, a greater portion of county than national roads are paved, so that it is assumed that factors uniquely associated with unpaved rural roads may be underrepresented in study findings.

There was a slight, though statistically insignificant tendency for rural accidents to be overrepresented in the in-depth sample, and underrepresented in the on-site sample. This differs from Phase II experience, where on-site also overrepresented rural accidents, although not as greatly as did in-depth. There are a number of factors which are known to influence these

Table 7-19

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Road Surface Condition

Road Surface Conditions	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Dry	214	76.2	41	67.2	2029	65.1
Wet	66	23.5	19	31.1	853	27.4
Snowy or Icy	1	.4	1	1.6	236	7.6
Total	281	100.0	61	100.0	3118	100.0
d.f. = 2 Chi-Square	26.16***		3.20 NS			

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

Table 7-20

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Urban and Rural Places

Urban and Rural Places	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Rural Area	91	31.5	27	42.9	1204	36.8
Urban Area	198	68.5	36	57.1	2068	63.2
Total	289	100.0	63	100.0	3272	100.0
d.f. = 1 Chi-Square	3.50 NS		.99 NS			

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

Table 7-21

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Light Condition

Light Condition	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Daylight	229	81.2	54	85.7	2161	68.8
Dawn or Dusk	6	2.1	1	1.6	144	4.6
Darkness	47	16.7	8	12.7	835	26.6
Total	282	100.0	63	100.0	3140	100.0
d.f. = 2 Chi-Square	20.45***		8.42*			

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

distributions, although none is clearly responsible, and of course the differences may have resulted merely as a matter of chance. The tendency toward overrepresentation of rural accidents in the in-depth sample may result because driver cooperation factors overrepresent *single-vehicle-run-off-road* accidents in this sample, and these are predominantly rural.

The in-depth, Monroe County, and national distributions for *road surface condition* are very close for both dry and snowy or icy categories. And while Monroe County appears to have a 4.6 percent overrepresentation of wet roads, this is difficult to assess because the national figure for "other or not stated" is so large (8.9 percent), and nearly twice that stated for Monroe County. It is clear, however, that the on-site teams have tended to over-sample accidents occurring on dry roads. This has probably resulted because accidents occurring on wet roads tend to cluster together only a few minutes apart, so that a single investigating team is able to investigate only a small number (perhaps one) from each cluster. This same tendency was apparent in Phase II, although not statistically significant.

With respect to *accident light condition,* daylight accidents are overrepresented and night underrepresented in Monroe County, and this bias is increased significantly in both the on-site and in-depth samples. This bias results from limiting on-site coverage to 11:30 am—10:30 pm. Although it is possible that the distribution of causal factors may be significantly different for night accidents, it is judged unlikely that the overall distribution of human, vehicular, and

Table 7-22

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Accident Type

Accident Type	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Collision with Pedestrian	3	1.0	0	0.0	30	.9
Collision with Non-Motor Vehicle	2	.7	1	1.6	26	.8
Collision with Fixed Object	7	2.4	2	3.2	199	6.1
Other Noncollision Running Off Road	40	13.8	17	27.0	351	10.7
Noncollision Over Turning	4	1.4	1	1.6	21	.6
Collision Involving Other Object or Animal	7	2.4	1	1.6	243	7.4
Collision with Other Motor Vehicles	226	78.2	41	65.1	2402	73.4
Total	289	100.0	63	100.0	3272	100.0
d.f. = 6 Chi-Square	22.19**		21.84**			

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

Table 7-23

Comparison of On-Site and In-Depth Investigated Accidents with All 1972 Monroe County Accidents by Severity of Accident

Severity of Accident	On-Site		In-Depth		Monroe County	
	N	%	N	%	N	%
Fatality	5	1.7	4	6.3	15	.5
Personal Injury	73	25.3	20	31.7	679	20.8
Property Damage	211	73.0	39	61.9	2578	78.8
Total	289	100.0	63	100.0	3272	100.0
d.f. = 2 Chi-Square	14.25***		53.64***			

* = p LE .05
**= p LE .01
***= p LE .001
NS Not Significant

environmental factors would be greatly changed if more night accidents had been considered. During the remaining period of the current study, 24 hour/day coverage will be resumed, making an accurate analysis of day versus night accidents possible.

The differences between the county and the nation as to *type of accident* are difficult to explain, since the county is so similar to the nation in terms of many variables which might reasonably alter accident type, including time and place of accident occurrence and driver sex. The difference is so pronounced and unexplainable with respect to "collision with non-motor vehicle" that differences in categorizational practices must be suspected. Whatever the explanation, similar differences were noted in last year's comparisons. In addition, the on-site and in-depth distributions vary significantly from the county, each in different ways. The largest percentage difference is for "other non-collision/running off road," which is over-represented in the in-depth sample. This same tendency was noted last year, and the same explanation is again believed proper: in-depth accidents require a very high level of cooperation from motorists, and it is more probable that cooperation will be obtained from one driver than from two. Another notable difference occurs for "collisions with fixed objects." Here, the county is underrepresented, and this tendency is further exaggerated in the in-depth and on-site samples. Reasons for this are not known. Monroe County certainly has a variety of road types, many with trees and poles in close proximity to travel surfaces.

In attempting to interpret these results it is helpful to remember that all in-depth accidents are drawn from the on-site sample. For example, when fixed object impacts are underrepresented in both the on-site and in-depth samples, but the degree of underrepresentation is less in the in-depth sample, this actually represents a sampling bias on the in-depth level **towards** acquisition of fixed object accidents. Similarly, collisions with other motor vehicles were overrepresented on the on-site level, and yet underrepresented in the in-depth sample, indicating the relatively great difficulty experienced in attempting to acquire multiple drivers and vehicles for in-depth investigation.

With regard to *accident severity,* for unknown reasons the national figure for personal injury accidents has increased considerably from that reported a year ago, the Monroe County figure has decreased, and as a result the extent to which the county is underrepresented on this variable has increased from 5.6 percent in 1971 to 15.7 percent in 1972. No dramatic changes in

Table 7-24

Comparison of Phase III Accident Sample Characteristics with National Accident Distributions

Comparison Variable	On-Site Sample	In-Depth Sample	Comment
Driver Sex	Female Drivers Slightly Over-Represented	(-)	Females More Prone To Cooperate with On-Site Investigators
Driver Age	Young Drivers Over-Represented	Young Drivers Over-Represented	Student Population At Indiana University
Vehicle Make	(-)	(-)	1
Vehicle Model Year	(-)	(-)	1
Vehicle Type	Passenger Vehicles Slightly Over-Represented	(-)	Artifact of Contract Requirement that Trucks or Buses Exceeding 8,000 lbs./GVW be Excluded from Investigation
System and Type of Road Surface	Possible Under-Representation of Accidents Occurring on Non-Surfaced Rural Roads	(-)	1

Table 7-24 continued

Comparison Variable	On-Site Sample	In-Depth Sample	Comment
Road Surface Condition	Dry Road Accidents Moderately Over-Represented	(-)	Logistical Data Collection Constraint Posed by Close Temporal Contiguity of Wet Road Accidents
Urban vs. Rural Accident Location	Urban Accidents Tend Toward Over-Representation	Rural Accidents Tend Toward Over-Representation	No Significant Sample Bias
Accident Light Condition	Daylight Accidents Highly Over-Represented	Daylight Accidents Highly Over-Represented	Hours of Coverage Provided for Under-Represented Accidents Occurring in Darkness
Type of Accident	"Collision with Other Motor Vehicle" Most Over-Represented	"Ran off Road" Most Over-Represented	Sample Bias Likely
Accident Severity	Property Damage Accidents Moderately Over-Represented	(-)	Sample Bias Likely

1 = Assessment of Sample Bias Not Possible
(-) = Sample is Representative of National Accidents

enforcement practices, roadways, or the driving population are known to have occurred which could explain such a large change. However, the on-site and in-depth teams have significantly over-sampled personal injury accidents, decreasing the disparity between national statistics for this variable and the accident samples investigated by IRPS.

Fatal accidents are much more overrepresented in the in-depth sample than they were a year ago. This has resulted because the on-site teams were more effective in acquiring fatal accidents, and in turn the in-depth team is nearly always able to acquire cooperation for investigation of a fatal accident. In Phase II, the in-depth team acquired two of the three fatal accidents investigated by the on-site team. In Phase III, they have acquired four of five.

In general, it is not believed that the differences which have been identified have substantially affected the majority of study findings. In particular, it is not believed that overall results regarding the role of human, vehicular, and environmental factors and subfactors would be altered more than a few percentage points if all study sampling biases were eliminated. This judgment is supported by the fact that Phase III results did not consistently change from Phase II despite some changes in sampling patterns, and that on-site results do not consistently differ from those from the in-depth level, despite some consistent sampling differences

With the planned expansion to 24 hour/day coverage, the representativeness of study samples will undoubtedly be increased. Not only will it be possible to obtain a proper distribution of day/night, dusk/dawn accidents, but the increased pool of accidents available for in-depth investigation will permit some stratification in the sampling process.

Some concern has been expressed that the absence in the study county of interstate-type, 4-lane/divided/controlled/-access highways providing the opportunity for extended periods of high speed driving, might have significantly affected the accident cause tabulations. As will be seen, however, such highways constitute only a small portion of national road mileage, and this, together with the unusually low accident rates for such roads, results in their having a minimal influence on tabulations of accident cause.

For example, tire failure is a factor which intuitively might be expected to play a more significant role on interstate-type roads, since tire failure is a function of heat, and such roads afford the opportunity for the kind of continuous running at high speeds which is conducive to excessive heat build-up. In fact, several studies have indicated a higher causal failure rate for such roads, although with considerable variations in the reported extent of involvement. A 1966-1967 study of nearly 1500 accidents occurring on portions of the Illinois State Toll Highway revealed that from .9 percent to 2.4 percent of these accidents were the result of tire failure (1). Other estimates for such highways have ranged as high as 10 percent (for accidents resulting from tire failure) (2). In contrast, IRPS has found that **none** of the 1305 accidents investigated during the three project phases has been caused by tire failure. It would be useful, then, to see what change would occur in the percent of accidents IRPS reported as being caused by tire failure, if Monroe County had a representative share of interstate-type roadway mileage, using the tire failure percentages reported in the literature for such roads.

One source has reported that there was a total of 3,758,942 miles of U.S. streets and roads at the end of 1971 (3), while completed Interstate System mileage was reported as 31,900 at the end of 1972 (4). It was further reported that 195,370 million miles of driving occurred on this road system during 1972 (4). Such interstate roads therefore comprise about .86 percent of total U.S. street and road mileage, and should therefore have accounted for about 7.5 miles of Monroe County's 867 miles of streets and roads. Another source has reported the accident rate for divided, controlled-access roads as 1.61 to 1.86 in urban areas, and 1.22 to 1.51 in rural areas, per million vehicle miles (5). For the sake of discussion, an interstate accident rate of 1.5 will be assumed. Using the annual mileage figure mentioned above (195,370 million miles), and the estimated average rate of 1.5, it may be calculated that about 293,000 accidents occur nationally on the Interstate System, which represents about 1.7 percent of the 17 million reported accidents which occurred in the U.S. during 1972. This in turn indicates that, were Monroe County representative as to such roads, approximately 56 of the 3,272 reported accidents which occurred in Monroe County during 1972 would have occurred on its (hypothetical) 7.5 miles of interstate highway.

