SCHOOL OF CIVIL ENGINEERING

JOINT HIGHWAY RESEARCH PROJECT

JHRP-76-18

CHARACTERISTICS OF HEAVY TRUCK ACCIDENTS

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PURDUE UNIVERSITY
INDIANA STATE HIGHWAY COMMISSION

Final Report

CHARACTERISTICS OF HEAVY TRUCK ACCIDENTS

TO: J. F. McLaughlin, Director
Joint Highway Research Project

June 23, 1976

Project: C-36-59U

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 8-5-21

The attached Final Report titled "Characteristics of Heavy Truck Accidents" is submitted on the Study of the same title approved as a JHRP Study on June 4, 1975. The research was performed and the report written by Mr. A. E. S. Radwan, Graduate Instructor in Research on our staff, under the direction of Professor H. L. Michael.

The major objective of this Study was to evaluate the effect on accidents of heavy trucks under the traffic condition where vehicles are not only travelling slower in 1975 than in 1970-72 but also where all vehicles are travelling at more nearly the same speed.

Truck accident rates on major truck routes were found to be higher than rates for passenger cars both before and after the 55 mph speed limit. However, the accident rates for trucks and cars were less and trending to be similar under the 55 limit where cars and trucks were travelling at nearly the same speed.

The Report is submitted for acceptance as fulfillment of the objectives of the Study.

Respectfully submitted,

Harold L. Michael

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Final Report

CHARACTERISTICS OF HEAVY TRUCK ACCIDENTS

by

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Graduate Instructor in Research

Joint Highway Research Project

Project No.: C-36-59U

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Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana State Highway Commission

Purdue University
West Lafayette, Indiana
June 23, 1976

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance, guidance, and the critical review of the manuscript provided by Professor Harold L. Michael, Head of Transportation and Urban Engineering Department.

Sincere appreciation is also expressed to Professor V. L. Anderson for his advice on the statistical design and analysis and for his review of the manuscript, and to Professor R. D. Miles for his review of the manuscript.

The financial support of this research from the Joint Highway Research Project and Purdue University is duly acknowledged.

Appreciation is also extended to personnel of the accident records area of the Indiana State Police in Indianapolis for their technical assistance.

The author is also thankful to Mrs. Marian Sipes for typing the manuscript.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

ABSTRACT

Radwan, Ahmed Essam Salah, M.S.C.E., Purdue University, May, 1976. Characteristics of Heavy Truck Accidents. Major Professor: Harold L. Michael.

The purpose of this research effort was to determine accident rates for heavy trucks on rural Interstate and primary highways in Indiana for 1974 and the first six months of 1975 under the 55 mph maximum speed limit and for 1970-1972 under the 70 mph and 65 mph limits. Another purpose was to determine the characteristics of heavy truck accidents on rural Interstate and primary highways for the same time periods. A third purpose was to evaluate heavy truck accident involvement for the same classes of highways during the same time periods. Finally, an evaluation was to be made of the effect on accident rates of the condition where all vehicles are travelling at nearly the same speed.

Twenty-four Interstate, twenty-six other four-lane, and seventy-five two-lane highway sections were used for this study. The exact length of each study section was measured. The traffic volumes for all study sections during the study time periods were calculated by using data of a 1972 ADT map together with suitable conversion factors.

The total number of truck accidents and number of accidents by type were collected from accident reports for each of the study sections for the years 1970, 1971, 1972, 1974, and the first six months of 1975. The eleven-station special loadometer survey of the Indiana State Highway Commission for each year of the study periods was used to calculate the average percentages of heavy trucks on the study sections.

Using number of accidents, section lengths, traffic volumes, and percentages of heavy trucks, the rates of heavy truck accidents and the rates of truck accident by type were calculated.

Under the 55 mph speed limit when compared with data from before the 55, it was found that average truck accident rates decreased significantly on Interstate and other four-lane highways; however, the reduction in average rates was not significant on two-lane highways.

The decreases in average rear end collision truck accident rates were significant on Interstate as well as on other four-lane. It was not significant on two-lane highways.

The changes in average rates of ran-off-road and side-swipe truck accidents were not significant on the three classes of highways.

The decreases in average right-angle truck accident rates were significant on other four-lane as well as on two-lane highways.

The ratio between truck and passenger car accident rates decreased significantly on Interstate highways under the 55 mph limit but truck rates were still greater than passenger car rates. On other four-lane highways, each passenger car and truck were similarly involved in accidents under the 65 mph speed limit but there is an indication that under the 55 mph limit a truck is more involved than a passenger car. The increase in ratio between truck and passenger car accident rates was found not significant.

On two-lane highways, a passenger car was found to be much more involved in accidents than a truck under the 65 mph speed limit. On the other hand, truck and passenger car rates were similar under the 55 mph limit. The increase in ratio between truck and passenger car accident rates was also significant for this highway class.

CHAPTER I. INTRODUCTION

Among the many factors cited as criteria on which the operating efficiency of the highway transportation system can be based, the most frequently mentioned parameters are speed of travel and economy of operation. Numerous studies have been undertaken in the broad domain of highway system analysis for the purpose of evaluating these parameters. Studies have spanned the spectrum from applied to theoretical and have ranged from specialized studies at a single location, with little general applicability, to extensive system-wide studies, frequently used as the basis for subsequent design, traffic operations, or analysis procedure. With some notable exceptions, the majority of the studies concentrate on passenger vehicle operation and tend to disregard trucks.

In the United States trucks constitute more than 17 percent of all vehicle registrations, are responsible for approximately 20 percent of all vehicle-miles of travel, and transport more than 20 percent of the intercity ton-miles of freight (17).

The characteristics of trucks are obviously different from those of passenger vehicles and some problems do result. Such important characteristics are as follows (17):

1. Truck weights and sizes are significantly greater than passenger car weights and sizes.
2. Trucks have poorer acceleration capabilities than passenger cars.
3. Trucks have a slower rate of deceleration in response to braking than passenger cars.

4. A truck's efficient operation on the street and highway system exists only in those locations where design elements are sufficient for its passage.
5. The property damage costs and injury severity for truck-involved accidents tend to be higher than for accidents involving only passenger cars.
6. Average operation and maintenance costs on a per-mile basis are higher for trucks than for passenger cars.
7. The average truck is 2 years older than the average car. Thus, new vehicle design standards require more time for implementation in the truck population.

Each of these factors introduces some complications into the evaluation of truck operation and may restrict alternatives for possible improvements. They are of special concern in consideration of the speeds at which trucks can operate safely and efficiently.

However, one of the more obvious heterogeneities in the operating environment, differential truck speed limits, has been the subject of only limited investigation. This type of speed limit restricts trucks to travel at speeds less than those posted for passenger cars. The supposed objective of differential speed limits for trucks is to increase highway safety by making the differences in braking distance more compatible. However, there is valid concern that enforced speed differentials may cause a higher number of vehicular conflicts, and thus increase the likelihood of certain types of accidents.

The current fuel shortage has generally resulted in a reduction of the maximum speed limit to 55 miles per hour for both trucks and passenger cars in the United States. Even in those states where truck and car speeds have been the same, it has resulted in a substantial decrease in the difference in speeds between heavy trucks and passenger cars for average and 85 percentile speeds. Under the 70 mph maximum speed limit on Interstate highways in Indiana in 1973, for example, the average speed of heavy trucks was 61.6 mph while for passenger cars it was 69.6 mph, a difference of 8.0 mph (2). Under the 55 mph maximum speed limit in 1975, the average speed for trucks was 56.4 mph and 58.7 mph for passenger cars, a difference of only 2.3 mph (2).

Under the 55 mph limit, heavy trucks and passenger cars are travelling much closer to the same speeds in Indiana. If similar speeds result in less accidents, accident rates under the 55 mph limit should be less than under the 70 mph limit. That is the hypothesis of this investigation.

CHAPTER II. LITERATURE REVIEW

Rates of Truck Accidents

Rates of truck accidents on highways are typically measured either by the number of accidents per mile or by the number of accidents per 100 million vehicle miles of travel.

An attempt was made by Wolf (23) to construct a measure of system safety in which the goal was to compare the overall safety performance of three classes of highway transport, i.e., trucks, buses and passenger cars, by means of a gross measure of system safety. The form of equation to be used was:

$$M_{ss} = \frac{N_E}{N_v \ A_v}$$

where:

M_{ss} = Measure of system safety,

$N_{E(a,f,\text{ or } i)}$ = Number of unsafe events (accidents or fatalities or injuries per year per vehicle class),

N_v = Number of vehicles in fleet class (truck, bus, passenger car),

A_v = Activity per vehicle of class t, b, p miles/year (it would also be nice to include tons of freight hauled or passengers moved in the denominator in an improved model).

The rates shown in Table 1 were computed for each vehicle class based on 100 million vehicle miles (23).

TABLE 1. MEASURE OF SYSTEM SAFETY

Type	Trucks	Buses	Passenger Cars
All Accidents	1510	4310	3000
Fatal Accidents	5.7	9.5	6.7
Occupant Fatalities	2.6	2.4	4.7

Note: Annual accident rates per 100 million vehicle miles for the year 1966.

Reported by Society of Automotive Engineering (23).

The National Safety Council published the rates shown in Table 2 (19).

Characteristics of Truck Accidents

Truck accidents are often classified as the following types:

1. Single vehicle accidents, such as:
    a. Ran off road.
    b. Hit a fixed object.
    c. Hit a pedestrian.
2. Multiple vehicle accidents, such as:
    a. Rear-end collision.
    b. Side swipe.
    c. Head on collision.
    d. Hit a parked vehicle.

More than half of the fatal motor vehicle traffic accidents on Interstate highways are of the ran-off-road type of accidents. Approximately 15% of the accidents are rear-end collision, and 12% of the accidents are head on collision (21).

Interstate Commerce Commission (ICC) reports contain some analysis dealing with accident types. The report for Society of Automotive Engineers ranked the types of accidents in descending order according to general injury frequency. It was found that "Truck-to-Auto" collisions produced the most frequent injury while "Truck-to-Truck" collisions were second and "Truck Running Off Road" accidents were third (23).

A study was conducted by Automotive Crash Injury Research (ACIR) for Utah highway accidents involving multi-purpose passenger vehicles, trucks, and buses. It was found that dump units, stake straight trucks, buses and camper pickups had a relatively high percentage of vehicles subjected to a rear impact (26).

TABLE 2. MOTOR TRANSPORTATION ACCIDENT RATES BY YEAR 1947-1973

Year	Accident Rates		
	Trucks	Buses	Passenger Cars
1947-48	47.10	30.20	12.60
1951-52	19.60	29.20	10.70
1955-56	16.34	24.30	5.70
1959-60	13.80	17.70	4.23
1963-64	13.13	16.64	5.64
1967-68	12.37	18.79	4.73
1971	10.52	21.59	9.06
1972	9.86	21.89	8.35
1973	9.36	22.34	7.48

Note: Rates are per million vehicle miles.

Reported by National Safety Council (19).

In a study by the University of Michigan (12), 1969 Texas truck accident data were used to identify the contribution of truck accidents to the total casualties in traffic accidents. Two-vehicle collisions were divided into two broad groups: those involving only passenger cars and those involving passenger cars and large trucks.

The data showed that a car occupant was more likely to be killed if his or her car collided with a truck rather than with a car. For head-on collisions the probability of a fatality in the accident was slightly higher for car-truck than for car-car mixes, while for rear-end collisions the probability of a fatality was about five times greater in the car-truck case (12).

Factors Affecting Truck Accidents

Accident rates have been found to be related to the classification of highways and their respective average daily traffic volumes. Freeways, because of their greater degree of access control, use of medians, and adequate setback distances of side interference, have lower accident rates than other highways (18).

Another study found that there is a direct relation between volume and accident rates until congestion slows down traffic (24).

Data compiled by the Bureau of Motor Carrier Safety indicate that the number of Interstate truck accidents varies from month to month by only $\pm$ 10 percent. For the three years 1967 through 1969, April was consistently the low month for such accidents, and December-January was consistently the peak period. For hour-of-the-day accidents, it was found that passenger cars were highly involved in accidents during evening hours (12).

The ACIR report (26) noted that tractor-trailers were involved in accidents on the Utah highway system during the period from midnight to 6 a.m. more often than other vehicle types. Multipurpose passenger vehicles and pickup trucks were more often involved in a weekend accident than other vehicle types. However, for vehicles used primarily for commercial purposes, tractor-trailer units were most often involved in a weekend accident.

According to this ACIR research, the road surface was reported to be wet or "snowy slippery" in the majority of cases involving a primary jacknife (26).

However, approximately four-fifths of all interstate accidents occur on dry pavement (21).

An important factor which must be taken into consideration is the driver condition of "fatigued or asleep". Surprisingly, it was found in the Texas study referenced previously (12) that truck drivers noted as being fatigued or asleep are seldom charged with any violation - only 25 percent received a citation, as compared with 67 percent of the passenger car drivers in the same situation. This suggests that fatigue is a sort of "acceptable" occupational hazard for truck drivers - a fact which is recognized by the law enforcement fraternity.

Truck driving appears to be almost exclusively a male occupation. There are very few female truck drivers and accident data show that females drive trucks very carefully (12).

The 1973 report (5) of the Bureau of Motor Carrier Safety (BCMS) divided motor carriers into two broad categories:

1. Private carriers are manufacturers, wholesalers, retailers and others who use their own (or leased) vehicles, as a part of their commercial operation, to transport their own goods.

2. For-hire carriers are trucking firms which haul freight owned by another party. There are three distinct types of For-hire carriers: Common, Contract, and Exempt.

The two distinct types of trips considered in this BCMS report were:

1. Over-the-road trips, which are trips running on the Interstate system of highways.
2. Local trips, which are usually within a metropolitan area.

The relative percentage of each type trip for private and authorized carriers are of interest in Table 3.

Overall, over-the-road truck accidents accounted for 78 percent of all reported truck accidents with 86 percent of the fatalities, 76 percent of the injuries and 89 percent of the total property damage.

With respect to number of lanes and divided versus undivided highway, the following conclusions for truck accidents were extracted from the BCMS Report (5).

1. Two lane, collision accidents accounted for 35% of accidents, and 49% of all the fatalities.
2. Accidents on two-lane undivided highways accounted for 38% of the total number of accidents and almost 47% of all fatalities.
3. Collision accidents on undivided highways accounted for 39% of the total accidents and almost 50% of the fatalities.
4. The fatality rate for collision accidents was at least double that of non-collision accidents.
5. The highest fatality rates were for two-lane and undivided highway accidents, with collision accidents contributing the most in both instances.

TABLE 3. RELATIVE PERCENTAGES OF EACH TYPE TRIP FOR PRIVATE AND AUTHORIZED CARRIERS

Type	Private		Authorized	
	Over-the-Road	Local	Over-the-Road	Local
Number of				
Accidents	14.5	25.2	76.3	66.0
Fatalities	21.6	35.1	65.5	48.8
Injuries	14.0	23.8	76.9	67.7
Property Damage	17.5	33.3	72.4	57.2

Note: Figures shown are percents of total over-the-road or local truck accidents.

Reported by Bureau of Motor Carrier Safety (5).

In the non-collision accident category the highest fatality rate (ran off road = 7.4) was lower than all but two of the collision object categories.

Ran off road, jacknife, and overturn accidents accounted for 85% of the non-collision accidents. These three categories comprised 83% of fatalities, 90% of the injuries, and 87% of the property damage in non-collision accidents. These statistics are shown in Table 4.

Four of five collision accidents involved vehicle movement by one of the vehicles of the following types; (a) Slowing/stopped; (b) Stopped; (c) Rear-end; (d) Left turn; and (e) Proceeding straight.

Over half of the time, vehicle movement by one of the vehicles was described as proceeding straight. The more serious vehicle movements in terms of accident severity were found to be of the following order:

1. Head-on, into opposing lane.
2. Vehicle-out-of-control.
3. U-turn.
4. Proceeding straight.
5. Parked.
6. Intersection.
7. Sideswiped - opposite direction.

Motor carrier driver fatality and injury accident numbers for the years 1968-1973 are shown in Figure 1 (5).

Truck Speeds and Accidents

Most previous research on the subject of the speed-safety relationships has concluded that higher speeds are more closely related to increased accident severity than to accident causation. In some of these studies a linear relationship was derived to represent injuries per 100 single-vehicle accidents (Y) and speed before the accident existed (X) in miles per hour:

$$Y = 0.1954 + .0132X. \quad (21)$$

TABLE 4. PERCENTAGES OF TOTAL FOR MAJOR NON-COLLISION ACCIDENTS

Type	Accidents	Fatalities	Injuries	Property Damage
Ran off Road	36.6	55.7	41.4	42.4
Jacknife	16.9	4.5	14.9	10.6
Overturn	31.3	22.6	33.4	34.0

Reported by Bureau of Motor Carrier Safety (5).

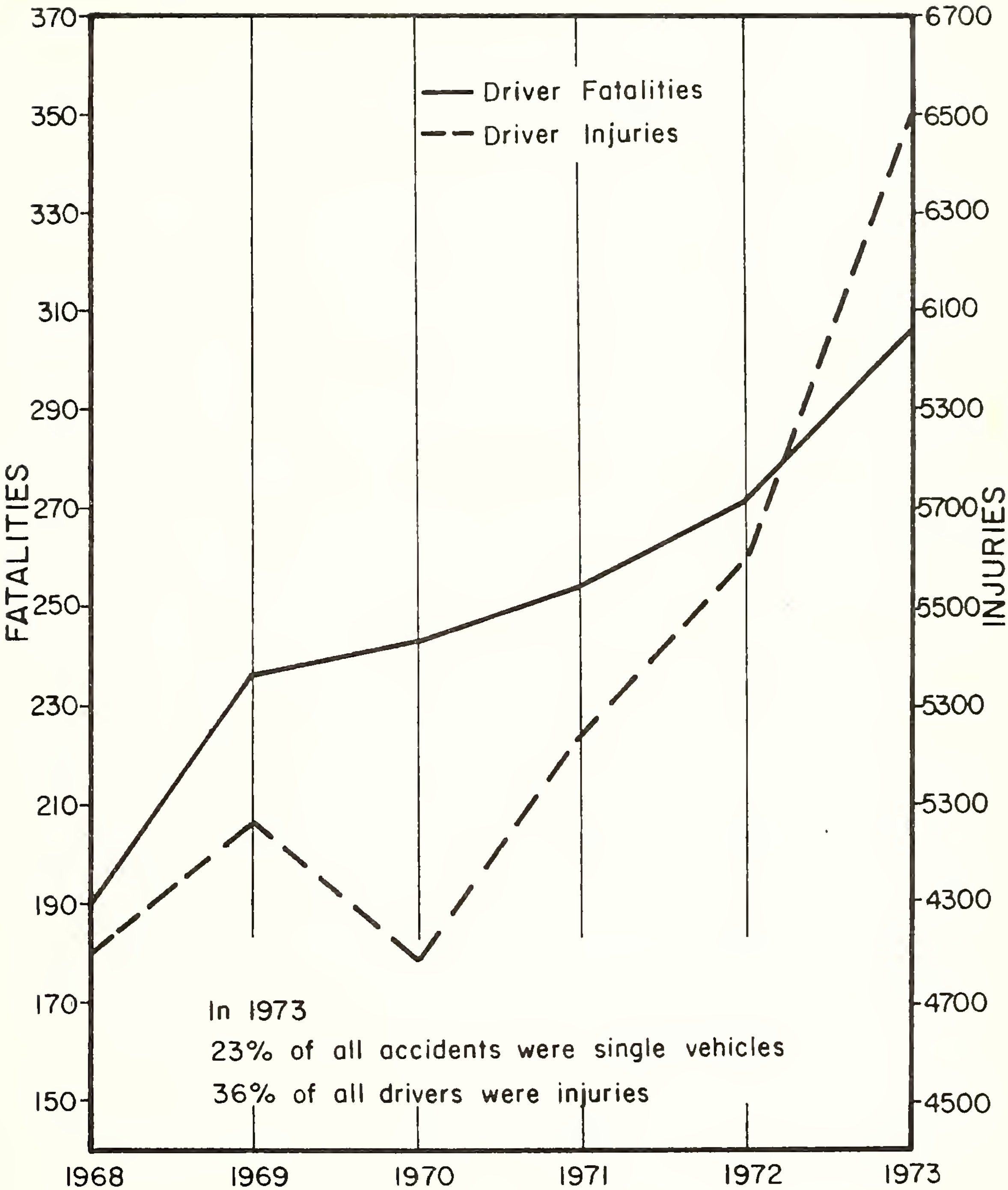

FIGURE I DRIVER FATALITY AND INJURY ACCIDENT NUMBERS Reported by Bureau of Motor Carrier Safety (5)

The report (12) on the data from the Texas truck and passenger car files for 1969 concluded that trucks have a relatively high accident involvement at very low speeds of 1-10 mph, and progressively lower involvement at higher speeds.

On the basis of reason as well as a few research studies, there is reason to believe that the relationship of speed to accidents is closely related to variation from the average speed. Accident involvement rates have been found to be the highest for vehicles travelling much less than the average speed and the lowest for vehicles within a 10 miles per hour speed range in the vicinity of the mean speed of travel (14).

