KRALL
TRUCK SAFETY CONSULTANCY
TRUCK RESEARCH SERVICES INC.

Ernst & Ernst Truck Accident Study

Report of Proceedings and Findings

August 1968

Prepared for Automobile Manufacturers Association, Inc.

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TRUCK ACCIDENT STUDY

REPORT OF
PROCEDURES AND FINDINGS

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August, 1968

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ERNST & ERNST
UNION COMMERCE BUILDING
CLEVELAND, OHIO 44115

August 30, 1968

Automobile Manufacturers Association, Inc.
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Gentlemen:

In October, 1966, your Motor Truck Safety Research Committee asked Ernst & Ernst to gather a large body of data from official reports of accidents involving truck type vehicles, and to subject this data to a preliminary search for statistically significant relationships which would be useful in the study of highway safety problems. This report describes the sources of data, the procedures used to select accident reports from these sources, the types of data gathered from these accidents reports, and the types of analyses made. It then presents statistically significant findings.

We established a sample size of 10,000 accident reports as being sufficiently large for the development of many meaningful relationships, and yet small enough to avoid undue difficulty in data collection and tabulation. We determined that two distinct sources of data would be used:

1. Accident reports contained in central files maintained by state governments.

2. Accident reports filed by large trucking companies to the Interstate Commerce Commission.

Rather than attempt to obtain accident report information from each of the states, we selected 10 which were geographically distributed throughout the continental United States, and represented broad ranges of terrain, weather conditions, population density, and commercial traffic. Similarly, we selected 10 large trucking companies with the objective of obtaining an additional 1,000 accident reports as a basis for a comparison with the larger sample.

The report contains a number of findings based on the statistical significance of the occurrence of accidents under specific circumstances compared to occurrences in the entire body of data. In addition, virtually every finding suggests the need for further analyses to find additional significant relationships that may be present.

Furthermore, there are attributes on which tabulations were made but which have not been included in these analyses. One type of information which appears most interesting is the vehicle identification number from which a detailed description of a truck-type vehicle can be drawn and matched to an accident in which the vehicle was involved. These and other analyses could provide substantive information pertinent to an understanding of the role of the truck in the national highway safety problem.

We are grateful for the cooperation of police agencies and departments of highways in the 10 states, and the trucking companies who participated in the study. We are also grateful for the assistance of the Motor Truck Safety Research Committee and the Data Collection Coordination Subcommittee of the Automobile Manufacturers Association, Inc.

Very truly yours,

Ernst & Ernst

STUDY OF ACCIDENT REPORTS FROM TEN STATES

STATE ACCIDENT REPORTS

Central accident report files in ten states were the source of the data for this study. From each of the states we obtained permission to make detailed analysis of individual accident reports. Full cooperation was granted by the ten states initially contacted.

The states were selected to provide a reasonably representative cross-section of the continental United States in terms of weather, terrain, and trucking. All major geographic regions of the country were represented:

- New England: Connecticut
- Middle Atlantic: Pennsylvania, Virginia
- South Atlantic: Florida
- East North Central: Ohio, Illinois
- West North Central: Minnesota
- Southwest: Texas
- Rocky Mountain: Colorado
- Pacific Coast: California

The Sample

The sample was drawn from the population of accident reports meeting the following conditions:

- The accident reported involved at least one vehicle in one of these categories (hereafter referred to as "trucks"[1]):

Pickup truck	Truck-tractor and semi-trailer
Panel truck	Truck-tractor and two trailers
Straight truck	Other truck types

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[1] Definitions of these categories are given in Appendix D.

large a sample from a state such as Connecticut, in which the accident total was low, or too small a sample from states such as California or Ohio. The procedure used to determine these estimates is detailed in our "Report of Sampling Techniques," submitted on March 7, 1967.

Individual accident reports were selected at random[1] from the files, using sampling methods designed to give each report involving a truck-type vehicle equal opportunity of being included in the sample for that state. The sequences used in filing reports and the availability of processed data determined the sampling method. In five states, a systematic sample[1] was used; in the other five, a cluster sample.[1] Details of sampling techniques are also given in the previous report listed above.

Content of Accident Report Forms

We found the following on at least eight of the accident report forms most commonly used in the ten states:

- General Information

  1. State and accident number
  2. Date and time
  3. Day of week

- Vehicle Data (for each vehicle involved)

  1. Year of manufacture
  2. Make
  3. License plate number and state where registered
  4. Type
     - Straight truck (not tractor-trailer)
     - Tractor and semi-trailer
     - Tractor with two trailers
     - Pickup truck
     - Panel truck
     - Other type truck
     - Passenger car
     - Bus
     - Other moving vehicle

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[1] See Appendix D for definition.

