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AN EXAMINATION OF THE EFFECTS OF THE LOWERED MAXIMUM SPEED LIMIT AND FUEL SHORTAGES IN NORTH CAROLINA

Andrew F. Seila

Mark A. Entsminger

Claudio Z. Silva

FINAL REPORT

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16. Abstract

Because of the energy crisis of early 1974 and the resulting measures (both voluntary and mandatory) to conserve fuel supplies, there were dramatic changes in both the highway environment and accident scene. This report examines North Caroli data on vehicle mileage, traffic volumes, accident frequencies and severity, crash rates, and driver characteristics in an effort to derive some insight into the nature of the changes that occurred, and to specifically identify those factors that may have had a significant influence on the lower number of fatal accidents. Most of the analyses involve a comparison of data for the first four months of 1973, 1974, and 1975. Where trends have been in effect for several years, certain variables such as overall vehicle mileage and accident rates are examined using techniques from time series analysis.

Estimates of total vehicle mileage (based on pre-crisis behavior since 1962) for the entire state for the first four months of 1974 and 1975 indicate that the observed figures were 13.7 and 11.3 percent below expectation, respectively. Mean travelling speeds decreased on all types of rural roads despite the fact that a substantial portion of the roads in North Carolina had posted speed limits of 55 mp or less prior to the energy crisis. In 1975, mean speeds returned to pre-crisis levels on all roads except Interstate highways where the speed limit changes were greatest. Of considerable import is the fact that speed variability which is

(Cont' on following page)

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Abstract (cont'd)

related to the rate of accident involvement, decreased on primary highway in 1974 and remained down in 1975.

In 1974, total crashes fell 10 percent from the previous year while fatal crashes dropped 22 percent. The number of total crashes returned to pre-crisis levels in 1975, but the number of fatal crashes continued to fall, resulting in a net decrease of 24 percent over 1973. As anticipated, overall crash severity as indicated by TAD severity scores decreased significantly in both 1974 and 1975 for rural roads. Surprisingly, the analysis of driver injury indicated a significant increase in severity between 1973 and 1974 on rural primary highways with posted speed limits originally greater than or equal to 55 mph. However, by 1975, the distribution had shifted away from the extremes so that the net result was a shift into the slight (C) and moderate (B) injury categories. Mean travelling speeds prior to accidents did not change during the three years. Furthermore, crash rates failed to reveal any dramatic interruption during the crisis period. A comparison of the percentage change in Average Daily Traffic (ADT) and total crashes revealed that a substantial portion of the reduction in total crashes for Interstate and US highways was not "predicted" by decreased volume.

This study illustrates the complex, interactive, and seemingly contradictory nature of the changes that took place in the North Carolina driving environment. It clearly demonstrates that reduced travel contributed significantly to the lower number of fatal accidents. The magnitude of the effect of the lowered speed limit on accident frequency was not so clear-cut as its beneficial effect on accident severity.

TECHNICAL SUMMARY

From December 1973 through April 1974, the United States experienced a severe shortage of petroleum fuels. This situation, generally referred to as the energy crisis, resulted in a number of changes, both direct and indirect, in the driving environment. While many of the factors that were affected have since resumed their pre-crisis behavior, several changes are still present. The 55 mph speed limit has been made permanent, the price of gasoline remains in the 60 cents per gallon range, and the American automobile manufacturers are producing more vehicles that are smaller and lighter in weight with a strong emphasis on fuel economy.

Perhaps the most noteworthy change during the crisis was the substantial reduction in the number of total and fatal accidents. Numerous studies have attempted to determine what proportion of the reduction in fatalities could be attributed to different factors. Although it is generally accepted that the lowered maximum speed limit and reduced travel were largely responsible, the relative importance of these two factors is still subject to considerable debate.

This report began with similar objectives using North Carolina data. However, it soon became apparent that any attempt at quantification of the variables responsible for the reduction in fatalities would necessarily involve making severe and perhaps unreasonable assumptions. Initial examination of the data revealed the complex and interactive nature of the changes that occurred during the crisis. In fact, some of the findings were not entirely consistent, in that analysis of different factors sometimes led to contradictory conclusions. Furthermore, the absence of detailed exposure data proved to be a major hurdle in the analysis. Data on exposure would have shown in what way the characteristics of the driving population and the vehicles, routes and trip purposes changed.

The analysis in this study is based almost entirely upon the observed changes in accident characteristics. For these reasons, it was deemed more appropriate to present a description and analysis of the many changes, both in the highway environment and in the traffic accident characteristics in North Carolina, that came about during the energy crisis period.

Figure S.1 displays the overall estimated monthly mileage for North Carolina between 1962 and 1975. It is apparent that mileage had been increasing in a linear fashion since 1962, but that this pattern was interrupted in 1974. Using techniques of time series analysis, a model was fit to that portion of the data prior to January 1974. From this model, mileage forecasts were obtained for the first four months of 1974 and 1975, and indicated that the observed mileages were 13.7 and 11.3 percent, respectfully, below expectation. As anticipated, weekend traffic volumes decreased substantially more than weekday volumes, while rural volumes dropped more than urban volumes.

In December of 1973, the 55 mph maximum speed limit was imposed in an attempt to conserve fuel supplies. Since North Carolina had relatively few miles of highway with a posted speed limit greater than 55, this change probably did not have as significant an impact as in other areas of the country. Curiously enough, while the mean speed on Interstate highways did fall substantially during 1974, decreases in mean speeds were also observed on roads where there was no change in posted speed limit.

By 1975, mean speeds on all non-Interstate highways had returned to pre-crisis levels. Speed variability, however, decreased substantially on main highways during the crisis and remained down the following year, even though mean speeds were increasing. As speed variability is directly related to the rate of accident involvement, this observation suggests a possible explanation of the lower accident frequencies observed during and after the energy crisis.

As noted earlier, the decrease observed in the number of crashes during this period is of primary concern. From Table S.1 it is seen that in 1974, total crashes fell 10 percent from the previous year, while fatal crashes dropped 22 percent. Both of these reductions were due primarily to decreases in rural, weekend accidents. In 1975, the number of total crashes returned to the pre-crisis level. However, the number

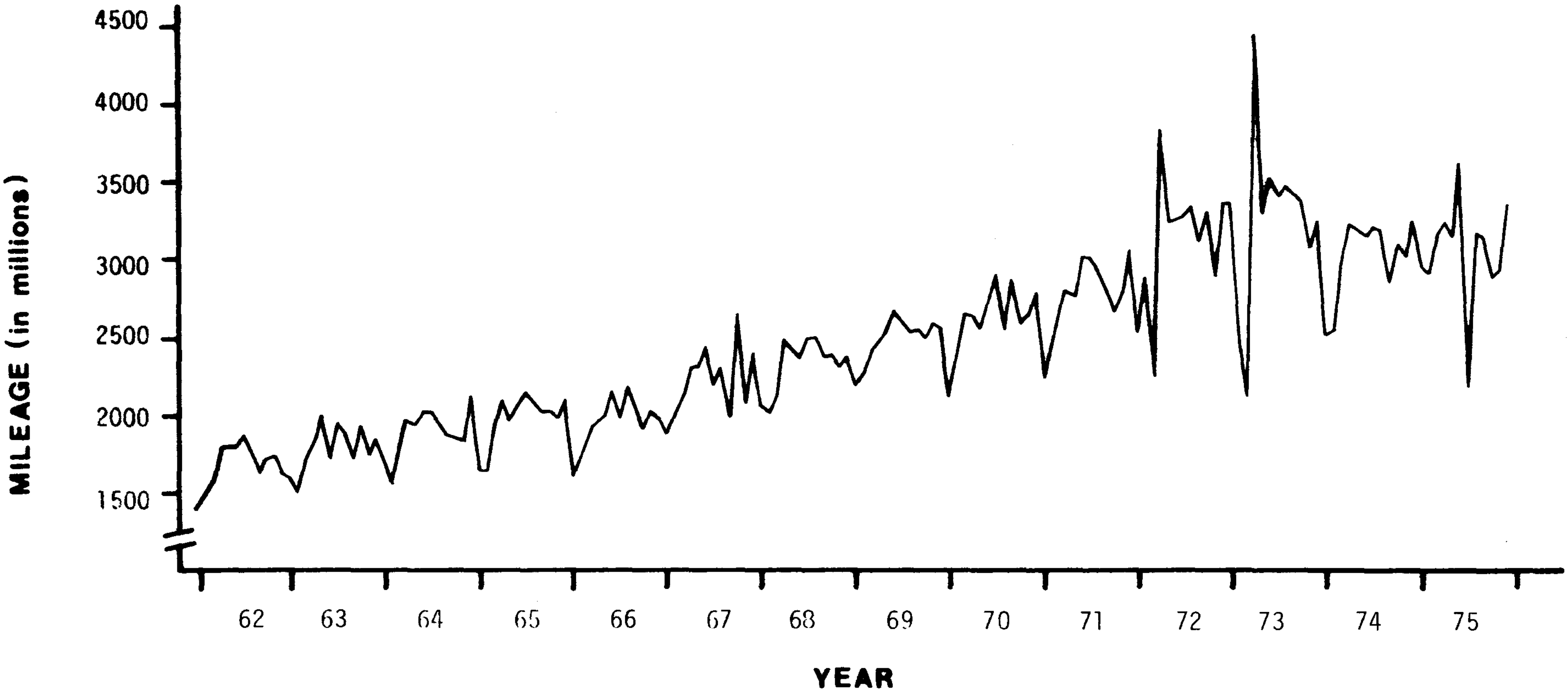

Figure S.1 North Carolina estimated motor vehicle mileage (in millions), 1962 through 1975.

of fatal crashes continued to fall resulting in a net decrease of 24 percent as compared with 1973.