In another study a plot of involvement rate as a function of variation from the average speed produced a concave upward curve with a minimum value in the vicinity of the average speed (8).

An Interstate accident research study demonstrated that on the Interstate highway system, as the speed of a vehicle varies from the mean speed of traffic, either above or below the mean speed, the chance of the vehicle being involved in an accident increases. This conclusion can be seen in Figure 2 (16).

Another approach was used in an investigation concerned with correlation of the mean absolute change of highway speed per minute of travel time with motor vehicle accident rates. The parameters which were used were: 1. acceleration noise and 2. the mean of the number of absolute 2-mile per hour speed changes per unit of highway travel time. This research showed that a visual rank order correlation existed between accident rates and the second parameter for five of the six highways investigated (6).

A recent study at the University of Maryland, however, showed that lower rates of truck involvement are associated with higher truck speeds. This phenomena was found to

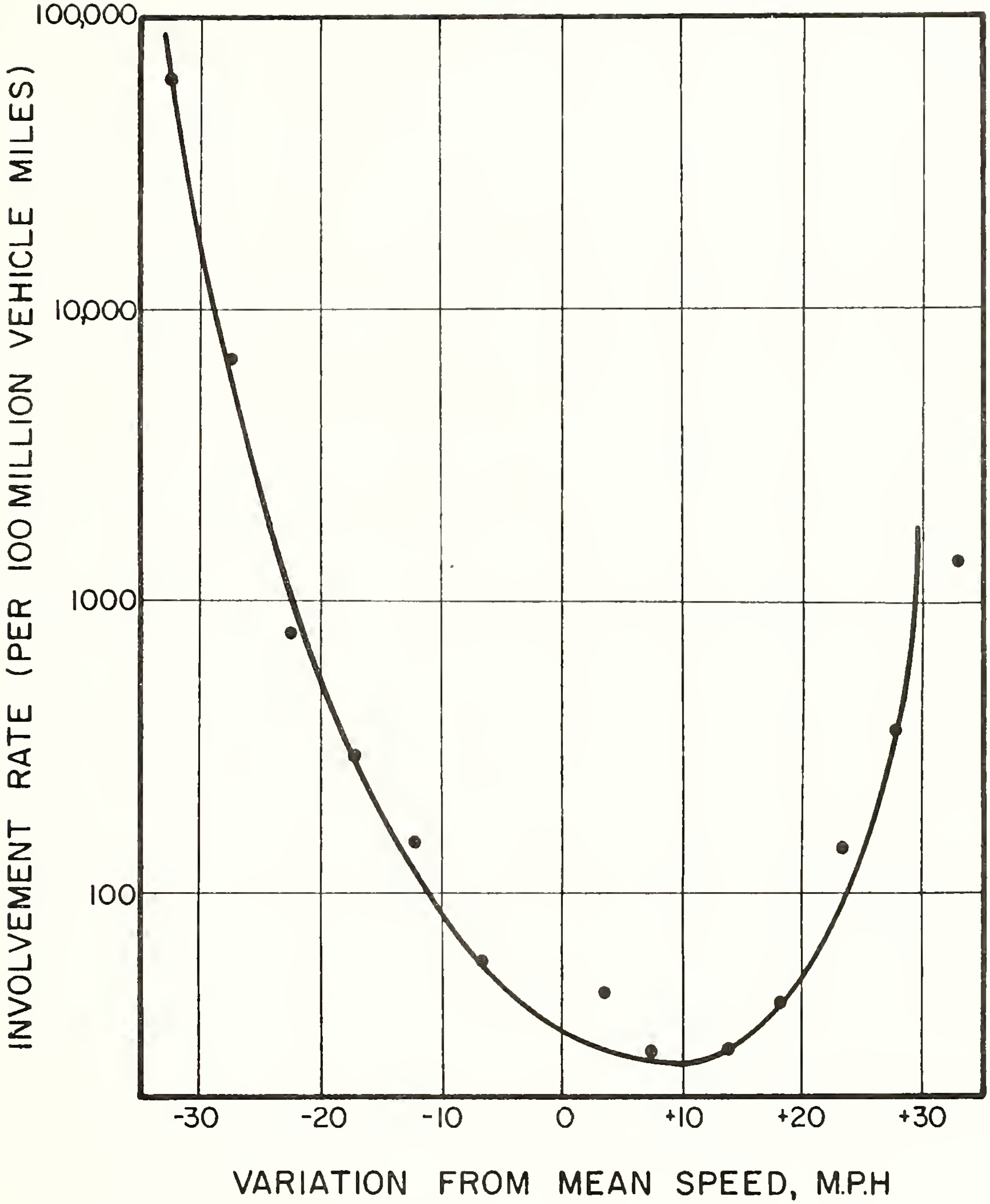

FIGURE 2 ACCIDENT INVOLVEMENT RATE BY VARIATION FROM MEAN SPEED ON STUDY UNITS
Reported by Public Roads (16)

exist for truck accidents which occurred on dry pavement (17).

Another study was done by the Michigan Department of State Highways and Transportation on the effect of the 55 mph speed limit on total accidents. The preliminary analysis revealed a general downward trend in all types of accidents on all roads after the fall of 1973.

The prediction formulas that were derived in this study indicate the sensitivity of accident variation to speed change and other variables (20).

Truck Accident Involvement

A determination of the relative collision involvement of trucks and other vehicles is often done by the exposure method. Exposure can be defined as the frequency of occurrence of events in traffic that create the risk of having an accident.

One common measure of exposure to accidents is the number of vehicle miles traveled over some period of time for the various classes of vehicles and drivers. The exposure information is then used as a normalizing factor.

The exposure technique and two others involving exposure were used to study collision data from the Ohio turnpike for the period January 1966 through June 1970. The results showed that trucks appeared to be overinvolved in rear-end and sideswipe collisions. Several theories were considered in attempts to explain this observation. The most highly regarded of these for rear-end collisions held that since trucks operate near full throttle to maintain highway speed, they do not have a large reserve of power for the passing maneuver and tend to travel closely behind other vehicles which they plan to pass (7).

CHAPTER III. PURPOSE AND DATA COLLECTION

Purpose

The purposes of this research were to:

1. Determine accident rates for heavy trucks and other vehicles on rural Interstate and primary highways in Indiana for 1974 and the first six months of 1975 under the 55 mph maximum speed limit and for 1970-1972 under the 70 mph and 65 mph speed limit.
2. Determine the characteristics of heavy truck accidents on rural Interstate and primary highways for 1974 and the first six months of 1975 and for the period 1970-72.
3. Evaluate changes in accident rates and characteristics of heavy truck accidents to determine conditions and problems which are resulting in increasing or decreasing accidents involving heavy trucks.
4. Evaluate the effect on accident rates of the condition where all vehicles are travelling at nearly the same speed.

Data Collection

Selection of Roadway Sections

Three classes of rural Indiana highways were evaluated to determine heavy truck accident rates and characteristics. Twenty-four Interstate, twenty-six other four-lane, and seventy-five two-lane rural highway sections, each about twelve miles long, were used. For a section to be acceptable, it had to meet certain criteria. The purpose of the criteria was to minimize variations in accident rates due to factors other than volume change and speed characteristics. These criteria included:

1. Homogeneous cross section.
2. Outside metropolitan areas.
3. No major change in land use along the section during the study period.
4. No alteration of roadway (other than regular maintenance) during the study period.
5. Previous speed limit was 65 mph for all highway sections except it was 70 mph for rural Interstate highways.

Sections were accepted or rejected based on data relevant to the above criteria made available by the Indiana State Highway Commission. The exact length of each study section was gathered at the same office. The highways on which the sections were located can be seen in Figure 3.

Roadway Traffic Volumes

The traffic volumes for the accepted sections were collected from a 1972 ADT map also obtained from the Indiana State Highway Commission.

Data provided by permanent counting stations were used to develop factors to convert the 1972 ADT of a section to the relative volumes for the six month study periods of the studied years 1970, 1971, 1972, 1974, and 1975. Of the total of twenty-three permanent volume stations in Indiana, eight were not used because at some time in the study periods traffic had been rerouted due to construction. Using the data from the remaining permanent volume stations, the average 24 hour traffic for each month of the study periods was calculated. Averaging each six months

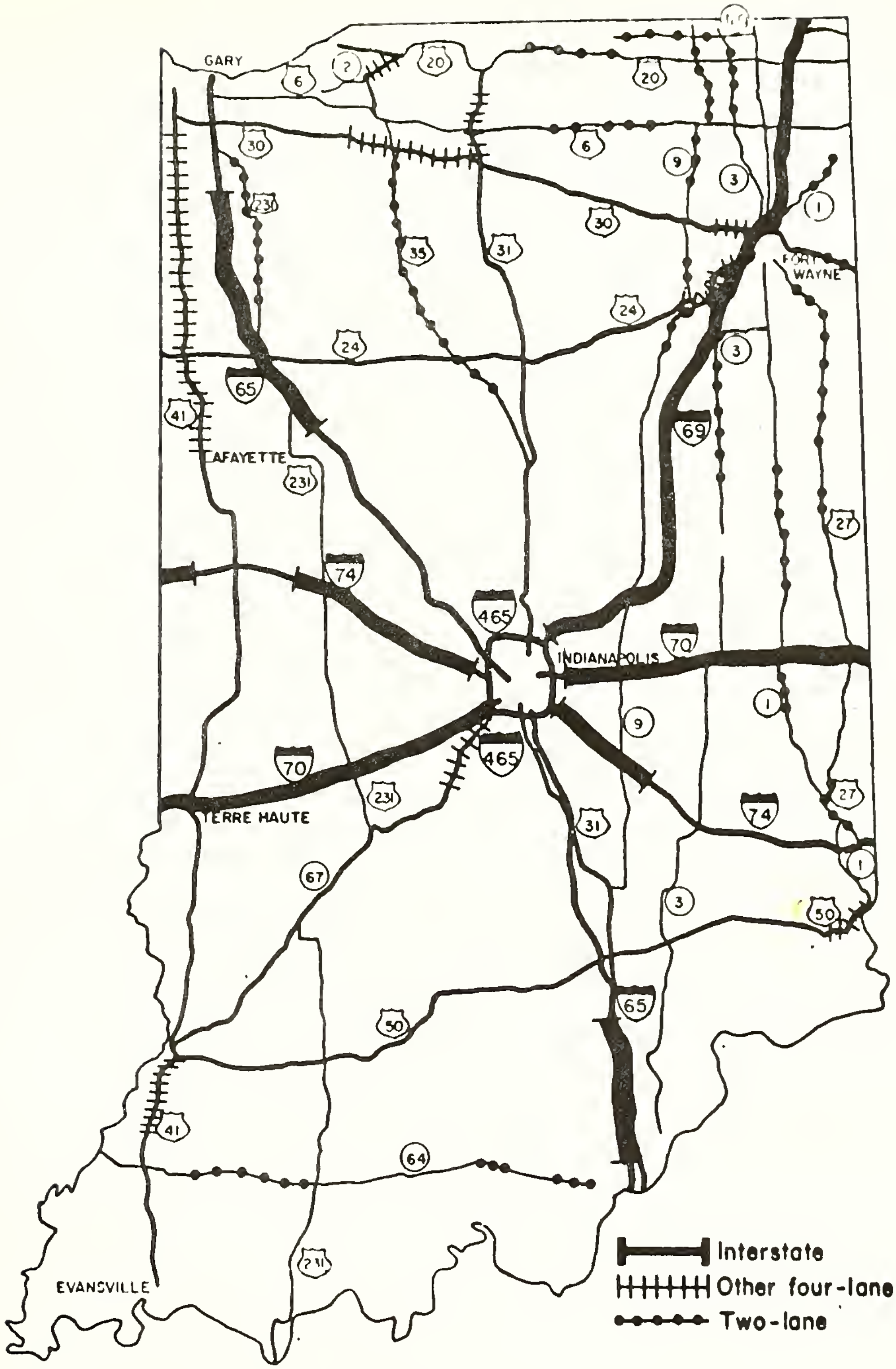

FIGURE 3 HIGHWAYS ON WHICH ACCIDENT STUDY SECTIONS WERE LOCATED

separately, the average monthly volumes for both the first and the second six months of each year were calculated. Individual factors were developed for the first and the second six month periods of each year by dividing the average monthly volume for the six months of each year by the average monthly volume for the same six months for the year of 1972.

The locations of the permanent counting stations used in this study are shown in Figure 4.

The fifteen permanent counting stations provided the monthly average daily volumes as shown in Table 5. One average, that for April 1974, was not used in calculating that six month average because it appeared to be in error relative to previous and following averages. Average daily volumes and conversion factors for every six months for the study periods are shown in Table 6.

Using these factors, together with the traffic volumes available from a 1972 ADT map for the study sections, the traffic volumes for each six month period other than 1972 were calculated for each section.

Accident Data

The Indiana State Police in Indianapolis made available the standard accident report form from which the following data were drawn for each study section.

1. Total number of truck accidents.
2. Number of accidents by type (rear-end, ran off road, side swipe, right angle, and others).
3. Light conditions (daytime, dark, dawn, and dusk).
4. Road surface condition (wet, dry, snow, and others).
5. Total number of all vehicle accidents and severity (property damage, personal injury, fatality).

These data were collected for each six month period of the studied years 1970, 1971, 1972, 1974, and the first six months of 1975.

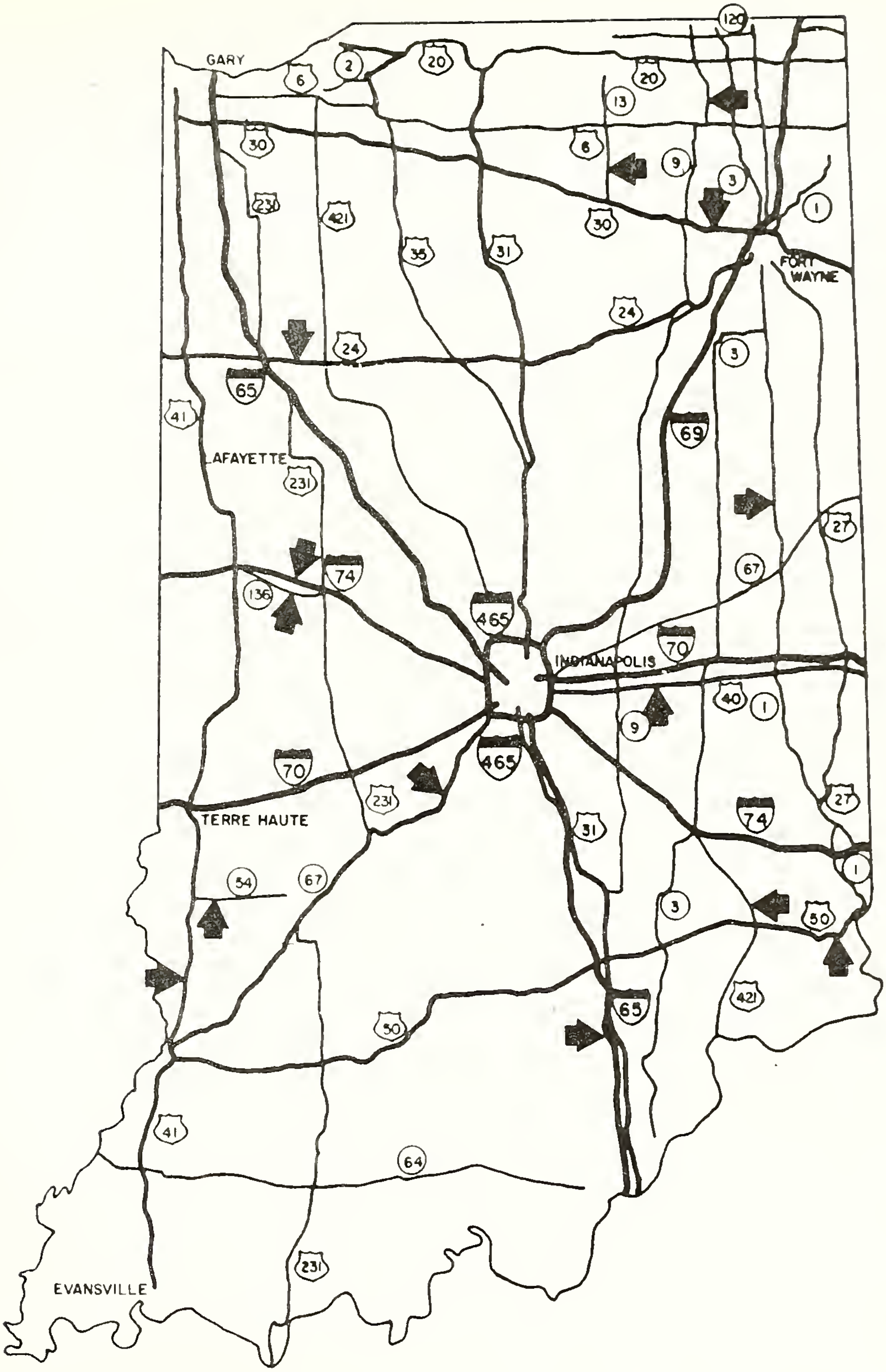

FIGURE 4 LOCATION OF PERMANENT COUNTING STATIONS

TABLE 5. MONTHLY AVERAGE DAILY VOLUMES AT FIFTEEN PERMANENT COUNTERS ON INDIANA HIGHWAYS

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1970	4206	4586	5028	5240	5784	6521	6865	6796	5996	5637	5330	5107
1971	4491	4567	5112	5859	6106	6808	7223	7265	6328	6072	6393	5532
1972	4812	5059	5819	6194	6756	7285	7596	7780	6777	6341	6146	5786
1974	4908	5160	5709	6531	6886	7358	7851	8155	6689	6598	6179	5954
1975	5262	5470	5952	6304	7071	7556						

TABLE 6. AVERAGE DAILY VOLUMES AND CONVERSION FACTORS FOR STUDY PERIODS

Periods	First Six Months		Second Six Months	
Years	Average	Factor*	Average	Factor*
1970	5228	.87307	5955	.88379
1971	5491	.91700	6469	.96007
1972	5988	1.00000	6738	1.00000
1974	6004	1.00267	6904	1.02463
1975	6269	1.04692		

$$\text{*Conversion Factor} = \frac{\text{Average Daily Volume for Appropriate Study Period}}{\text{ADT for the same Period of 1972}}$$

To minimize changes in accident rates due to seasonal variations, the unit period of study was taken to be six months. The number of study periods, therefore, was nine units. The first six units were for the years 1970, 1971 and 1972, during which the maximum speed limit on the highway system was 70 or 65 mph. The remaining three units were for the year 1974 and the first six months of 1975, during which the maximum speed limit was 55 mph.

Figure A-1 in Appendix A shows a typical form which was used for collecting the accident data. The collected data were regrouped and classified to facilitate the statistical analysis. Figure A-2 in Appendix A shows a sample of these forms.

Percentages of Trucks on Highways

The eleven-station, special loadometer survey for each year of the study periods was a great help in measuring the average percentage of heavy trucks on the Indiana highway network. These surveys were available from the Planning Division of the Indiana State Highway Commission. The locations of truck loadometer stations are shown in Figure 5.

Using the form shown in Figure A-3 of Appendix A, the total number of trucks and passenger cars were calculated at these stations. Pickups, panels, and two axle, dual-tire trucks were not counted as trucks in the computations. The results of the computations showed that the following routes had very low truck percentages: US-40, US-52, SR-44, US-36, US-421, US-460, SR-8, SR-10, SR-14, SR-37, SR-55, SR-114, SR-16, SR-39, and SR-49.

Excluding all the study sections which were located on these routes reduced the total number of sections from 125 down to 77. Twenty-four of these were on Interstate, sixteen on other four-lane, and thirty-seven on two-lane highways.