9000 T.A.

5. Owner of truck
   - Driver
   - Other

6. Vehicle defects
   - Brakes
   - Lights
   - Steering
   - Tires
   - No defects known

7. Vehicle speed (known or estimated)

8. Movement of vehicle (just prior to accident)
   - Straight ahead
   - Passing
   - Making left turn
   - Making right turn
   - Slowing/stopping
   - Stopped in traffic
   - Pulling into traffic
   - Skidding
   - Jackknifing
   - Crossing over median

9. Amount of damage to vehicle (estimated)

10. Nonvehicular property damage (estimated)

— Driver Data (for each driver involved)

1. Age (or date of birth)
2. Sex
3. Physical condition (at time of accident)
   - Had been drinking
   - Had not been drinking

4. Injury
   - Fatal
   - Non-fatal
   - Not injured

5. Arrested (or citation issued)
   - Yes
   - No

— Environmental Data

1. Type of Area
   - Urban
   - Rural

2. Type of Road
   - Not divided:
     - One way
     - One lane each way
     - Two lanes each way
     - Three lanes or more each way
   - Divided
   - Other

3. Road Geometry
   - Straight
     - — Level
     - — Grade
   - Curve
     - — Level
     - — Grade
   - Hill crest
   - Intersection
   - Railroad crossing
   - Other

4. Road Condition
   - Dry
   - Wet
   - Icy or snowy
   - Other

5. Traffic Control
   - Stop and go lights
   - Stop sign
   - No control

6. Light Conditions
   - Daylight
   - Dawn or dusk
   - Dark

7. Weather Conditions
   - Clear
   - Raining
   - Snowing or sleeting
   - Fog or smog

— Contributing Circumstances

Improper speed
Failure to yield
Following too closely
Left of center
Improper turn
Improper pass
Ignored traffic control
Other

— Passenger Data (for each passenger)

1. Vehicle in which passenger was riding
2. Passenger location in vehicle (if known)
3. Injury
   Fatal
   Non—fatal
   Not injured

— Injured Pedestrian Data (for each one)

1. Pedestrian actions
   Crossing or entering at intersection
   Crossing or entering <u>not</u> at intersection
   Getting on or off vehicle
   Walking in roadway
   Standing in roadway or hitchhiking
   Pushing vehicle or working on it
   Playing in roadway
   Not in roadway

2. Pedestrian injury
   Fatal
   Non—fatal

The following from the above list were lacking on as many as three of the data forms:

1. Vehicle speed
2. Type of area — urban or rural
3. Light conditions
4. Movements of vehicle
5. Amount of damage to vehicle
6. Other property damage

There are a number of items which are generally not obtainable from the standard form:

1. Cargo Factors: Type and weight of cargo, extent damaged, spillage, involvement as a cause of the accident or as a cause of injury, or whether truck was not loaded.
2. Type of Truck Operation: Differentiation between regulated and nonregulated operation was difficult unless the report listed ICC number in the accident description. Some clues were available from the name of the owner, particularly if he was a listed common or contract carrier, or if the truck carried an out-of-state registration.
3. Trailer Make and Type: Indicated only under "notes" or "remarks".
4. Cab Type: Only the year and make of truck were available. In-depth examination of photos (if available) could have revealed type of cab, but in most states where photos had been taken, the photo files were kept separately and would have required considerable additional time and effort to obtain and examine.
5. Seat Belt Usage: This information was included on only four of the standard forms used.
6. Passenger/Driver Ejection: Data on whether or not occupants were ejected or remained in the cab was obtainable only as it might be included in the accident diagram.

7. Cause of Injury: The direct cause of personal injury, such as striking through windshield, etc., was not found on the accident reports, except in isolated cases.

8. Vehicle Identification Number (serial number): This was included only on Illinois and Pennsylvania standard forms.

In addition, the following items were not directly covered by the wording of the accident reports, but had to be developed from study of the diagrams. These are discussed in the section on special coding instructions.

1. Intersection
2. Type of Accidents
3. Movement of vehicle

DATA PREPARATION

Preparation for Coding

Coding Form

A coding form (Appendix A) was prepared in order to simplify and standardize the gathering and analysis of accident report data. The form was divided into three major parts:

1. Section I, including general information, environmental data, accident data, and pedestrian data;
2. Section II – IV, containing data about Vehicle #1; and
3. Section V – VII, containing data about Vehicle #2. Sections II – IV and V – VII were identical.

If the accident involved more than two vehicles, a second coding form was used. Where more than four vehicles were involved, the number of vehicles in the accident was recorded, but details on the vehicles were collected for only the first four trucks.

Reference Numbers

Each accident report coded had an identifying number which would permit location of the original accident report in the state file.