Table S.1. Total and fatal crashes in North Carolina (January through April).

Population		Number of Crashes			Percent Change		
		1973	1974	1975	73-74	74-75	73-75
Entire State	Total	37832	33946	37979	-10.27	11.88	0.39
	Fatal	478	375	361	-21.55	-3.73	-24.48
Urban	Total	17236	16919	19278	-1.84	13.94	11.85
	Fatal	88	53	60	-39.77	13.21	-31.82
Rural	Total	20596	17027	18701	-17.33	9.83	-9.20
	Fatal	390	322	301	-17.44	-6.52	-22.82
Weekday	Total	22336	21422	24055	-4.09	12.29	7.70
	Fatal	233	211	185	-9.44	-12.32	-20.60
Weekend	Total	15496	12524	13924	-19.18	11.18	-10.14
	Fatal	245	164	176	-33.06	7.32	-28.16

An examination of the proportion of total crashes that resulted in fatalities for different road systems produced some unexpected results. Table S.2 illustrates that the only significant ($p \leq .05$) change in this proportion occurred on city streets where there were no reductions in posted speed limits. Even more surprising was the fact that the proportion of fatal crashes actually increased during the energy crisis (although not in a statistically significant sense) for Interstate highways where the speed limit changes were largest.

Table S.2. Proportion of total crashes that resulted in one or more fatalities by road type.

Road Type		Year 1973	1974	1975	Percent Change in Proportion of Fatal Crashes 73-74	74-75	73-75
I	$\hat{p}$	.033	.043	.031	30.3	-27.9	-6.1
	N	794	438	511			
US	$\hat{p}$	.019	.018	.016	-5.3	-11.1	-15.8
	N	6067	4606	4850			
NC	$\hat{p}$	.023	.021	.019	-8.7	-9.5	-17.4
	N	4432	3646	4073			
RPR	$\hat{p}$	.016	.018	.015	12.5	-16.7	-6.3
	N	8807	7801	8707			
CS	$\hat{p}$	.005	.003	.003	-40.0*	0.0	-40.0*
	N	17746	17566	19684			

* Change significant ($p \leq .05$)

While the ratio of fatal crashes to total crashes is representative of accident severity, more direct measures are provided by the distribution of driver injury, most severe injury in an accident, and TAD (vehicle crush). Ridit analysis was used to investigate possible changes in these distributions for urban, Interstate and rural primary (US and NC) highways. Table S.3 presents the mean ridits for each category along with the results of tests on the differences between years. As would be expected, TAD severity decreased during the energy crisis, although the change was only significant ($p \leq .03$) on rural primary highways, and not significant on Interstates where the posted speed limit (PSL) was greater than or equal to 55 mph. An examination of driver injury and most severe injury revealed changes in severity for all three road categories during the energy crisis, but only the change in driver injury for rural primary highways with PSL $\geq$ 55 was significant ($p = .03$).

This observation is quite surprising as one would have expected the lower mean travelling speeds during 1974 to reduce accident severity.

Table S.3. Changes in accident severity indicated by mean ridits for driver injury, most severe injury, and TAD.

Severity Measure	Road System	Mean Ridit 1973	1974	1975	P-values[2] 73-74	74-75	73-75
Driver Injury	Interstate, PSL[1]≥ 55	.4973	.5105	.4948	.26	.23	.83
	Rural Primary, PSL≥55	.4967	.5047	.4999	.03	.23	.37
	Rural Primary, PSL<55	.4977	.5011	.5017	.46	.89	.38
Most Severe Injury	Interstate, PLS≥55	.5033	.5109	.4850	.60	.11	.20
	Rural Primary, PSL≥55	.4978	.5058	.4976	.10	.10	.96
	Rural Primary, PSL<55	.4957	.5018	.5034	.33	.80	.22
TAD Severity	Interstate, PSL≥55	.5137	.4967	.4819	.33	.43	.04
	Rural Primary, PSL≥55	.5160	.4967	.4819	.00	.00	.00
	Rural Primary, PSL<55	.5172	.5027	.4803	.03	.00	.00

[1]Posted speed limit

[2]P-values for the corresponding difference of mean ridits

An examination of the mean estimated speed prior to impact for crashes where the driver was killed or seriously injured suggests one possible explanation for this phenomenon. Tests on the mean speed prior to impact revealed no significant changes during the entire three year period either for roads with PLS<55 or roads with PSL≥55. This suggests that perhaps the slightly lower mean speeds may have enabled some drivers to avoid potential accident situations, but that those drivers who were involved continued to crash at roughly similar speeds throughout the period of study.

Crash rates based on vehicle mileage also failed to reveal any dramatic interruptions during the crisis period. Figure S.2 displays the rates for total, fatal and non-fatal injury crashes for the first four months of the years 1962 through 1975. The total crash rate appears to have been experienc-

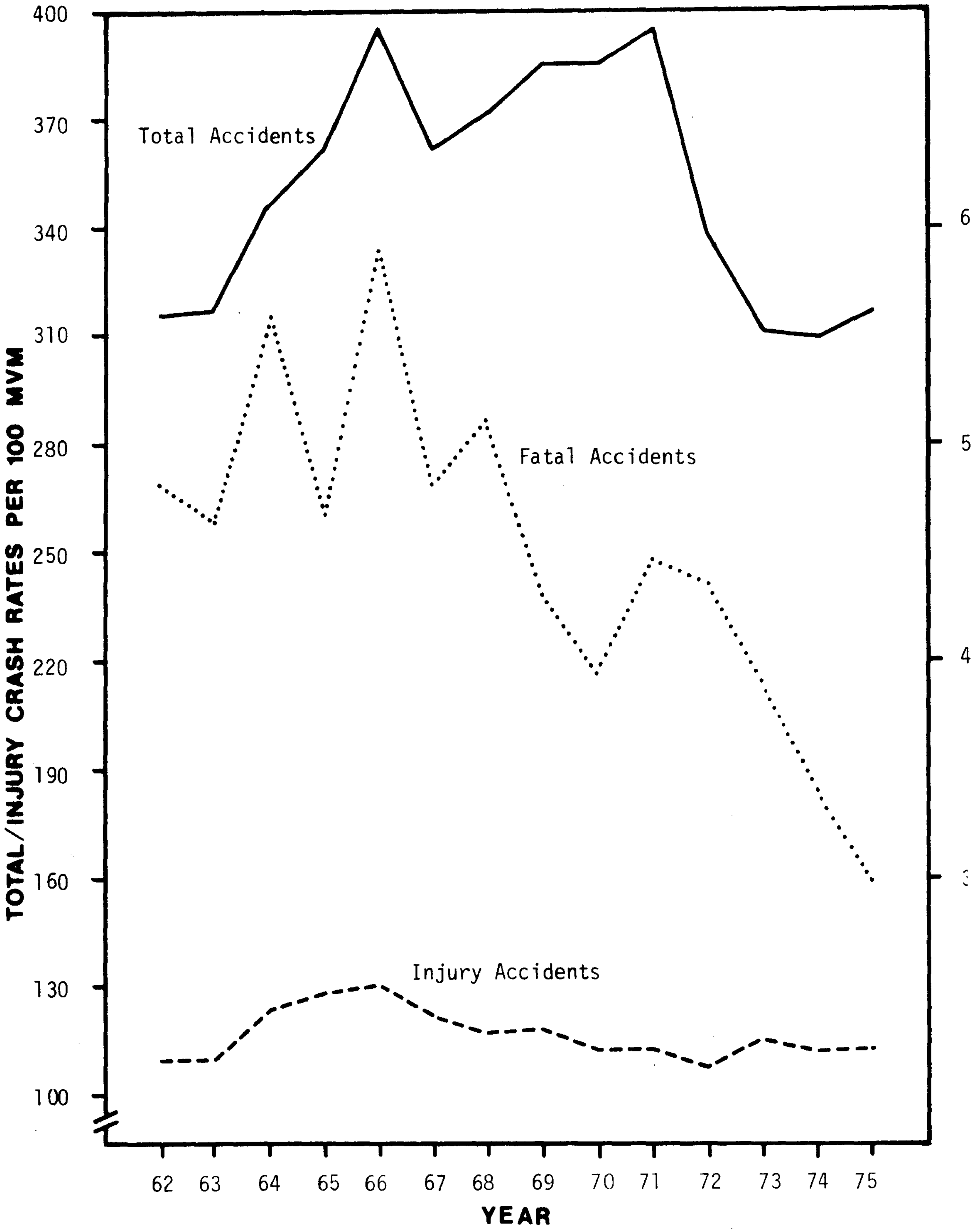

Figure S.2 Crash rates per 100 MVM (January through April).

ing an upward trend since 1962, but then dropped 14.4 percent between 1971 and 1972, two years before the fuel shortage. The 13.1 percent decrease in the fatal crash rate between 1973 and 1974 appears to be largely a continuation of the previous downward trend.