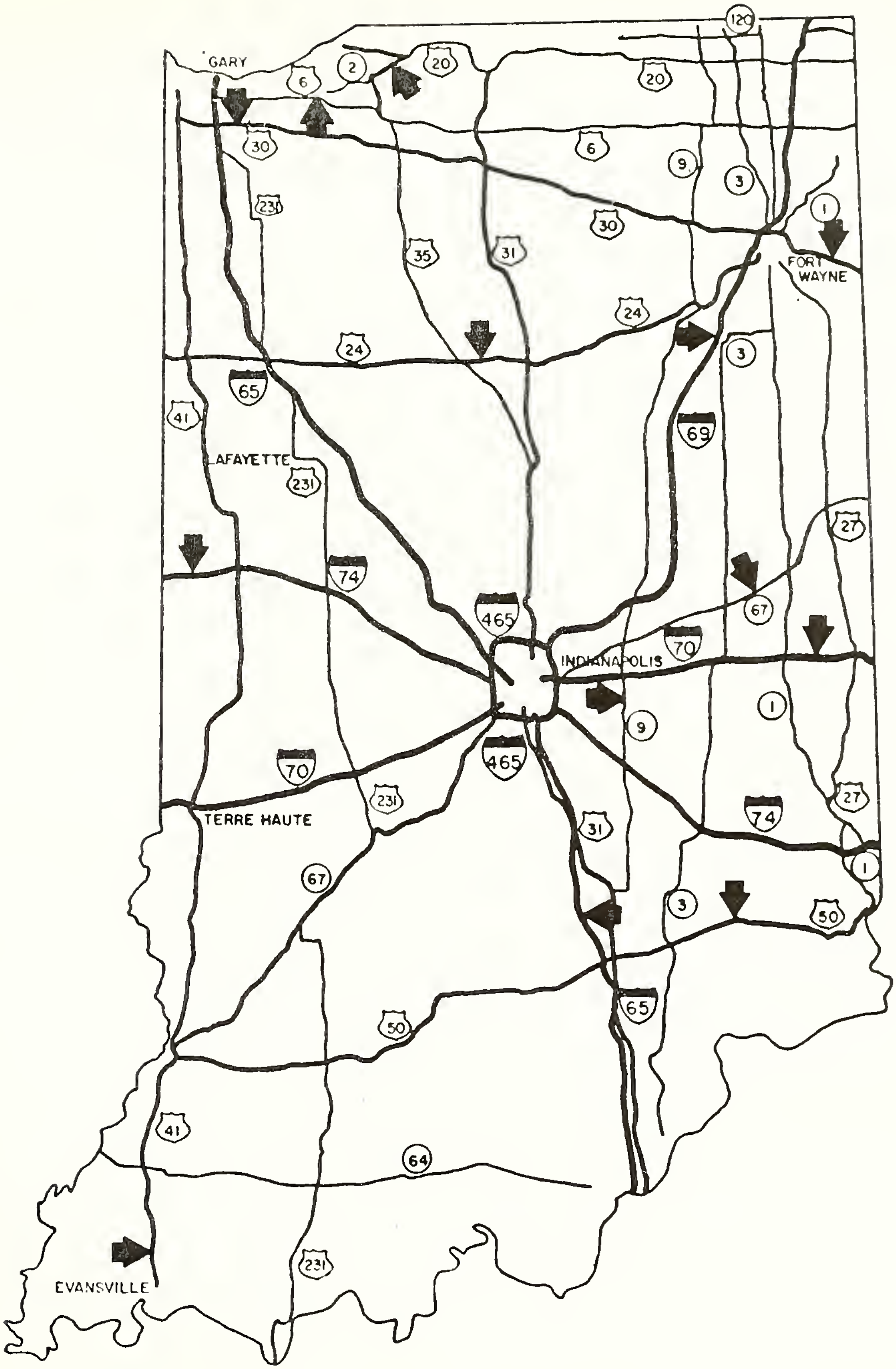

FIGURE 5 LOCATION OF TRUCK LOADOMETER STATIONS

CHAPTER IV. DATA ANALYSIS

Truck Volumes

In order to determine rates of truck accidents it was necessary to obtain data on the volume of heavy trucks in the traffic of each study section. These volumes were calculated from the percentage of heavy trucks in the total traffic obtained at the special loadometer stations by the Indiana State Highway Commission. The loadometer station or stations used for a particular study section were the most similar ones in the same geographic area or on the same highway.

I-65 Sections

The results of loadometer station counts on I-65 are shown in Table 7. The sections are located in Clark, Jackson, Scott, and White counties as shown in Figure 6. The data available for this highway were collected from the two loadometer stations located in Jackson and Lake counties. Simple computations shown in Table 7 gave that the average percentage of trucks over the studied periods as 22.56%.

I-70 Sections

The seven sections which were chosen covered all the highway from the Ohio state line in the east to the Illinois state line in the west. Percentages of trucks are shown in Table 8. The average percentage of trucks on this Interstate was found to be 25.65% for the studied time periods.

TABLE 7. PERCENTAGES OF HEAVY TRUCKS FOR TWO STATIONS ON I-65

Year	County Jackson	Lake
1970		
1971	25.65	
1972	28.26	
1973	25.85	
1974	14.27*	
1975	28.89	(10.64)
	(11.19)	
	(11.41)	

Percentages shown in parentheses are for weekend counts and the others for weekday counts.

Average weekdays = 27.16%

Average weekends = 11.08%

$$\text{Average truck percentage} = \frac{5x27.16 + 2 \times 11.08}{7} = 22.56\%$$

*Excluded due to energy crisis effect on the pattern of traffic.

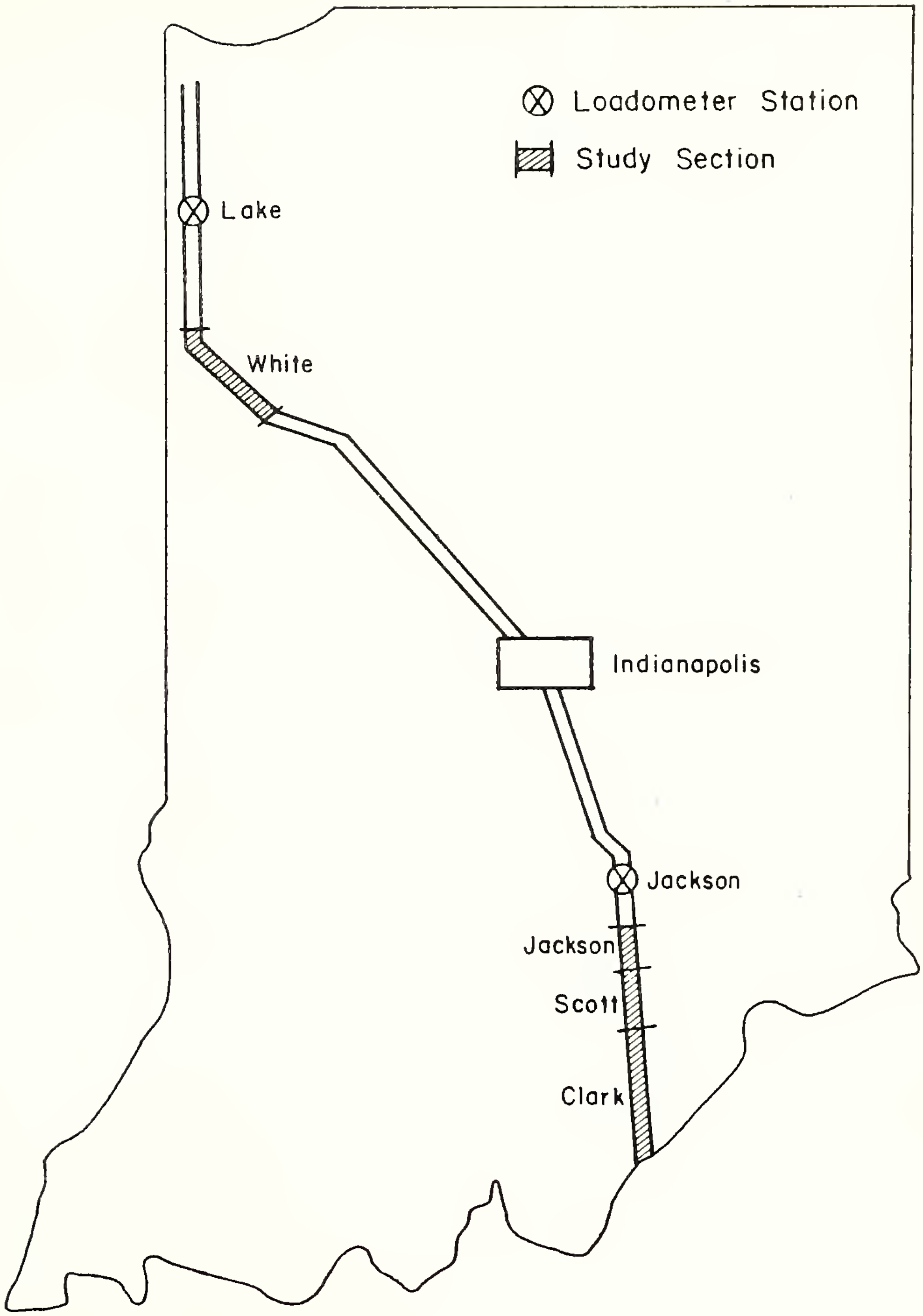

FIGURE 6 SECTIONS & LOADOMETER STATIONS ON I-65

TABLE 8. PERCENTAGES OF HEAVY TRUCKS FOR TWO STATIONS ON I-70

Year	County Wayne	County Hancock
1970	26.31	-----
1971	21.65*	-----
1972	29.63	-----
1973	28.73	-----
1974	33.00	-----
1975	19.13*	29.66
	(1.25)*	(17.18)
		(15.02)

Percentages shown in parentheses are for weekend counts and the others are for weekday.

Average of weekdays = 29.47%

Average of weekend = 16.10%

Average truck percentage = 25.65%

*Excluded from average computations because of non-comparative value.

I-69 Sections

The eight sections for this highway extend south from the northern part of Indiana at the Michigan state line down to Indianapolis. Only weekday counts were available for this highway. According to Table 9 it was concluded that the average percentage of trucks along this route for the studied time periods was 27.76%.

I-74 Sections

A permanent loadometer station located in I-74 in Dearborn county provided sufficient data for percentages of trucks during weekdays. Two stations started working in January 1975 in Ripley and Fountain counties. The collected data are shown in Table 10. The location of sections are shown in Figure 7. The five study sections extend through Boone, Hendricks, Montgomery, Shelby, and Vermillion counties. Using the average weekend percentages for I-65 and I-70 together with the weekday averages available for I-74, the percentage of trucks for the years 1970, 1971, 1972 and 1973 was found to be 19.38%, while in 1974 and 1975 it was 24.88%.

US-41 Sections

Four loadometer counting stations were located on this highway. The four study sections were scattered on this road (see Figure 8) and are located in Gibson, Knox, Lake, and Newton counties.

A weekend factor was derived from the data of one of these stations and was also used in calculating a weekend to weekday factor for other four-lane and two-lane highways as no other stations on such highways had weekend truck volume data.

The average truck percentage for the studied time periods for this route was 13.3% as shown in Table 11.

TABLE 9. PERCENTAGES OF HEAVY TRUCKS FOR ONE STATION ON I-69

Year	Huntington County
1970	24.82
1971	25.16
1972	28.26
1973	26.68
1974	34.56
1975	27.78

Percentages shown are for weekday counts only.

Average of weekday = 33.45%

Average weekend count used was the average for I-65 and I-70 = 13.59%

Average truck percentage = 27.76%

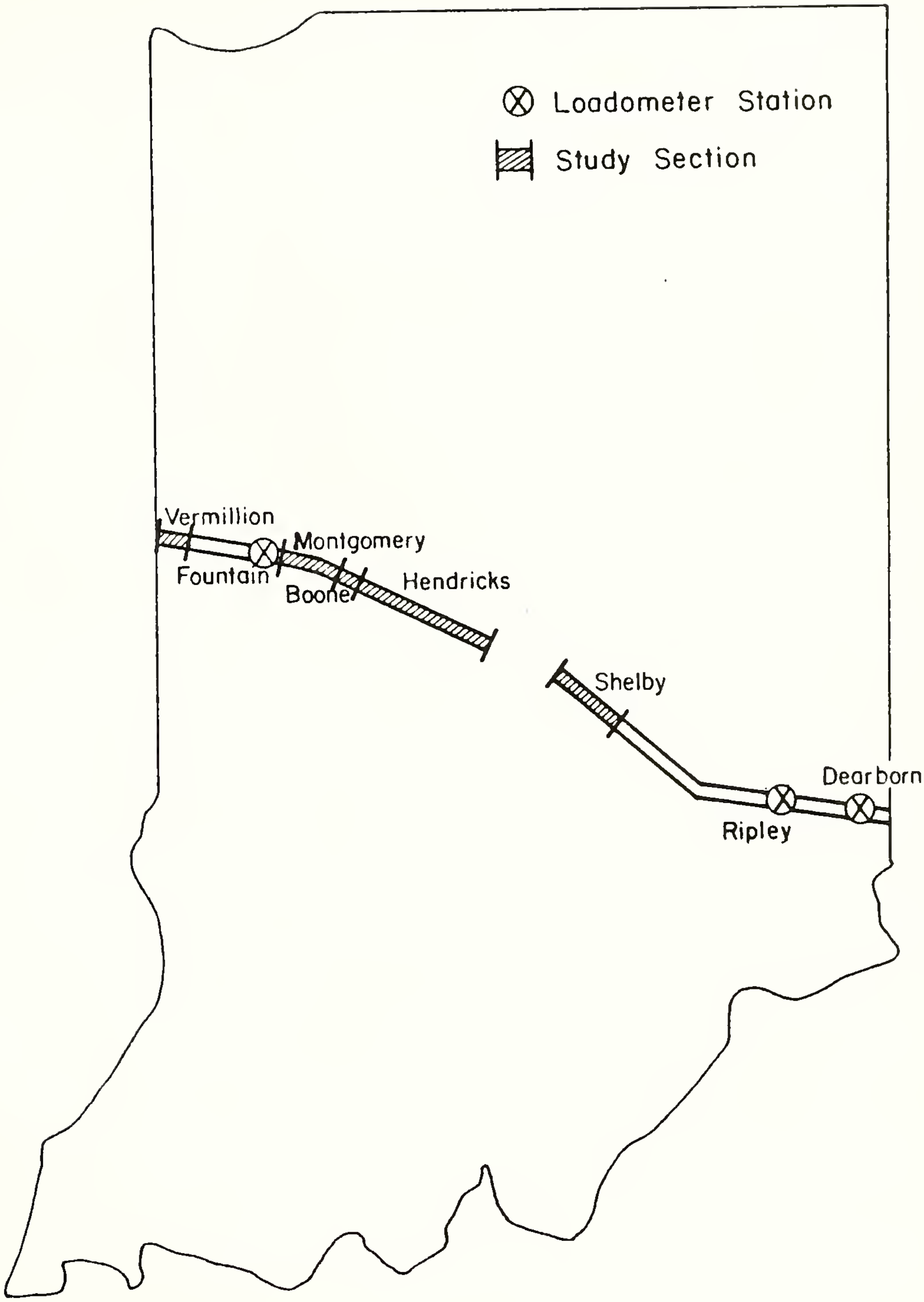

FIGURE 7 SECTIONS & LOADOMETER STATIONS ON I-74

TABLE 10. PERCENTAGES OF HEAVY TRUCKS FOR THREE STATIONS ON I-74

	County		
Year	Dearborn	Ripley	Fountain
1970	21.58	-----	-----
1971	21.88	-----	-----
1972	21.31	-----	-----
1973	22.00	-----	-----
1974	29.74	-----	-----
1975	-----	26.88	31.21

Percentages shown are for weekday counts only.

Average weekday (1970-1973) = 21.69

Average weekday (1974-1975) = 29.39

Average weekend I-65, I-70 = 13.59

Average truck percentage (1970-1973) = 19.38

Average truck percentage (1974-1975) = 24.88

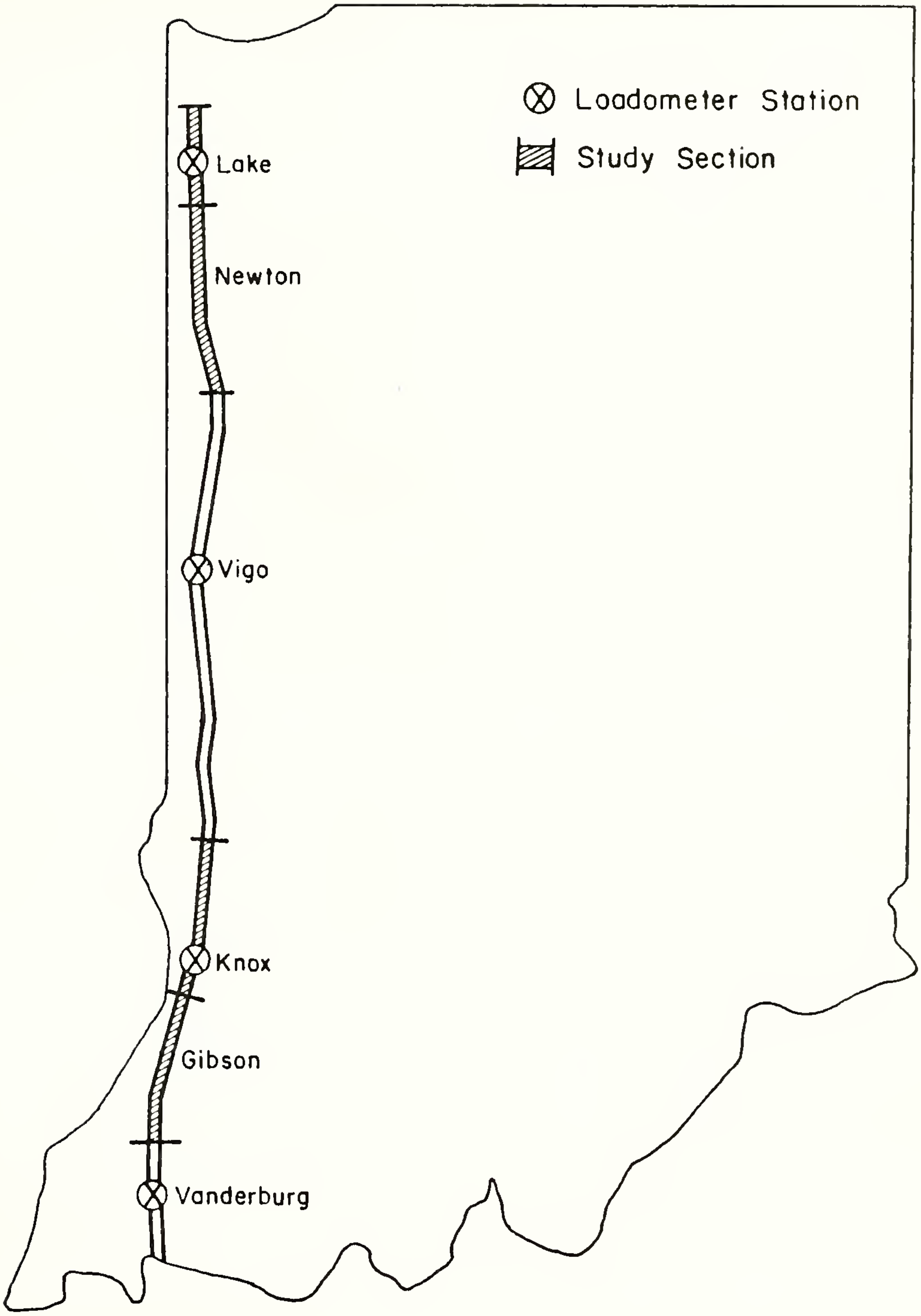

FIGURE 8 SECTIONS & LOADOMETER STATIONS ON US-41

TABLE 11. PERCENTAGES OF HEAVY TRUCKS FOR FOUR STATIONS ON US-41

		County		
Year	Vanderburg	Vigo	Knox	Lake
1970	15.76	9.17*	-----	-----
1971	14.56	-----	-----	-----
1972	18.00	-----	-----	-----
1973	16.19	-----	-----	-----
1974	17.00	-----	-----	-----
1975	13.75	-----	18.77	15.70
				(5.39)

Percentages shown between parentheses are for weekend counts and the others are for weekday counts.

Average weekday = 16.22%

Average weekend = 5.39%

Average truck percentage = 13.13%

*Excluded from average calculations.

Note: Weekend to weekday factor for other 2-lane and other 4-lane highways

$$\frac{5.39}{15.70} = .34$$

Calculated from this data as no other weekend data was available on other 2-lane and other 4-lane highways.

US-24 Sections

Three sections were located on this route in Allen, Whitley, and Huntington counties as shown in Figure 9. The data available from the Huntington station was used to derive the required percentage of trucks. According to Table 12 the percentages at the Huntington station are higher than the percentages at the Cass station. This probably results because most of the highway between the Ohio line and Huntington is multilane divided.

US-30 Sections

Four sections were used on this highway. They are located in Allen, LaPorte, Starke, and Marshall counties and are shown in Figure 10. The data from two loadometer stations were available. The data of the Lake station were excluded because most truck drivers change their route just before this station from US-30 to I-80 and I-94 on their way to Chicago. The average truck percentages of interest are in Table 13.

US-31 Sections

Two sections were used on this road in St. Joseph and Marshall counties. The data of one loadometer station were available in Marshall county for two years, 1971 and 1975. Using the data of this station together with the weekend adjusting factor the average truck percentage for the years 1970-1974 was found to be 10.96%, and an average of 17.62% for the year 1975. The reason for the difference in truck percentages is probably due to route widening in October 1974 in Marshall county. This attracted some truck drivers to the new widened highway.