Special Coding Instructions

Coders were instructed to read carefully the description of the accident and study the accident diagram before proceeding with any of the coding. In most states, every question on the coding form could be answered if the accident report instructions had been followed and the

report completely filled out. In some states; however, either restrictions imposed on the coders or the structure of the report form caused certain questions to be left blank or to be estimated by the coder:

- Type of Area – In coding those forms which did not have an "urban–rural" blank, the coder was instructed to search the location description. If the notation was "X miles from city limits", the instruction was to code as rural. If "within the city limits", the instruction was to code as urban.

- Intersection – In coding those forms with no "intersection" blank, the coders examined the diagram of the accident for the presence of an intersection.

- Type of Accident – None of the accident report forms included a "type of accident" listing. The coder was instructed to read the accident description and circle the number most closely describing the initial accident occurrence (i.e., a vehicle running off the road and colliding with another vehicle not on the road was coded as a "ran off road").

- Movement of Vehicle – This information was also obtained from the accident diagram and description, if a blank was not provided on the accident report.

- Vehicle Identification Number – This was available only on reports from Illinois and Pennsylvania.

- Name of Owner (if not driver) – Several states prohibited the coder from using this information. One state masked out the names of owners, drivers, passengers, witnesses, etc., on accident report copies prepared for this study.

- Drinking Driver – This question was answered only if there was a specific notation on the accident report as to whether the driver had or had not been drinking.

Coding

All coding was under direct supervision of Ernst & Ernst personnel. In five of the states (California, Connecticut, Minnesota, Ohio and Texas) coding was done in the state capitals in the locations where the reports were maintained. Coding was supervised by management personnel

from Ernst & Ernst offices located in the five capital cities. The other five states (Colorado, Florida, Illinois, Pennsylvania, and Virginia) permitted copies to be made. In these cases, coding was done in Cleveland.

Keypunching

Instructions for keypunching were included on the data forms. After coding was completed, all forms were gathered in Cleveland, punched, verified and transferred to magnetic tape.

Editing

Eliminating Inconsistencies

Data for each accident was checked electronically against a list of 37 possible omissions or inconsistencies (Appendix B) that could result from missing data elements on the accident reports, or from inconsistencies in reporting or coding. We found 8,310 accident reports (79.8% of the original 10,416) to be free from inconsistencies and complete as to key data. These reports involved vehicles from every state in the continental U.S. except Idaho. A tape of the data from the 8,310 reports was prepared. This served as the basis for analysis.

In many cases, the presence of one, two, or three inconsistencies or errors might not necessarily have invalidated the basic data. However, because of the relatively small number affected, we felt that analysis should be restricted to reports complete as to key data and free of inconsistencies.

Vehicle Identification Numbers

Where accident reports did not contain the vehicle identification number, information on the state issuing the license and on the license plate number and year was used to obtain the vehicle identification numbers from state registration files.

Cooperation was obtained from most states in providing this information. In several states registration information was not available because it was more than one year old. In others, the state registration records did not include certain classes of vehicle owners (e.g., farmers, local or state government), so that these vehicle identification numbers could not be obtained. Out of the total of 9,102 truck-type vehicles involved in the 8,310 accidents, 7,539 vehicle identification numbers were obtained.

Names of Owners

Where the driver of the truck was indicated as not being the owner, the coder was instructed to enter the name of the owner, if permitted. These names were keypunched and included on the master record tape. The purpose of recording this information was to make possible an identification of the type of truck operation (Class I regulated carrier, private carrier, etc.).

DATA TABULATIONS, ANALYSES AND FINDINGS

Introduction

Background, Limitations and Cautions

The collection procedure described in the previous sections produced a large amount of data about each of a large number of truck accidents. Statistically significant information was extracted from this data, but further knowledge must be obtained before the findings can be considered conclusive. While many computations and analyses have been made as part of this study, and are reported here, there are undoubtedly many other informative ones that would have led to statistically significant findings.

An illustration is given to show the care that must be used in interpreting findings. The data show that there were more truck accidents between 8:00 and 9:00 p.m. than between 1:00 and 2:00 a.m. However, it cannot be concluded that 8:00 to 9:00 p.m. was a more dangerous or accident-prone time for individual trucks, because data on the number of vehicles on the road or vehicle miles driven was not available.[1]

Further examples of the limitations in accepting statistically significant findings as conclusions are illustrated by the following:

> Finding: Mechanical defects of brakes, steering, and tires were reported more frequently for trucks in accidents involving injury than in non-injury accidents.