The analysis of accident severity measures and crash rates suggests that at least for North Carolina, the impact of the 55 mph maximum speed limit may not have been very substantial. However, there is evidence that prevents one from drawing this conclusion. For example, past studies into the relationship between average daily traffic counts and total crashes suggest that a percentage change in the former gives rise to a similar percentage change in the latter. From Figure S.3, it is obvious that the percent decrease in total crashes for Interstate and US highways during the energy crisis was substantially greater than what would have been "predicted" by the change in average daily traffic. Since it was these two road systems that were most affected by the speed limit changes, it appears that other factors, in addition to volume changes, had a sizeable impact on accident frequency.

Along with the changes noted above, several other factors such as vehicle size, occupancy, driver characteristics, etc., also experienced minor changes during and after the energy crisis. Together they illustrate the extremely complex nature of the changes that took place in the driving environment during this period. These is little doubt that the lower traffic volumes contributed substantially to the reduction in fatal accidents in North Carolina, and perhaps unlike other areas of the nation, the lowered maximum speed limit may have had more of an indirect, but nevertheless important, impact on accident frequency.

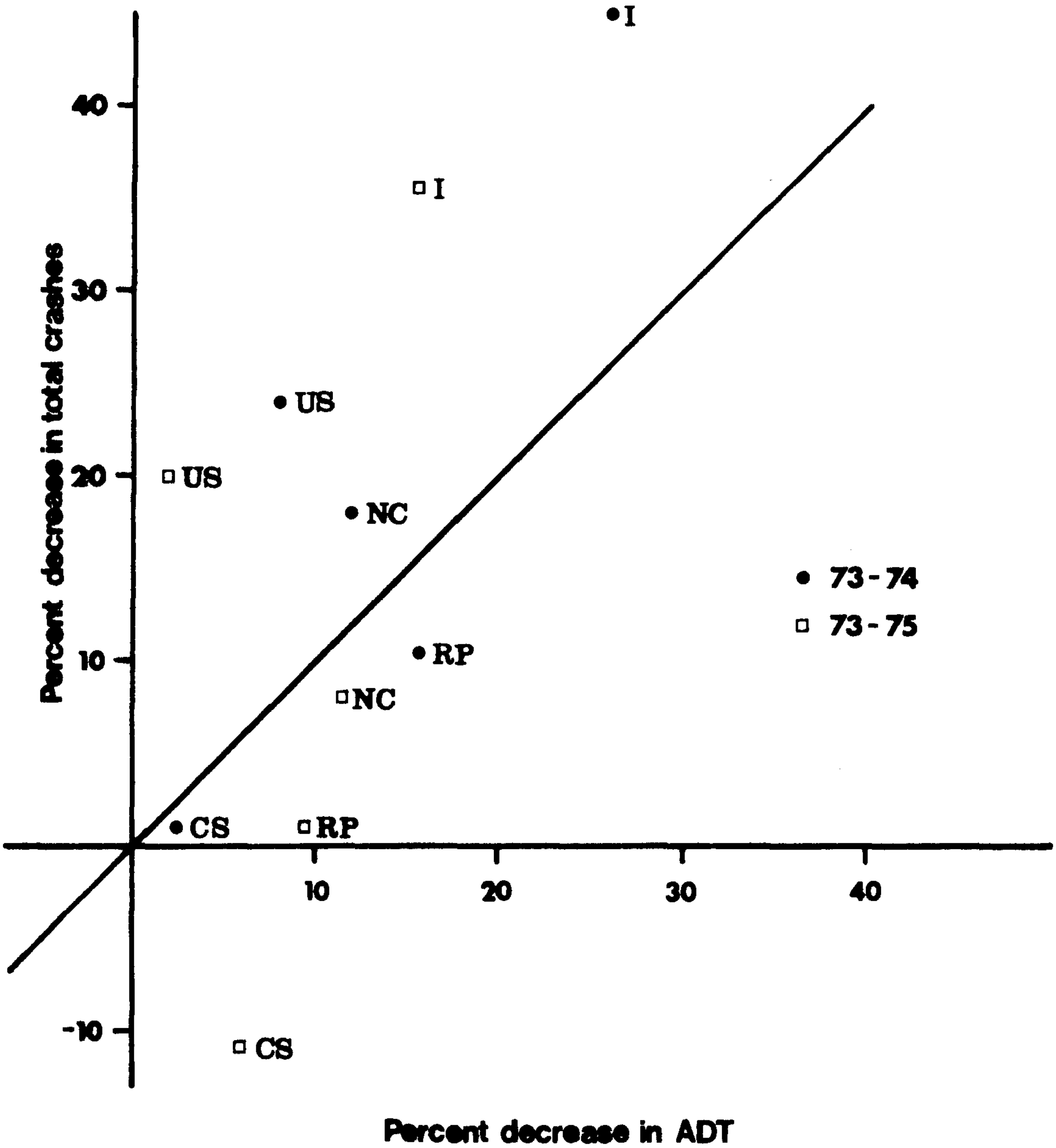

Figure S.3 Percentage decrease in average daily traffic by percentage decrease in total crashes for U.S., N.C., and rural paved roads and city streets.

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While all of these individuals have contributed greatly to this report, the authors themselves accept full responsibility for any errors or inconsistencies it may contain.

1. INTRODUCTION

1.1 Background

From December 1973 through April 1974 the United States experienced a severe shortage of petroleum fuels. As a result of gasoline cutbacks, a number of changes occurred in the driving environment. Specifically, the maximum speed limit was reduced to 55 mph nationwide; the cost of gasoline increased from approximately 35 to 40 cents per gallon to approximately 60 cents per gallon; nonessential travel, especially weekend travel, was heavily discouraged by public officials; and much emphasis was placed on fuel economy and the use of smaller cars. During this time a crisis atmosphere prevailed, and for this reason the collective events occurring between the months of December 1973 and April 1974 have been referred to as the "energy crisis." This report presents a description and analysis of those changes, both in the highway environment and traffic accident characteristics in North Carolina, that came about during this energy crisis period.

Discussed herein are changes in the following highway and accident characteristics:

a. Changes in the number and severity of crashes;
b. Changes in traffic flow patterns;
c. Changes in the nature, frequency and severity of accidents involving trucks and passenger cars;
d. Changes in vehicle occupancy;
e. Changes in driver characteristics and violations.

1.1.1 Review of events during the energy crisis.

First, a chronology of events in the energy shortage that could be considered to have affected driver behavior is presented.

On November 7, 1973, following King Faisal's November 4 announcement that all shipments of petroleum to the U.S. from the Arab countries would be halted, President Nixon announced to the American public via television and radio that he would request from Congress emergency legislation involving measures to conserve energy. Although reports and predictions of an impending petroleum shortage had circulated through the news media for several months, it was then that the public became aware of the reality of the shortage. In his November 7 address, President Nixon asked for legislation to establish year-round Daylight Savings Time and to lower the maximum speed limit, among other measures. In response to his plea, North Carolina's Governor Holshouser announced on November 13 that the maximum speed limit on all roads in the state would be reduced to 55 mph as of December 1. On November 25, President Nixon announced a 15 percent reduction in gasoline deliveries to retail dealers and called for a voluntary ban on Sunday gasoline sales. A study by the National Opinion Research Center (1974) reported that, by the end of November, motorists were having significant difficulty obtaining gasoline.