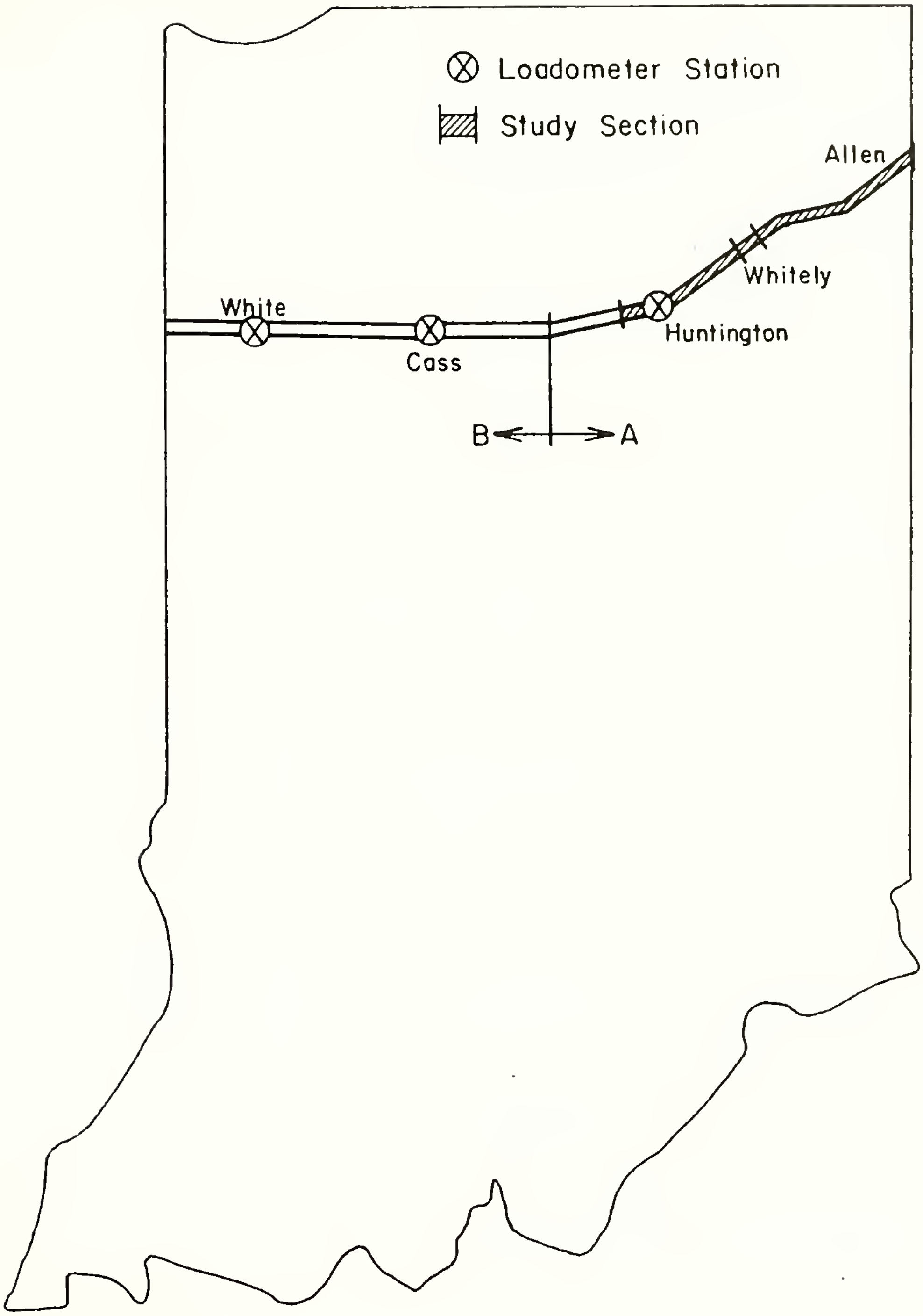

FIGURE 9 SECTIONS & LOADOMETER STATIONS ON US-24

TABLE 12. PERCENTAGES OF HEAVY TRUCKS FOR THREE STATIONS ON US-24

Year	Cass	County Huntington	White
1970	8.78	-----	-----
1971	9.44	-----	-----
1972	-----	17.89	-----
1973	-----	15.78	-----
1974	10.98	-----	-----
1975	12.57	-----	*19.01

Percentages shown are for weekday counts only.

For Part (A) in Figure 9

Average weekday = 16.83%

Average weekend = 16.83 x .34 = 5.72%

Average truck percentage = 13.66%

For Part (B) in Figure 9

Average weekday = 10.44

Average weekend = 10.44 x .34 = 3.55%

Average truck percentage = 8.47%

Note: All Study Sections were in Part A.

*Excluded from average computations because of non comparative value.

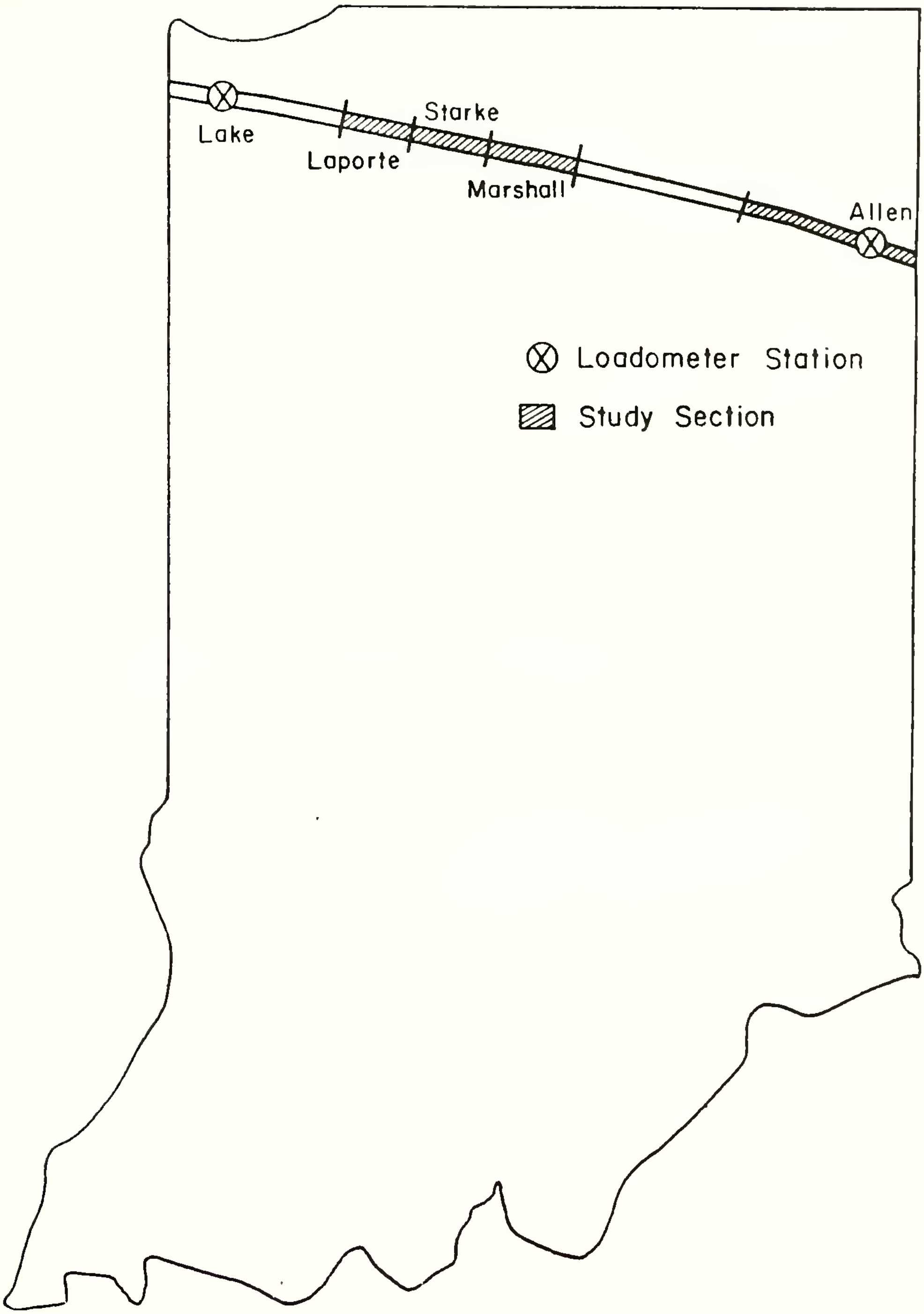

FIGURE 10 SECTIONS & LOADOMETER STATIONS ON US-30

TABLE 13. PERCENTAGES OF HEAVY TRUCKS FOR TWO STATIONS ON US-30

Year	County	
	Lake	Allen
1970	7.03	-----
1971	7.46	24.30
1972	7.10	25.89
1973	7.40	-----
1974	8.36	-----
1975	10.64	-----

Percentages shown are for weekday counts only.

Average weekdays = 25.10%

Average truck percents = 20.37%

Note: All Lake County counts were excluded from the average computations because many trucks from or to US 30 use parallel I-80 and I-94 in this area.

US-50 & 150 Section

Only one section in Dearborn county was used for this highway. The data for three loadometer stations were available for this study. Using the data from the Ripley station, the nearest station to the studied section, it was found that the average truck percentage for this route during the study periods was 13.3%.

SR-67 Section

One section in Hendricks county was located for this route. The data of two counting stations were available. The data of Morgan station was used in the computations because of its proximity. The average truck percentage for this route was found to be 8.80%.

SR-2 Section

This route has truck traffic very similar to that of US-20. Truck percentage on this route, therefore, was taken as that of US-20 - 12.17% as noted in the following paragraph.

US-20 Sections

Two sections were used for this route in Elkhart and Lagrange counties. Two loadometer stations were located in LaPorte and Elkhart counties. The data of Elkhart station only were used because of its proximity to derive an average truck percentage of 12.17% for the studied periods.

US-6 Sections

Three sections were used for this road, two of them in Elkhart county and the third in Noble county. Three loadometer stations, located in Porter, Elkhart, and Marshall counties, had data available. Porter station had very low percentages of trucks during the study periods because truck drivers had the opportunity to use other routes rather than US-6 on their way to Chicago. The most reliable data among the three stations appeared to be the Elkhart station data and it alone was used. An average truck percentage equal to 24.00% was calculated.

US-27 Sections

Five sections were used for this highway in Allen, Adams, Jay, and Union counties. One loadometer station was located in Adams county. The data collected from this station showed an average truck percentage of 9.95%.

US-35 Section

The traffic on this route has the same characteristics as US-24 traffic, so the average truck percentage for this section was 13.66%.

US-231 Sections

The three studied sections were located in Porter, Jasper, and White counties. According to the volume counts taken for the Lafayette Transportation Study for SR-43, it was found that the average heavy truck percentage for the study periods was 6.39%. That percentage was used for the US-231 sections.

SR-3 Sections

This highway was divided into two parts. The first part was located north of Fort Wayne which had two sections located in Allen and Lagrange county. The southern part was located south of Fort Wayne which had three sections located in Huntington, Rush, and Wells counties. Two loadometer stations were located in Allen and Delaware counties as shown in Figure 11.

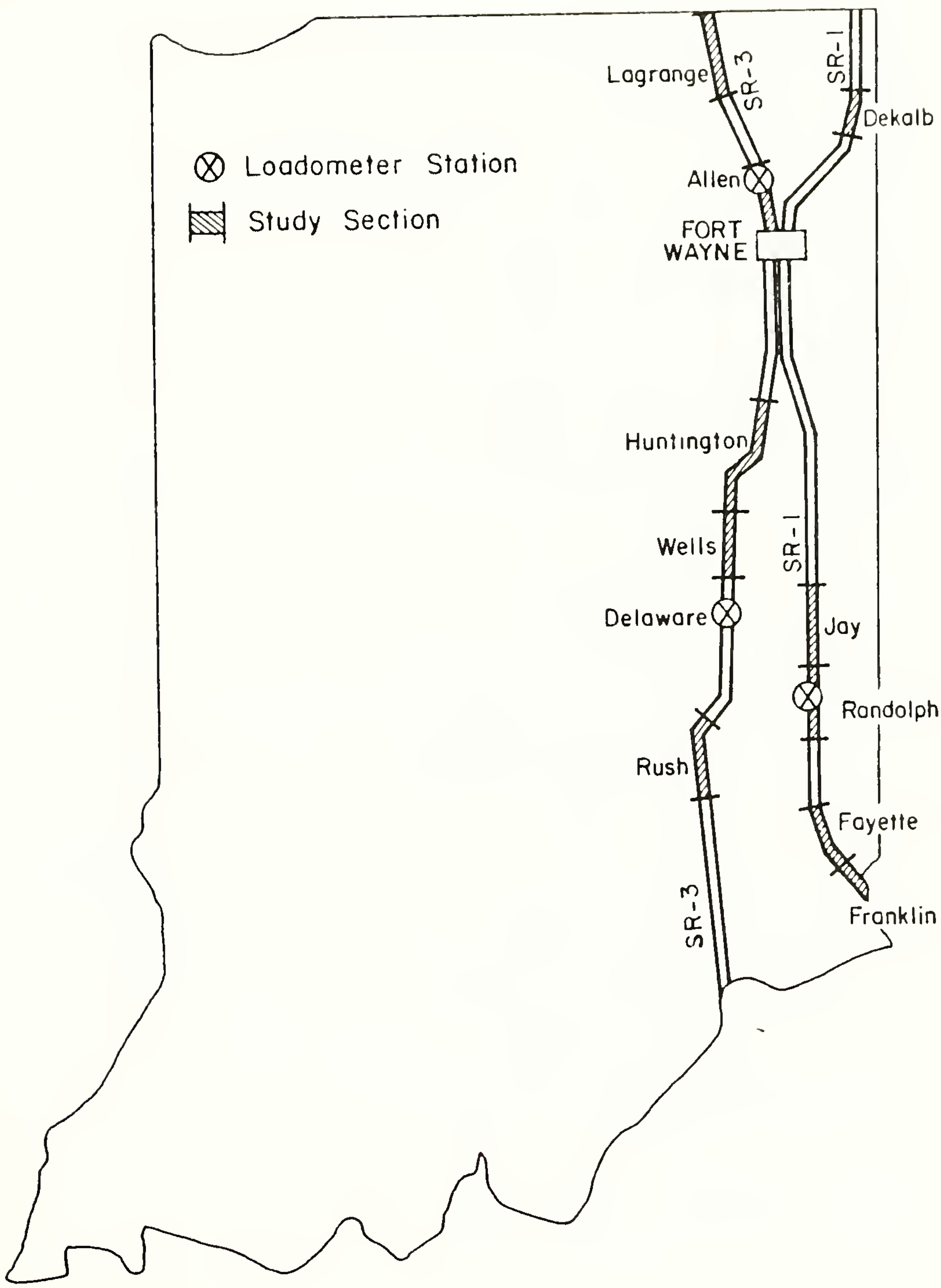

FIGURE 11 SECTIONS & LOADOMETER STATIONS ON SR-1 & SR-3

The average truck percentage for the northern part of SR-3 was found to be 5.33% while the percentage for the southern part was 7.22% as shown in Table 14.

SR-1 Sections

Five sections were used on this route. Four of them were located south of Fort Wayne in Fayette, Franklin, Jay, and Randolph counties. The fifth section was located north of Fort Wayne in Dekalb county. The one loadometer station was south of Fort Wayne and had truck data for only one year. As it was similar to the average for the southern part of SR-3 and has similar characteristics, so the average truck percentage for SR-1 was taken to be as for the southern part of SR-3, 7.22%.

SR-9 Sections

Three sections were used for this road located in Huntington, Lagrange and Noble counties. The data extracted from the Hancock loadometer station gave an average truck percentage of 5.23% for all time periods.

SR-64 Sections

Five sections were chosen for this route located in Crawford, Dubois, Gibson, Harrison and Pike counties. Because of the relatively high accident numbers on this highway with truck accidents scattered all over the five sections, extra care in determining truck percentages was given to this route.

Previous studies by the Indiana State Highway Commission on this highway indicated the following:

1. A count of truck volumes was done at the west edge of Princeton in 1973 and showed an average percentage of 10%.

TABLE 14. PERCENTAGES OF HEAVY TRUCKS FOR TWO STATIONS ON SR-3

Year	County	
	Allen	Delaware
1970	-----	-----
1971	-----	-----
1972	-----	-----
1973	6.00	-----
1974	6.80	9.94
1975	6.90	7.86

Percentages shown are for weekday counts only.

North of Fort Wayne

Average weekday percents = 6.27%

Average truck percentage = 5.33%

South of Fort Wayne

Average weekday percents = 8.90%

Average truck percentage = 7.22%

2. A volume study was made at the JCT of SR-145 and SR-64 east of Birdsey and it yielded an average of 45% heavy trucks. The reason for this high percentage is that a quarry is located six miles east of this location. As these trucks typically travelled short distances on SR-64, this value was not used in calculating the truck percentage for SR-64.
3. A third study at Morengo east of the JCT of SR-66 with SR-64 gave an average percentage of 28% heavy trucks for the year 1970.
4. Another study at Miltown west of the JCT of SR-66 with SR-64 found the average percentage of heavy trucks to be 22% for the year 1970.

Using the three percentages noted above for weekday truck volumes and the same weekend factor mentioned before, the average percentage for this route was found to be 21.3%.

SR-120 Sections

Two sections were used for this road in Elkhart and Lagrange counties. This highway has similar traffic characteristics as US-20. Consequently, the average truck percentage for this route was taken as that of US-20, 12.17%.

Tables 15, 16, and 17 show a summary of the average truck percentages for the different periods and the different highways.

Accident Rates

Accident rates for each six month period for each study section were expressed as accidents per hundred million vehicle miles using the formula:

$$\frac{(\text{Number of accidents})(100{,}000{,}000)}{(\text{Section length})(\text{A.D.T.})(\%\ \text{Truck})\left(\frac{365}{2}\right)}$$

TABLE 15. AVERAGE HEAVY TRUCK PERCENTAGES FOR INTERSTATE HIGHWAYS

Highway	Percentages
I-65	22.56
I-69	27.76
I-70	25.65
I-74*	19.38
I-74**	24.88

Note: Percentages of trucks are for all study periods unless indicated.

* For the years 1970, 1971, 1972, and 1973.

** For the years 1974, and 1975 only.

TABLE 16. AVERAGE HEAVY TRUCK PERCENTAGES FOR OTHER FOUR-LANE HIGHWAYS

Highway	Percentages
US-41	13.13
US-24*	13.66
US-24**	8.47
US-30	20.37
US-31(*)	10.96
US-31(**)	17.62
US-50 & 150	13.33
SR-67	8.80
SR-2	12.17

* All sections east of Huntington.

** All sections west of Huntington.

(*) For the years 1970-1974.

(**)For the year 1975 only.

TABLE 17. AVERAGE HEAVY TRUCK PERCENTAGES FOR TWO LANE HIGHWAYS

Highway	Percentages
US-20	12.17
US-6	24.00
US-27	9.95
US-35	8.47
US-231	6.39
SR-3*	5.33
SR-3**	7.22
SR-1	7.22
SR-9	5.23
SR-64	21.30
SR-120	12.17

* All sections north of Fort Wayne.

** All sections south of Fort Wayne.

The rates of truck accidents were calculated for the seventy-seven study sections for each of the nine six month periods for the years 1970, 1971, 1972, 1974, and the first six months of 1975. Also, the rates of truck accidents by type were measured for the sections with the types of accidents as follows:

1. Rear-end collision
2. Ran off road
3. Side swipe
4. Right angle

Statistical Analysis

The seventy-seven sections were not equally distributed over the four interstate, five other 4-lane, and seven 2-lane highways. To perform a statistical analysis relevant to the objectives of this research (25, 28), the following actions were taken:

1. As one interstate highway had only four study sections, four sections out of all the available sections were randomly chosen for each interstate highway.
2. For four-lane highways, two sections, the minimum number for all but two highways, were chosen randomly for each highway. The two highways, US-50 and SR-67, were excluded from the study because each had only one section. The differences in characteristics between these two highways made it unfavorable to pool them.
3. For two-lane highways, five sections per highway were available on five highways. Sections on the remaining highways were combined into groups of five sections as follows:

a. Five sections were chosen at random from the sections on US-20, US-6, and SR-120 because these highways have similar characteristics.

b. Three sections of highway on SR-9 were combined with the two sections of highway on US-231, again because of similar traffic characteristics.

The total number of highways which were analyzed were 16 with a total of 61 sections as follows:

1. Four interstate highways with four sections each.
2. Five four-lane highways with two sections each.
3. Seven two-lane highways with five sections each.

To evaluate changes in truck accident rates as well as rates by accident type for the study periods the following steps were followed in sequential order:

1. Check the homogeneity of variances for accident rates between the study sections within each highway type. If the sections are homogeneous, jump to step 3 but if not continue to step 2.
2. Try a transformation form for accident rates, by using a square root (if data indicates a Poisson distribution) or logarithms (if data indicates an exponential distribution), and then recheck the homogeneity of sections within the highway.
3. Check homogeneity of variances for rates or transformed accident rates between the studied highways within the highway class.
4. Apply the analysis of variance (ANOVA) test to the rates or transformed accident rates to check for significance in rates for different sections within the highway as well as the significance in rates for the different time periods.

5. Average the rates or transformed accident rates for all the study sections within a highway class. This will give nine values for each type of highway, one for each of the nine time periods.
6. Try to fit an orthogonal polynomial model for the average transformed accident rates and time period.
7. Using the orthogonal contrast analysis (Bonferroni procedure) with equal type 1 error allocation to study the significance between the rates before and after the 55 mph maximum speed limit.

These steps are shown in Figure 12.

The statistical tests which were used in the analysis of data for this research are briefly reviewed in the following paragraphs.