Next, although IRPS has identified no causative tire failures in 1,305 accidents, assume that the true value is .50 percent, meaning that about 16 of the 3,216 non-interstate Monroe County accidents in 1972 would have resulted from tire failure. Assuming that tire failure accounts for 10 percent of accidents on interstate-type roadways, about 6 of the 56 interstate-type Monroe County accidents should have resulted from tire failure. This would raise total Monroe County accidents resulting from tire failure per year from 16 to 22, and would change the figures for percent of accidents resulting from tire failure from the assumed value of .50 percent to .66 percent. If the upper value reported in the Illinois State Toll Highway study is used (2.4 percent), rather than the probably excessive 10 percent (tire causation) figure, the resultant effect on an assumed .50 percent value (tire causation on all roads excluding interstates) would be an increase to .53 percent (for all roads including interstates). This, for example, would indicate that 17 accidents rather than 16 out of the 3,272 Monroe County accidents in 1972 should have resulted from tire failure. Such minimal absolute differences are judged to be insignificant in the characterization of the relative importance of different types of accident causes.

8.0 Summary and Conclusions

A. Human factors are the predominant causes of accidents, followed by environmental and vehicular factors, respectively. Human factors were definite causes in 83.2 percent of the combined Phase II/III accidents investigated by the in-depth team. In contrast, environmental factors were definite causes in 16.4 percent of these accidents, and vehicular factors in 4.2 percent (Sections 3.4 and 3.5).*

1. Improper lookout (especially at intersections), inattention (especially to traffic stopping or slowing ahead), and excessive speed (especially for road design, regardless of weather or traffic conditions) are the human factors which most frequently cause accidents (Section 3.4).
2. The environmental factors which most frequently cause accidents are view obstructions (especially parked cars) and slippery roads (Section 3.4).
3. The vehicular factors which most frequently cause accidents involve brake systems (especially gross brake failure) and tires (especially inadequate tread depth and underinflation) (Section 3.4).

B. Causal results obtained in Phase III are similar to those obtained in Phase II; the most notable exception is that vehicular factors were identified significantly less frequently by the in-depth team in Phase III (Section 3.6).

C. Accident severity varies significantly from expected values for accidents caused by some factors. However, only for one causal factor—alcohol impairment—was the severity significantly different in both the on-site and in-depth samples; personal injury accidents were overrepresented to a statistically significant extent in accidents caused by alcohol-impairment (Section 3.7).

D. Older model year vehicles are significantly overrepresented among vehicles involved in accidents as a result of their deficiencies or failures (Section 3.8). However, considering all accidents and accidents causes, older vehicles *per se* are **not** significantly overrepresented in accidents (Section 4.0).

E. Percentage results obtained by the on-site and in-depth teams are generally similar, and no major areas of deficiency in the on-site (technician) causal-assessment process were identified (Section 3.9).

F. No vehicle make or model year was either over- or underrepresented in the accident sample to a statistically significant extent. In contrast, involvement as a function of many driver-related variables (sex, age, marital status, education, income, occupation, driving experience, yearly mileage, vehicle familiarity, and driver training) varied significantly (Section 4.0).

*These percentages do not, and would not be expected, to add up to 100 percent. This is because more than one kind of factor might be identified as playing a causal role in the same accident; for example, both human and environmental factors might be involved as causes.

G. Results of the cluster analysis indicate that either there are no distinct types of traffic accidents (e.g., types of drivers, circumstances, and accident causes mix arbitrarily in accidents), or that greater numbers of accidents must be considered and brought into finer focus if typologies are to be discerned (Section 5.0).

   1. Nevertheless, preliminary cluster and problem driver analysis results indicate that accidents in which alcohol is a causal factor may typically differ from general accidents in several respects. General accidents most typically involved young males driving relatively new vehicles in daylight, in moderate to heavy traffic, were the result of side impacts with other vehicles, and resulted in only property damage. In contrast, the alcohol-caused accident more typically involved an older male driver driving an older vehicle at night, occurred in light traffic, involved running off the road, and resulted in personal injury or a fatality (Sections 5.0 and 6.0).

H. The Monroe County study area is representative of the United States in terms of most variables compared, differing principally in having an overabundance of young drivers, and in having a disproportionately high percentage of its rural roads paved (Section 7.0).

   1. Both the Phase II and Phase III accident samples are generally similar to county accidents in terms of most variables tested, although several significant differences were observed (Section 7.0).

I. Study samples are sufficiently representative to provide a valid indication of the causative role of human, vehicular, and environmental factors in the national accident picture (Section 7.0).

9.0 Recommendations

A. Efforts should be undertaken to ensure that drivers are made aware of the results of this and other reports indicating the relative importance of different human, vehicular, and environmental factors in causing accidents (HSPS Nos. 4 and 5). An awareness and an appreciation for the most frequently causative errors, conditions, and situations should be generated. Primary means of communication include:

1. driver education and training programs.
2. state driver manuals.
3. public information programs.
   a. As a part of this effort, information communicated should emphasize the role of the driver, including:
      (1) Specific driving errors--the factors indicated to be of greatest importance in this regard were improper lookout, excessive speed, and inattention (Section 3.4).
      (2) Important conditions and states—the role of alcohol, in particular—should be emphasized (Section 3.4). The increased driving risk associated with the problem drinker or alcoholic should be explained, along with guidelines for identifying the problem drinker or alcoholic, and the various sources of assistance and treatment (i.e., the alternatives to continuing to drink and drive). While this information may be aimed towards the driver, it should be recognized that having this information may enable family, friends, employers, or others to beneficially intervene on behalf of a problem drinker or alcoholic driver.
   b. Information communicated should also deal with safe driving practices, including:
      (1) The importance of attentiveness to safe driving, especially with respect to vehicles immediately ahead, vehicles approaching on perpendicular courses at intersections, and both warning and regulatory signs and signals (Section 3.4).
      (2) The importance of, and proper technique for, gradually easing-out while visually observing for oncoming traffic at intersection where parked cars or other factors tend to limit sight distance of oncoming traffic (Section 3.4).
      (3) The importance of appropriate evasive action, and the realization that many potential collisions can be avoided at the "last minute" by appropriate steering, braking, or accelerating actions. In particular, drivers should be made familiar with the loss of steering control which

results from locking-up the front wheels during "panic" braking (Section 3.4).

(4) Proper road-recovery techniques. A distinct class of accidents observed was that in which drivers lost control as a result of inappropriate recovery techniques after leaving the pavement edge (Section 3.4).

c. This driver information program should also identify the primary environmental hazards which cause accidents, and in particular:

(1) The importance of rain, ice, or snow-slickened roads should be indicated. Added information could be provided, such as the tendency for traction to be especially poor immediately after moisture begins to accumulate on the pavement, and the tendency for travel-polished pavements to become unusually slick when moisture is present (Section 3.4).

(2) The great risk posed at non-signalized intersections where parked cars or other obstacles limit sight distance of traffic having the right-of-way should be emphasized (Section 3.4).

d. Although the role of vehicular factors in accident causation was determined to be less than that of either human or environmental factors, this driver information program should emphasize the vehicular factors of greatest importance to safety (Section 3.4). In particular, it should emphasize:

(1) That brake systems and tires merit particularly close attention.

(2) That brake system failures occur with sufficient frequency to be of concern, and that such failures can best be prevented by periodic brake maintenance by qualified service personnel. With regard to brake maintenance, it might also be beneficial to indicate:

(a) That drums which have been turned too many times, such that the diameter exceeds recommended limits, can result in a total brake failure, either by allowing the wheel cylinder pistons to move out an excessive distance, or as a result of a fracture of the drum.

(b) That proper installation of the brake mechanism and, in particular, self-adjusting mechanisms is critical. Several instances have been observed by IRPS where brakes which apparently had been worked on by unqualified personnel had been improperly reassembled. For example, some accidents have occurred where the adjusting mechanism lever was not in contact which the star wheel, with the result that this assembly contracted and dislodged from between the brake shoes, producing a total brake failure.

(c) That brake linings and pads wear, need to be periodically inspected and/or replaced, and that adequate lining or pad thickness is important to safety.

(d) That contamination of linings by brake fluid or grease is important, especially in that it can produce imbalances in braking force which become critical when high levels of braking force are required. This study has identified such side-to-side braking imbalances as among the most important of vehicular causal factors.

(e) That brakes which need to be pumped are potentially dangerous, and further, that this condition may often be corrected by merely "having the brakes adjusted," a relatively inexpensive procedure.

(f) That brake fluid level should be checked regularly, and that a continuous loss of fluid indicates a problem which could become more serious and should be repaired immediately.

(3) That tires with inadequate tread depth, and particularly those which have worn smooth, generally have poor traction on wet roads, and that such tires are particularly a factor where vehicles lose control during wet-road cornering maneuvers.

(4) That proper tire inflation is important to vehicle safety, and must be checked periodically (e.g., once per month). This might include the information that:

(a) Improper inflation, and especially under-inflation, can adversely affect vehicle stability, and both stopping and cornering performance.

(b) That under-inflation decreases tire life and increases gas consumption.

(c) That over-inflation can also cause accelerated and irregular tread wear.

(d) That improper tire inflation increases the risk of tire failure.

(e) That lowering tire pressures below those recommended does **not** increase traction on snow or ice.

(5) As a part of this public information effort, it is suggested that the cooperation of the major oil companies in publicizing the importance

of tire inflation and in routinely checking tire pressures at each fill-up or service stop, should be solicited.

e. While it is recommended that this information should be incorporated in driver education courses, this study does not offer encouragement that driver education, as currently practiced, is effective in reducing accidents. Drivers who had taken driver education were found to be overrepresented in the accident population, although this result may be explained as a function of accident driver age, and sample sizes did not permit control for this factor (Section 4.0).

B. At such time as accident causation and risk identification information is incorporated in the state driver manuals, knowledge of such information should be tested as a part of:

1. written driver examinations, and
2. license-related driving tests.

   Project results suggest that the driving tests should emphasize:

   a. the driver's attention level, with emphasis on attention to the vehicle ahead, to traffic approaching from right-angles at intersections, and to regulatory and warning signs and signals;
   b. control of vehicle speed and sensitivity to the need for adjustment of speed due to changes in the driving environment, including wet roads;
   c. selection and maintenance of a safe following distance (e.g., using the *two second* rule);
   d. proper *easing-out* and visual surveillance at non-signalized urban intersections having limited sight distance in which to observe oncoming traffic having the right-of-way; and
   e. proper recovery techniques after leaving a pavement edge (HSPS No. 5).

3. Such testing might incorporate both actual in-car driving, and driving simulators. The use of simulators might serve to test for a broader range of traffic and environmental conditions than are present in the immediate area of the license branch and, for example, would ensure that "urban intersections with limited sight distance" and inclimate weather conditions (e.g., a wet traffic-polished road) could be replicated. Further, it is believed that simulated emergency situations, requiring proper evasive response, might prove useful both in testing for adequate skills, and in conditioning a driver to continuously maintain a higher level of attentiveness.

C. Study results are not definitive as to groups which are over-involved in particular driving errors; additional validation efforts through the remaining period of the program will be required (Section 6.0). However, results do suggest that groups with particular tendencies may be able to be identified, to which it may then be feasible to apply selective training, restrictions, tests, sanctions, and/or remedial procedures (HSPS Nos. 4, 5, and 6).

1. For example, when drivers in the 55-65 age group were involved in accidents, it was unusually often the result of "inattention," and the same was true of drivers 65 and over with respect to "improper lookout." Overall, inattention and improper lookout were the two causal factors most frequently implicated, and both might be termed primarily "careless mistakes." Thus, these older drivers appear to have a predominant, identifiable type of careless mistake problem which usually accounts for their involvement in accidents. A computerized search of recent accident records might enable older drivers with a developing trend of involvement to be "flagged" for special treatment, at least warned of their susceptibility to these mistakes at licensing time, and possibly referred for additional testing and/or special training. The same might be said of young male drivers with records of speeding violations; excessive speed was significantly overrepresented as a cause of accidents among male drivers under 20 years of age.
2. Another class which results indicate might also be flagged for special attention are divorced or separated drivers. Such drivers were significantly overrepresented in accidents although no clear trend in terms of type of error was identified. To a lesser extent, male drivers; both young (under 20) and old (over 65) drivers; drivers with less than high school education; drivers with low income; and laborers, skilled or semi-skilled workers, and students, were observed to be overrepresented in accidents, and might thus be appropriate subjects for special attention at licensing time, or in the application of sanctions.
3. In general, it is suggested that the entire driver licensing and control system should aim towards diagnosing the difficulties and accident risks of particular drivers, and then suggesting remedial training aimed towards the needs of each individual. At a minimum, each driver could at least be given a written advisory, perhaps in the form of computer printout, indicating any significant trends revealed by his accident or violation history, and possibly based upon a complete profile of medical, attitudinal, personality, biographical, driving knowledge, and vision test data. One of the aims of the current IRPS program is to relate information on individuals to specific types of driving errors and causal factors.