On December 2, the first "gasless Sunday" in North Carolina, traffic was reported to be much lighter than usual and most service stations were closed. During this time, gasoline prices across the U.S. were also on the increase so that, by December 19, the nationwide average retail price of gasoline was 44.6 cents per gallon, as compared to 37.2 cents for January, 1973. All of these effects tended to heavily discourage unnecessary driving and this had a decided effect on Christmas travel. In North Carolina, a majority of service stations were closed from Saturday, December 22 to Wednesday, December 26. During the New Year's weekend (Sunday, December 30 through Tuesday, January 1), about 75 percent of local service stations were closed in North Carolina. Holiday travelers chose trains and airlines over automobiles as their means of transportation. The National Opinion Research Center study (1974) reported a large increase (from 21 to 37 percent) in the percentage of people reporting difficulty in getting fuel just prior to Christmas.

By the first of January, service station hours of operation were being sharply curtailed, which made gasoline more difficult to obtain and made it appear more scarce. On January 6, Daylight Savings Time was put into effect, resulting in an additional hour of darkness between approximately 7:30 and 8:30 a.m. and an additional hour of daylight between approximately 5:30 and 6:30 p.m. During January, gasoline prices continued a steady spiral, ranging from 42 cents to 50 cents per gallon, and many service stations implemented varied types of rationing plans to assure "regular customers" some gasoline and to try to make the monthly allocation last until February 1. Nevertheless, toward the end of January, many stations were dry.

During February, gasoline supplies continued far below demand, with North Carolina's allocation being 78.2 percent of the February 1973 sales. Voluntary rationing at the station level continued, with the most common plans being a three dollar limit or a 10 gallon limit. Most stations were closed on nights and weekends, and daytime hours of operation were restricted. On February 17, Governor Holshouser outlined an odd-even rationing plan for North Carolina, under which vehicles with odd-numbered tags would be allowed to purchase gasoline on Monday, Wednesday, and Friday, while vehicles with even-numbered tags could buy gasoline on Tuesday, Thursday, and Saturday. The plan also requested that service stations sell more gas per customer and that customers not buy gas unless they had less than half a tank. This plan appeared to dispel some apprehension about gas availability and to produce shorter lines. There was a truckers' strike from January 31 through about February 8, and a significant decrease in the number of trucks on the road was noted. Toward the end of February, however, long gas lines were still common, with many customers waiting over an hour to purchase gas. Prices during February were in the 49 cents to 54 cents per gallon range.

The March allocation for North Carolina was announced to be 82 percent of the March, 1973 supply. Prices were up also, ranging in the 55 to 60 cents marks. As a result of increased supply, and perhaps decreased demand, gasoline lines were shorter in early March, and by March 11, the supply of gasoline exceeded the March 1973 supply. Gas lines were greatly diminished, stations were operating longer hours, and the situation was considerably eased. On March 13, the Arab oil embargo was lifted. President Nixon rescinded the Sunday ban on gasoline sales on March 19, and many N.C. stations were open the following Sunday.

By the end of March, the fuel shortage itself could be considered to be over; however, many of its effects still remained. The maximum speed limit in all states, including North Carolina, stayed at 55 mph; a number of motorists had shifted to smaller cars to conserve fuel and decrease the cost of driving; and the price of gasoline remained high, continuing to be a discouragement to unnecessary driving.

Through 1975 the 55 mph speed limit remained in effect in all states. Fuel was readily available to the motorist and the price of gasoline dropped from over 60 cents a gallon to about 51 cents a gallon in North Carolina -- an encouragement to motor vehicle travel. Emphasis continued to be placed on fuel economy, as EPA gas ratings were highly stressed in new car advertisements. Trends were toward the purchase of smaller cars and motorcycles which would enable the motorist to travel on less gasoline.

During 1975, the U.S. also suffered a period of economic recession resulting in many job layoffs. The Bureau of Economic Analysis of the Department of Commerce reported a 141 percent increase in the number of job losses in the second quarter of 1975, compared to the second quarter of 1974. North Carolinians were not exempted, as many industries across the state laid off workers in response to poor economic conditions. This is notable in that the motor vehicle death rate has traditionally fallen during times of economic hardship.

1.1.2 Review of the literature.

Several studies have been conducted in an effort to determine what actually occurred before, during, and after the energy crisis. The studies have usually tried to arrive at some assessment of the impact of the lowered speed limit on highway safety. Logical reasoning or "heuristic arguments," applying assumptions which are not universally accepted, as well as statistical techniques have been used in attempts to assess the effects of the 55 mph speed limit in relation to other changes which were in operation at the same time (i.e., reduced travel, changes in the economy, Daylight Savings Time, vehicle safety improvements, highway safety programs, changes in travel patterns, etc.). A review of some of the major studies follows:

National Safety Council (1974)

The National Safety Council (1974) reported a 24 percent decrease in U.S. traffic deaths for the first four months of 1974 as compared with the same period in 1973. Information for their analysis was obtained from various sources including 15 state motor vehicle authorities, 35 state vital statistics authorities, the U.S. Department of Transportation (including the Federal Highway Administration), the International Bridge, Tunnel and Turnpike Association, the Bureau of Public Roads, the Motor Vehicle Manufacturers Association, and various polls.

Estimates for the number of lives saved nationally and percentages for various changes in the U.S. during the energy crisis were derived independently of one another assuming no interactions. For example, an indirect estimate of the number of lives saved by a reduction in speed was obtained by using research findings that indicated that the chances of being killed or seriously injured, if involved in an accident, double with each 10 mile per hour increase over 50 mph. A range of 12 to 19 percent reduction in fatal and serious injuries was expected to be possible with full compliance of the lowered speed limit; however, assuming a 70 percent compliance level, the effect would be from 8 to 13 percent. Since the ratio of the number of injuries to the number of deaths increased 13 percent, a reduction in accident severity is indicated. The authors concluded that of the factors which would produce such an effect -- improvements in vehicle design and engineering, better highway design and removal of roadside obstacles, and lowering of speeds -- only reduced speeds could produce such a large reduction in accident severity. Thus, a conservative estimate of 11 percent was attributed to a reduction in speed. Similar lines of reasoning were presented for other changes which were noted during the energy crisis, and an estimate made for each: reduction in gasoline and travel (-5 percent), reduction in average occupancy (-3 percent), change in day-night travel (-2 percent), change in type of road used (-1 percent), increase in the use of safety belts (-1 percent), and increase in the use of motorcycles, pedalcycles, and small cars and increased age of driver (+1 percent). Since the total of these percentages was not -24 percent, the remaining -2 percent was attributed to an "other" category, consisting of both known and unknown changes. Table 1.1 shows the results of this analysis.

Table 1.1 Preliminary analysis of reduction of motor-vehicle traffic fatalities (January-April 1974 vs January-April 1973).

Reduction in speed	-11%
Reduction in gasoline and travel	- 5%
Reduction in average occupancy	- 3%
Change in day-night travel	- 2%
Change in type of road used	- 1%
Increased use of safety belts	- 1%
Other (both known and unknown)	- 2%
Motorcycles, pedalcycles, small cars, age of driver	+ 1%
Four month fatality reduction	-24%

American Association of State Highway and Transportation Officials (1974)

An evaluation of the 55 mph speed limit was conducted by an "ad hoc" committee of the American Association of State Highway and Transportation Officials (1974). Data was collected from 48 states for the first six months of 1973 to be compared with the same time period of 1974. Some states provided information for 1971 and 1972. The states were asked to provide speed, accident, and travel data in a prescribed format. Although not all states had all data available in the prescribed format, the committee felt that the data available was sufficiently reliable to use for the study.

The committee found that the 55 mph speed limit reduced speeds by up to 10 mph and that travel speeds were more uniform. Vehicle miles of travel were reduced about five percent for the first six months of 1974 as compared with the same time period in 1973. Furthermore, the committee concluded that since the variation in travel fluctuated with the availability of fuel, it was primarily the fuel shortage which caused this reduction in travel.

The AASHTO report showed that rural travel decreased more than urban travel (7 percent vs. 5 percent), night travel decreased more than day travel (7 percent vs. 6 percent), and weekend more than weekday (8 percent vs. 5 percent), all of which indicate changes in the type of travel, such as a curtailment in pleasure or recreational travel. Shifts in travel patterns did not appear to affect a large reduction in fatalities. Both freeways and non-freeways experienced reductions in travel, with substantial reductions in fatalities on the freeways where fatality rates were already lowest. The committee could not conclude that shifts in travel from one road type to another significantly reduced the overall fatality rate. Based on past studies relating Average Daily Traffic (ADT) Volumes and accident rates, it was surmised that the reduction in travel in 1974 could not have caused a reduction in fatalities of more than 5 percent, which would be slightly more than one-fifth of the 23 percent reduction in fatalities.