Bartlett Test of Homogeneity

Two populations are called homogeneous when they have equal variances for a certain level of significance. A Chi-square test of homogeneity (Bartlett test) was used in this research for this purpose. The sections within the same highway as well as the highways within the same class were checked by this test, for further details refer to (25,28).

Analysis of Variance Test (ANOVA)

To study the effect of time periods on truck accident rates, a nested factorial model was used. The analysis resulted in the following linear model:

$$Y_{ijk} = \mu + H_i + S_{(i)j} + w_{(ij)} + P_k + HP_{ik} + SP_{(i)jk} + \epsilon_{(ijk)}$$

Where

Y_{ijk} = The measured variable, i.e., truck accident rates per 100 million vehicle miles,

μ = True mean effect for population,

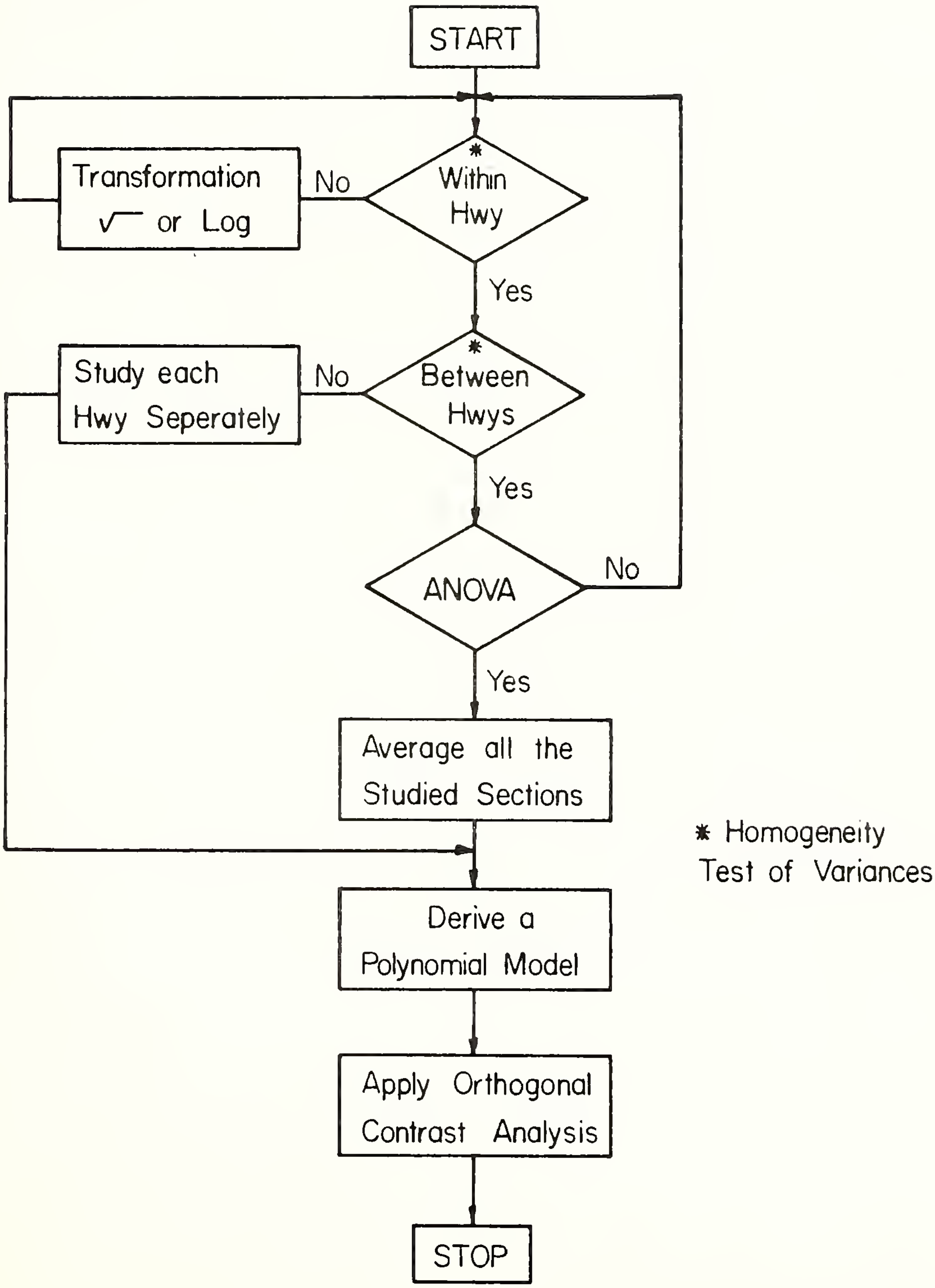

FIGURE 12 FLOW CHART FOR THE STATISTICAL ANALYSIS PROCEDURE

H_i = True effect of the i^{th} highway type (Fixed),

$S_{(i)j}$ = True effect of the j^{th} section (random) in the i^{th} value type NID (o, σ_s^2),

$W_{(ij)}$ = Restriction error, zero d.f., due to studying all sections of each highway before the next one.

P_k = True effect of the k^{th} period type (fixed),

HP_{ik} = Effect of interaction of the i^{th} highway type with the k^{th} period,

$SP_{(i)jk}$ = Effect of interaction of the j^{th} section in the i^{th} highway type by the k^{th} period,

$\varepsilon_{(ijk)}$ = True random error, zero df.

The subscripts assume the values:

$i = 1, 2, \ldots. m$

$j = 1, 2, \ldots. n$

$k = 1, 2, \ldots. \ell$

Where

m = Number of highways within the same class.

n = Number of sections within the highway.

ℓ = Number of time periods.

The values m, n, and ℓ for this research were:

1. Interstate highways: $m = 4$, $n = 4$, $\ell = 9$.
2. Other four-lane highways: $m = 5$, $n = 2$, $\ell = 9$.
3. Two-lane highways: $m = 7$, $n = 5$, $\ell = 9$.

In the ANOVA model, the main effects H and P are fixed while the effect S is random. The linear model was formulated with the assumptions of homogeneity of both main effects H and S, normality, additivity and independence of errors. Table 18 summarizes the steps for testing the significance of sections within highway type and significance between time periods.

The nature of the study resulted in a restriction on randomization. The restriction error $W_{(ij)}$ appears because all sections of each highway were studied separately before considering another highway.

TABLE 18. SUMMARY OF "ANOVA" - EFFECT OF TIME PERIODS ON HEAVY TRUCK ACCIDENT RATES

Source of Variation	Degrees of Freedom	Sum of Squares	Expected Mean Squares	Mean Square	F-Test
Highway H_i	$m-1$	$(S.S)_H$	$\ell\sigma_W^2+\ell\sigma_s^2+m\ell\phi(H)$	$(M.S)_H=A$	A/B*
Section $S_{(i)j}$	$m(n-1)$	$(S.S)_s$	$\ell\sigma_W^2+\ell\sigma_s^2$	$(M.S)_S=B$	
Restriction Error $W_{(ij)}$	0		$\ell\sigma_W^2$		
Period P_k	$\ell-1$	$(S.S)_p$	$\sigma_{sp}^2+mn\phi(P)$	$(M.S)_p=C$	C/D**
Interaction HP_{ik}	$(\ell-1)(m-1)$		$\sigma_{sp}^2+n\phi(HP)$		
Interaction $SP_{(i)jk}$	$m(n-1)(\ell-1)$	$(S.S)_{SP}$	σ_{sp}^2	$(M.S)_{sp}=D$	
Within Error $E_{(ijk)}$	0		σ_E^2		

* Cut off point: $F_{(m-1),\ (m(n-1)),.05}$

**Cut off point: $F_{(\ell-1),\ m(n-1)(\ell-1),.05}$

The tests of significance were performed as indicated by the arrows shown in Table 18. The highway types, H_i, were tested against the sections within the highway $S_{(i)j}$. The time periods P_k were tested against the interaction $SP_{(i)jk}$.

Tests of Orthogonal Contrasts

Several treatments were used in this research to check significancy over the study periods. The "Bonferroni" test with equal error allocation was adopted for this purpose. Tables of t and Chi-square percentage points provided the capability for unequal type 1 error allocation over a family of statistical tests. For more information, the reader is referred to Dayton and Schafer (28). To test the required orthogonal contrasts, three treatments were used in this research:

1. The average rate of accidents for the first six months of the year for the years 1970, 1971, and 1972 versus the average rate of accidents for the first six months of the year for the years 1974 and 1975.
2. The average rate of accidents for the second six months of the year for the years 1970, 1971, and 1972 versus the average rate of accidents for the second six months of the year for the year 1974.
3. The average rate of accidents for both first and second six months of the year for the years 1970, 1971, and 1972 versus the average rate of accidents for both the first and second six months of the year for the year 1974 and the first six months only of 1975.

These three treatments are as follows:

$$\frac{C_{1,70} + C_{1,71} + C_{1,72}}{3} \text{ vs } \frac{C_{1,74} + C_{1,75}}{2} \qquad 1$$

$$\frac{C_{2,70} + C_{2,71} + C_{2,72}}{3} \text{ vs } C_{2,74} \qquad 2$$

$$\frac{C_{1,70} + C_{2,70} + C_{1,71} + C_{2,71} + C_{1,72} + C_{2,72}}{6} \text{ vs }$$

$$\frac{C_{1,74} + C_{2,74} + C_{1,75}}{3} \qquad 3$$

Where

$C_{1,70};C_{1,71};C_{1,72};C_{1,74};C_{1,75}$ = Average rates of accidents for the study highways for the first six months of the year for the years 1970, 1971, 1972, 1974 and 1975.

$C_{2,70};C_{2,71};C_{2,72};C_{2,74}$ = Average rates of accidents for the study highways for the second six months of the year for the years 1970, 1971, 1972, and 1974.

The hypotheses of this test are:

Null hypothesis $H_0: B > o$

Alternative hypothesis $H_1: B \leqslant o$.

Where

. B = The difference between the first and second average rates of accidents for the treatments shown in equations 1, 2, and 3.

The t-statistics were computed in the usual manner with the pooled within-groups estimate of experimental error according to the following equation:

$$t = (\Sigma_j\ C_{ji})\ \bar{Y}_j / \sqrt{M\ S_e\ (\Sigma_j\ C_{ji})/n} \qquad 4$$

Where

C_{ji} = Coefficient of the j^{th} contrast in the i^{th} treatment,

$\bar{Y}_j$ = Average of the average rates for the i^{th} treatment,

MS_e = Expected mean square for experimental error,

n = Number of observations used for the average rates.

Assuming equal type 1 error allocation over the three treatment tests, the cut-off points for these tests were taken from Bonferroni tables for a one sided test for level of significance (α = .05).

The measured values in equation 4 were compared with cut-off points to check if there was a significant change in average rates between the before and after periods.

Truck Accident Rates

The rates of truck accidents per 100 million vehicle miles as calculated for the 61 study sections were used in the statistical analysis procedure. Following the flow chart shown in Figure 12, the results obtained are reviewed in the following paragraphs.

The chi-square test of homogeneity was conducted on heavy truck accident rates for the study sections within the same highway and the results showed that these rates were not homogeneous.

A square root transformation form was used on the rates and the test was run once more. It was found that the sections were homogeneous for level of significance α = .01-.001 as shown in Table B-1 of Appendix B (25).

The test of homogeneity between the highways was performed by adding the nine transformed values for each section separately. The conclusions of this test are shown in Table B-2 of Appendix B. The highways were found to be homogeneous for level of significance α = .01.

The analysis of variance test was carried out on the square roots of the accident rates and the following results were obtained.

For Interstate highways:

1. Time periods were significant at $\alpha = .01$.
2. Highway sections were not significant at $\alpha = .05$.

For other four-lane highways:

1. Time periods were significant at $\alpha = .05$.
2. Highway sections were not significant at $\alpha = .05$.

For two-lane highways:

1. Time periods were significant at $\alpha = .10$.
2. Highway sections were not significant at $\alpha = .05$.

The ANOVA analysis is shown in Table 19. From this Table, where the M.S for S(H) > M.S for SP(H)

$$F_{12,96} = \frac{24.89}{4.72} = 5.27 > F_{12,96,.25} = 1.28,$$

the errors were not poolable. A conservative way to investigate the trend over the time periods is to use only the mean of all the sections within the highway class for each time period separately. This average base was also applied for the analysis of heavy truck accident rates by type. Orthogonal polynomial models were tried for the average transformed rates for the nine time periods. The small number of sections, the limited accident experience (3 years), and possible effects of location for the chosen sections caused unreliability of models developed from the data.

For each class of highway, the Bonferroni procedure of orthogonal contrasts was performed. The final results are shown in Table 20.

The upper and lower limit values of average heavy truck accident rates for the 3-year period before the 55 mph speed limit and the first 1.5 years of the 55 mph limit for the three classes of highways are shown in Table 21.

TABLE 19. ANOVA FOR SQUARE ROOT OF HEAVY TRUCK ACCIDENT RATES

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Interstate	H	209.82	3	69.94	2.80*	3.49	$(N.S.)_{.05}$
	P	161.41	8	20.17	4.27**	2.69	$(Sig)_{.01}$
	S(H)	298.74	12	24.89			
	SP(H)	453.64	96	4.72			
Other Four-Lane	H	103.03	4	25.75	1.26*	5.19	$(N.S.)_{.05}$
	P	138.89	8	17.36	2.15**	2.13	$(Sig)_{.05}$
	S(H)	101.59	5	20.31			
	SP(H)	322.70	40	8.06			
Two-Lane	H	551.84	6	91.97	.699	2.44	$(N.S.)_{.05}$
	P	1174.57	8	146.82	1.66**	1.67	$(Sig)_{.01}$
	S(H)	3939.63	28	140.70			
	SP(H)	19854.83	224	88.63			

H: Highway type, S: Highway sections, P: Time periods, Sig: Significant, N.S.: Not Significant.

$$* \quad F = \frac{M.S.(H)}{M.S.(S(H))}$$

$$** \quad F = \frac{M.S.(P)}{M.S.(SP(H))}$$

TABLE 20. ORTHOGONAL CONTRASTS - TEST RESULTS FOR THE SQUARE ROOT OF RATES OF HEAVY TRUCK ACCIDENTS

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Interstate	First	2.53	2.16	S
	Second	2.74	2.16	S
	Third	3.65	2.16	S
Other Four-Lane	First	2.29	2.20	S
	Second	2.23	2.20	S
	Third	3.54	2.20	S
Two-Lane	First	1.02	2.14	N.S.
	Second	.03	2.14	N.S.
	Third	.83	2.14	N.S.

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, S: Significantly decreased, N.S.: Not significantly decreased.

TABLE 21. AVERAGE HEAVY TRUCK ACCIDENT RATES FOR THREE CLASSES OF RURAL HIGHWAY

Time Period	Interstate	Other Four-Lane	Two-Lane
	Upper Limit Rates*		
Before the 55 mph speed limit	87.56	249.56	244.41
After the 55 mph speed limit	62.68	192.44	212.61
	Average Rates		
Before the 55 mph speed limit	78.04	198.89	167.28
After the 55 mph speed limit	54.68	148.81	141.37
	Lower Limit Rates*		
Before the 55 mph speed limit	68.52	148.23	90.15
After the 55 mph speed limit	46.69	105.18	70.13

Note: Rates are in 100 MVM.

*95 Percentile Confidence Limits.

A chi-square test of homogeneity was performed on the square root of the heavy truck accident rates for the classes of highways together. The results of this test showed that the three classes of highways are homogeneous for level of significance $\alpha = .01$.

The average of all the 61 sections rates were calculated for each time period separately. A linear polynomial model was fitted for the six time periods of the years 1970, 1971, and 1972 (before the 55 mph speed limit). The predictive model is shown in Figure 13. The rates of heavy truck accidents were then predicted from this model for the last three time periods of the years 1974 and 1975 (after the 55 mph speed limit). The difference in rates between the actual and the predicted values were calculated. The change in accident rates from that predicted from the before 55 mph speed limit data and actual rates under the 55 mph maximum speed limit are shown in Table 22.

The Benforroni procedure of orthogonal contrasts was performed. The results showed a non significant decrease in heavy truck accident rates on all highways which can be seen in Table 23.

Summary

In general, there was a decrease in the average heavy truck accident rates in the years 1974 and 1975 from the average heavy truck accident rates in the years 1970, 1971, and 1972. The decrease was significant for Interstate and other four-lane highways. However, the decrease was not significant for two-lane.

The upper limit values of the average rates of heavy truck accidents per 100 MVM, for the years 1970-1972 during which the maximum speed limit was 70 and 65 mph, for Interstate, other four-lane and two-lane highways were found to be 87.56, 249.56, and 244.41 respectively. The lower limit

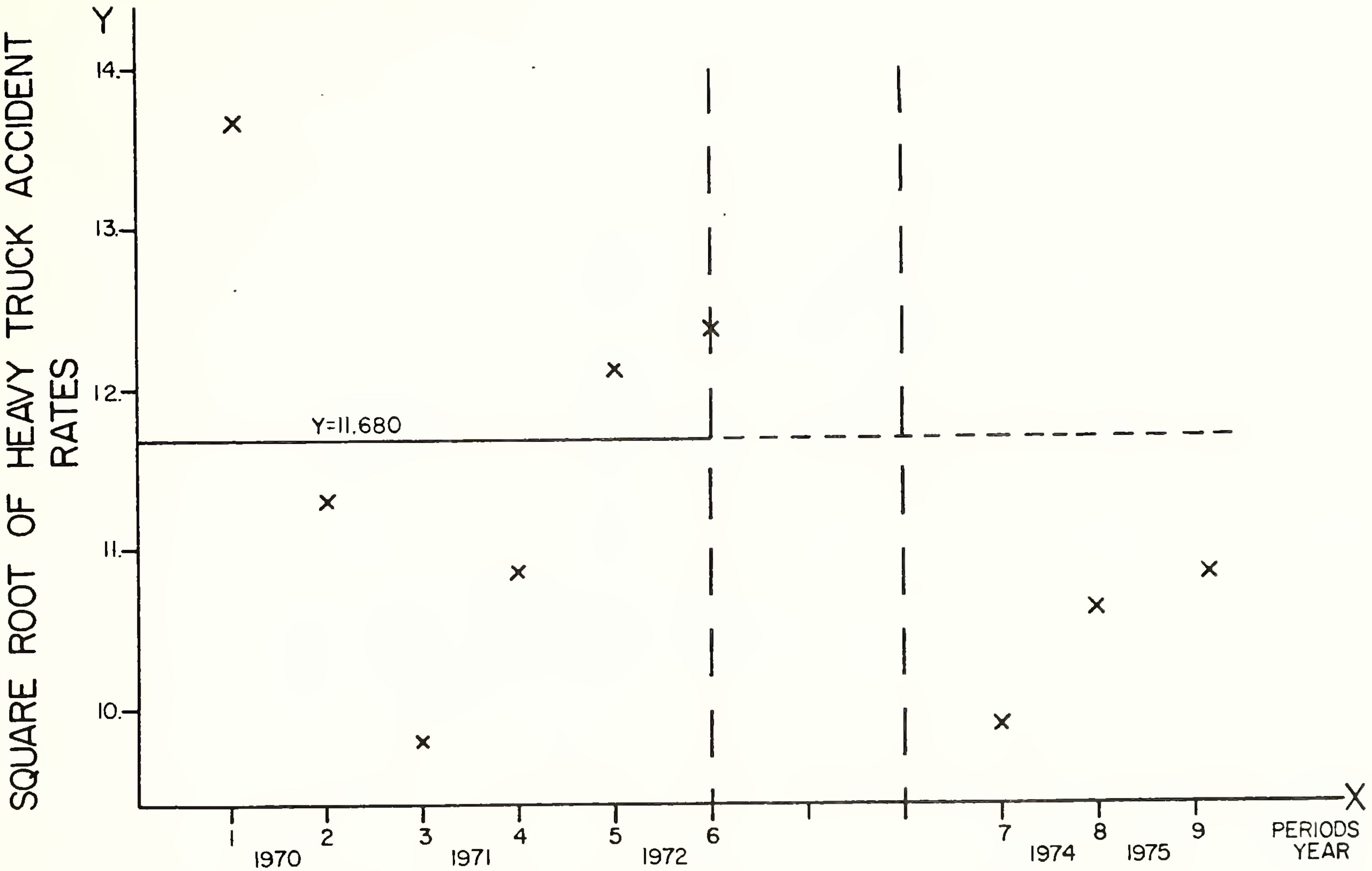

FIGURE 13 PREDICTIVE MODEL FOR ALL HIGHWAYS

TABLE 22. ESTIMATED CHANGE IN HEAVY TRUCK ACCIDENT RATES DUE TO THE 55 MPH MAXIMUM SPEED LIMIT FOR ALL HIGHWAYS

Time	Rate Type	P	A	D	Conclusion
First Period 1974	L.L.	95.06	63.84	32.22	Decrease
	Average	140.14	102.13	38.01	
	U.L.	185.23	140.42	44.81	
Second Period 1974	L.L.	95.06	75.69	19.37	Decrease
	Average	140.14	116.72	23.42	
	U.L.	185.23	157.75	27.48	
First Period 1975	L.L.	95.06	78.85	17.21	Decrease
	Average	140.14	120.57	19.57	
	U.L.	185.23	162.30	22.93	

Note: P: Predicted heavy truck accident rates.
A: Actual heavy truck accident rates.
D: Difference of heavy truck accident rates
U.L.: Upper limit rate value.
L.L.: Lower limit rate value.