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[1] We investigated sources of such data and have found only a limited amount. The U.S. Bureau of Public Roads has gathered vehicle-mile data by state and type of truck, and truck miles by type of road system (interstate, primary, secondary, urban streets, etc.) Certain states have collected more detail on some specific road sections. However, data in the form that would be very useful here (for example, truck miles by time of day, or on wet and dry roads) appears to be unavailable.

Limitation: There is a temptation to conclude that reported defects caused these accidents, but this would be unwarranted since presence of a defect tells nothing as to causal relationships and contributing circumstances.

Each finding that is reached in this study is limited by such consideration as those presented above. Findings are accordingly given as findings, not as conclusions. In addition, the findings are only as good as the data recorded on the accident report forms.

Classifications of Data

There were 21 attributes[1] that formed the basis of analyses in this study. These were:

1. Time of day
2. Day of the week
3. Type of area
4. Type of road
5. Road geometry
6. Road condition
7. Light condition
8. Weather condition
9. Type of accident
10. Pedestrian injury (fatal/non-fatal)
11. Vehicle defects
12. Vehicle speed
13. Vehicle movements
14. Driver-owner
15. Driver's age
16. Driver's sex
17. Drinking driver
18. Driver's injury (fatal/non-fatal)
19. Seat belts, driver
20. Passenger injuries (fatal/non-fatal
21. Seat belts, passenger(s)

It must be recognized that the data was based on (and limited by) what was recorded on the various accident report forms. Part of each

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[1] See Appendix D for definition.

record consists of facts about the accident, such as the time of day, day of the week, driver's age, and road geometry. These will be correct, barring errors in recording. Fortunately, 13 of the 21 attributes are in this category.

The other category of data consisted of a mixture of facts and estimates and incorporated the following data elements:

- Weather conditions (no standard set of definitions)
- Type of accident (may be statement by a witness or a driver)
- Pedestrian injury, fatal/non-fatal (death may have occurred some time after the accident report was completed. This also applies to "Driver injury" and "Passenger injuries")
- Vehicle defects (it could not be determined whether these were contributing factors or whether the defect may have been caused by the accident)
- Vehicle speed (estimated by the driver, a witness, or a police officer)
- Vehicle movements (what occurred before the accident as remembered by a witness or a driver)

Findings based on these attributes are not necessarily invalid, but must be drawn with extra caution.

Levels of Compilation and Analysis

The compilations and analyses of accident data were at several levels:

1. Single-attribute compilations; for example, the number of accidents by hour of day.

2. Dual-attribute analyses; for example, the number of accidents by: (1) hour of day, and (2) day of the week.

3. Triple-attribute analyses; for example, the number of accidents (1) by hour of the day, (2) by day of the week, and (3) by type of truck.

Using the data elements listed previously, there are 21 possible single-attribute tabulations, and 210 possible dual-attribute analyses. Not only would it be impractical to produce all of the dual-attribute analyses, but a substantial number of them would be of little or no value. We produced 43 of them, as follows:

Number of vehicles by type of vehicle, and by attributes 1 through 21	21 analyses
Number of vehicles by state, by attributes 1 through 21, plus type of vehicle	22 "
	43 "

A total of 1,330 triple-attribute tabulations could be produced. Since these compilations would require about 10,000 pages, such a project would be impractical. Also, many of the tables would be difficult to intrepret, because they would contain data on so few accidents.

To limit the search process in triple-and-higher-attribute analyses, we used an analytical technique called "Interaction Analysis"[1] to identify important factors in the seriousness of accidents, in terms of injuries/non-fatal and fatal.

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[1] This required adapting the AID program developed at the University of Michigan to a Univac 1107 computer.

Interaction analysis can reveal much about the circumstances under which fatal and non-fatal personal injury accidents occur. This technique assisted us in deciding what detailed data analyses to perform and what findings to include in this report.

Statistical Criteria Applied to Dual-Attribute Tabulations

As we have discussed previously, a very large number of dual-attribute tabulations could be made. To find those that were statistically significant,[1] two criteria were generally followed. These criteria establish that, when the percentage of vehicles exhibiting an attribute was significantly higher or lower than average,

1. the percentage was either more than 1.5 times the average percentage or less than .66 of it; and
2. there were at least 25 vehicles in the category.

An example of the application of the two criteria is illustrated by the following data on the number of accidents during two different time periods for two different types of vehicles. The question is: Does the accident rate for the different vehicles differ significantly for the two time periods?

NUMBER OF ACCIDENTS AT TIME GIVEN

TYPE OF VEHICLE	BETWEEN 1:00 AND 2:00 A.M.	ALL OTHER TIMES	TOTAL
Tractor-Trailer	79	2,067	2,146
All other	158	12,833	12,991
	237	14,900	15,137

[1] See Appendix D for definition.