The report indicated that the largest reduction in fatalities was observed on rural roads where the speeds were highest and speed reductions the greatest. Based on past studies and the fact that fatalities were still down 13 percent after travel increased, and that fatalities were reduced twice as much on roads where the speed limit was changed as compared to roads where the speed limit was not changed, the report attributed roughly 50 percent of the reduction in fatalities to the 55 mph speed limit. Other factors such as Daylight Savings Time, improved driving behavior and safety belt usage were determined to have contributed only small amounts to the reduction in fatalities. Table 1.2, which was taken from the report, summarizes the reduction in fatalities.

The committee concluded by recommending that the authority and responsibility for setting a maximum speed limit rest with the individual states, with a strong recommendation that maximum speed limits remain at 55 mph.

Table 1.2 Factors contributing to the reduction in fatalities during the energy crisis (AASHTO, 1974).

Item	Percent Reduction
Reduced Speeds and More Uniform Speeds	11%
Reduced Travel	5%
Others	7%
TOTAL	23%

Michigan (1974)

A study by Enustun, Hornbeck, Lingeman and Yang (1974) for the Michigan Department of State Highways and Transportation reported that Michigan experienced a downward trend in all types of accidents after the fall of 1973 but experienced only a slight drop in the number of miles traveled. Speeds in Michigan were reported to have decreased long before the legal speed limit was reduced. The conclusions presented in this report are as follows:

1. Comparing the seven-month period of the Fuel Crisis (October 1973 through April 1974) with the corresponding seven month period one year earlier, travel on conventional trucklines decreased by 4.8 percent. Total, injury, and fatal accidents decreased by 12.8, 17.2, and 30.0 percent, respectively.

2. For freeways, travel decreased by 6.3 percent with total, injury, and fatal accidents decreasing by 19.7, 19.6, and 17.0 percent, respectively.

3. During this period, 85th percentile freeway speeds steadily decreased from 73 mph (just prior to the oil embargo) to 63 mph (end of oil embargo). From the end of the embargo to October 1974, the speed had gradually increased to about 65 mph.

4. For two-lane high speed conventional highways, 85th percentile daytime speeds steadily decreased from approximately 66 to 59 mph during the oil embargo. They had increased to about 60 mph by October 1974.

5. For four-lane divided high speed conventional highways, 85th percentile daytime speeds steadily decreased from approximately 70 to 62 mph during the oil embargo. After the embargo they had increased to about 60 mph.

6. The data indicated that the greatest decrease in the 85th percentile speed occurred prior to the time that the 55 mph speed limit took effect but after the President of the United States had urged the nation to drive under 50 mph. It appeared that the greatest reduction in speed resulted from a short-term change in driver attitude due to factors (availability of fuel, response to the President's appeal to conserve fuel, etc.) other than the lowering of the speed limit to 55 mph.

7. Statistical analysis of accident data for the 30-month period (January 1972 through June 1974) indicated that there was a relationship between average speed of travel for a particular roadway system and total and fatal accidents. This relationship suggested that conventional highways are more sensitive to speed changes in terms of accidents than are freeways.

The report recommended that considering the high priority of energy consumption, Michigan adhere to the 55 mph speed limit in spite of increases in the 85th percentile speed.

California (1974)

In contrast to the conclusions of the AASHTO report, a California study by Pudinski (1974) attributed the greatest number of lives saved to decreases in traffic volume. Based on data collected by the California Highway Patrol (CHP) and other accident reporting agencies, it was shown that 54.9 percent of all fatalities occurred in under 55 mph zones where the reduced speed limit could have had little or no effect.

Only unpredictable forces, such as volume changes, Daylight Savings Time, bicycle and pedestrian changes, and speed changes, were examined in California, as it was assumed that only these factors would cause deviations from the trend line. Predictable forces such as improved highways, belt usage, etc., would be accounted for in the trend line. Calculations were made of the number of lives saved due to a decrease in volume of traffic, unexplained bicycle and pedestrian fatalities, Daylight Savings Time, a tighter speed distribution, and absolute speed decreases. Table 1.3 shows the results for data collected from January through March, 1974, while Table 1.4 shows provisional data results for the Highway Patrol for April through June, 1974 (as extracted from the report).

Large proportions of the drops from expectation were unexplained; the percentages for non-CHP fatalities (which occurred where there were no changes in the speed limit) were the same as for CHP fatalities. For this reason, the author concluded that the 55 mph speed limit was not responsible for those drops.

Colorado (1974)

The Colorado State Department of Highways compared the number of fatal accidents for February through August, 1974, with the same period in 1973 for zones with previous speed limits above 55 mph. The comparison showed that the entire reduction in fatalities occurred where the speed limit had been lowered. All state highway systems exhibited reductions in average speed, number of accidents, number of injury accidents, and number of injuries in all categories, both rural and urban. A combination of reduced speed and travel and the Colorado Safety Improvement Program were credited with the reduction in rural fatalities. The report concluded that, in urban areas, the decreases were mostly the result of decreased travel, although average speeds were found to have been lowered.

The 55 mph speed was found to have reduced the average speed of vehicles traveling in previously 60-70 mph zones by approximately 11 percent. There was a slight decrease in the average speed of vehicles involved in fatal accidents in these areas. The authors could not assign the entire fatality reduction to either rural areas or urban areas or to a particular highway system. Alcohol usage, light condition, driver age, and urban/rural distribution showed no significant trend changes.

Table 1.3 Observed changes in accident frequency and severity (California Highway Patrol, 1974).

January - March Accident Data	CHP[1] Accidents			Fatalities	
	Fatal	Injury	PDO[2]	CHP	Non-CHP
Expected Total	551	12,559	29,729	626	443
Experienced Total	326	8,795	20,416	395	342
Numerical Decrease	225	3,764	9,313	231	101
Percent Decrease	40.8	30.0	31.3	36.9	22.8
Factors Responsible by Percent of Total Decrease					
Reduced Travel	28	38	36	31	50
55 mph Speed Limit	31	8	--	34	--
New Speed Distribution	11	15	15	12	--
Permanent Daylight Saving	1	--	--	1	4
Unexplained	29	39	49	22	46

[1]California Highway Patrol

[2]Property Damage Only

Table 1.4 Provisional April through June CHP fatalities.

	April	May	June	Total
Expected Total	265	249	284	798
Experienced Total	184	195	212	591
Numerical Decrease	81	54	72	207
Percent Decrease	30.6	21.7	25.4	25.9
Reduction Categories				
Reduced Travel	17[1] (21%)[2]	16 (30%)	19 (26%)	52 (25%)
Unexp. Bicycle-Ped.	6 (7%)	3 (6%)	9 (12%)	18 (9%)
Daylight Saving	-- --	-- --	-- --	-- --
Speed Distribution	15 (19%)	12 (22%)	10 (14%)	37 (18%)
Speed Decrease	29 (36%)	29 (54%)	35 (49%)	93 (45%)
Normal Stat Variance[3]	14 (17%)	-6 (-12%)	-1 (-1%)	7 (3%)

[1]Numerical decrease attributed to category.

[2]Percent total decrease attributed to category.

[3]This category includes all unexplained decreases except those involving bicycles and pedestrians.

Kentucky (1975)

An examination was made of traffic volume, speed, and accident data for the rural highway system in Kentucky by Agent, Herd, and Rizenbergs (1975). Traffic counts taken at automotive traffic recording stations (ATR stations) showed that traffic volumes decreased beginning in December of 1973 and continued at a reduced level through September of 1974. Total traffic on the rural highways for the time period December 1973 - November 1974 decreased by 2.3 percent as compared with a 5 percent increase for the comparable period in 1973. It was noted that Interstates and parkways had the largest decreases in traffic volume during this time period, as long distance travel had been curtailed.

Reductions in median speed occurred as early as November of 1973, although the reduced speed limit was not imposed until March of 1974. After the speed limit was put into effect in March, median speeds were reduced by 14.2 mph for cars and 8.5 mph for trucks. By April of 1975, however, median speeds had increased from March of 1974 by 3.2 mph for cars and 1.5 mph for trucks, with the 85th percentile speed remaining around 60 mph for cars and trucks. There also appeared to be greater uniformity in driving speeds, as a larger percentage of vehicles were operating within the 10 mph pace than in the prior year, particularly on Interstates.

Concerning accident involvement, the authors found that all major highway types showed decreases in accident rates for almost every month in 1974. The largest drops were noted on interstates and four-lane divided roads. Injury rates, which had fluctuated in the past on Interstates, parkways and four-lane divided limited access highways, decreased in 1974. Fatality rates decreased on all major highway types except on four-lane divided roads having no access control. There was a 23 percent increase on four-lane divided (no access control), 81 percent decrease on parkways, 34 percent decrease on Interstates, and a 31 percent decrease on two-lane roadways. The overall drop in the fatality rate was 32 percent. The authors advised that the 55 mph speed limit be continued due to the dramatic decrease in accident rates, which they felt was due primarily to lower travel speeds.