TABLE 23. ORTHOGONAL CONTRASTS - TEST RESULTS FOR THE SQUARE ROOT OF HEAVY TRUCK ACCIDENT RATES ON ALL HIGHWAYS

Contrasts	Calculated t	$\bar{t}$	Conclusion
First	1.65	2.12	N.S.
Second	.75	2.12	N.S.
Third	1.74	2.12	N.S.

Note:

First Contrast:

1st 6 months (1970-1972) vs. 1st 6 months (1974-1975).

Second Contrast:

2nd 6 months (1970-1972) vs. 2nd 6 months (1974).

Third Contrast:

All 6 months (1970-1972) vs. All 6 months (1974-1975).

$\bar{t}$: Cut-off points for test.

N.S.: Not significantly decreased.

values were 68.52, 148.23 and 90.15.

On the other hand, the upper limit values of the average rates of heavy truck accidents per 100 MVM, for the year 1974 and the first 6 months of 1975 under the mandatory speed limit of 55 mph, for Interstate, other four-lane, and two-lane highways were found to be 62.68, 192.44, and 212.61 respectively. The lower limit values were 46.69, 105.18, and 70.13 respectively.

From the averages of these upper and lower limit values, it can be seen that the reduction in number of heavy truck accidents per 100 MVM after the 55 mph maximum speed were 18.36, 50.00 and 25.89 for Interstate, other four-lane and two-lane highways respectively.

The upper and lower limits for the average accident rates mentioned above confirm that accident rates on other four-lane as well as on two-lane highways are much higher than on Interstate highways. This can be attributed to full control of access on Interstate highways as opposed to the other highway types.

The reduction of truck accident rates on Indiana rural highways may be due to several reasons. Two major ones probably are reduction in speeds for heavy trucks after the 55 mph maximum speed limit. Previous speed studies (2) indicated that the average heavy truck speeds for the years 1970-1972 for Interstate, other four-lane and two-lane highways were 61, 56 and 55 mph respectively. The average speeds were found to be 57, 55 and 54 for the year 1974 and the first six months of 1975. Average speed reductions after the 55 mph maximum speed limit were 4, 1 and 1 mph for the Interstate, other four-lane, and two-lane highways respectively. As can be seen the speed reduction for trucks was small.

A second reason for the lesser truck accident rates under the 55 mph is the lesser variability in speeds between heavy trucks and passenger cars. The differences in average speeds between heavy trucks and passenger cars before the 55 mph maximum speed limit on Interstate, other four-lane, and two-lane highways were 10, 9, and 6 mph. The difference in average speeds after the 55 mph speed limit were 2, 3, and 2 respectively. This big decrease to the point where both trucks and passenger cars are now travelling at virtually the same speed is probably the major reason for the truck accident rate decrease.

Rates of Truck Accidents by Type

Rear-End Collision Accidents

The rates of rear-end collision accidents per 100 MVM were calculated for each of the highway sections. The square root form of transformation was applied to these rates. Following the steps of the flow chart shown in Figure 12, the results are discussed in the following paragraphs.

The chi-square test of homogeneity was run on the transformed rates (i.e. square root) for all the sections within the same highway and it was found that these sections were homogeneous as shown in Table B-3 of Appendix B.

The chi-square test of homogeneity between highways within the highway class indicated that all the highways were homogeneous. The results of this test are shown in Table B-8 of Appendix B.

The analysis of variance test was performed on the transformed rates and the following conclusions were derived.

For Interstate highways:

1. Time periods were significant for $\alpha = .01$.
2. Highway sections were not significant for $\alpha = .05$.

For other four-lane highways:

1. Time periods were not significant for $\alpha = .10$.
2. Highway sections were not significant for $\alpha = .05$.

For two-lane highways:

1. Time periods were not significant for α = .25.
2. Highway sections were not significant for α = .05.

These results are shown in Table 24.

Orthogonal polynomial models were tried for the average transformed rates for the nine time periods but no reliable models were found to fit these data.

Bonferroni procedure was used to perform a comparison test on the time periods for each class of highway. The results of this test are shown in Table 25. The analysis showed that the rates of rear-end collision heavy truck accidents decreased significantly on Interstate as well as on other four-lane highways, after the 55 mph maximum speed limit for level of significance α = .05. The decrease in rates on two-lane highways was not significant for the same level of significance. The upper and lower limit values of average heavy truck accident rates for the three classes of highways are shown in Table 26.

One cause of the rear-end collision accident type is speed differential between vehicles moving in the same platoon. A report of Speed Studies on Indiana main rural highways (2) showed that the difference between the average speeds of heavy trucks and passenger cars before and after the 55 mph maximum speed limit decreased from 8.5 mph to 3.0 mph on Interstate and other four-lane highways. On the other hand, the decrease in speed differential was found to be from 6.3 mph to 2.3 mph on two-lane highways. This may be the reason for rear-end collision heavy truck accidents decreased more on Interstate and other four-lane highways than on two-lane highways.

Ran Off Road Accidents

Following the same procedure used before for rear-end collision accident type and using a square root form of transformation the results were as noted in the following discussion.

TABLE 24. ANOVA FOR SQUARE ROOT OF RATES OF REAR-END HEAVY TRUCK ACCIDENTS

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Interstate	H	116.47	3	38.82	1.89*	3.49	$(N.S.)_{.05}$
	P	144.77	8	18.09	4.16**	2.72	$(Sig)_{.01}$
	S(H)	246.28	12	20.52			
	SP(H)	418.03	96	4.35			
Other Four-Lane	H	97.57	4	24.39	.244*	5.19	$(N.S.)_{.05}$
	P	93.35	8	11.66	1.54**	1.83	$(N.S.)_{.10}$
	S(H)	499.49	5	99.89			
	SP(H)	303.32	40	7.58			
Two-Lane	H	489.71	6	81.61	1.33*	1.30	(N.S.) .05
	P	386.16	8	48.27	1.05**	1.30	$(N.S.)_{.25}$
	S(H)	1717.87	28	61.35			
	SP(H)	10285.34	224	45.91			

H: Highway type, S: Highway sections, P: Time periods, Sig: Significant, N.S.: Not Significant

* $F = \frac{M.S.(H)}{M.S.(S(H))}$

** $F = \frac{M.S.(P)}{M.S.(SP(H))}$

TABLE 25. ORTHOGONAL CONTRASTS TEST RESULTS FOR THE SQUARE ROOT OF RATES OF REAR-END COLLISION HEAVY TRUCK ACCIDENTS

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Interstate	First	3.852	2.160	S
	Second	2.377	2.160	S
	Third	4.102	2.160	S
Other Four-Lane	First	.508	2.204	N.S.
	Second	2.740	2.204	S
	Third	7.537	2.204	S
Two-Lane	First	.464	2.142	N.S.
	Second	2.132	2.142	N.S.
	Third	1.789	2.142	N.S.

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, S: Significantly decreased, N.S.: Not significantly decreased.

TABLE 26. AVERAGE REAR-END COLLISION HEAVY TRUCK ACCIDENT RATES FOR THE THREE CLASSES OF HIGHWAYS

Time Period	Upper Limit Rates*		
	Interstate	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	34.11	96.63	54.43
After the 55 mph speed limit	22.17	70.70	31.00
Time Period	**Average Rates**		
	Interstate	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	26.45	68.42	31.65
After the 55 mph speed limit	14.59	47.42	16.56
Time Period	**Lower Limit Rates***		
	Interstate	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	18.80	40.21	8.87
After the 55 mph speed limit	7.02	24.15	2.13

Note: Rates are in 100 MVM.

*95 Percentile Confidence Limits.

The chi-square test of homogeneity indicated that the sections within the same highway were homogeneous. The results of this test are shown in Table B-4 of Appendix B.

The chi-square test of homogeneity between highways within a highway class indicated that all the highways were found to be homogeneous as shown in Table B-8 of Appendix B.

The analysis of variance test was performed on the transformed rates and it was found that for the three classes of highways (Interstate, other four-lane and two-lane) the conclusions were that time periods were not significant for α = .25, and highway sections were not significant for α = .05. The results are shown in Table 27.

No reliable polynomial models were found to fit the transformed rates of ran off road accident type.

The Bonferroni procedure of orthogonal contrasts was used for each class of highway. The results of this test are shown in Table 28. The analysis showed that the decreases in rates of ran-off-road heavy truck accidents on Interstate and other four-lane highways under the 55 mph maximum speed limit were not significant for level of significance α = .05. The change in rates on two-lane highways also was not significant for the same level of significance.

Side Swipe Accidents

The square root transformation was applied on the calculated rates for this type of accident on all the study sections. The results of the statistical analysis procedure are reviewed in that which follows.

The chi-square test of homogeneity for all the sections within the same highway showed that all the sections were homogeneous. The results of this test are shown in Table 6 of Appendix B.

TABLE 27. ANOVA FOR SQUARE ROOT OF RATES OF RAN-OFF-ROAD HEAVY TRUCK ACCIDENTS

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Interstate	H	66.81	3	22.27	2.93*	3.49	$(N.S.)_{.05}$
	P	50.78	8	6.34	.979**	1.31	$(N.S.)_{.25}$
	S(H)	90.91	12	7.57			
	SP(H)	622.36	96	6.48			
Other Four-Lane	H	8.94	4	2.2366	.28*	5.19	$(N.S.)_{.05}$
	P	148.55	8	18.5688	.79**	1.35	$(N.S.)_{.25}$
	S(H)	39.49	5	7.8993			
	SP(H)	934.50	40	23.3625			
Two-Lane	H	252.24	6	42.04	.55	2.44	$(N.S.)_{.05}$
	P	390.99	8	48.87	1.02	1.28	$(N.S.)_{.25}$
	S(H)	2134.68	28	76.23			
	SP(H)	10724.50	224	47.87			

H: Highway type, S: Highway sections, P: Time periods, N.S.: Not Significant

$$* \quad F = \frac{M.S.(H)}{M.S.(S(H))}$$

$$** \quad F = \frac{M.S.(P)}{M.S.(SP(H))}$$

TABLE 28. ORTHOGONAL CONTRASTS TEST RESULTS FOR THE SQUARE ROOT OF RATES OF RAN-OFF-ROAD HEAVY TRUCK ACCIDENTS

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Interstate	First	- .228	-2.160	N.S.
	Second	1.606	2.160	N.S.
	Third	.775	2.160	N.S.
Other Four-Lane	First	- .079	-2.204	N.S.
	Second	.113	2.204	N.S.
	Third	.231	2.204	N.S.
Two-Lane	First	- .924	-2.142	N.S.
	Second	- .054	-2.142	N.S.
	Third	-1.042	-2.142	N.S.

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, N.S.: Not significantly decreased.

The chi-square test of homogeneity between highways within the highway class showed that all the highways were homogeneous. The results of this test are shown in Table 8 of Appendix B.

The analysis of variance test was used for the transformed rates and the following conclusions were found:

For Interstate highways:

1. Time periods were significant for $\alpha = .05$.
2. Highway sections were not significant for $\alpha = .05$.

For other four-lane highways:

1. Time periods were not significant for $\alpha = .10$.
2. Highway sections were not significant for $\alpha = .05$.

For two-lane highways:

1. Time periods were not significant for $\alpha = .25$.
2. Highway sections were not significant for $\alpha = .05$.

The results are shown in Table 29.

Orthogonal polynomial models were tried for the average values of the transformed rates for all the time periods; however, no reliable models were fitted for the data.

The Bonferroni procedure of orthogonal contrasts was used for each class of highway. The results of this test can be seen in Table 30. The analysis showed that the decreases in rates of side-swipe heavy truck accidents on Interstate and two-lane highways under the 55 mph maximum speed limit were not significant for level of significance $\alpha = .05$. The increase in rates on other four-lane highways was not significant for the same level of significance.

Right Angle Accidents

This type of accident occurs on other four-lane and two-lane highways only. The rates of right angle accidents per 100 million vehicle mile were calculated for all the study sections. The square roots of the previous rates were calculated to apply the same transformation form used before.

TABLE 29. ANOVA FOR SQUARE ROOT OF RATES OF SIDE-SWIPED HEAVY TRUCK ACCIDENTS

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Interstate	H	66.51	3	22.17	2.18*	3.49	$(N.S.)_{.05}$
	P	60.45	8	7.55	2.15**	2.06	$(Sig)_{.05}$
	S(H)	121.86	12	10.15			
	SP(H)	336.85	96	3.50			
Other Four-Lane	H	59.22	4	14.80	.39*	5.19	$(N.S.)_{.05}$
	P	128.32	8	16.04	1.53**	1.83	$(N.S.)_{.10}$
	S(H)	187.60	5	37.52			
	SP(H)	418.87	40	10.47			
Two-Lane	H	223.48	6	37.24	.81*	2.44	$(N.S.)_{.05}$
	P	345.23	8	43.15	1.53**	1.30	$(N.S.)_{.25}$
	S(H)	1282.04	28	45.78			
	SP(H)	6308.55	224	28.16			

H: Highway type, S: Highway sections, P: Time periods, Sig: Significant, N.S.: Not Significant

* $F = \frac{M.S.(H)}{M.S.(S(H))}$

** $F = \frac{M.S.(P)}{M.S.(SP(H))}$

TABLE 30. ORTHOGONAL CONTRASTS TESTS RESULTS FOR THE SQUARE ROOT OF RATES OF SIDE-SWIPE HEAVY TRUCK ACCIDENTS

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Interstate	First	1.301	2.160	N.S.
	Second	1.639	2.160	N.S.
	Third	2.013	2.160	N.S.
Other Four-Lane	First	1.572	2.204	N.S.
	Second	-1.674	-2.204	N.S.
	Third	- .126	-2.204	N.S.
Two-Lane	First	-1.087	-2.142	N.S.
	Second	2.298	2.142	S
	Third	.565	2.142	N.S.

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, S: Significantly decreased, N.S.: Not significantly decreased.

The chi-square test of homogeneity for all the sections within the same highway indicated that all the sections were homogeneous. The results of this test are shown in Table B-6 of Appendix B.

The chi-square test of homogeneity between highways within the highway class showed homogeneity between all the highways and these results are shown in Table B-8 of Appendix B.

The analysis of variance test was used for the square root of accident rates and the conclusions which follow were noted.

For other four-lane highways:

1. Time periods were not significant for $\alpha = .10$.
2. Highway sections were not significant for $\alpha = .05$.

For two-lane highways:

1. Time periods were significant for $\alpha = .05$, however, they were not significant for $\alpha = .01$.
2. Highway sections were not significant for $\alpha = .05$.

The results can be seen in Table 31.

Orthogonal polynomial models were tried for the average values of the square root of rates for the time periods; no reliable models were found to fit the data.

The Bonferroni procedure of orthogonal contrasts was applied for both classes of highway. The results are shown in Table 32. The analysis showed that the decreases in rates of right-angle heavy truck accidents on other four-lane as well as on two-lane highways under the 55 miles per hour maximum speed limit were significant at level of significance $\alpha = .05$.

The upper and lower limit values of the average heavy truck accident rates for the two classes of highways are shown in Table 33.

One cause of the right angle accident type is the misjudgment of drivers in choosing a gap through the main flow. This frequently occurs because crossing drivers are

TABLE 31. ANOVA FOR SQUARE ROOT OF RATES RIGHT-ANGLE HEAVY TRUCK ACCIDENTS

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Other Four-Lane	H	156.12	4	39.03	.82*	5.19	$(N.S.)_{.05}$
	P	152.27	8	19.03	1.42**	1.83	$(N.S.)_{.10}$
	S(H)	235.30	5	47.06			
	SP(H)	534.19	40	13.35			
Two-Lane	H	381.20	6	63.53	2.03*	2.44	$(N.S.)_{.05}$
	P	443.53	8	55.44	2.33**	1.94	$(Sig)_{.05}$
							$(N.S.)_{.01}$
	S(H)	876.23	28	31.29			
	SP(H)	5317.13	224	23.73			

H: Highway, S: Highway sections, P: Time periods, Sig: Significant, N.S.: Not Significant

$$* \quad F = \frac{M.S.(H)}{M.S.(S(H))}$$

$$** \quad F = \frac{M.S.(P)}{M.S.(SP(H))}$$

TABLE 32. ORTHOGONAL CONTRASTS TEST RESULTS FOR THE SQUARE ROOT OF RATES OF RIGHT-ANGLE HEAVY TRUCK ACCIDENTS

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Other Four-Lane	First	4.366	2.204	S
	Second	22.575	2.204	S
	Third	17.165	2.204	S
Two-Lane	First	32.889	2.142	S
	Second	-31.229	-2.142	S*
	Third	16.679	2.142	S

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, S: Significantly decreased, N.S.: Not significantly decreased, S*: Significantly increased.

TABLE 33. AVERAGE RIGHT-ANGLE HEAVY TRUCK ACCIDENT RATES FOR THE TWO HIGHWAY CLASSES

Time Period	Upper Limit Rates*	
	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	40.21	34.33
After the 55 mph speed limit	24.50	33.80
Time Period	**Average Rates**	
	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	31.68	29.03
After the 55 mph speed limit	18.24	25.28
Time Period	**Lower Limit Rates***	
	Other Four-Lane	Two-Lane
Before the 55 mph speed limit	23.16	23.74
After the 55 mph speed limit	11.99	16.77

Note: Rates are in 100 MVM.

*95 Percentile Confidence Limits.

not able to estimate accurately the speed of an approaching vehicles and their choice is based only on distance. The probability of being involved in a right angle accident due to a wrong choice under the higher speeds of the 65 mph maximum speed limit is higher than for the lower speeds of a lower speed limit. This may be the reason for the significant decreases in rates of right-angle heavy truck accidents under the 55 mph maximum speed limit.

Figures 14, 15 and 16 show the average rates of heavy truck accidents by type per 100 MVM for all the study time periods on Interstate, other four-lane, and two-lane highways respectively.

Summary

The decreases in average rate for rear-end collision heavy truck accidents under the 55 mph maximum speed limit were found to be significant on Interstate as well as on other four-lane but not significant on two-lane highways.

The upper limit values of the average rates of rear-end collision heavy truck accidents per 100 MVM for the time period before the 55 mph maximum speed limit for Interstate, other four-lane and two-lane highways were found to be 34.11, 69.63, and 54.43, respectively. The lower limit values were 18.80, 40.21, and 8.87.

The upper limit values of the average rates for the same type of accidents for the periods after the 55 mph maximum speed limit for Interstate, other four-lane and two-lane highways were found to be 22.17, 70.70 and 31.00, respectively. The lower limit values were 7.02, 24.15, and 2.13. From the average of the upper and lower limit values, the reductions in number of rear-end collision heavy truck accidents per 100 MVM under the 55 mph maximum speed were 11.86, 20.98, and 15.09 for Interstate, other four-lane and two-lane highways respectively.