Of all the vehicles involved in accidents between 1:00 a.m. and 2:00 a.m., 79/237 or 33.33% were tractor–trailers. Also, tractor–trailers represented 2146/15,137 or 14.18% of all the vehicles in the sample. 33.33% is more than 1.5 times 14.18%, so the first criterion is satisfied. Moreover, there were 79 tractor–trailers involved in accidents between 1:00 a.m. and 2:00 a.m., which satisfies the second criterion. Accordingly, it is statistically significant[1] that there was a high incidence of tractor–trailers involved in accidents between 1:00 a.m. and 2:00 a.m.

Findings

Only statistically significant findings have been included in this report, and, then only those findings in the following two general areas where our investigation was concentrated:

1. Areas the Automobile Manufacturers Association suggested for exploration.
2. Where preliminary explorations, using the statistical technique of interaction detection analysis described earlier, showed that statistical significance was very high. For example, interaction analysis indicated that speed was statistically the most significant attribute in relation to driver injuries.

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[1] On file in the working papers is a mathematical demonstration that meeting the two criteria guarantees odds of at least 19 to 1 (and often with more) against the data representing a freak of sampling.

We cannot say that all important points have been found; there are undoubtedly other points that would be revealed by further analysis. The findings tend to fall into three classes:

1. Those that are qualitatively well known, but are quantified here, perhaps for the first time. For example, tractor–trailers accounted for only 8.4% of the vehicles in urban accidents, but for 19.7% of vehicles in rural accidents.
2. Those that are newly established relationships and significant in themselves. For example, the incidence of drinking was much higher among pickup truck drivers than among drivers of other vehicles.
3. Those that are significant indicators toward future research. For example, usage of installed seat belts was low in Minnesota and Virginia and high in Texas. Was this due to some difference in emphasis in these states?

Significant Attributes in Accidents, for Different Types of Vehicles

Table I presents a summary of the statistically significant findings with regard to 12 of the 21 attributes for which data was available, and for 5 types of vehicles. The table shows where the incidence of a particular attribute was significantly higher or lower for a particular type of vehicle than for all vehicles.

TABLE I

Analysis of Attributes in Accident Reports among Vehicle Types

ATTRIBUTE	VEHICLE TYPE				
	STRAIGHT TRUCK	TRACTOR–TRAILER	TRACTOR WITH TWO TRAILERS	PICKUP	PASSENGER CAR
Time of Day					
Midnight to 5 a.m.		H			
11 p.m. to 4 a.m.	L				
4 a.m. to 5 a.m.					L
Day of Week					
Sunday	L				
Saturday		L			
Area					
Urban		L			
Rural		H			
Road Geometry					
Intersection		L	L		H
Curve		H	H		
Road Condition					
Icy/snowy		H			
Light Condition					
Darkness	L	H			
Weather Condition					
Snow/sleet		H			
Accident Type					
Collision with pedestrian	H				
Collision with fixed object		H			
Run off road		H			
Overturned on road		H			
Parked vehicle rolling	H	H			
Speed					
60 – 89	L	L			H
Age of Driver					
15 – 19					H
Under 20	L				
Under 25		L			
Over 60	L	L			
65 and Over					H
Drinking Driver		L		H	
Driver Killed	L				
Seat Belt in Use					
Driver	L	L	L		H
Passenger	L	L			

H – High incidence
L – Low incidence
No entry – Not significantly different from average

Significant Attributes in Accidents, for Each of Ten States

Table II is similar to Table I in that it shows where the indicence of a particular attribute was significantly higher or lower for a particular state than for all states in the sample. The data, for some states, cover both urban and rural areas, in other states rural only. Table II differs from the preceding table in that the significant attributes are not all the same ones.

TABLE II

Analysis of Attributes in Accident Reports
Among States Sampled

ATTRIBUTE	DATA AVAILABLE FOR URBAN AND RURAL ACCIDENTS					DATA AVAILABLE FOR RURAL ACCIDENTS ONLY				
	CALIF.	COL.	FLA.	MINN.	OHIO	CONN.	ILL.	PA.	TEX.	VA.
Time of Day										
1 a.m. to 6 a.m.			L							
2 a.m. to 6 a.m.	H									
3 a.m. to 5 a.m.		L		L	H	H				
Noon to 1 p.m.			H							
Day of Week										
Sunday			L						H	
Type of Road										
Three lane	L		H				L	H		
Four or more lane – highways					L					
Four or more lane								L		
Major divided roads	H			L						
Road Geometry										
Merging lanes							H			
Tunnel or bridge					H				H	
Weather Condition										
Fog or smog	L	H		L	L	L	L	H	L	H
Type of Accident										
Sideswipe							H			
Rear–end collision									L	
Right angle collision				H						
Head–on collision	H		L						H	
Collision with pedestrian	H									
Parked vehicle		H								
Running off road			L		H	H				
Overturned in road			L						H	
Collision with fixed object				L	H					
Vehicle Speed										
Below 30 m.p.h.			H							
Above 60 m.p.h.	H		L		L				H	
Drinking Driver							L		H	
Injury or Death[1]										
Driver	H	L	L	L						L
Passenger	H									
Seat Belts in Use										
Driver				L					H	L
Passenger				L					H	L
Vehicle Type										
Pickup truck		H							H	
Straight truck								H	L	
Tractor trailer		L	L		H	H		H		