D. Study results regarding vehicle causes do not provide many strong implications as to manufacturing or design changes required (Section 3.4). Measures to ensure that brake systems will continue to perform as manufactured appear to be the most important, in terms of minimizing the incidence of both brake failure and side-to-side imbalance (HSPS No. 1, FMVSS No. 105). Failures have most frequently arisen from drums being turned beyond normal limits, while imbalances typically have resulted from contamination of pads or linings with brake fluid or wheel bearing grease.

1. The frequent involvement of "inattention to vehicles stopping or slowing ahead" indicates that radar augmented braking systems may provide a significant payoff in preventing accidents, although most of the accidents caused by this factor involved only property damage.
2. Study results indicate that from 4 to 6 percent of the combined Phase II/III accidents were definitely caused by vehicular factors, and that from 12 to 14 percent of accidents were either the definite or probable result of such factors. The advisability of periodic inspection can be assessed only by considering these involvement figures along with estimates of cost and effectiveness of the inspection programs. However, study results do indicate that if such inspection programs are conducted:
   a. Inspection procedures should require visual inspection of the brake mechanism, including an inspection for:
      (1) Lining/pad thickness, condition, and contamination,
      (2) Drum/disc condition and diameter/thickness,
      (3) Mechanism function and integrity, including adjustment mechanisms,
      (4) Brake adjustment, and
      (5) Ideally, brakes should be dynamically tested for balance, with emphasis on side-to-side balance.
   b. Tread depth requirements, which typically have been incorporated in PMVI procedures, are supported by this study as being appropriate, and such standards should be strictly enforced. However, IRPS has found that despite a once per year PMVI system in Indiana, approximately 30 percent of accident-involved vehicles had one or more tires with less than 2/32" tread depth. Therefore, the need for more frequent inspections may be indicated, and it is suggested that law enforcement officers should check this item as a part of each routine enforcement contact with motorists.
   c. As an educational function for the public, it is recommended that inspection for tire pressure be incorporated as a part of PMVI, even though not made a part of the pass/fail criteria.
   d. Taillight, stop light, and rear turn signal operation have all been shown by

the study to be sufficiently important in terms of accident prevention to merit inspection as a part of PMVI.

e. Older vehicles, and especially those manufactured before 1962, are indicated by the study to be especially appropriate targets of an inspection program, since they are overrepresented in accidents caused by vehicular problems.

E. Roadway improvement efforts should concentrate on reducing the causal role of slippery roads and view obstructions (HSPS Nos. 9 and 12). For the former, this means both increasing the wet road coefficient of friction, and emphasizing efficient control and removal of snow and ice (Section 3.4). For the latter, measures to reduce the dangers of parked cars at non-signalized urban intersections appear necessary. In addition to restricting parking for greater distances and enforcing such restrictions, other economical solutions, including mirror systems, should be considered.

F. Future research efforts should focus on further defining specific driver subgroups in terms of accident experience and specific pre-crash errors, so that conclusive driver control recommendations can be formulated (Section 6.0).

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CAUSAL FACTORS GLOSSARY

Section Organization:

Chart of Top-level Breakdown of Causal Factors

I. Human Direct Causes
   1. Organizational Chart
   2. Outline of Factors
   3. Definitions

II. Human Conditions and States
   1. Organizational Chart
   2. Outline of Factors
   3. Definitions

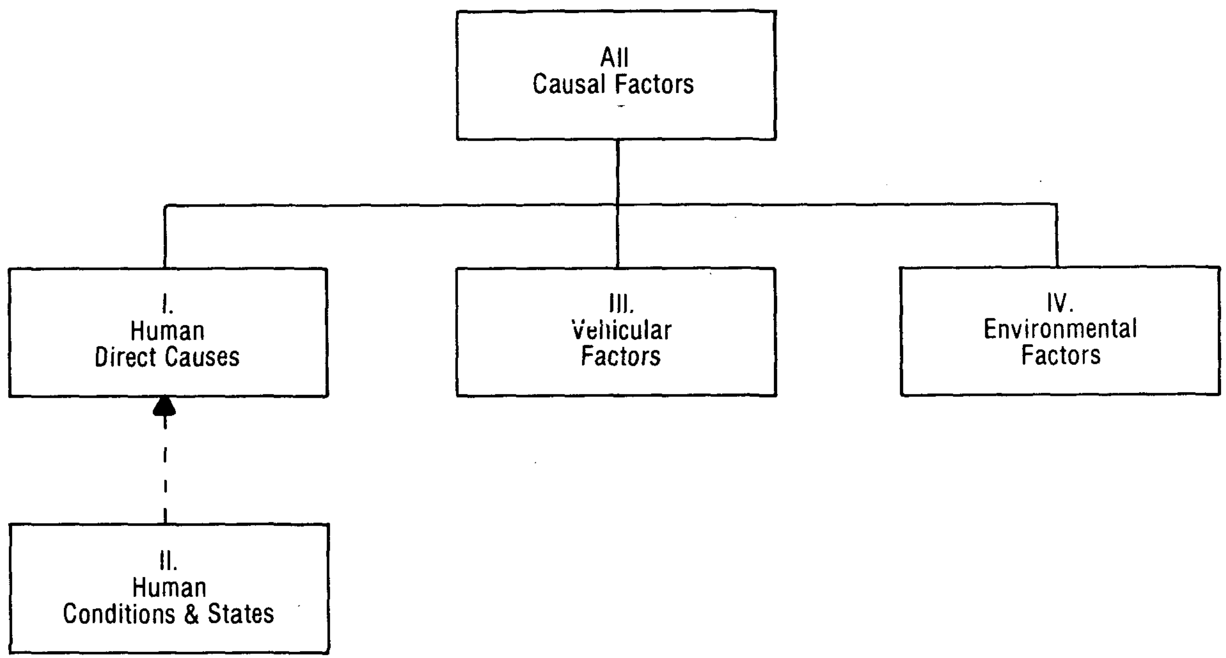
III. Environmental Factors
   1. Organizational Chart
   2. Outline of Factors
   3. Definitions

IV. Vehicular Factors
   1. Organizational Chart
   2. Outline of Factors
   3. Definitions

NOTE: Several of the human condition and state definitions were taken directly, or with minimal changes, from a Cornell Aeronautical Laboratories, Inc., report by K. Tharp, T. Calderwood, J. Downing, J. Fell, J. Carrett, and E. Mudrowsky, entitled "Multidisciplinary Investigations to Determine Automobile Accident Causation: Findings," March 1970 (CAL Report No. VJ-2224-V-4). These factors are identified in the human conditions and states definition by the parenthetical notation of (CAL) at the end of applicable definitions.

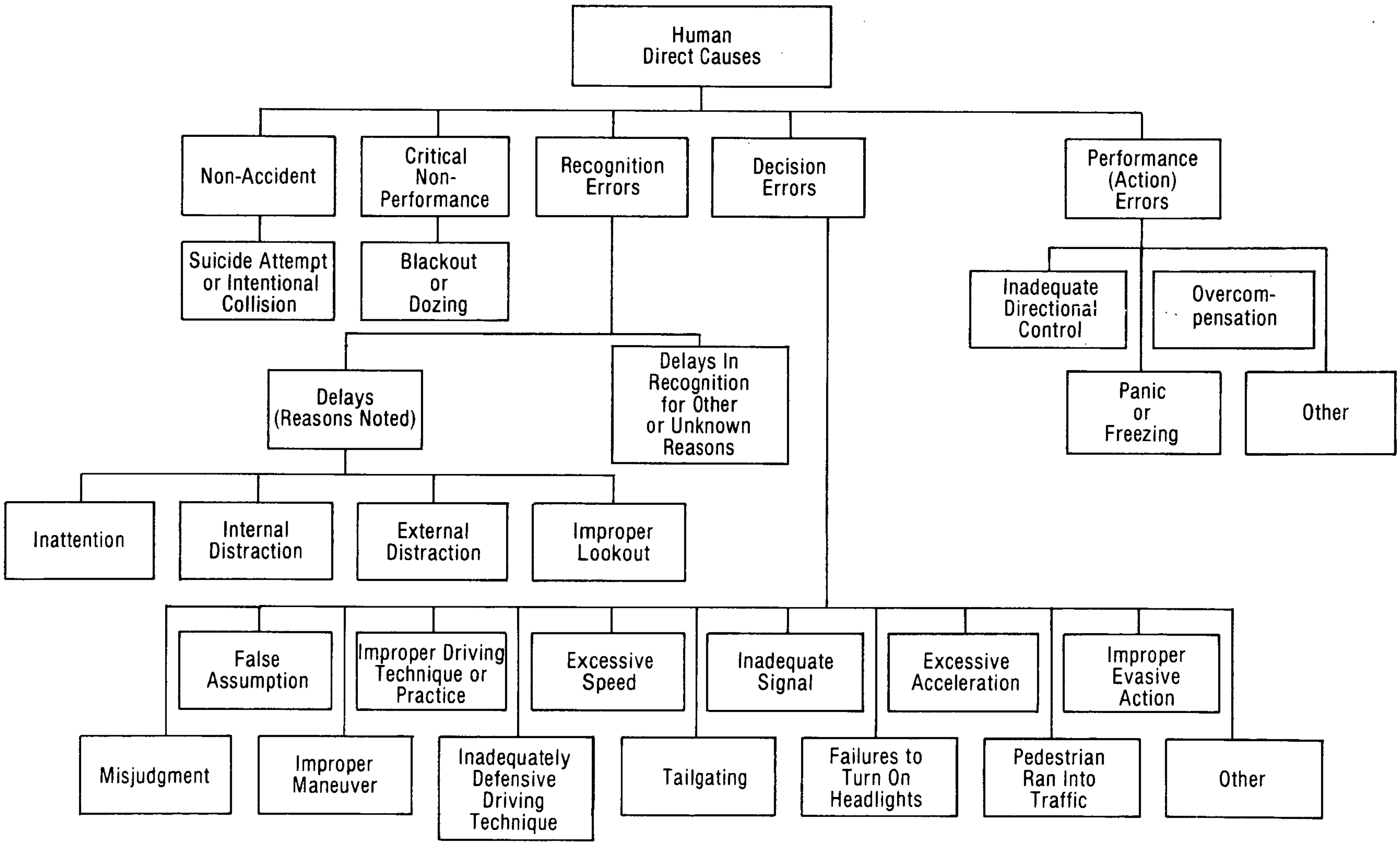
Glossary Figure 1

Top-Level Breakdown of Causal Factors



Glossary Figure 2

Causal Factor Tree for Human Direct Causes



Outline

I. Human Direct Causes

A. Critical non-performance

1. Blackout
2. Dozing

B. Non-accidents—(suicide attempts, etc.)

C. Recognition Errors

1. Driver failed to observe and stop for stop sign (special interest category)
2. Delays in recognition (reasons noted)

(a) Inattention

(1) To traffic stopped or slowing ahead
(2) To position of car on road
(3) To road features, such as on-coming curves, lane narrowing, etc.
(4) To road signs or signals providing driver information
(5) To cross-flowing traffic, such as merging or intersecting traffic
(6) Other