North Carolina (1975)

Council, Pitts, Sadof, and Dart (1975) examined the effects of the lowered speed limit on North Carolina accidents using 1) speed data collected from 36 "permanent" stations across the state, 2) traffic count data from 59 permanent traffic count stations in the state, and 3) accident data from the North Carolina accident file.

According to the report, speed analyses showed that all roadways, including those where the speed limit was not changed, experienced decreases in average speeds, 85th percentile speeds, and percent of speeds over 55 mph from April to December, 1973. However, these decreases were fully recovered on all roads except Interstates by November of 1974. The largest decreases were noted for Interstates as compared with all other roadway types, (i.e., main U.S. highways, former Interstates, other main highways, and secondary roads). Judging from the appropriate number of vehicles within the 10 mph pace speed, speed variation decreased for all roadways from April 1973 to November 1974.

The authors reported that the 1974 accident data showed a 3.7 percent decrease in total accidents and a 11.2 percent drop in fatal accidents compared with 1973. There were significant decreases in fatalities for all roadway classes except rural paved roads. The largest percentage of decrease was on Interstates where there was also greatest speed reduction. These reductions were: 1) 43 percent on Interstates, 2) 29 percent on U.S. highways, 3) 31 percent on N.C. highways, and 4) 19 percent on city streets. Accident severity data was somewhat inconsistent, as TAD and estimated speed prior to impact showed less damage while driver injury data appeared to shift upward.

Council et al. (1975) also addressed the question of changes in driver age. They found that the proportion of drivers aged 25 and younger in accidents in 1974 decreased during the months of January through March, but that the trend shifted for July through September.

The proportion of accidents involving younger drivers (15-19 years of age) was slightly greater in 1974 than in 1973. None of these changes was significant, however.

The authors also found that traffic volumes were lower in 1974 than in 1973 for all classes of roadways, with less weekend travel in the first months of the year. Utilizing regression techniques, it was determined that volume changes were not totally responsible for the decreases in accidents, indicating the presence of other causative factors. An additional cause of reduction could have been the decrease in speed variance as a product of the changes in speed limit. Changes in types of travel, driver sex and race, vehicle types, and occupancy were not examined.

Sacco and Hajj (1974)

In a study conducted by Sacco and Hajj (1974), comparisons were made between the Dutch Fork area of Columbia, South Carolina and the rest of the nation with regard to the impact of the energy shortage on travel patterns and attitudes. Based on telephone interviews of a ten percent sample of Dutch Fork area households in 1972 and personal interviews in 1974, the study showed that the energy shortage did not greatly reduce the amount of automobile travel and did not seem to change the travel patterns or attitudes of the residents. National trends were in accord.

A 10 to 15 percent reduction in auto travel was seen, with the largest decreases on weekends. Rather than changing their mode of travel, people simply drove slower and limited their shopping and recreational trips. It was the gas shortage rather than the price of gas which affected driving patterns. The price of gas did, however, lead to the purchase of more economy cars.

National Opinion Research Center (1974)

A survey by the National Opinion Research Center (1974) of the University of Chicago sought information on the effects of the energy crisis on transportation patterns. A Continuous National Survey (CNS) was conducted in 1973 using public interviews. In general, the study showed that following the Arab boycott and the President's nationwide appeal, the majority of the public considered the energy shortage an important problem, but only about 25 percent felt it was the most important problem facing the U.S. There were pervasive but modest efforts at energy conservation, and there was little indication of any serious change in lifestyle. Those interviewed were resistant to car pools, and a majority believed that the country would have as much energy as it needed within five years. "In the area of transportation, conservation came mainly in the form of driving slower and reduced use of the automobile for social, recreational, or driving purposes; there is little indication of intermodal shifts."

Braddock, Dunn, and McDonald (1974)

Braddock, Dunn, and McDonald, Inc. (1974), in their interim report to the National Science Foundation on the physical, economic, and social impacts of the 55 mph speed limit, documented findings that showed that travel speed was reduced nationally in 1974. There were also large reductions in accidents and fatalities in 1974. Compliance with the 55 mph limit was very high during the energy crisis, but decreased once gasoline became available. Average speeds, however, remained down from 1973. The Gallup, Harris, and Opinion Research Center public opinion polls reported that about three-fourths of the respondents favored the 55 mph speed limit, whereas a mini survey conducted by Braddock et al. showed three-fourths of the respondents favored raising the limit to 60 mph or repealing it altogether and letting the states decide.

Summary of Findings

Although there are conflicting findings in the various studies as to the magnitude of the effect of the 55 mph maximum speed limit on highway safety, some commonalities are evident. These include the following:

1) All studies show that during the energy crisis average speeds were lower, whether in response to the fuel shortage, the President's appeal to conserve fuel by reducing travel speed, or the imposition of the lower speed limit;

2) Total accidents, fatal accidents, and fatalities decreased from 1973 to 1974 rather sharply;

3) Indications are that vehicle speeds were more uniform which would affect accident rates;

4) The amount of travel was reduced during the energy crisis. The degree to which this contributed to accident reduction is not agreed upon. Some indications are that long distance pleasure driving was reduced as evidenced by reductions in weekend traffic. Data is not available to characterize shifts from one roadway type to another. Generally, the reduction in travel has been discounted as minimal in the reduction of fatalities;

5) Average vehicle speeds have risen since the height of the energy crisis;

6) The lowering of travel speeds along with the reduction in traffic volume have been noted as having much greater impact than other factors such as Daylight Savings Time, highway improvement programs and safety belt usage.

1.2 Methodology; Data Sources

A national trend toward decreased fatalities has been observed. Early in 1974 the National Safety Council reported that fatalities for December 1973 were 19 percent below those of the previous December, and in the first three months of 1974, fatalities were 25 percent below those for the same period in 1973. The events of the fuel shortage had clearly interrupted the upward climb of fatalities. Although the fuel shortage has passed, fatalities have not returned to their previous levels. Fatalities for 1974 were 17 percent below those in 1973 and monthly fatality statistics for the National Highway Traffic Safety Administration showed decreases ranging from 18 to 23 percent for the period January through June of 1975 as compared to the same period of 1973.

Questions have been posed as to the relationship of the fuel shortage and the imposition of the 55 mph speed limit to the observed reductions in fatalities. It must be noted that the events of the energy crisis did not occur as part of a designed experiment. Rather, most of the changes occurred simultaneously -- the lowering of the speed limit, the changes in travel and vehicle occupancy, the shift to smaller vehicles, etc. For this reason, it is not possible to give a definitive answer to questions such as "What would have been the reduction in fatalities if the 55 mph limit had been implemented without the other changes experienced during the energy crisis?" or "What proportion of the reduction in fatalities is due to a reduction in travel, independent of other factors?" Therefore this report will seek to present a clear and concise description of the changes that have occurred, and to present a plausible analysis of the extent to which accident reductions can be attributed to various changes which have come about. The details of these analyses will be presented in a later section.

Although the period during which the events of the energy crisis seemed to have the greatest impact was December 1973 through April 1974, the period January through April 1974 is considered the time of the energy crisis in this report. The month of December was omitted because a new accident report form (see Appendix A) and new reporting definitions were placed into service in North Carolina in January 1973, and this would make the December 1972 accident data not comparable to the December 1973 and 1974 data. In the remainder of this report, when reference is made to data for 1973, 1974, or 1975, it will be assumed that the data is for the period January through April, unless a statement to the contrary is made.

Information for this study was obtained from four sources:

1) The North Carolina Division of Motor Vehicles publishes a monthly report on traffic accidents, the N.C. Traffic Accident Summary. This report presents data on the total number of accidents, accident types, injuries and fatalities as well as other information recorded by traffic accident reporting agencies across the state (municipal police, sheriffs, and highway patrolmen). The reports are delayed two months in publication to incorporate any traffic deaths which may occur sometime after an accident.

2) HSRC accident data tapes contain the same basic data recorded at the Division of Motor Vehicles with the following additions: accidents occurring on private property; accidents involving less than $200 property damage and no personal injury; and detailed research information on the vehicle and occupants.

3) Speed data was obtained from the North Carolina Department of Transportation through the Planning and Research Branch of the North Carolina Division of Highways. Every year, in April or May, speed data is collected at 36 stations on rural primary and secondary roads during daylight hours of weekdays. Speeds of "free flowing" vehicles are measured by concealed radar units and recorded along with information on highway class and vehicle type. This yearly information was available for 1962 through 1975, with supplemental surveys in the winter of 1973 (December) and fall of 1974 and 1975.