1 High incidence of injury or death in urban California is expected because only accidents with injury were reported.

H – High incidence
L – Low incidence
No entry – Not significantly different from average

Accident Frequency and Truck Type

In response to interest expressed by the Automobile Manufacturers Association, a special computer program was prepared to examine the frequency of different types of accidents for different types of trucks. The program was used to aggregate data from the edited tape. This data was further aggregated manually to produce the tables which follow in this section.

The first set of tables (III and IV) presents basic data as to number of vehicles involved in various types of accidents, while the second set of tables (V and VI) goes into deeper detail as to the truck-to-truck accidents:

TABLE III

Number of Trucks in One and Two-or-more Vehicle Accidents, by Truck Type

TRUCK TYPE	ONE	TWO OR MORE			
		TWO TRUCKS	TRUCK AND PASSENGER CAR	OTHER[1]	TOTAL
Pickup	527-21%	394-15%	1,465-57%	167-7%	2,553
Panel	106-17	82-13	405-64	38-6	631
Straight	625-18	499-15	2,046-60	236-7	3,406
Tractor-Trailer	637-30	404-19	977-45	128-6	2,146
Tractor-2 Trailers	30-17	38-21	98-55	11 6	177
Other	43	37	101	8	189
	1,968	1,454	5,092	588	9,102

[1] Includes the following: (1) a small number of trucks in two-vehicle accidents involving a truck and a bus or a truck and a vehicle other than truck, passenger car, or bus, and (2) trucks in accidents involving three or more vehicles.

An analysis of this data was made using the chi square technique. This technique works on the assumption that values within cells of a matrix would, all else being equal, depend upon proportionality factors among sums of rows, sums of columns, and grand total. Thus, to cite an example, if 50 of the total in a sample of 250 were red, and 60 were heavy, the expectation would be that 12 would be both red and heavy. The logic followed in this:

$$\frac{50}{250} = 20\% \text{ are red, while } \frac{60}{250} = 24\% \text{ are heavy.}$$

Therefore, 24% of 20%, or 4.8% would be both red and heavy; 4.8% of 250 is the 12 stated above as the expected value.

The chi square analysis compares the actual data against the expected values and permits conclusions as to which differences are statistically significant.

Table IV presents the same data as the previous table, plus the computed expected values and the differences between the actual values and the expected values.

TABLE IV

Actual versus Expected Number of Trucks in One and Two-or-more Vehicle Accidents by Truck Type

TRUCK TYPE		ONE	TWO OR MORE			TOTAL
			TWO TRUCKS	TRUCK AND PASSENGER CAR	OTHER[1]	
Pickup	Actual	527	394	1,465	167	2,553
	Expected	552	408	1,428	165	2,553
	Difference	-25	-14	+37	+2	0
Panel	Actual	106	82	405	38	631
	Expected	136	101	353	41	631
	Difference	-30	-19	+52	-3	0
Straight	Actual	625	499	2,046	236	3,406
	Expected	737	544	1,905	220	3,406
	Difference	-112	-45	+141	+16	0
Tractor-trailer	Actual	637	404	977	128	2,146
	Expected	464	343	1,201	139	2,147
	Difference	+173	+61	-224	-11	-1
Tractor-2 trailer	Actual	30	38	98	11	177
	Expected	38	28	99	11	176
	Difference	-8	+10	-1	0	+1
Other truck	Actual	43	37	101	8	189
	Expected	41	30	106	12	189
	Difference	+2	+7	-5	-4	0
Total	Actual	1,968	1,454	5,092	588	9,102
	Expected	1,968	1,454	5,092	588	9,102
	Difference	0	0	0	0	0

[1] Includes the following: 1) a small number of trucks in two-vehicle accidents involving a truck and a bus or a truck and a vehicle other than truck, passenger car, or bus; and 2) trucks involved in accidents of three or more vehicles.