(b) Internal distraction

(1) Event in car (e.g., loud noise, yell, scream, sick passenger, dropped cigarette, fire)
(2) Adjusting radio or tape player
(3) Adjusting window, vent, heater, or similar control
(4) Conversation with passenger
(5) Other

(c) External distraction

(1) Other traffic
(2) Driver-selected outside activity (e.g., looking for house number, looking for street signs, examining particular property, etc.)
(3) Activity of special interest (e.g., fight, girl in bikini, accident, fire, etc.)
(4) Sudden event; loud noise, explosion, flash of light, sudden screech, etc.
(5) Other

(d) Improper lookout

(1) Pulling out from parking place
(2) Entering travel lane from intersecting street, alley, intersection
(3) Prior to changing lanes or passing
(4) Other

3. Delays in Recognition (for other or unknown reasons)

(a) Of traffic stopped or slowing ahead
(b) Of position of car on road
(c) Of road features, such as on-coming curves, lane narrowing, etc.
(d) Of road signs or signals providing driver information
(e) Of cross-flowing traffic, such as merging traffic or intersecting traffic
(f) Other

D. Decision errors

1. Misjudgment (of distance, closure-rate, etc.)
2. False assumption

(a) Assumed other driver had to stop or yield at intersection
(b) Assumed other driver would stop or yield at intersection without assuming traffic control
(c) Assumed on-coming car would move left or right, out of way
(d) Assumed vehicle was going to make a turning maneuver, which it did not
(e) Assumed there was no traffic coming (or that traffic was stopped) when in fact there was traffic coming
(f) Other

3. Improper maneuver

(a) Turned from wrong lane or position
(b) Drove in wrong lane but correct direction (e.g., went straight in turn lane)
(c) Drove in wrong direction of travel for lane (e.g., one-way street)
(d) Passed at improper location
(e) Other

4. Improper driving technique or practice

(a) Cresting hills driving in center of road
(b) Braking later than should have or at inappropriate location
(c) Stopping too far out in road or intersection
(d) Driving excessively close to center line or edge of road

(e) Slowed too rapidly (e.g., slammed on brakes to make turn at last minute)
(f) Other

5. Inadequately defensive driving technique

   (a) Strategic error—should have positioned car differently in anticipation of possible problems
   (b) Strategic error—should have adjusted speed in anticipation of possible problems
   (c) Strategic error—should not have taken other driver's obedience of traffic signal for granted
   (d) Other

6. Excessive speed

   (a) For road design—regardless of condition or traffic
   (b) Solely in light of traffic, pedestrians, number of accesses, etc.
   (c) Solely in light of weather conditions (including slick roads)
   (d) Due to combinations of above
   (e) Other

7. Tailgating

8. Inadequate signal

   (a) Failure to signal for turn
   (b) Failure to use horn to warn
   (c) Other

9. Failure to turn on headlights
10. Excessive acceleration
11. Pedestrian ran into traffic
12. Improper evasive action

   (a) Locked brakes/could not steer
   (b) Above does not apply, but driver could have steered out of danger and did not
   (c) Driver could have accelerated out of danger but did not
   (d) Other or unspecified

E. Performance errors

1. Overcompensation
2. Panic or freezing

3. Inadequate directional control

    (a) On-curve—allowed car to enter opposing lane of travel
    (b) On straight—allowed car to enter opposing lane of travel
    (c) On straight or curve—allowed car to go off road edge to right

F. Other Human Causal Factors

Definitions

I. Human Causal Factors (Direct Causes)

This heading comprises one of the three main groups into which all accident-causative factors are separated—*human, vehicular,* and *environmental.* This category refers to all human acts and failures to act in the minutes immediately preceding an accident, which increase the risk of collision beyond that which would have existed for a conscious driver driving to a high but reasonable standard of good defensive driving practice. Thus, the failure of a driver, engaged in animated conversation, to notice that the car in front of him has stopped, is categorized as a *human causal factor* for purposes of this study. However, the improper repair activities of a driver, which several minutes later result in a catastrophic brake failure, are not categorized as human causal factors for purposes of this study. That failure would be classified as a *vehicular factor,* though the human error involved would be noted in the case report on the accident.

A. Critical non-performances

This refers to a situation where a driver loses consciousness, either in the sense of blacking-out or falling asleep, and as a result is involved in an accident. These are termed critical non-performances in the sense that a catastrophic interruption in the driver's performance as an information-processor occurs, and he drops totally out of the information-processing system.

B. Non-accident

This refers to situations where collision is intentional. It thus includes both suicide attempts, and a situation where a driver, annoyed by the proximity of a following vehicle, slams on his brakes in anger, and as an inevitable result, is rear-ended.

C. Recognition errors

This category heading includes the next-level (more specific) categories designated *inattention, internal distraction, external distraction, improper lookout,* and *other* *delays in perception, comprehension or reaction.* To a large extent, it is defined by the categories which comprise it.

This category intends to include all situations where a conscious driver does not properly perceive, comprehend, and/or react to a situation requiring adjustment of speed or path of travel for safe completion of the driving task.

1. Driver failed to observe and stop for stop sign

   This category is unique among others presented in that it does not define what is considered for purposes of this study to be a causative driver error. Instead, it is used merely to tally cases where driver errors had a particular result. It is thus often not mutually exclusive of other categories.

   This category applies whenever a conscious driver for any reason fails to notice a stop sign which should have been visible to him, and is as a result involved in an accident because of not stopping for that stop sign. This category was developed because this particular type of accident was noted to occur frequently.

2. Delays in recognition (reasons noted)

   This refers to all *recognition errors,* as previously defined, for which specific explanations or reasons were determined. These reasons include *inattention, external distraction, internal distraction,* and *improper lookout.*

   (a) Inattention (preoccupation)

      This category applies whenever a driver is delayed in the recognition of information needed to safely accomplish the driving task, because of having chosen to direct his attention elsewhere for some *non-compelling reason.* Specifically excluded from this category are cases where a circumstance or event compels or tends to induce a shift away from the driving-task matters requiring attention. The category thus denotes an unnecessary wandering of the mind, or a state of being engrossed in thought in matters not of immediate importance to the driving task.

      A driver may be inattentive to traffic stopping or slowing ahead; to the position of his car on the road; to features such as on-coming curves, lane narrowings, etc.; to road signs or signals providing driver information; or to cross-flowing traffic; such as merging or intersecting traffic.

      Inattention is to be distinguished from the *distraction* categories, wherein a circumstance *compels* or tends to induce a shifting of attention away from the driving task, and from the *improper and/or inadequate lookout* category, wherein the driver encounters situations requiring a distinct visual surveillance activity (in addition to that which is always required), for safe completion of the driving task.

(b) Internal distraction

This category applies whenever a driver is delayed in the recognition of information needed to safely accomplish the driving task, because some *event, activity, object,* or *person within his vehicle, compelled* or tended to induce the driver's shifting of attention away from the driving task; a radio might act as an object of special attention, tending to induce the driver to shift his attention from the driving task to adjustment of the radio. Conversation with a passenger which diverts attention from the driving task is considered an internal distraction.

Examples of events or activities which are ordinarily considered internal distractions include sudden or unusual events in the car such as loud noises, yells, a sick passenger, or a dropped cigarette, and mechanisms requiring driver-adjustment, such as radios, tape players, windows, and heaters.

Inattention is to be distinguished from the *inattention (preoccupation)* category, wherein a driver shifts his attention from the driving task, but no event, activity, or object compels or tends to induce such a shift. Mere driver-chosen mental activity falls under the inattention category, rather than internal distraction.

Internal distraction is particularly to be distinguished from *improper lookout,* in that *internal distraction* takes precedence over *improper lookout.* Thus, if a driver's lookout is inadequate or improper and this is due to an internal distraction, only the internal distraction category will apply.

(c) External distraction

This category applies whenever a driver is delayed in his recognition of information needed to safely accomplish the driving task, because an *event, activity, object,* or *person* outside his vehicle *compelled,* or tended to induce, a shifting of attention away from the driving task. For example, a pretty girl might tend to induce a driver to shift his attention; a sudden event outside the car, such as an explosion or screech of tires, might *compel* such a shift of attention.

Other examples of external distractions include the actions of other traffic; driver-selected outside activity such as looking for street signs, looking for house numbers, and examining particular pieces of property; activities of special interest, such as a fight, person in bikini, accident, or fire; or other sudden events such as loud noises, explosions, flashes of light, sudden screech of tires.

External distraction is to be distinguished from *inattention (preoccupation),* in which the driver shifts his attention from the driving task, but is not compelled or induced to by any event, activity, or object. External distraction is especially to be distinguished from *improper lookout,* over which it takes precedence; in other words, if a driver fails to maintain an adequate or proper lookout because of an external distraction, only the external distraction category will apply.

(d) Inadequate or improper lookout

This category applies whenever a driver is delayed in his recognition of information needed to safely accomplish the driving task, because he encountered a situation requiring a distinct visual surveillance activity (for safe completion of the driving task), but either did not look or did look, but did so inadequately. Thus, included are both cases where a driver "looks but does not see," and the cases where a driver needed to look but did not even attempt to, as for example in pulling out to pass without first checking for traffic in the passing lane.

The improper lookout category frequently applies in situations where a driver is pulling out from a parking place; entering the travel lane from an intersecting street, alley, or driveway; or prior to changing lanes or passing.

Inadequate or improper lookout is to be distinguished from the *inattention, internal distraction,* and *external distraction* categories; these three categories all take precedence when they are *known* to apply. The distinction between this category and inattention may be particularly difficult, and hence this rule of thumb will ordinarily apply: if the driver has shifted his attention from the driving task so that he does not recognize that he has encountered the driving situation which gave rise to the need to look, inattention shall apply; otherwise, the inadequate or improper lookout category is appropriate. In using this rule, note that for inadequate or improper lookout to apply it is not necessary that the driver recognize the need to look; it is only necessary that he be aware that he has encountered the situation which gave rise to the need (e.g., knew that he was entering an intersection, or that he was overtaking another vehicle).

Note also that when a driver entering or crossing a one-way street fails to check for wrong-way traffic, this is classified as an *inadequately defensive driving technique,* rather than as an *inadequate or improper lookout.*

3. Delays in recognition for other or unknown reasons

   This includes all *delays in recognition* (as previously defined), which though known to have occurred, cannot be explained in detail. Thus, the fact of a delay in perception or comprehension of needed information is established in these cases, but a precise reason for these delays cannot be established.

D. Decision errors

This refers to all situations where a driver is involved in an accident, or experiences an unnecessarily severe impact, because having received information indicating the need for a change in speed or path of travel, he chooses an improper course of action, or takes no action.

To a large extent, this top-level category is defined by the next-level (more specific) categories included under it. These are *misjudgment, false assumption, improper maneuver, improper driving technique or practice, inadequately defensive driving technique, excessive speed, tailgating, inadequate signal, failure to turn on headlights, excessive acceleration, pedestrian ran into traffic,* and *improper evasive action.*

1. Misjudgment

   This category applies whenever a driver miscalculates the separation in time and space, or the closure rate, of his own vehicle with respect to other objects, and then acts to his detriment on the basis of this improper evaluation.

2. False assumption

   This category applies whenever a driver takes action, or fails to take action, based on a decision or opinion arrived at by assuming that to be true which in fact is not true. For example, if a driver pulls out in front of another driver who is signaling a turn, assuming that the other driver will turn before reaching his location, when in fact that driver has no intention of turning until he is past that location, the original driver's mistake is properly classified as a *false assumption.* In this instance, the *false assumption* category is to be distinguished from *inadequately defensive driving technique,* over which it takes precedence when the fact of a false assumption has been clearly established.

   Additional examples of *false assumption* include assumptions that other drivers must stop or yield at intersections, when in fact they do not; that a vehicle is going to make a turning maneuver which it does not, and assuming that no traffic is coming when in fact there was traffic coming (as in the "good-Samaritan" situation).