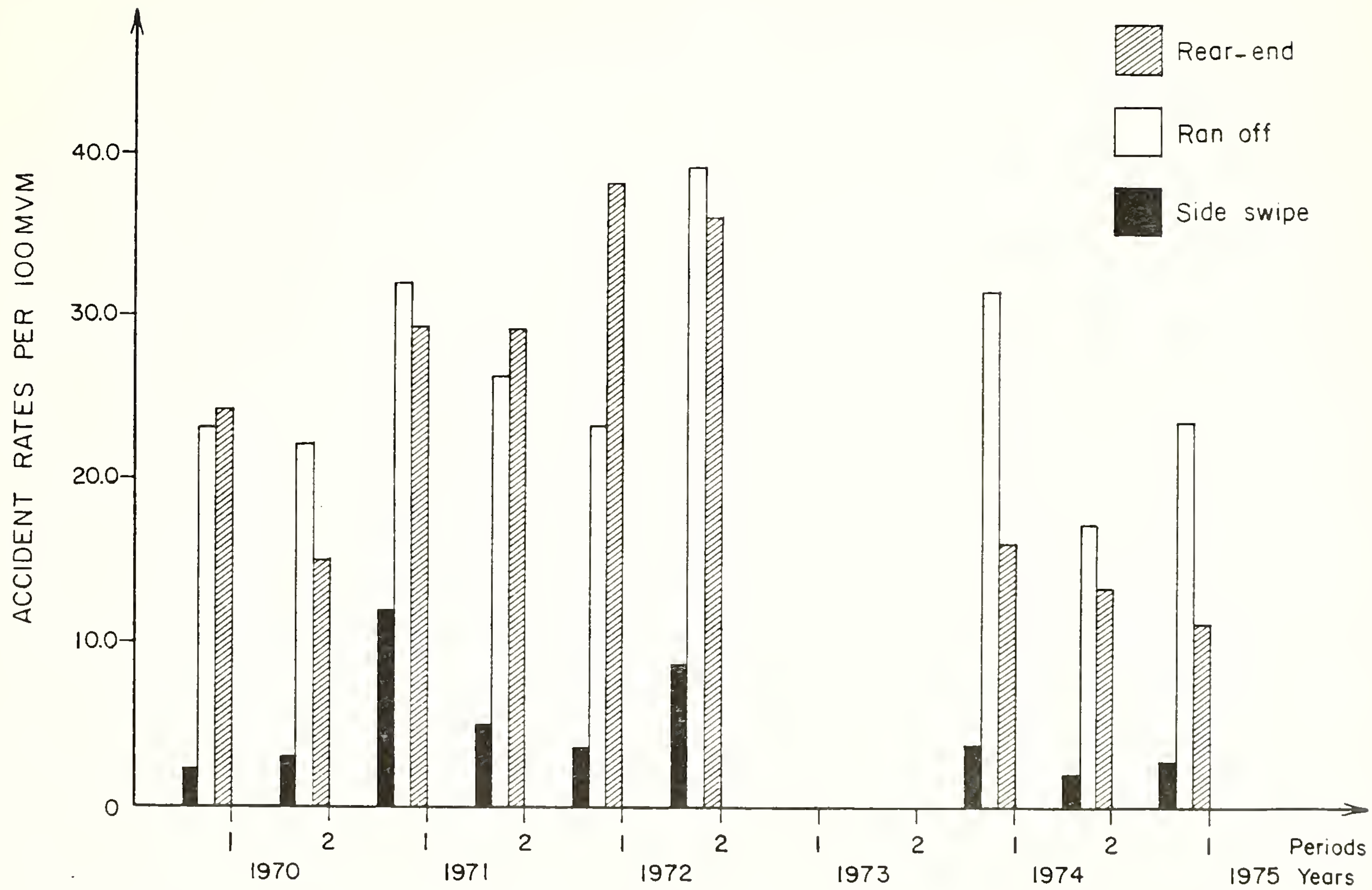

FIGURE 14 ACCIDENT RATES BY TYPE FOR INTERSTATE HIGHWAYS

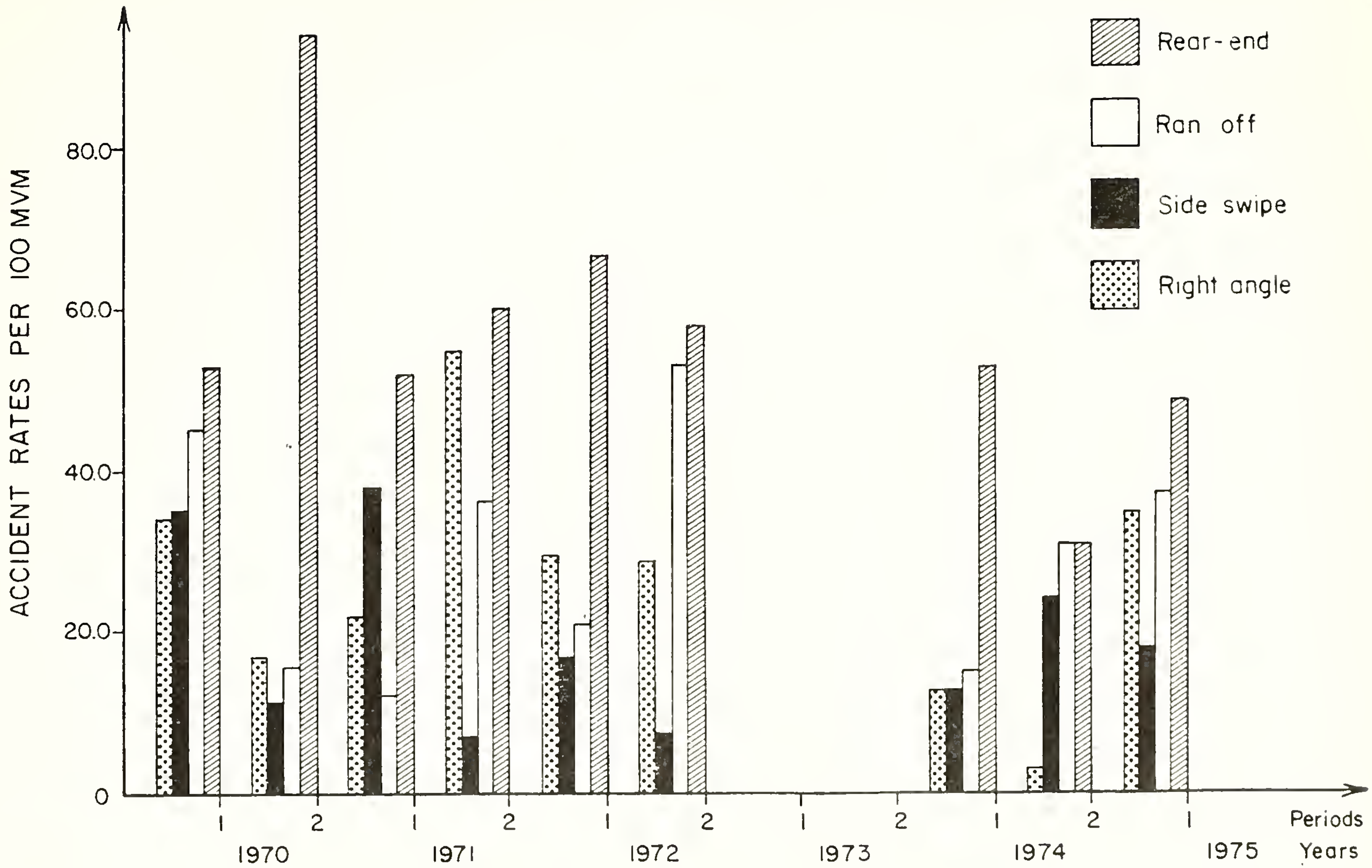

FIGURE 15 ACCIDENT RATES BY TYPE FOR OTHER FOUR LANE HIGHWAYS

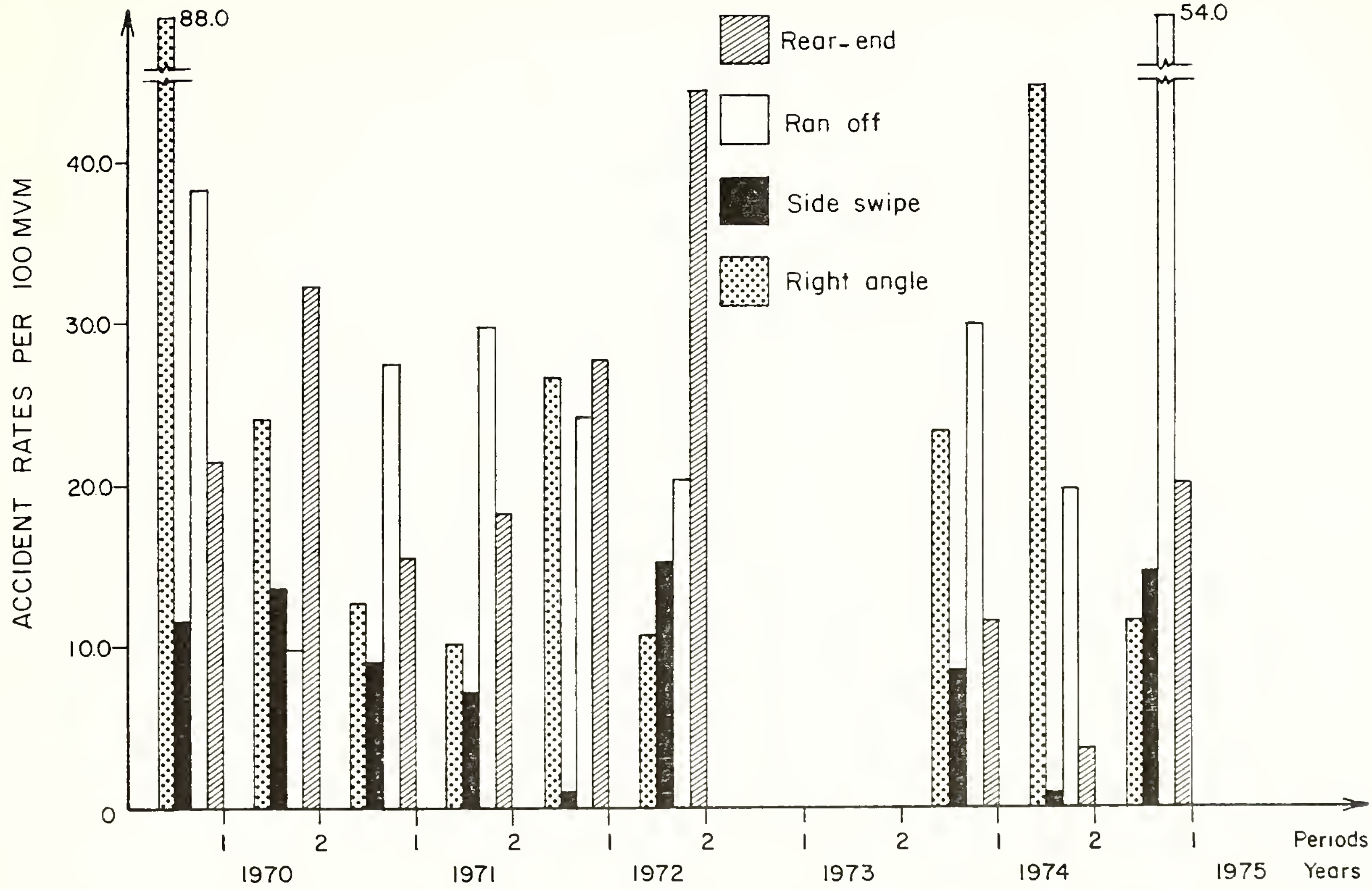

FIGURE 16 ACCIDENT RATES BY TYPE FOR TWO-LANE HIGHWAYS

On the other hand, the decreases in average rate on Interstate and other four-lane highways and the increase in average rate on two-lane highways for ran-off-road heavy truck accidents were found to be not significant for the study time periods.

As for side-swipe heavy truck accidents, the changes in average rate under the 55 mph maximum speed limit were found to be not significant on all three classes of highways.

Finally, the decreases in average rate of right-angle heavy truck accidents under the 55 mph maximum speed limit were found to be significant on both other four-lane and two-lane highways.

The upper limit values of the average rates of right-angle heavy truck accidents per 100 MVM for the time period before the 55 mph maximum speed limit for other four-lane and two-lane highways were 40.21 and 34.33. The lower limit values were 23.16 and 23.74.

The upper limit values of the average rates for the same type of accidents for the periods after the 55 mph maximum speed limit for other four-lane and two-lane highways were found to be 24.5 and 33.80. The lower limit values were 11.99 and 16.77. From the average of the upper and lower limit values the reduction in number of right-angle heavy truck accidents per 100 MVM under the 55 mph maximum speed were 13.43 and 8.75 on other four lane and two lane highways respectively.

Truck and Passenger Car Accident Involvement

Previous studies and researches showed that heavy trucks, in general, have a higher involvement rate in accidents than passenger cars (7). However, because of total miles driven, passenger car accident involvement occurs more frequently than heavy truck involvement.

The ratio between average rates of heavy truck accidents to average rates of passenger car accidents was used, in this research, as a relative measure of heavy truck and passenger accident involvement. If such a ratio is more than 100 percent, it indicates that a heavy truck is more involved in accidents than is a passenger car.

An accident involving one or more passenger cars and one or more heavy trucks was included in passenger car rates of accidents as well as in heavy truck rates of accidents.

The same statistical analysis procedure as previously conducted was again performed. The chi-square test of homogeneity was applied to the ratio between heavy truck and passenger car accident rates for each of the sections within the same highway and it was found that these sections were not homogeneous. A square root transformation form was used for these ratios and the test was tried once more. The test results indicated that highway sections were homogeneous after transformation, as shown in Table B-7 of Appendix B.

The chi-square test of homogeneity was used for the transformed ratios between highways within highway class and it was found that all the highways were homogeneous. The results are shown in Table B-8 of Appendix B.

The analysis of variance test was used on the transformed ratios and the following conclusions were derived.

For Interstate highways:

1. The time periods were significant for $\alpha = .01$.
2. The highway sections were not significant for $\alpha = .05$.

For other four-lane highways:

1. The time periods were not significant for $\alpha = .25$.
2. The highway sections were not significant for $\alpha = .05$.

For two-lane highways:

1. The time periods were significant for $\alpha = .05$ and not significant for $\alpha = .01$.

2. The highway sections were not significant for $\alpha = .05$.

The results of this test are shown in Table 34.

Orthogonal polynomial models were tried for the average values of the transformed ratios for the studied time periods; however, no reliable models were found to fit these data.

The average ratios between heavy truck and passenger car accident rates are shown, for the studied time periods on Interstate; other four-lane; and two-lane highways, in Figures 17, 18, and 19 respectively. The figures indicated that each heavy truck was much more involved in accidents than each passenger car on Interstate highways under the 70 mph speed limit. On the other hand, a passenger car was found to be much more involved in accidents than heavy truck on two-lane highways under a 65 mph speed limit. For other four-lane highways, a passenger car and a heavy truck were similarly involved under the 65 mph speed limit with an indication that under the 55 mph limit a heavy truck is more involved than a passenger car. On Interstate and two-lane highways under the 55 mph speed limit, heavy truck and passenger car rates are similar.

The Bonferroni procedure of orthogonal contrasts was used to perform a comparison test on time periods for each class of highway. The results of this test are shown in Table 35.

The ratio between heavy truck and passenger car accident rates decreased significantly on Interstate highways for level of significance $\alpha = .05$, from the 70 mph speed periods to the 55 mph periods. The increase in the ratios, however, were found to be not significant on other four-lane highways for level of significance $\alpha = .05$. The increase in ratios, on the other hand, were significant on two-lane highways for level of significance $\alpha = .05$. This indicates, even though passenger car accident rates are

TABLE 34. ANOVA FOR SQUARE ROOT OF PERCENTAGES OF HEAVY TRUCK ACCIDENT INVOLVEMENT

Type	Source	S.S.	D.F.	M.S.	F	F_{Table}	Conclusion
Interstate	H	166.12	3	55.37	1.61*	3.49	$(N.S.)_{.05}$
	P	417.24	8	52.15	3.09**	2.75	$(Sig)_{.01}$
	S(H)	412.22	12	34.35			
	SP(H)	1618.35	96	16.85			
Other Four-Lane	H	180.05	4	45.01	2.45*	5.19	$(N.S.)_{.05}$
	P	70.26	8	8.78	.58**	1.35	$(N.S.)_{.25}$
	S(H)	91.66	5	18.33			
	SP(H)	602.96	40	15.07			
Two-Lane	H	600.14	6	100.02	2.22*	2.44	$(N.S.)_{.05}$
	P	652.27	8	81.53	2.12**	1.94	$(Sig)_{.05}$
						2.51	$(N.S.)_{.01}$
	S(H)	1261.28	28	45.04			
	SP(H)	8607.75	224	38.42			

H: Highway type, S: Highway sections, P: Time periods, Sig: Significant, N.S.: Not Significant