In Table IV the following were statistically significant:

1. Relative to the other truck types, tractor–trailers showed a very strong tendency toward single–vehicle accidents. They also showed a strong tendency to collide with other trucks, and a very strong tendency not to be involved in accidents with passenger cars.
2. Also, relative to the other truck types, straight trucks showed a strong tendency toward freedom from single–vehicle accidents, but also a strong tendency toward involvement in accidents with passenger cars.

A tabulation follows of the data on truck–to–truck accidents involving two vehicles per accident:

TABLE V

Number of Two–Truck Accidents by Truck Types Involved

TRUCK TYPE	PICKUP	PANEL	STRAIGHT	TRACTOR–TRAILER	TRACTOR–2 TRAILERS	OTHER	TOTAL
Pickup	80						80
Panel	19	5					24
Straight	112	31	133				276
Tractor–trailer	84	15	76	105			280
Tractor–2 trailers	13	2	7	10	3		35
Other	6	5	7	9	0	5	32
TOTAL							727
Total number of trucks involved[1]	394	82	499	404	38	37	1,454
These trucks as percent of all trucks of corresponding type	15.4%	13.0%	14.4%	18.8%	21.5%	19.6%	16.0%

1 Total across row and total down column. Thus, for straight trucks, total across row = 112 + 31 + 133 = 276; total down column = 223. Sum = 276 + 223 = 499, as shown in table.

The table that follows presents the data from the preceding table, plus the expectation values and the differences between the actual values and the expectation values:

TABLE VI

Actual versus Expected Number of
Two–Truck Accidents by Truck Types Involved

TRUCK TYPE		PICKUP	PANEL	STRAIGHT	TRACTOR– TRAILER	TRACTOR– 2 TRAILERS	OTHER	TOTAL
Pickup	Actual	80						
	Expected	53						
	Difference	+27						
Panel	Actual	19	5					
	Expected	22	2					
	Difference	–3	+3					
Straight	Actual	112	31	133				
	Expected	135	28	86				
	Difference	–23	+3	+47				
Tractor– trailer	Actual	84	15	76	105			
	Expected	110	23	139	56			
	Difference	–26	–8	–63	+49			
Tractor–2 trailer	Actual	13	2	7	10	3		
	Expected	10	2	13	11	0		
	Difference	+3	0	–6	–1	+3		
Other	Actual	6	5	7	9	0	5	
	Expected	10	2	13	10	1	0	
	Difference	–4	+3	–6	–1	–1	+5	
Total accidents	Actual							727
	Expected							726
	Difference							+1
Total trucks involved[1]	Actual	394	82	499	404	38	37	1,454
	Expected	393	81	500	405	37	36	1,452
	Difference[2]	+1	+1	–1	–1	+1	+1	+2

[1] Total across row + total down column. Thus, for straight trucks (actual), total across row = 112 + 31 + 133 = 276; total down column = 223. Sum = 276 + 223 = 499, as shown in table.

[2] Because of rounding, does not sum to zero for each entry or in total.

Especially noteworthy, and statistically highly significant, is that there was a strongly marked tendency for vehicles to have more than the expected number of accidents with vehicles of the same kind. There was no example of a reversal of this tendency, in any category:

	NUMBER OF ACCIDENTS		
	ACTUAL	EXPECTED	DIFFERENCE
Pickup to pickup	80	53	+27
Panel to panel	5	2	+ 3
Straight to straight	133	86	+47
Tractor–trailer to tractor–trailer	105	56	+49
Tractor–2 trailers to tractor–2 trailers	3	0	+ 3
Other to other	5	0	+ 5
TOTAL	331	197	134

The tendency was especially marked in straight truck to straight truck and tractor–trailer to tractor–trailer accident frequencies.

Also statistically highly significant was the following:

- The low number of accidents between tractor–trailers and straight trucks, relative to accidents between all vehicles and straight trucks.

These findings would appear to be evidence of a mixture of rivalry and avoidance patterns on the highways; rivalry among trucks of the same type, as well as avoidance of larger trucks by pickups and straight trucks.

Driver and Passenger Injuries and Vehicle Type

This section deals primarily with relative frequency of injury (fatal, non-fatal) to drivers and passengers in one-vehicle and two-vehicle accidents involving trucks. The analysis here is in less depth than in some other portions of the study, because this portion is intended as more of a preliminary exploration than other portions. It would appear worthwhile to carry further the work begun here, and, wherever sample size is adequate, to consider also the effects of the speed.

In a later study, or even in a further in-depth study of the data gathered and presented here, it should be worthwhile to try to measure the effect of relative speed on frequency of injury, and to take account of severity of injury in gradations other than the coarse ones of fatal and non-fatal.

What immediately follows (Table VII) sets forth the data base by type of vehicle involved in the one-vehicle and two-vehicle accidents.