3. Improper maneuver

   This category applies whenever a driver willfully chooses a vehicle path which is wrong, in the sense of being obviously calculated to generate an exceedingly high *risk* of collision. Examples include turns from the wrong lane, proceeding straight in a turn lane, driving the wrong-way on a one-way street, or passing at an improper location, such as an intersection.

   In Phase I results only, *improper driving techniques* and practices were included under *improper maneuvers*.

   Improper driving techniques and practices are subsequently defined, and were separately categorized in Phase II.

4. Improper driving technique or practices

   This category applies when a driver engages in the improper control of path or speed, in a manner which unduly increases the risk of accident-involvement, *and* involves practices which are (or might be) habitual to a particular driver (the risk involved not being fully appreciated). Examples include cresting hills while driving in the center of the road, and stopping too far out into roads or intersections as a matter of choice.

   This category is to be distinguished especially from *improper maneuver,* due to the similarity of these categories. In some cases, the distinction between these categories is difficult, being one of degree rather than kind. The key distinction is that of driver recognition of risk, and hence likelihood of habitual reoccurrence; it is unlikely that a driver would habitually repeat what he realized to be an unnecessarily risky practice. Hence, for example, a turn from the middle lane of a one-way three-lane street would be classified as an *improper maneuver;* it is not likely that a driver will engage in this maneuver if he recognizes that traffic could be approaching from behind in the lanes that he crossed. However, for years a driver might crest hills on country roads driving in the center, or stop too rapidly to make turns, without accident involvement, and without realization of the risks involved. Such cases are categorized as *improper driving techniques or practices.*

5. Inadequately defensive driving technique

   This category applies whenever a driver unnecessarily places his vehicle in a position where there is a foreseeable and substantial risk of collision *if* another driver performs contrary to normal expectations, or places his vehicle in such a position without adequately checking to ensure that another driver is not engaged in such an unexpected action. Examples include entering an intersection on reliance that an on-coming vehicle will stop for its traffic signal, despite the fact that it has given no indication of slowing to do so. Another example would be crossing or entering a one-way street without looking for wrong-way traffic.

This category is to be distinguished from categories which are used when drivers place their vehicles in positions (or do so without adequately checking first) where they become subject to risks in the normal course and flow of traffic. The key distinction is that in this case, the risk is generated by the *improper* and *ordinarily unexpected action* of other traffic units.

6. Lxcessive speed

   This category applies when a driver excessively increases the risk of accident involvement, by choosing to travel at too great a speed. The judgment that a vehicle's speed is excessive is necessarily a highly subjective one; an *excessive speed* is one greater than a person driving to a high, but reasonable standard of good defensive driving practice, would choose to travel under existing conditions.

   It should be noted that the evaluation that speed is excessive is specifically not to be determined with reference to the prevailing speed limit. Prevailing speed limits are to be considered, but primarily in the context of determining the reasonable expectations of other drivers as to the speed of traffic likely to be encountered.

   Excessive speed in this context may be excessive for the road design, regardless of its condition or prevailing traffic conditions; in light of traffic, pedestrians, or number of accesses; in light of prevailing weather conditions, or in light of combinations of these factors.

7. Tailgating

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

8. Inadequate signal

   This category applies whenever a signal would ordinarily be expected from a person driving at a standard of good defensive driving practice, *and* it is determined that had such a signal been given, it would have been received and acted on by other persons (drivers, pedestrians, etc.), so that the accident would have been prevented or its severity reduced. Included are all types of signals which communicate information between traffic units, including turn signals, indications of braking or slowing, or warning or alerting signals given by the honking of a horn.

9. Failure to turn on head lamps

   This category applies whenever a driver fails to turn on his headlights despite the fact that the sky has sufficiently darkened to substantially hinder his ability to see or be seen, and this fact is in turn related to the accident occurrence or severity.

10. Excessive acceleration

   This category refers to a situation where a driver accelerates so rapidly that his ability to maintain directional control is hindered to the point that control is lost. This category is to be distinguished from excessive speed; it refers specifically to the situation where wheelspin or similar phenomena associated with rapid acceleration induce directional instability.

11. Pedestrian ran into traffic

   This category applies whenever a pedestrian moves into a traffic lane at such a place and in such a manner, as to create a high risk of contact from even lawfully and prudently driven vehicles. These thus represent cases where the pedestrian is culpable, without regard to whether a striking driver was at all blameworthy. Typically, such accidents have involved people running out into traffic, often without looking at all; many such pedestrians have been children.

12. Improper evasive action

   This category refers to a situation where an alert driver, driving to a high but reasonable standard of good defensive driving practice, could by braking, steering, accelerating, or by engaging in combinations of these actions, have either avoided collision entirely, or have significantly reduced the severity of the impact which resulted. This category does *not* apply merely because it is determined by investigation that there was an evasive action which *could* have been taken successfully; it must also be an evasive action which was *apparent* (or should have been apparent) to the driver on the basis of information available to him, and which was *reasonable*, based on that information. It might not be reasonable, for example, to swerve into an opposing traffic lane and risk a head-on collision, even though it might later be determined by investigation that in fact no such collision would have occurred, and hence the accident could have been avoided by taking that chance.

An especially notable example of *improper evasive action* is the situation where a driver locks his brakes and is therefore unable to initiate an evasive steering action to avoid a car stopped ahead, where had the brakes not been locked it could easily have been accomplished.

E. Performance (action) errors

This category refers to situations where a driver properly perceives and comprehends information indicating the need for an adjustment in speed or path of travel, but commits driving errors which involve either impulsive improper actions (as in panic or freezing), or lack of adequate *skills* (as in over-compensation). These are to be distinguished from errors involving an improper choice of action from among available alternatives, which are termed *decision errors.*

To a large extent, this category grouping is defined by the next-level (more specific) categories which comprise it; these are *over-compensation, panic or freezing,* and *inadequate directional control.*

1. Overcompensation

This refers to situations where a driver improperly reacts to a situation impairing the maintenance of control over the vehicle. Such overcompensations include improper or excessive acceleration, braking, and/or steering inputs. This category is most typically applied when a driver allows his vehicle to deviate from its intended path, as in the case where he allows the right-side tires to drop off the pavement edge, and then looses control by attempting to regain the intended path in too abrupt a manner.

2. Panic or freezing

This refers to the situation where a driver perceives the risk of collision, and as a result is unable or does not have the presence of mind to take any significant remedial action. He is either unable to estimate what remedial action is required, or realizing it, is unable to initiate the muscle responses necessary to cause that action to be taken.

This category also refers to situations where, in recognition of risk of collision or loss of control, a driver takes an impulsive, irrational action, which is obviously not calculated to reduce the risk. For example, preceding collision, such a driver might remove his hands from the wheel and throw them up in front of his face, in a situation where had he not panicked a reasonable evasive action would have been possible.

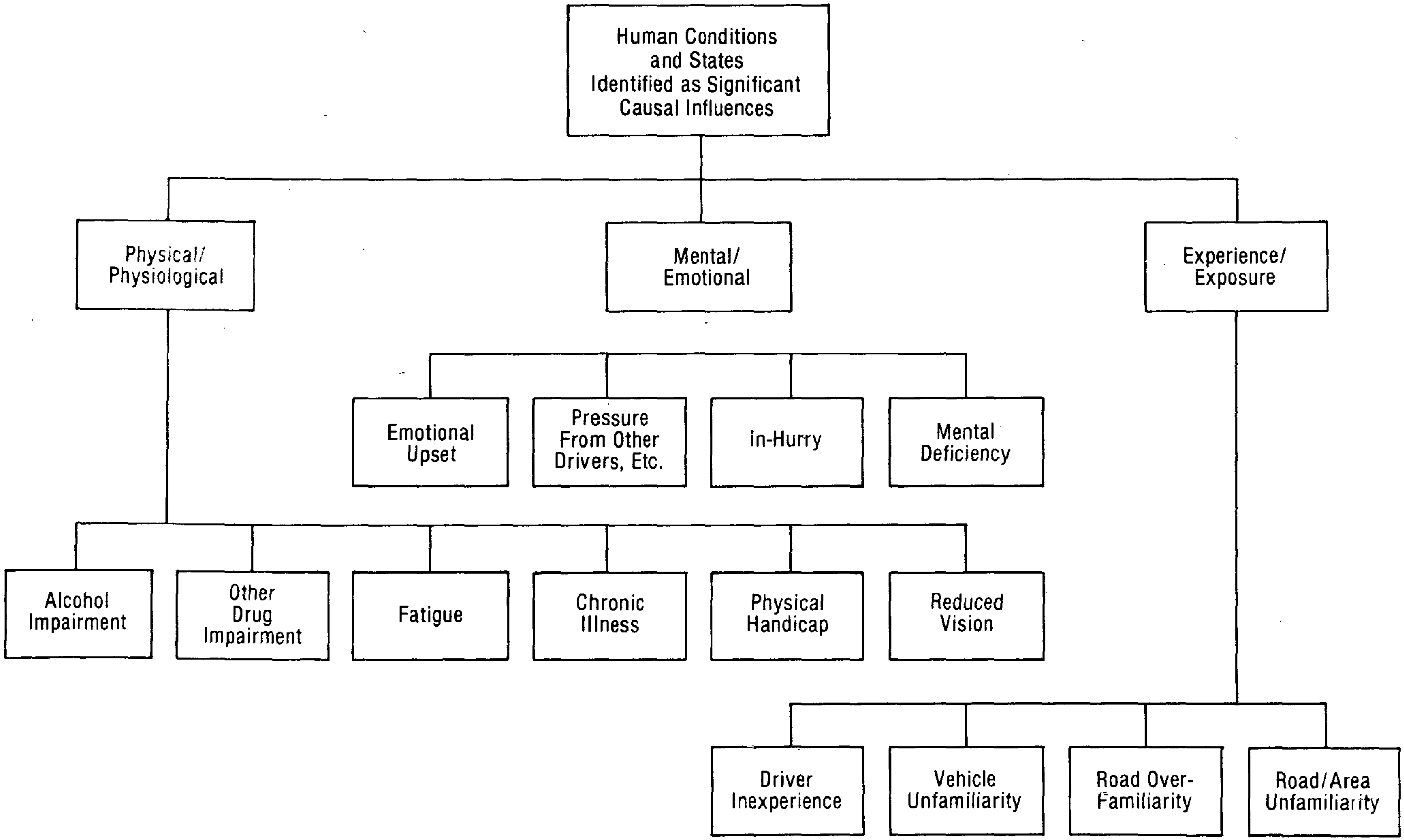
3. Inadequate directional control

   This category refers to situations where a conscious driver does not maintain adequate control over the path of his vehicle, although such control would have easily been possible had appropriate steering inputs been applied. This does not apply to the situation where high lateral loads make continued control a delicate matter, and overtax the skills of the driver. Rather, these are situations where adequate lateral traction is available, so that had the driver adequately monitored information regarding the need for steering inputs, and then applied these inputs with skill reasonably expected from an ordinary driver, control could easily have been maintained.

   Frequently, this category is applied when a conscious driver fails to maintain directional control in a relatively untrying situation, and information is not available to allow a more precise category to be applied. For example, where there is information that the driver was *distracted* or was *preoccupied,* and hence did not notice the deviation of his vehicle from the intended path in sufficient time, those specific categories would apply. However, where such information cannot be obtained, but it is known that the driver was conscious and should have easily been able to complete the necessary steering task, the *inadequate directional control* category applies.