4) Traffic count data was also available from the Planning and Research Branch of the N.C. Division of Highways. A series of 59 permanent traffic count stations across the state use loop detectors and a recording device to obtain hourly vehicle counts around the clock. The computer tape recording this information includes hourly counts, location and date of information along with a code signifying whether the data is accurate or "bad." "Bad" data simply denotes that the data was collected under atypical circumstances (i.e., road construction or while the equipment was malfunctioning).

2. CHANGES OBSERVED DURING THE FUEL SHORTAGE

2.1 Changes in the Highway Environment

The events of the energy crisis period, especially the 55 mph speed limit, the difficulty in obtaining fuel, and the "gasless Sundays," had the effect of discouraging unnecessary travel and encouraging a reduction in vehicle speeds. As a part of this research, an effort was made to determine the changes that occurred in the amount and type of driving that was done and to estimate the magnitude of these changes. Unfortunately, detailed exposure surveys were not conducted during the energy crisis period nor was there exposure information available in the pre-crisis period. Therefore, it is not possible to determine the specific changes in the overall vehicle population and in the driver population that were induced by the fuel shortage. Rather, less specific measures of vehicle mileage, volumes and speeds are used to surmise gross changes in the highway environment.

2.1.1 Vehicle mileage.

Monthly estimates of motor vehicle mileage (MVM) in North Carolina were obtained from the North Carolina Traffic Accident Summary which is published by the North Carolina Division of Motor Vehicles (DMV). Total sales of gasoline and special fuel (diesel and aviation fuel, primarily) are reported to the North Carolina Department of Revenue each month by wholesale distributors. The monthly motor vehicle mileage figures are computed by multiplying wholesale gasoline sales for the previous month by the estimated mean number of miles per gallon experienced by motor vehicles in N.C. This figure was 11.80 miles per gallon for 1973 and 1974, and 12.57 miles per gallon for 1975. (These compare with figures for California of 12.14 miles per gallon during 1973 and 12.40 miles per gallon during 1974.)

Several warnings should be kept in mind. First, it is difficult to accept the assumption that mean miles per gallon remained unchanged in 1974, a period when many drivers were switching to smaller, more fuel-efficient vehicles and driving at lower speeds. For this reason alone, the reader must be wary of the mileage estimates, since a small error in the mean miles per gallon figure could lead to serious errors in the total estimated mileage figure. Nevertheless, because of the importance of investigating total vehicle mileage, and the lack of more accurate information for North Carolina, an examination using these estimates seemed warranted.

Second, in the vehicle mileage estimates, no adjustment has been made for non-highway use of fuels such as farming, construction, aviation, lawn mowers, etc. This should have some effect upon comparisons between 1973, 1974 and 1975, because the non-essential non-highway use of fuel would presumably be affected more by the fuel shortage than highway use. Thus, a portion of the decrease in mileage between the first four months of 1973 and the same period in 1974 could be attributed to a reduction in non-highway use of fuel. However, since non-highway use of fuel tends to be at a low point in the winter months, this absence of an adjustment should have a minimal effect.

Finally, an additional difficulty with the mileage estimates is the fact that they are computed from the previous month's wholesale fuel sales. Presumably, all of the fuel will be consumed within one to two months following its sale; however, differences in this lag between the time of wholesale fuel sale and the time of consumption could distort the apparent changes in motor vehicle mileage between 1973, 1974 and 1975.

With these precautions in mind, some observations can be made regarding changes in MVM as a result of the "energy crisis." Figure 2.1 shows the estimated monthly vehicle mileage for 1962 through 1975. It is clear that, until 1973, the number of miles driven in North Carolina was increasing linearly.

Table 2.1 gives the estimated North Carolina MVM for the first four months only of 1974 and 1975. These figures are compared with similar figures for 1973, as well as predictions based on linear regression and other estimation techniques. Looking at Column 3, it can be seen that the estimated MVM values for 1974 and 1975 are 9.1 and 1.8 percent, respectively, below the 1973 value.

The predicted values presented in Column 4 of Table 2.1 were obtained from the linear regression displayed in Figure 2.2. The

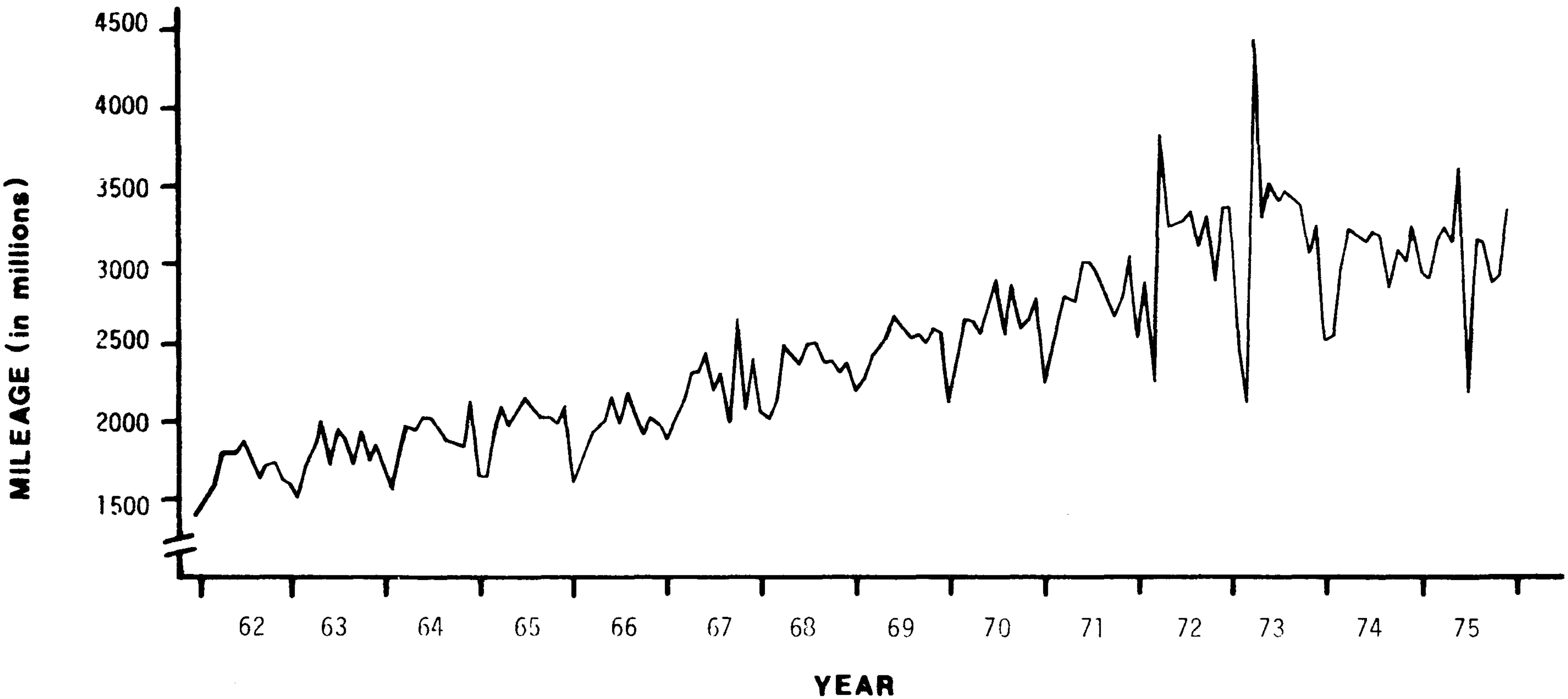

Figure 2.1 North Carolina estimated motor vehicle mileage (in millions), 1962 through 1975.