TABLE VII

Number of Drivers and Passengers Injured in Accidents
Between Different Vehicle Types

	NUMBER OF DRIVERS				NUMBER OF PASSENGERS			
	TOTAL	FATAL INJURIES	NON-FATAL INJURIES	NO INJURIES REPORTED	TOTAL	FATAL INJURIES	NON-FATAL INJURIES	NO INJURIES REPORTED
PASSENGER CAR IN ACCIDENT WITH								
No other vehicle				NO DATA				
Passenger car				NO DATA				
Truck:								
Pickup	1,465	4	223	1,238	773	5	197	571
Panel	405	2	61	342	155	1	52	102
Straight	2,046	36	505	1,505	891	22	299	570
Tractor-trailer	977	69	377	531	553	31	257	265
Tractor-2 trailer	98	13	68	17	53	7	45	1
Other type trucks	101	0	19	82	59	0	9	50
Truck Subtotal	5,092	124	1,253	3,715	2,484	66	859	1,559
PICK-UP TRUCK IN ACCIDENT WITH								
No other vehicle	527/22	10/29.5	166	351	231	2	116	113
Passenger car	1,465	7	154	1,304	432	3	92	337
Truck:								
Pickup	160	1	19	140	68	0	15	53
Panel	19	0	5	14	7	1	1	5
Straight	112	4	39	69	30	1	12	17
Tractor-trailer	84	7	43	34	29	4	19	6
Tractor-2 trailer	13	5	6	2	4	0	4	0
Other type trucks	6	0	2	4	1	0	0	1
Truck Subtotal	394	17	114	263	139	6	51	82
TOTAL	2,386	34	434	1,918	802	11	259	532
PANEL TRUCK IN ACCIDENT WITH								
No other vehicle	106/17.8	3/50	33	70	43	0	15	28
Passenger car	405	2	61	342	105	1	37	67
Truck:								
Pickup	19	0	3	16	1	0	0	1
Panel	10	0	2	8	0	0	0	0
Straight	31	0	4	27	12	0	6	6
Tractor-trailer	15	0	9	6	4	0	4	0
Tractor-2 trailer	2	1	1	0	2	0	2	0
Other type trucks	5	0	2	3	0	0	0	0
Truck Subtotal	82	1	21	60	19	0	12	7
TOTAL	593	6	115	472	167	1	64	102

TABLE VII—CONTINUED

	NUMBER OF DRIVERS				NUMBER OF PASSENGERS			
	TOTAL	FATAL INJURIES	NON-FATAL INJURIES	NO INJURIES REPORTED	TOTAL	FATAL INJURIES	NON-FATAL INJURIES	NO INJURIES REPORTED
STRAIGHT TRUCK IN ACCIDENT WITH								
No other vehicle	625/19.7	9/53	207/43.6	409	145	7	66	72
Passenger car	2,046/65	4	173	1,869	391	1	89	301
Truck:								
Pickup	112	0	17	95	13	0	5	8
Panel	31	0	1	30	8	0	1	7
Straight	266/8.4	1	48	217	50	0	10	40
Tractor—trailer	76	3	21	52	9	1	4	4
Tractor—2 trailer	7	0	6	1	1	0	0	1
Other type trucks	7	0	1	6	2	0	1	1
Truck Subtotal	499	4	94	401	83	1	21	61
TOTAL	3,170	17	474	2,679	619	9	176	434
TRACTOR—TRAILER IN ACCIDENT WITH								
No other vehicle	637/31.5	14/52	201/58	422	63	2	30	31
Passenger car	977/48.5	4	74	899	80	0	14	66
Truck:								
Pickup	84	1	8	75	14	0	3	11
Panel	15	2	1	12	0	0	0	0
Straight	76	0	13	63	13	0	7	6
Tractor—trailer	210/10.4	6	46	158	20	0	8	12
Tractor—2 trailer	10	0	3	7	1	0	0	1
Other type trucks	9	0	2	7	0	0	0	0
Truck Subtotal	404	9	73	322	48	0	18	30
TOTAL	2,018	27	348	1,643	191	2	62	127
TRACTOR—2 TRAILER IN ACCIDENT WITH								
No other vehicle	30/18	3/43	16	11	4	0	4	0
Passenger car	98/59	1	6	91	0	0	0	0
Truck:								
Pickup	13	0	5	8	0	0	0	0
Panel	2	0	0	2	0	0	0	0
Straight	7	0	2	5	0	0	0	0
Tractor—trailer	10	1	5	4	0	0	0	0
Tractor—2 trailer	6	2	4	0	0	0	0	0
Other type trucks	0	0	0	0	0	0	0	0
Truck Subtotal	38	3	16	19	0	0	0	0
TOTAL	166	7	38	121	4	0	4	0