Glossary Figure 3

Causal Factor Tree for Human Conditions and States



Outline

II. Human Conditions and States

A. Physical/physiological

1. Alcohol impairment
2. Other drug impairment
3. Fatigue
4. Physical handicap
5. Reduced vision
6. Chronic illness

B. Mental/emotional

1. Emotionally upset
2. Pressure or strain
3. In-hurry
4. Mental deficiency

C. Experience/exposure

1. Driver inexperience
2. Vehicle unfamiliarity
3. Road over-familiarity
4. Road/area unfamiliarity

Definitions

II. Human Conditions and States

These are factors which adversely affect the ability of the driver to perform the information processing functions necessary to safe performance of the driving task. As such, these conditions and states may result in information processing errors which, in turn, are the direct causes of traffic accidents. In a sense, these are "causes of accident causes." Due to the remoteness of their involvement, such factors are difficult to implicate with certainty through the clinical examination of individual accidents. Nevertheless, in some cases unusual evidence does enable a causal relationship to be established, and the causal involvement of such factors has been tabulated according to the same assessment system as was utilized for human direct causes.

A. Physical/physiological

1. Alcohol impairment

Alcohol impairment may be cited as a causative condition or state whenever it is concluded that consumption of alcohol has occurred which may account for a driving error which has played a causal role in an accident. As such, this factor may be cited both where a driver is clearly intoxicated, and where he has been drinking but has not reached a state of intoxication.

Intoxication is the intake of alcoholic beverages to the point of obvious physical impairment. Determination of the legal blood-alcohol definition of intoxication is of minor concern (and often not available), although a BAC in excess of .10% should be considered indicative of intoxication. What is more important is the degree of involvement of the intoxicated driver in the accident. If he was stopped legally at a stop sign or signal and is hit in the rear then his intoxication probably had nothing to do with the cause of the accident and should be given less consideration. If his involvement includes misjudgment, speeding, delayed reaction, illegal maneuvers, etc., then alcohol impairment should be considered as at least a possible causal factor.

The weight, or degree of assurance, that intoxication was a (1) possible cause, (2) probable cause, or (3) definite cause depends mainly upon the degree of involvement and driver error in the accident. In this case actions such as walking, talking, pupil dilation, eye focusing, breath odor, etc., serve as strong clues as to the extent of intoxication.

Drinking is the admission or detection by the investigator that the driver had a few alcoholic drinks. The major difference between drinking and intoxication is the physical appearance of the driver. Many times the driver will not appear intoxicated although admitting to "having a couple of drinks," or there is a faint smell of alcohol on his breath. The term drinking may not refer exclusively to physical impairment but may imply a psychological change. Drinking may have reduced mental alertness and driver attitude.

In many cases the drinking driver may appear to be physically capable of driving but be in a belligerent mood which the investigator may suspect to be induced by the alcohol (CAL).

2. Other drug impairment

This is the intake by a driver of some drug (other than alcohol) which could physically affect reaction. This refers to a driver who had admitted taking tranquilizers, benzedrene, strong cold tablets, pain killers, sleeping pills, amphetamine, etc. within a 12 hour period before the accident occurrence. The effects on driving behavior and reaction time might be observed in the form of slow movements, incoherence, glassy eyes and an intoxicated appearance. Drivers who appear intoxicated (by their actions) with no evidence or admission of drinking alcoholic beverages should be questioned about the use of drugs. The 12 hour time period may appear high but is realistic in the case of strong drugs. In the case of cold tablets and milder drugs, a 4-6 hour time period may be more appropriate (CAL).

3. Fatigue

   Fatigue is a condition of mental or physical exhaustion, or both, which is induced by an inordinate level of, or a prolonged period of, activity. In general, fatigue results in a decrease in a driver's ability to respond to stimulation. Less than a normal night's sleep, a long day on the job, a new work-shift, three to five hours of continuous driving, a recent illness, or a full day of recreational activity are examples of the conditions that might cause a driver to be fatigued.

   Observations of the driver which would indicate fatigue include droopy eyelids, slow movements, hesitant responses to questions or slight incoherence, bloodshot eyes, yawning, and an overall pale, exhausted look.

4. Physical handicap

   Such handicaps might be either temporary or permanent. It includes a temporary condition which physically limits the driver in performing normal driving functions—and is especially critical in those maneuvers requiring extra effort from the driver. Examples are (1) broken limbs, (2) some injury which a cast or extreme amount of tape is covering, (3) a recent operation leaving the driver uncomfortable, or (4) pregnancy.

   Examples of permanent handicaps to a driver which may affect his driving ability would be, an amputation or permanent defect to an arm or leg, a crippling disease, etc.

   Handicapped drivers who have no use of their legs generally have special hand controls on their vehicles and all vehicle control (acceleration, braking and steering) is accomplished with the hands (CAL).

5. Reduced vision

   This factor refers to both temporary and permanent impairment. Temporary vision impairment is a condition of reduction in a driver's normal vision due to some temporary eye defect or hindrance. Visual acuity is generally affected. It may be the consequence of a foreign particle ledged in an eye, a stye, eye strain from driving into bright sunlight, or wearing required corrective lenses, or wearing sunglasses on an overcast day or at night, for examples.

Permanent vision impairment is a condition of permanent reduction or defect in a driver's vision. A damaged or missing eye, color blindness, cataracts, or extremely poor vision (e.g., 20/150 or poorer) are a few examples of this condition. Permanent eye defects inhibit the driver's ability to adequately monitor the driving situation and thus expose him to an increased risk of collision.

6. Chronic illness

A chronic illness is a long-lasting, recurrent illness which detracts from driver efficiency. Long term or chronic illnesses not only affect the driver's comfort and state of mind, but also may affect his driving ability. Illnesses such as arthritis, asthma, hay fever and rheumatism can diminish driver ability to maneuver and driver comfort during the driving task.

Indications of chronic illness include delayed or slowed reactions and complaint that an illness was bothering the driver (CAL).

B. Mental/emotional

1. Emotional upset

Emotional upset is an acute affective disturbance (positive or negative) arising from the psychological situation and expressing itself in conscious experience, behavior, and physiological processes. The dynamic determinants of emotion include conflict, frustration, thwarted (or satisfied) expectation, tension (or its release), painful stimulation, threat, insult, and similar conditions of stress or relief. The emotionally upset driver functions at a reduced level of efficiency due to the impairment of his normal rational, intellectual, and mental capabilities and hence becomes more vulnerable to dangerous situations and less perceptive of external cues. Consequently his driving may include an angry or careless maneuver, hesitant or unsure decision, and a delayed reaction.

The most prominent emotional states which may cause these effects are:

- anger (i.e., fight with spouse; just got cut off by another vehicle; traffic moving too slowly)

- confusion (i.e., lost—insufficient information; wrong maneuver—information overload)
- depression (i.e., just lost job; family problems; recently divorced)

2. Pressure or strain

Pressure or strain is a condition of excessive demands for action exerted on a driver that produces disturbances of the psychological or physiological systems, or both. Typically the source of pressure or strain is the "other driver" who instigates the driver to take action immediately without careful consideration of the driving situation. Thus the driver reacts to the pressure rather than acting rationally in terms of the driving situation. A driver stopped at a red light with no intention of turning may be pressured to turn without carefully checking for cross traffic by another driver intent on turning right on red, for example.

3. In-hurry

A driver is in a hurry when he feels compelled to extend himself to or beyond the safe limits of the driving system due to a heightened sense of urgency. This compelling sense of urgency may depend all or in part on the driver's subjective judgment (feeling) about the adequacy of available time, regardless of the objective time parameters of the situation.

In addition to generally taking more chances, the hurried driver might: speed, tailgate, run a stop sign or red light, "stretch out" an amber light, change lanes carelessly, cut corners, etc.

4. Mental deficiency

Mental deficiency refers to a mentally disturbed driver or one whose intelligence is far below normal. If obvious deficient behavior is observed during the interview with the driver, or if he has been known to have been in a mental institution, or has had several nervous breakdowns, this deficiency must be taken into consideration. The behavior of such drivers in emergency situations may be critically delayed or improper (CAL).

C. Experience/exposure

1. Driver inexperience

Driver inexperience refers to a lack of adequate exposure to the overall driving task. Common occurrences induced by driving inexperience include inability to control the vehicle, distance-velocity misjudgments, improper evasive actions, and panic maneuvers. Empirically, drivers with less than 2 years experience or drivers who drive less than 5,000 miles per year fall into this category. Also, truck or bus drivers with limited experience in that type of vehicle could also be termed "inexperienced," as could drivers who have not driven for a long period of time (i.e., military service). However, if inexperience had nothing to do with the accident situation, it obviouly should not be considered as a factor (CAL).

2. Vehicle unfamiliarity

   Vehicle unfamiliarity refers to a lack of driving time in a particular vehicle. Borrowed, rented, or owned vehicles driven for less than 6 months are considered unfamiliar to the driver. Characteristics such as different locations of controls and accessories, different transmissions, different sized vehicles, different power outputs, etc. could all contribute to an accident situation. If the handling aspects of the involved vehicle generated responses different than anticipated during the accident sequence then vehicle unfamiliarity should be considered as a potential factor (CAL).

3. Road over-familiarity

   Over-familiarity is overexposure to a driving routine which can introduce complacency, contempt, etc. Just as unfamiliarity with the road could be a contributing factor to driver confusion or inattention in an accident event, at the other extreme, the driver who has driven the accident route a large number of times (i.e., back and forth to work for 2-3 years or several times daily as a delivery route) so that the trip has become routine, may become over-familiar with the route. He has become accustomed to signal timings, traffic density, road configuration, etc. to the point of possible complacency. Any unexpected events may not be perceived or recognized immediately due to a certain monotony and inalertness to the driving task. This complacent behavior with a normally routine environment may induce a delay in reactions to unexpected events (CAL).

4. Road/area unfamiliarity

   Road unfamiliarity is lack of driving exposure to a particular road. Drivers who seldom drive on a particular road are at a disadvantage because of their lack of knowledge of the configuration, speed limit, signals, signs, intersections, turns, etc.

   Indications of road unfamiliarity include: seeking street names or house numbers; excessive speed on a curve; confusion with the signal system; falsely assuming other traffic controlled by stop signs at intersections; etc. (CAL).

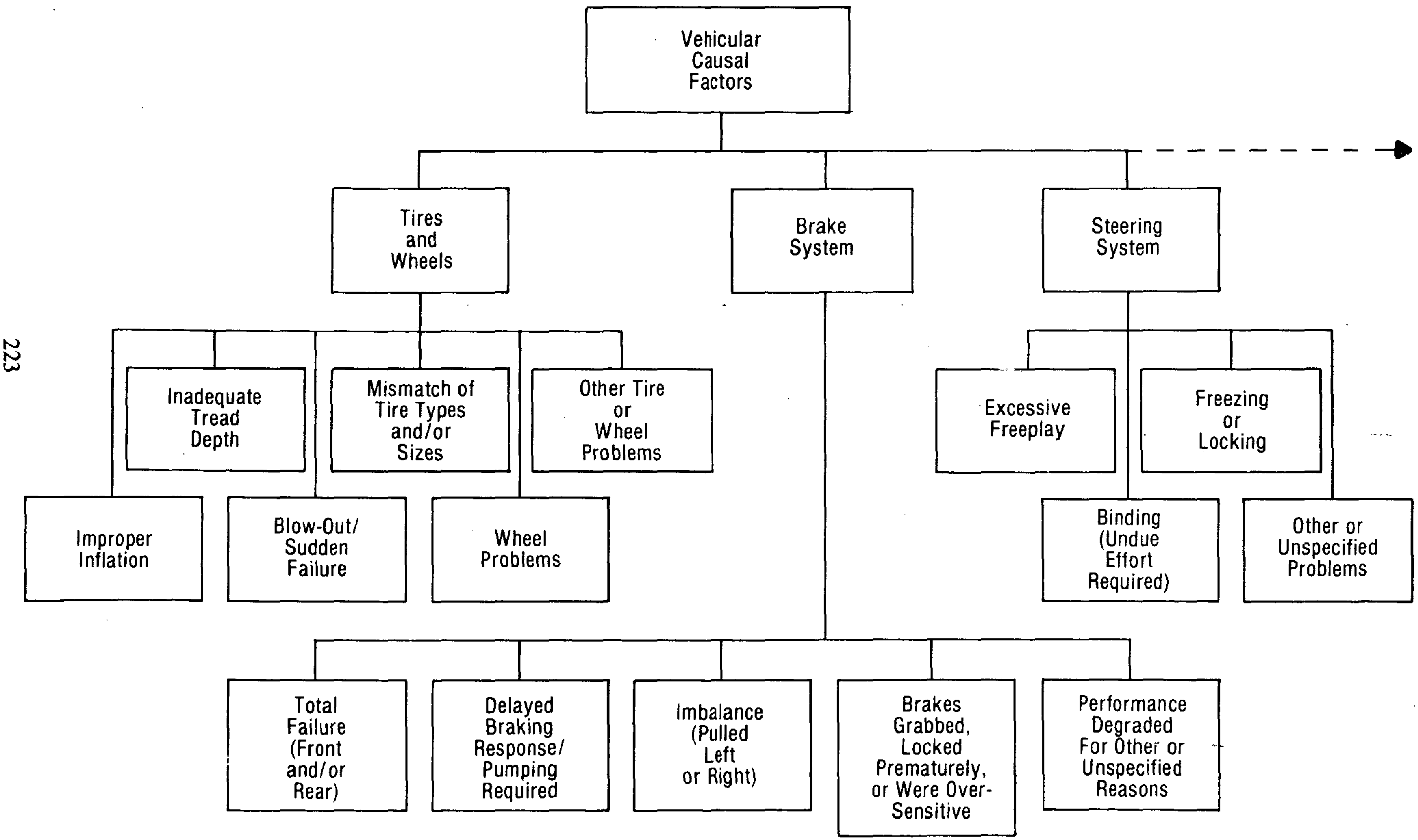
Area unfamiliarity is lack of exposure to the road, traffic and traffic control system of a particular area. Unfamiliarity with the area in which the accident occurred may have had some of the following effects on the driver:

- traffic density and speed for prevailing conditions are unknown and confusing
- traffic regulations, placement of signs, signals, etc. may be unfamiliar
- driver may be distracted by reading road signs and following directions
- drivers when lost often become confused, angry, upset, etc. thus reducing their attentiveness

Drivers from other geographic areas (especially from other states) and those who have been in the area only once or twice qualify for this factor. Inattentiveness and hesitative driving behavior are strong clues that the driver was unfamiliar with the area (CAL).

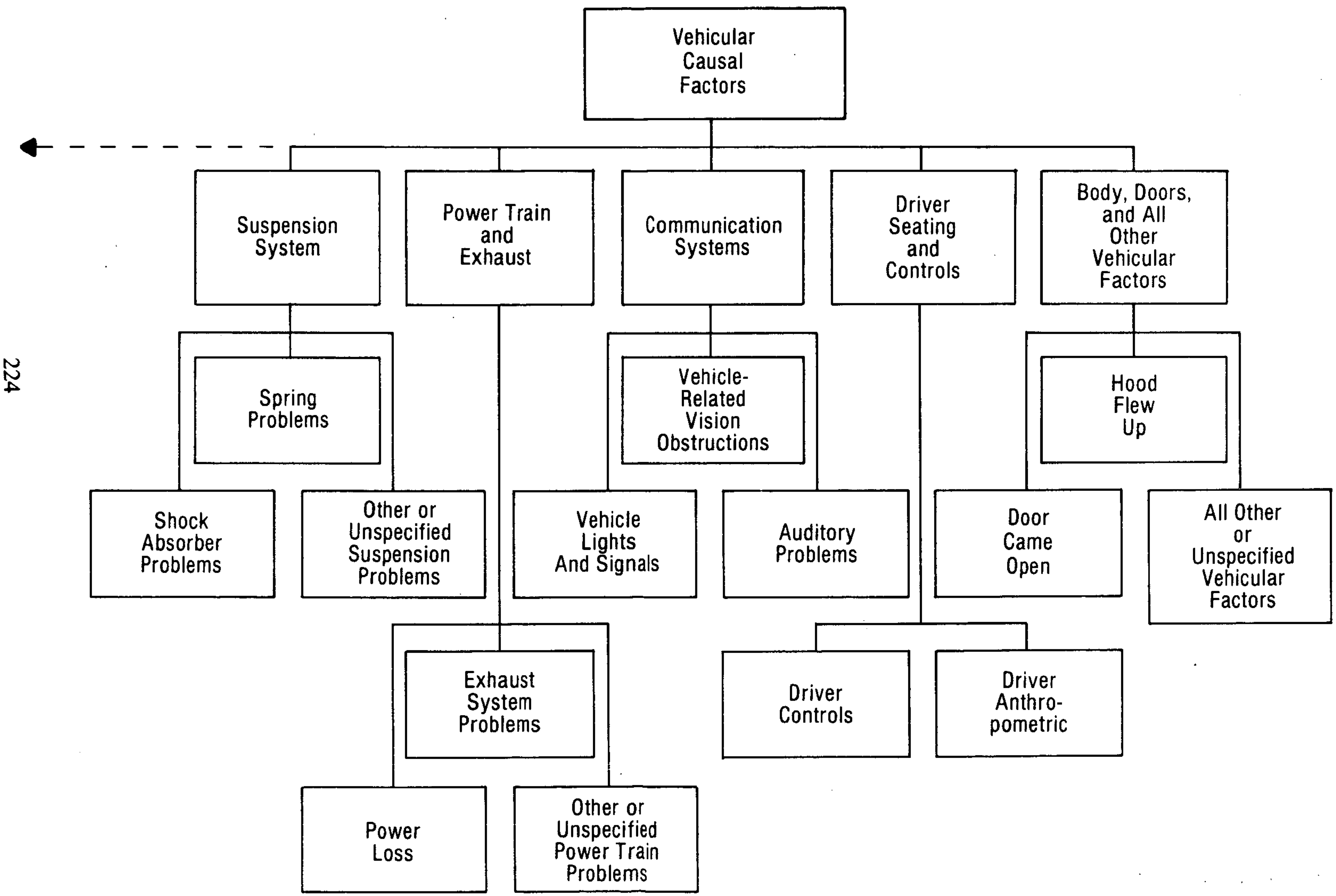
Glossary Figure 4

Causal Factor Tree for Vehicular Causal Factors



Glossary Figure 4 (continued)

Causal Factor Tree For Vehicular Causal Factors



Outline

III. Vehicular Causal Factors

A. Tires and wheels

1. Inflation

   (a) Under-inflation
   (b) Over-inflation
   (c) Improper pressure distribution

2. Inadequate tread depth
3. Blow-out/sudden failure
4. Mismatch of tire types and/or sizes
5. Wheel problems (failures, etc.)
6. Other tire or wheel problems

B. Brake system

1. Total failure (front *and/or* rear)

   (a) Total failure—front *and* rear

      (1) Wheel cylinder failed
      (2) Brake line failed
      (3) Master cylinder defect
      (4) Insufficient fluid level
      (5) Adjustment mechanism loss or failure
      (6) Other or unspecified reasons

   (b) Failure-related front only

      (1) Wheel cylinder failed
      (2) Brake line failed
      (3) Master cylinder defect
      (4) Insufficient fluid level
      (5) Adjustment mechanism loss or failure
      (6) Other or unspecified reasons

   (c) Failure-related rear only

      (1) Wheel cylinder failed
      (2) Brake line failed
      (3) Master cylinder defect

(4) Insufficient fluid level
(5) Adjustment mechanism loss or failure
(6) Other or unspecified reasons

(d) Total failure—unknown or unspecified as to portion affected

(1) Wheel cylinder failed
(2) Brake line failed
(3) Master cylinder defect
(4) Insufficient fluid level
(5) Adjustment mechanism loss or failure
(6) Other or unspecified reasons

2. Delayed braking response/pumping required

(a) Required pumping due to improper adjustment
(b) Other or unspecified reasons

3. Imbalance (pulled left or right)

4. Brakes grabbed, locked prematurely, or were over-sensitive

(a) Improper proportioning front-to-rear (e.g., rear wheel lock-up)
(b) Brakes, "grabbed," locked prematurely, or were over-sensitive, etc.

5. Performance Degraded for other or unspecified reasons

C. Steering system

1. Excessive freeplay
2. Binding (undue effort required)
3. Freezing or locking
4. Other or unspecified problems

D. Suspension problems

1. Shock absorber problems

(a) Weak shock absorbers
(b) Missing, broken, or other shock absorber problems

2. Spring problems

(a) Broken, missing, or defective springs
(b) Raised rear-end
(c) Spring imbalances (due to helper springs, overload springs, spring spacers, etc.)

3. Other or unspecified suspension problems

E. Power train and exhaust

1. Power loss

(a) Ran out of fuel
(b) Other or unspecified problems

2. Exhaust system

(a) CO leaked into driver's compartment
(b) Other or unspecified problems

3. Other or unspecified power train problems

F. Communication systems

1. Vehicle lights and signals

(a) Headlamp problems

(1) Inoperable headlamps
(2) Mis-aimed headlamps
(3) Dirt-obscured headlamps

(b) Inoperable taillights
(c) Inoperable turn signals
(d) Taillights or turn signals obscured by dirt, road grime, etc.
(e) Other light problems

2. Vehicle-related vision obstruction

(a) Due to ice, snow, frost, water, or condensation on windows
(b) Due to cracked or opaque windows (e.g., cardboard or stickers on windows)
(c) Due to design or placement of windows
(d) Due to objects in or attached to vehicle
(e) Due to inoperative or deficient vision hardware

(1) Inoperable or mis-aimed windshield washer
(2) Inoperable or ineffective wiper
(3) Inoperable or inadequate defroster
(4) Absence or condition of mirrors

(f) Other

3. Auditory problems

    (a) Inoperable or weak horn
    (b) Excessive radio or tape player volume inside car
    (c) Other or unspecified problems

G. Driver seating and controls

1. Driver controls

    (a) Steering wheel problem; (e.g., spinner snagged clothing)
    (b) Brake pedal problem; (e.g., pedal broke off)
    (c) Accelerator problem; (e.g., stuck)
    (d) Other or unspecified problem

2. Driver anthropometric

    (a) Seat loose or became detached
    (b) Driver not positioned to adequately reach controls
    (c) Driver not positioned to see adequately
    (d) Other or unspecified problems

H. Body, doors, and all other vehicular factors

1. Door came open
2. Hood flew up
3. All other or unspecified vehicular factors

Definitions

III. Vehicular Causal Factors

This refers to all vehicle-related deficiencies which result in an accident, or increase the severity of vehicle impact which results. Included are system failures, degradations, and worn components. For the most part, *deficiency* was assessed based on comparison to typical OEM standards. To a large extent, these were determined by the pass-fail criteria established (see Appendix C).

Included under this heading were visual limitations associated with the vehicle, including those caused by objects or substances in, attached, or adhering to the vehicle.

A. Tires and wheels

This includes all causal failures and improper conditions associated with *tires and* *wheels,* as determined by the established pass-fail criteria. Included are inadequate tread depths, blow-outs, mismatches of tire types and/or sizes, improper inflation, and wheel failures.

B. Brake system

This includes all accidents resulting from the failure, or degraded or abnormal performance, of the braking system. This includes both gross failure of all or part of the braking system, delayed braking (as where pumping is required), brake imbalances (as where hard application causes a marked change in vehicle path), etc.

C. Steering system

This includes all failures or degradations of the steering system whereby accurate steering control is negated or made grossly more difficult than ordinarily expected. Examples include excessive freeplay and freezing or locking of the steering gear.

D. Suspension problems

Suspension problems include failures or degradations of shock absorbers, springs, bushings, locating links and arms, etc., which hinder vehicle control.