* $F = \frac{M.S.(H)}{M.S.(S(H))}$

** $F = \frac{M.S.(P)}{M.S.(SP(H))}$

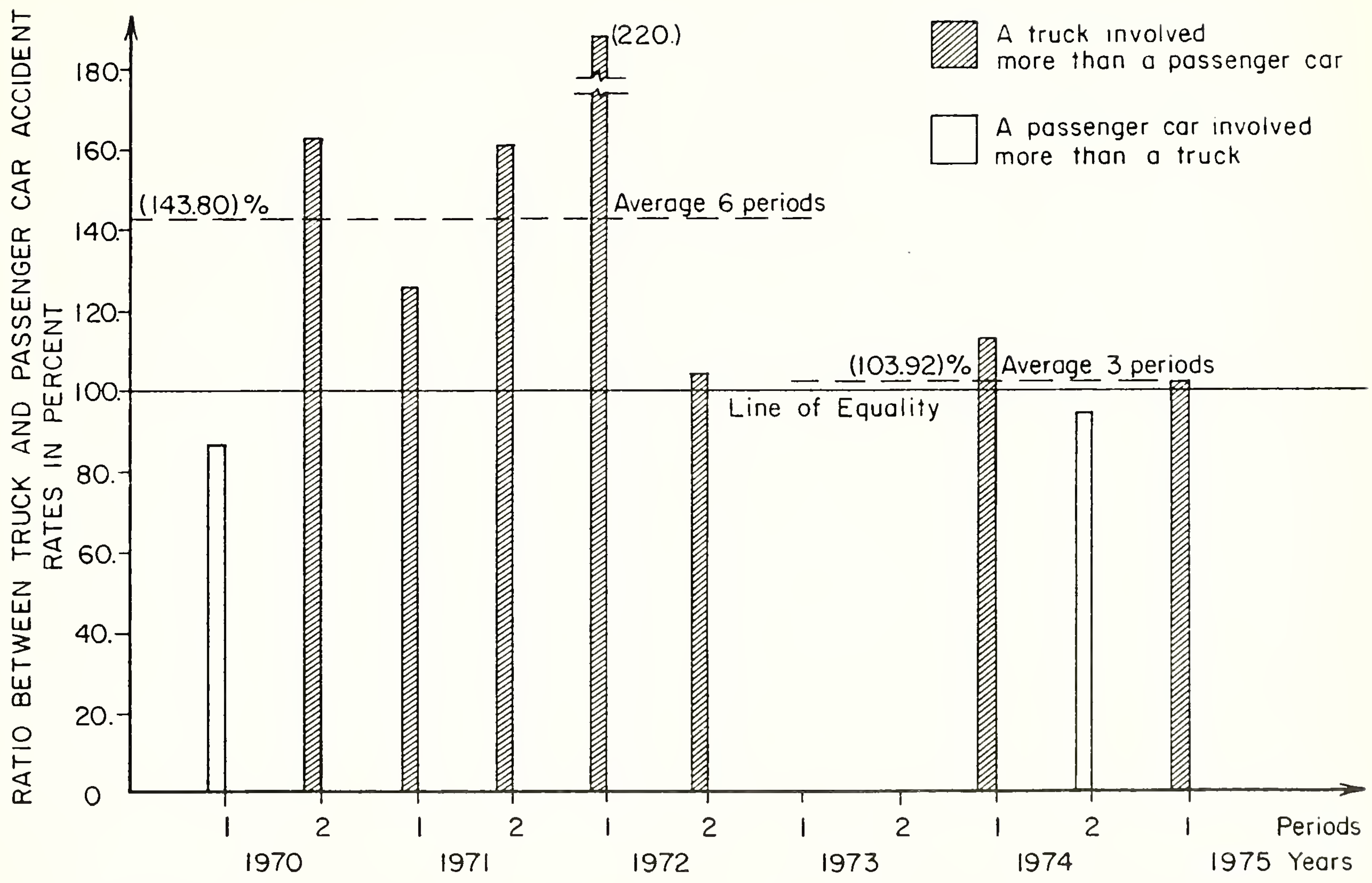

FIGURE 17 RATIO BETWEEN TRUCK AND PASSENGER CAR ACCIDENT RATES ON INTERSTATE HIGHWAYS

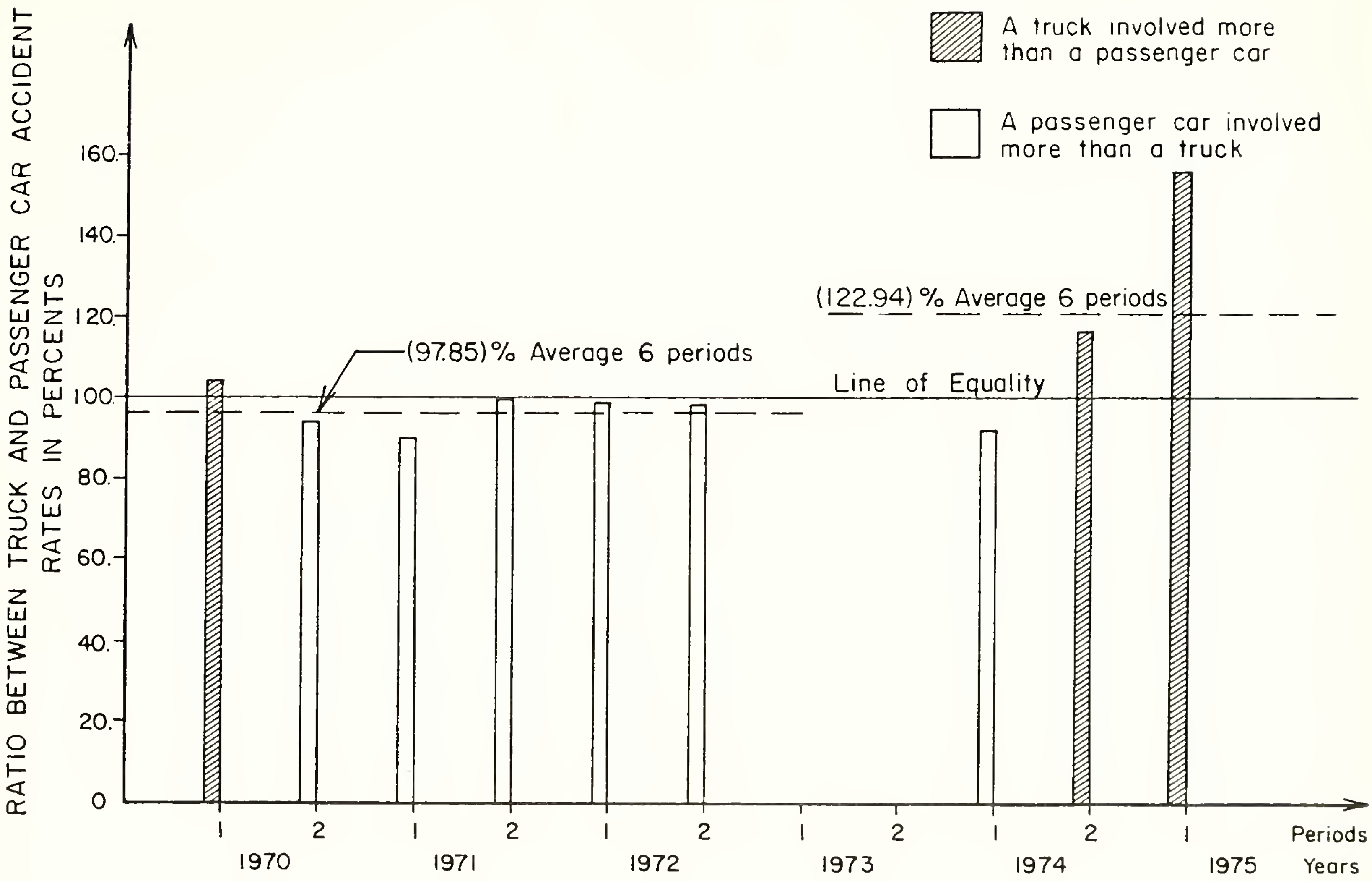

FIGURE 18 RATIO BETWEEN TRUCK AND PASSENGER CAR ACCIDENT RATES ON OTHER FOUR-LANE HIGHWAYS

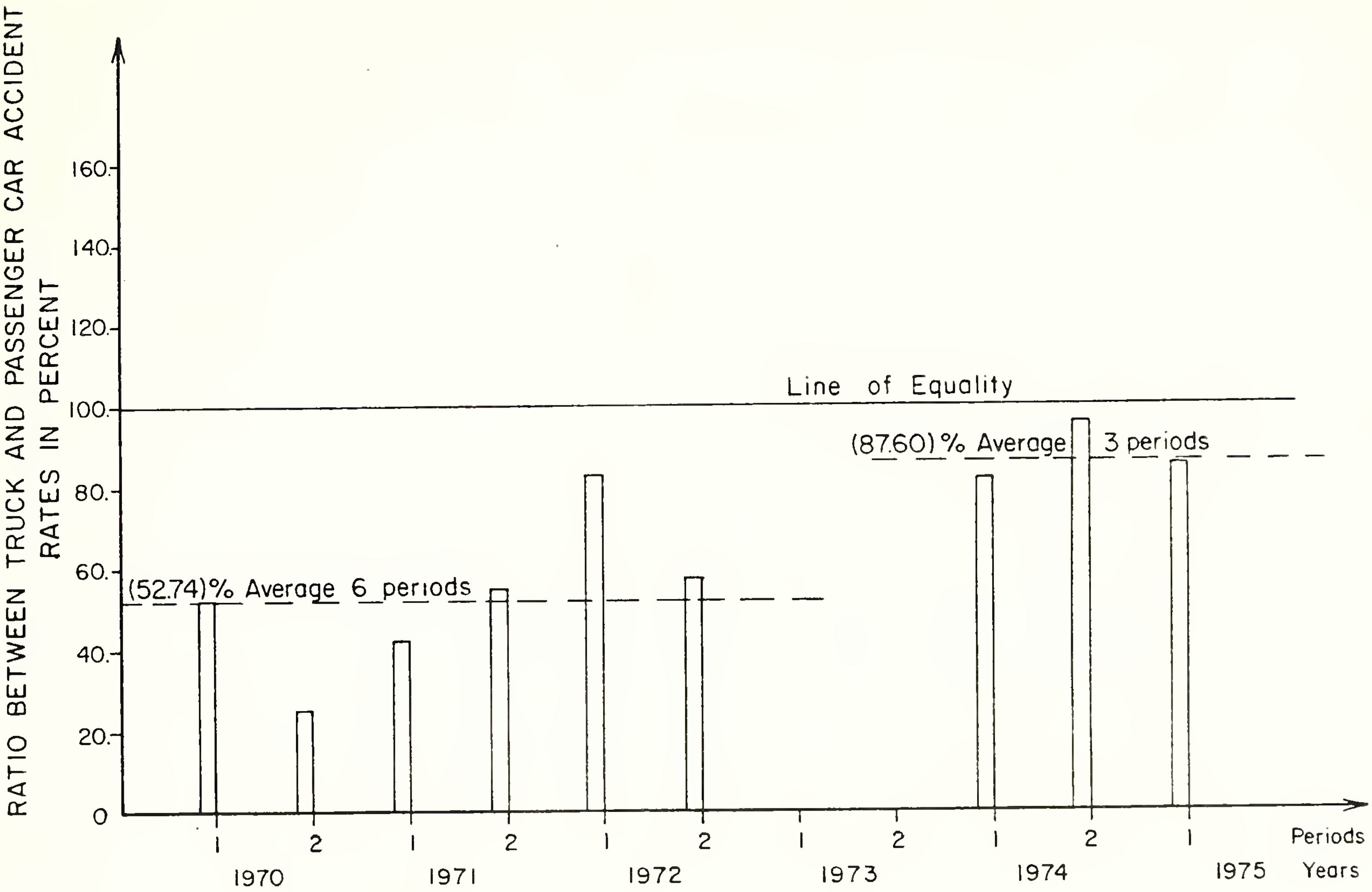

FIGURE 19 RATIO OF TRUCK AND PASSENGER CAR ACCIDENT RATES ON TWO-LANE HIGHWAYS

TABLE 35. ORTHOGONAL CONTRASTS TEST RESULTS FOR THE SQUARE ROOT OF RATIOS BETWEEN HEAVY TRUCK AND PASSENGER CAR ACCIDENT RATES

Highway Type	Contrast	Calculated t	$\bar{t}$	Conclusion
Interstate	First	1.492	2.160	N.S.
	Second	1.797	2.160	N.S.
	Third	2.290	2.160	S
Other Four-Lane	First	-1.103	-2.204	N.S.
	Second	- .661	-2.204	N.S.
	Third	-1.308	-2.204	N.S.
Two-Lane	First	-1.585	-2.142	N.S.
	Second	-2.601	-2.142	S*
	Third	-2.959	-2.142	S*

First Contrast: 1st 6 months (1970-1972) vs. 1st 6 months (1974-1975)
Second Contrast: 2nd 6 months (1970-1972) vs. 2nd 6 months (1974)
Third Contrast: All 6 months (1970-1972) vs. All 6 months (1974-1975)

$\bar{t}$: Cut off points for test, S: Significantly decreased, N.S.: Not significantly decreased, S*: Significantly increased.

still higher on two-lane highways than heavy truck rates, that under the 55 mph speed limit heavy truck accident rates on two-lane highways have increased significantly over those when the speed limit was 65. These results are shown in Table 35.

CHAPTER V. CONCLUSIONS

This study has evaluated the changes in total heavy truck accident rates, heavy truck accident rates by type, and heavy truck accident involvement on Indiana rural primary highways for the years 1970, 1971, 1972, 1974, and the first six months of 1975. On the basis of findings during the investigation the following conclusions are made:

1. Average heavy truck accident rates per 100 million vehicle miles in Indiana on other four-lane and two-lane highways are much higher than the average rates on Interstate highways.
2. The rates of heavy truck accidents per 100 million vehicle miles for the years 1970, 1971, and 1972, prior to the 55 mph maximum speed limit, were found to be 78, 199, and 167 for Interstate, other four-lane, and two-lane highways respectively. The rates were 60, 149 and 141 for the year 1974, and the first six months of 1975 under the 55 mph maximum speed limit.
3. The decrease in average heavy truck accident rates was significant on Interstate and other four-lane highways, however, it was not significant on two-lane highways. The amounts of reduction in accidents per 100 MVM were 18 and 50 for Interstate and other four-lane highways respectively.
4. The rates of rear-end-collision heavy truck accidents per 100 million vehicle miles for the years 1970, 1971, and 1972, prior to the 55 mph maximum speed limit, were found to be 26, 68, and 32 for Interstate, other four-lane, and two-lane

highways respectively. The rates were 15, 47, and 17 for the year 1974, and the first six months of 1975 under the 55 mph maximum speed limit.

5. The decreases in average rear-end-collision heavy truck accident rates were significant on Interstate as well as on other four-lane. However, it was not significant on two-lane highways. The amounts of reduction in accidents per 100 MVM were 11 and 21 on Interstate and other four-lane highway classes respectively.
6. The changes in average rates of ran-off-road heavy truck accidents were not significant on the three classes of highways.
7. The changes in average rates of side-swipe heavy truck accidents were not significant on the three classes of highways.
8. The rates of right-angle heavy truck accidents per 100 million vehicle miles for the years 1970, 1971, and 1972, prior to the 55 mph maximum speed limit, were found to be 32 and 29 for other four-lane and two-lane highways respectively. The rates were 18 and 20 for the year 1974, and the first six months of 1975 under the 55 mph maximum speed limit.
9. The decreases in average right-angle heavy truck accident rates were significant on other four-lane as well as on two-lane. The amounts of reduction in accidents per 100 MVM were 14, and 9 for the two highway classes.
10. Each heavy truck was much more involved in accidents than each passenger car on Interstate highways under the 70 mph speed limit. The ratio between heavy truck and passenger car accident rates decreased significantly under the 55 mph limit for this highway class but heavy truck rates were still greater than passenger car rates.

11. On other four-lane highways, each passenger car and heavy truck were similarly involved in accidents under the 65 mph speed limit but there is an indication that under the 55 mph speed limit a heavy truck is more involved than a passenger car. The increase in ratio between heavy truck and passenger car accident rates was found not significant.
12. On two-lane highways, a passenger car was found to be much more involved in accidents than a heavy truck under the 65 mph speed limit. On the other hand, heavy truck and passenger car rates were similar under the 55 mph maximum speed limit. The increase in ratio between heavy truck and passenger car accident rates was significant for this highway class.
13. Reductions in the average heavy truck accident rates after the 55 mph maximum speed limit is probably primarily due to the lesser variability in speed differences between passenger cars and trucks with possibly some effect of reduced speeds by both types of vehicles.

CHAPTER VI. RECOMMENDATIONS FOR FURTHER RESEARCH

Through the course of this research, additional areas were identified that could be further studied to more fully understand the effect of the 55 mph speed limit. Some of these of greatest interest would be:

1. A comparison of heavy truck accident rates on Indiana and Ohio main rural highways prior to the 55 mph maximum speed limit. A major portion of this research should evaluate the effect on accident rates of the difference in maximum speeds for heavy trucks and passenger cars in Ohio.
2. A study of the effect of the 55 mph maximum speed limit on the degree of accident severity for both heavy trucks and passenger cars.
3. A detailed study of heavy truck accident types on urban and suburban Indiana arterials.

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Appendix A

_____________ County, Year _______, From ____, To _____

Section# ______, ______ Lane, Highway _____, Length _____

Prescription \ Accident #					
1. Day of the Week					
2. Time of the Day					
3. Type of Vehicle					
Vehicle # 1					
Vehicle # 2					
4. Property Damage(100$)					
5. Personal Injuries & Fataleties					
6. Condition before Acc					
Vehicle # 1					
Vehicle # 2					
7. Road Condition					
8. Weather Condition					
9. Speed Limit					
10. Speed before Acc.					
Vehicle # 1					
Vehicle # 2					
11. Light Conditions					
12. Character					
13. Type of Accident					
14. Officers Opinion					

FIGURE A-1 ACCIDENTS DATA COLLECTION FORM

Accidents Information / Time Periods	Types of Vehicles Involved				Property Damage	Personal Injuries	Fataleties	Type of Accident				
	Total	Truck-P.Car	Truck-Truck	Sing. Truck				Rear-end	Run-off	Side Swiped	Right Angle	Others
First 6 months for 1970												
Second 6 months for 1970												
First 6 months for 1971												
Second 6 months for 1971												
First 6 months for 1972												
Second 6 months for 1972												
First 6 months for 1974												
Second 6 months for 1974												
First 6 months for 1975												

FIGURE A-2 ACCIDENTS DATA COLLECTION FORM

INDIANA STATE HIGHWAY COMMISSION

HIGHWAY PLANNING SURVEY

DAILY SUMMARY SHEET OF MANUAL COUNT

STATION NO.________ SYSTEM________ DATE________ DAY________ SHEET NO.____ OF____

ROUTE IDENTIFICATION________ TO________ DIRECTION FROM STATION________ COUNTY________

LOCATION________

HOURS	PASSENGER CARS							SINGLE UNIT TRUCKS					TRACTOR & SEMITRAILER COMBINATIONS						TRUCK & TRAILER COMBINATIONS			2-TRAILER COMB.		BUSSES			THREE PERIOD 8-HOUR TOTALS
	LOCAL			FOREIGN				PICK-UP & PANELS		2-D	3 OR MORE AXLES																
	Standard	Compact	Small	Standard	Compact	Small	Motorcycles	2 P	2-S	2-D	3-A	4-A	2S1	2S2	3S1	3S2	2S3	3S3	2-2	2-3	3-2	2S1-2	2S2-2	School	Other	Miscellaneous (As noted below)	
PERIOD 1 12^{00} M to 8^{00} AM																											
PERIOD 2 8^{00} AM to 4^{00} PM																											
PERIOD 3 4^{00} PM to 12^{00} M																											
COLUMNAR TOTALS																											
% TOTALS																											

FIGURE A-3 INDIANA STATE HIGHWAY COMMISSION DAILY SUMMARY SHEET OF MANUAL SURVEY

Appendix B

TABLE B-1. CHI-SQUARE TEST OF HOMOGENEITY ON HIGHWAYS

Highway	χ^2 Calculated Rates	χ^2 Calculated $\sqrt{\text{Rates}}$	$\chi^2_{.01}$	$\chi^2_{.001}$
I-65	11.780	5.833	11.3	16.3
I-69	5.132	3.826	11.3	16.3
I-70	3.169	1.543	11.3	16.3
I-74	3.902	6.323	11.3	16.3
US-41	.965	.204	6.63	10.8
US-24	.008	.258	6.63	10.8
US-30	1.597	1.720	6.63	10.8
US-31	.024	.046	6.63	10.8
SR-2	1.251	.124	6.63	10.8
US-6+US-20	6.211	6.33	13.3	18.5
US-27	6.084	5.98	13.3	18.5
US-35	6.841	3.19	13.3	18.5
US-231+SR-9	36.79*	15.59**	13.3	18.5
SR-3	30.16*	18.48**	13.3	18.5
SR-1	16.94	4.28	13.3	18.5
SR-64	33.37*	11.30	13.3	18.5

Note: All the transformed rates are homogeneous at $\alpha = .01$.

* Significant at $\alpha = .001$ unless indicated.

**Homogeneous at $\alpha = .001$.

TABLE B-2. CHI-SQUARE TEST OF HOMOGENEITY FOR HEAVY TRUCK ACCIDENT RATES

Highway Class.	X^2 Calculated	$X^2_{.01}$	$X^2_{.001}$
Interstates	13.418	11.30	16.3
Other Four-lane	5.955	13.3	18.5
Two-lane	8.243	16.8	22.5

TABLE B-3. CHI-SQUARE TEST OF HOMOGENEITY FOR REAR-END COLLISION HEAVY TRUCK ACCIDENTS

Class	Highway	χ^2 Calculated	$\chi^2_{.01}$	$\chi^2_{.001}$
Interstate	I-65	3.037	11.3	16.3
	I-69	6.822	11.3	16.3
	I 70	1.901	11.3	16.3
	I-74	1.210	11.3	16.3
Other Four-Lane	US-41	.336	6.63	10.8
	US-24	2.457	6.63	10.8
	US-30	2.645	6.63	10.8
	US-31	1.575	6.63	10.8
	SR-2	5.349	6.63	10.8
Two-Lane	US-6+US-20	18.672	13.3	18.5
	US-27	5.039	13.3	18.5
	US-35	1.222	13.3	18.5
	US-231+SR-9	2.520	13.3	18.5
	SR-3	8.814	13.3	18.5
	SR-1	11.315	13.3	18.5
	SR-64	7.529	13.3	18.5

TABLE B-4. CHI-SQUARE TEST OF HOMOGENEITY FOR RAN OFF ROAD HEAVY TRUCK ACCIDENTS

Class	Highway	X^2 Calculated	$X^2_{.01}$	$X^2_{.001}$
Interstate	I-65	10.061	11.30	16.30
	I-69	5.110	11.30	16.30
	I-70	8.354	11.30	16.30
	I-74	1.398	11.30	16.30
Other Four-Lane	US-41	.086	6.63	10.80
	US-24	.353	6.63	10.80
	US-30	.112	6.63	10.80
	US-31	.949	6.63	10.80
	SR-2	.103	6.63	10.80
Two-Lane	US-6+US-20	1.744	13.30	18.50
	US-27	14.201	13.30	18.50
	US-35	1.3886	13.30	18.50
	US-231+SR-9	8.700	13.30	18.50
	SR-3	8.279	13.30	18.50
	SR-1	10.623	13.30	18.50
	SR-64	15.211	13.30	18.50

TABLE B-5. CHI-SQUARE TEST OF HOMOGENEITY FOR SIDE SWIPE HEAVY TRUCK ACCIDENTS

Class	Highway	X^2 Calculated	$X^2_{.01}$	$X^2_{.001}$
Interstate	I-65	5.256	11.30	16.30
	I-69	.369	11.30	16.30
	I-70	4.468	11.30	16.30
	I-74	1.196	11.30	16.30
Other Four-Lane	US-41	.033	6.63	10.80
	US-24	.089	6.63	10.80
	US-30	5.532	6.63	10.80
	US-31	.015	6.63	10.80
	SR-2	.406	6.63	10.80
Two-Lane	US-6+US-20	8.231	13.30	18.50
	US-27	1.658	13.30	18.50
	US-35	5.307	13.30	18.50
	US-231+SR-9	14.235	13.30	18.50
	SR-3	11.671	13.30	18.50
	SR-1	11.902	13.30	18.50
	SR-64	6.352	13.30	18.50

TABLE B-6. CHI-SQUARE TEST OF HOMOGENEITY FOR RIGHT ANGLE HEAVY TRUCK ACCIDENTS

Class	Highway	χ^2 Calculated	$\chi^2_{.01}$	$\chi^2_{.001}$
Other Four-Lane	US-41	1.741	6.63	10.80
	US-24	.876	6.63	10.80
	US-30	.163	6.63	10.80
	US-31	2.792	6.63	10.80
	SR-2	.560	6.63	10.80
Two-Lane	US-6+US-20	5.517	13.30	18.50
	US-27	14.203	13.30	18.50
	US-35	11.306	13.30	18.50
	US-231+SR-9	12.169	13.30	18.50
	SR-3	9.875	13.30	18.50
	SR-1	6.093	13.30	18.50
	SR-64	10.631	13.30	18.50

TABLE B-7. CHI-SQUARE TEST OF HOMOGENEITY FOR HEAVY TRUCK ACCIDENT INVOLVEMENT PERCENTAGES

Class	Highway	χ^2 Calculated	$\chi^2_{.01}$	$\chi^2_{.001}$
Interstate	I-65	14.93	11.30	16.30
	I-69	4.82	11.30	16.30
	I-70	3.50	11.30	16.30
	I-74	16.28	11.30	16.30
Other Four-Lane	US-41	8.241	6.63	10.80
	US-24	1.439	6.63	10.80
	US-30	.123	6.63	10.80
	US-31	.228	6.63	10.80
	SR-2	.558	6.63	10.80
Two-Lane	US-6+US-20	17.417	13.3	18.5
	US-27	6.239	13.3	18.5
	US-35	11.118	13.3	18.5
	US-231+SR-9	12.301	13.3	18.5
	SR-3	19.344	13.3	18.5
	SR-1	2.478	13.3	18.5
	SR-64	2.426	13.3	18.5

TABLE B-8. CHI-SQUARE TEST OF HOMOGENEITY FOR HEAVY TRUCK ACCIDENT CHARACTERISTICS

Type	Highway Class	X^2 Calculated	$X^2_{.01}$	$X^2_{.001}$
Rear-end Collision	Interstate	11.604	11.30	16.30
	Other Four-Lane	10.409	13.30	18.50
	Two-Lane	7.699	16.80	22.50
Ran off Road	Interstate	9.760	11.30	16.30
	Other Four-Lane	8.026	13.30	18.50
	Two-Lane	10.542	16.80	22.50
Side Swipe	Interstate	3.770	11.30	16.30
	Other Four-Lane	1.151	13.30	18.50
	Two-Lane	15.512	16.80	22.50
Right angle	Other Four-Lane	3.858	13.30	18.50
	Two-Lane	12.654	16.80	22.50
Percentage of truck accident involvement	Interstate	6.389	11.30	16.30
	Other Four-Lane	5.177	13.30	18.50
	Two-Lane	8.104	16.80	22.50

COVER DESIGN BY ALDO GIORGINI