E. Power train and exhaust

This includes any failure or substandard performance of the engine, drive train, or exhaust system that causes an accident, such as a sudden loss of power or the leakage of exhaust fumes into the driver compartment, with a consequent detrimental effect on driver behavior. Power loss as a result of running out of fuel is included.

F. Communication system

This includes all failures and degradations of systems by and through which drivers send and receive the visual and auditory information necessary for safe completion of the driving task. These systems thus include lights, glazed surfaces, horns, and windshield wipers and washers.

G. Driver seating and controls

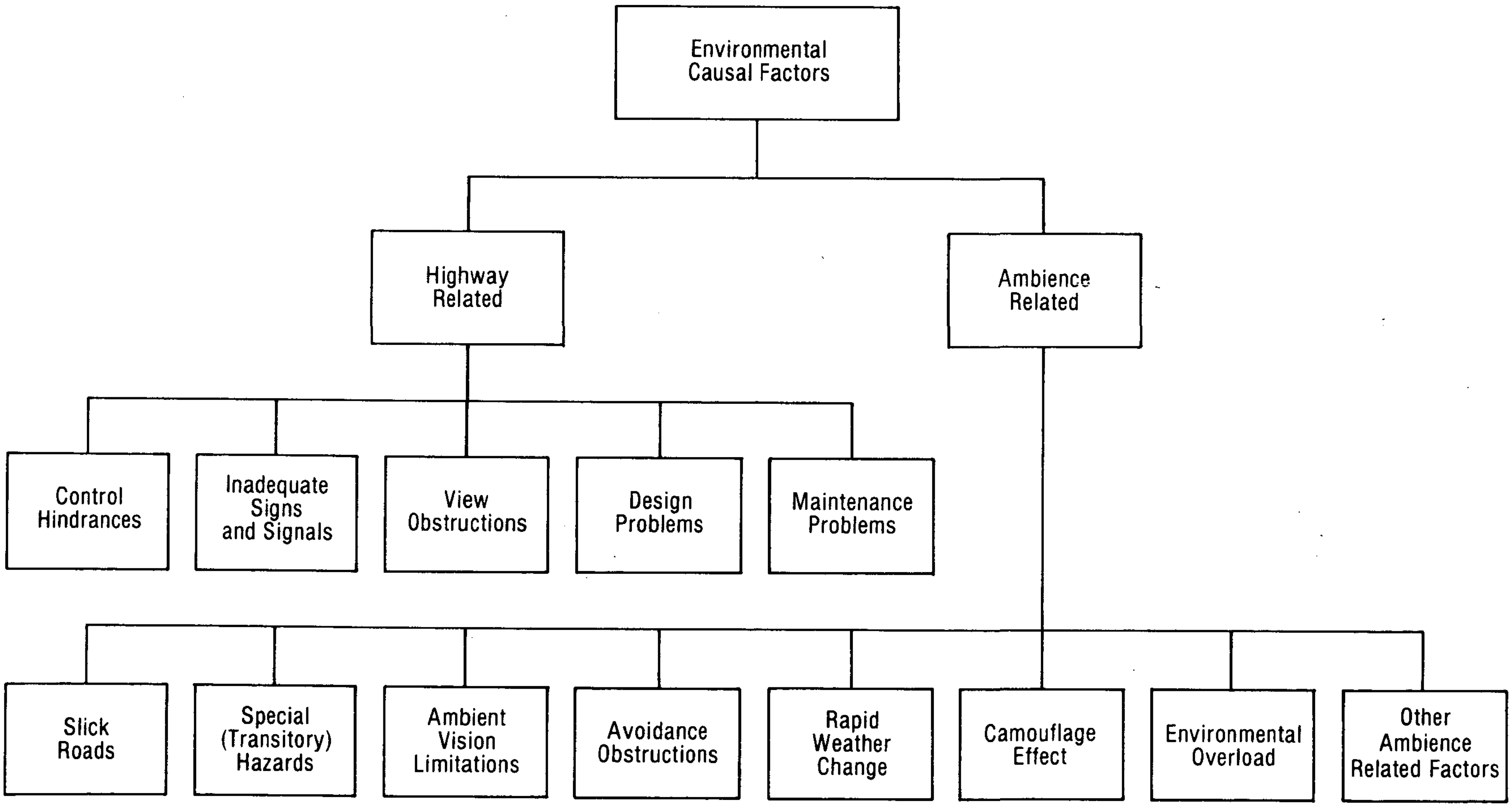
This includes all instances where driver seat location failures and deficiencies impair the driver's ability to safely complete the driving task, as by limiting his ability to see and/or manipulate controls, as well as where difficulty is experienced with driver controls, such as when an accelerator pedal sticks.

H. Body, doors, and all other vehicular factors

This category includes all failures in the integrity of body and doors, which act to impede vehicle control, and hence are pre-crash accident-causative factors. In addition, all vehicular factors not categorized elsewhere were placed under this heading. Examples are doors which come open while rounding curves, causing drivers to lose control, and hoods which fly up, thereby blocking vision, with the same result.

Glossary Figure 5

Causal Factor Tree for Environmental Causal Factors



Outline

IV. Environmental Causal Factors

A. Highway related

1. Control hindrances

   (a) Drop-offs at pavement edge
   (b) Excessive road crowns
   (c) Improperly banked curves
   (d) Soft shoulders
   (e) Ditches, embankments, and other road side features
   (f) Unexpected wet or slick spots
   (g) Other or unspecified control hindrances

2. Inadequate signs and signals

   (a) Stop sign needed but not provided
   (b) Stop sign present but not adequate
   (c) Curve warning signs needed
   (d) Curve sign present but not adequate
   (e) Signal light poorly placed and/or not adequately visible
   (f) Poor signal timing
   (g) Center or lane lines not present or inadequate
   (h) Edge lines not present or inadequate
   (i) Other or unspecified

3. View obstructions

   (a) Hillcrests, dips, etc. (road surface features)
   (b) Roadside embankments, escarpments, etc.
   (c) Roadside structures and growth
   (d) Stopped traffic
   (e) Parked traffic
   (f) Other or unspecified view obstructions

4. Design problems

   (a) Accesses not sufficiently limited or improperly placed
   (b) Intersection design problems
   (c) Road overly narrow, twisting, etc.
   (d) Trees and other fixed objects too close to road presenting excessive collision hazard

(e) Other or unspecified design problems

5. Maintenance problems

   (a) Signals inoperative
   (b) Traffic control sign missing
   (c) Traffic control sign or signal obscured
   (d) Other or unspecified problems

B. Ambience-related

1. Slick roads

   (a) Road wet
   (b) Road snow and/or ice covered
   (c) Gravel and/or sand on paved surface
   (d) Road slick due to traffic polishing
   (e) Wet and traffic polished asphalt
   (f) Gravel road
   (g) Other or unspecified problems

2. Special (transitory) hazards

   (a) Animal in road
   (b) Object in road
   (c) Non-contact vehicle caused problem
   (d) Stopped vehicle in road
   (e) Other

3. Ambient vision limitations

   (a) Rain
   (b) Snow
   (c) Fog
   (d) Darkness
   (e) Glare from sun
   (f) Glare from headlights
   (g) Other

4. Avoidance obstructions

   (a) Parked or stopped traffic
   (b) Trees and other fixed objects
   (c) Other or unspecified

5. Rapid weather change
    (a) Suddenly-encountered fog
    (b) Suddenly-encountered slick roads
    (c) Other or unspecified
6. Camouflage effect
    (a) Motor vehicle blended in with background
    (b) Other or unspecified
7. Environmental overload
8. Other ambience-related factors

Definitions

IV. Environmental Causal Factors

Environmental factors are those factors external to the driver or vehicle which increase the risk of accident involvement unnecessarily or to an excessive extent. Such factors are categorized as being either *ambience-or highway-related.* For the most part, an ideal norm is assumed, based on ideal ambient conditions (including dry roads and good visibility), and published design and control standards in common usage.

A. Highway-related environmental factors

These are generally factors of a relatively permanent nature, and are those closely associated with highway design, construction, and/or maintenance.

To a large extent this category is defined by the next-level (more specific) categories which it includes. These are *control hindrances, inadequate signs and signals, view obstructions, design problems,* and *maintenance problems.*

1. Control hindrances

This category refers to road surface configurations which tend to excessively disturb directional stability. Examples of such factors include drop-offs at pavement edges, soft shoulders, and unforseeable wet or slick spots.

2. Inadequate signs and signals

This category refers to all situations where due to lack of adequate information, or modification of traffic flow, the risk of accident involvement is increased so greatly that even an alert and prudent driver might be caused to be involved in an accident.

3. View obstructions

   This category refers to situations where environmental factors prevent or limit the receipt of visual information needed for safe completion of the driving task, and thereby significantly increases the risk of accident involvement. Factors considered to be view obstructions include hillcrests and dips in road surfaces, roadside structures and growth, and stopped or parked traffic. For consistency both permanent and transitory obstructions are included in this category.

4. Design problems

   This category designates roadway and intersection designs configurations which deviate from some reasonable ideal, such as standards recommended by AASHO or DOT, and by doing so significantly increase the risk of accident involvement. Examples in the study area include major shopping center accesses located in close proximity to high volume intersections, and country roads which are unexpectedly narrow. In each case, these are situations which are felt to create significantly increased risks of involvement, so that even an alert and prudent driver might occasionally be expected to fail to safely complete the driving task.

5. Maintenance problems

   This category refers to environmental situations which significantly increase the risk of accident involvement, arising out of the need for roadways and/or signs to be restored to their intended status. Examples of factors falling in this category include inoperative signals and missing or obstructed traffic control signs or signals. *Maintenance problems* is to be distinguished from *control hindrance,* in that *control hindrance* takes precedence when it is known to apply.

B. Ambience-related environmental factors

This category primarily refers to transient environmental factors, such as those associated with weather and with transient traffic situations.

1. Slick roads

   This category applies whenever it is determined that an accident has occurred which would have not occurred had the road surface present been dry, clean, paved, non-travel polished, and in otherwise good repair.

2. Special hazards (or transients hazards)

   This category refers to transient hazards which increase the risk of an accident. Included are animals and objects in the road, and non-contact vehicles and drivers which cause problems. Examples of the latter kind include vehicles which force accident-involved vehicles off the road, and then continue without involvement. Since it cannot be determined what the nature of the human, vehicular, or environmental causes are which caused the errant behavior of the non-contact vehicle, it is desirable to view the actions of such a non-contact vehicle as transient environmental hazards for the involved driver who is the subject of investigation; consistency can only be achieved in this manner.

3. Ambient vision limitations

   This refers to all natural, atmospheric, and other conditions which reduce visibility or otherwise excessively hinder a driver's or pedestrian's ability to see. This category thus includes the influence of fog, haze, rain, snow, and glare from the sun or headlights, on vision and/or visibility.

4. Avoidance obstructions

   This category refers to objects which are located excessively close to road surfaces, and thereby close off evasive routes to a driver which (1) he did in fact consider, and which (2) were feasible escape routes, and which (3) he was reasonable in expecting would be available to him. Examples include traffic stopped or parked on the road brim, and trees or other fixed objects interrupting an otherwise relatively continuous road shoulder.

5. Rapid weather change

   This refers to situations where a change in weather is so rapidly encountered as to surprise the driver, and thereby subjects him to an increased risk of involvement which he did not intend to generate. The key element is that of surprise, and a rate of change so great that it significantly exceeds normal expectations.

6. Camouflage effect

   This category refers to situations where a traffic unit (e.g., motor vehicle or pedestrian) blended into its background to such a significant extent that its *perception was delayed or even totally negated.*

7. Environmental overload

   Environmental overload refers to situations where so many simultaneous circumstances requiring monitoring by the driver occur, that he cannot successfully monitor all of them, so that despite being alert in attempting to cope with the situation, he fails to adequately monitor an item of information required for safe completion of the driving task, and is therefore involved in an accident.