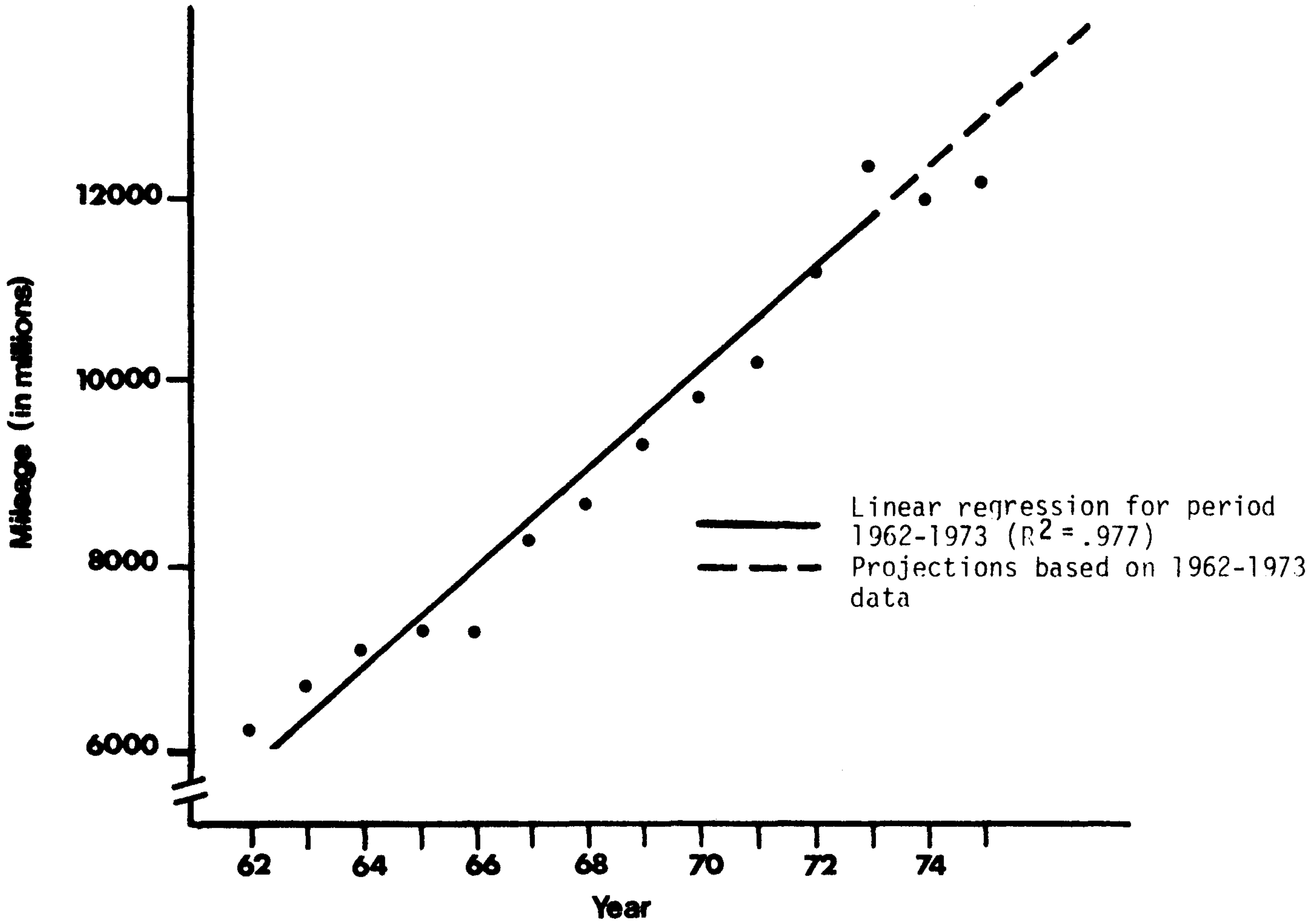

Figure 2.2 North Carolina annual motor vehicle mileage (in millions) 1962-1975.

Table 2.1 Motor vehicle mileage (in millions) for North Carolina - January through April.

Year	Estimated MVM[1]	Estimated MVM for 1973[1]	Linear Regression Estimate	Mean Yearly Increase	Time Series Analysis
1974	11222	12347 (-9.1%)	12146 (-7.6%)[2]	12899 (-13.0%)	13001 (-13.7%)
1975	12126	12347 (-1.8%)	12673 (-4.3%)	13451 (- 9.9%)	13664 (-11.3%)

[1]Source: North Carolina Traffic Accident Summary (1973, 1974, 1975).

[2]$\frac{\text{Estimated MVM (1974) - Predicted MVM (1974)}}{\text{Predicted MVM (1974)}} \times 100$

observed MVM are 7.6 percent and 4.3 percent below the predictions for 1974 and 1975.

Using another approach to obtain the figures in Column 5 of Table 2.1, the mean of the yearly increase in vehicle mileage between 1962 and 1973 is computed to be 552 MVM. Thus, if vehicle mileage increased in the first four months of 1974 at its mean rate of increase, the predicted vehicle mileage would be 12899, and the predicted mileage for the first four months of 1975 would be 13451. With this approach, the estimated mileage for 1974 is 13.0 percent below the predicted value, and for 1975 it is 9.9 percent below the corresponding predicted value.

Finally, time series analysis was used to model the estimated monthly vehicle mileage series for the period 1962 through 1973 (see Appendix C for details). Using the model, predicted values of vehicle mileage for 1974 and 1975 were computed. The figures for January through April are presented in Column 6 of Table 2.1. It was found that the 1974 and 1975 mileages were 13.7 and 11.3 percent below the predicted values. Because the time series model incorporates the cyclic nature of the data as well as the general upward trend, it is felt that this approach is superior to the methods previously described.

Conclusions: Vehicle Mileage

From the data presented, the following conclusions can be made concerning vehicle mileage in North Carolina:

1) In the period from 1962 through 1973, total vehicle mileage in North Carolina increased approximately linearly.

2) Vehicle miles driven show a 9.1 percent drop in 1974 below the value for 1973. However, in 1975, a major portion of this decrease was recovered.

3) Estimates of expected mileage in 1974 and 1975 indicate that mileages observed during this time show a clear departure from previous trends. The "best" estimate (from time series modeling) indicates that mileage in 1974 was perhaps 13.7 percent below the expected amount and, in 1975, approximately 11.3 percent below expectation.

2.1.2 Traffic volume.

Data on traffic volumes were obtained from the Planning and Research Branch of the Division of Highways, North Carolina Department of Transportation. These data consist of hourly traffic counts which were obtained from 59 permanent count stations located across the state. Each count station consists of a magnetic loop detector and a recording device which accumulates and records hourly vehicle counts. The data, along with information about the location, date, and reliability (e.g., presence of road construction), are then keypunched in 12 hour blocks and placed on a magnetic tape file at the Division of Highways.

Analysis of the vehicle count data consisted of two phases: first, the data were edited to remove all data for which the reliability was questionable, and second, average daily counts were computed separately for weekend days (Saturday and Sunday) and weekdays, for five classes of roads (Interstates, U.S. highways, N.C. highways, rural paved roads, and city streets) and for each month (January - April) of the years 1973, 1974, and 1975. In the editing process, if any data for a given location and day were questionable, then all data for that day were discarded. Thus, all accumulated vehicle counts are for a full 24-hour day. By computing average daily counts for weekdays and weekends separately, an adjustment has implicitly been made for the fact that the number of weekend days in a given month is different for the years 1973, 1974, and 1975.

Average daily traffic (ADT) counts for each road class during the period January through April of 1973, 1974, and 1975 for weekdays and weekends are presented in Table 2.2. This table indicates that 1974 decreases in weekday traffic volumes were concentrated in rural roads, primarily on Interstate highways. In 1975, weekday traffic volumes remained substantially below 1973 levels on all rural roads except U.S. highways, where volumes were approaching pre-energy crisis levels. Weekday volumes in urban areas actually increased slightly in 1974, while in 1975 a decrease was observed.

Table 2.2 also reveals that on the weekends, volumes were down for both urban and rural roads in 1974, with a dramatic decrease occurring on Interstate highways. Although weekend traffic volumes remained down on all roads in 1975, both Interstate and U.S. highways recovered about 59 percent of the 1974 decrease, while N.C. and rural paved roads only recovered 21 percent and 34 percent, respectively. Weekend volumes on urban roads continued to fall in 1975.

Monthly average daily traffic counts for each road type by weekdays and weekends are plotted in Figures 2.3 through 2.7. These plots indicate that for city streets, traffic volumes remained relatively constant both on weekdays and weekends. However, for rural roads, volumes were subject to seasonal fluctuations, with the winter months having lower than average traffic volumes. There appears to be a decreasing trend in volumes on rural paved roads over the three year period. Other roads show large fluctuations in traffic volumes, but no discernible trends.

Conclusions: Traffic Volumes

On the basis of the above observations, the following conclusions can be made concerning average daily traffic volumes in North Carolina:

1) There was a substantial decrease in traffic volumes in North Carolina in 1974, and this decrease was partially, but certainly not completely, recovered in 1975.

2) Weekend volumes decreased more than weekday volumes.

Table 2.2 Average daily traffic counts by road class and time of week (January - April).

Road Class	Time of Week	Traffic Volume 1973	1974	1975	Percentage Change 73-74	73-75
Urban[1]	Weekday	12728	12761	12393	+ 0.26[3]	- 2.63
	Weekend	10281	9188	8841	-10.63	-14.01
Rural[2]	Weekday	5724	5316	5561	- 7.13	- 2.85
	Weekend	5839	4686	5500	-19.75	- 5.81
Interstate	Weekday	15380	12158	12966	-20.95	-15.70
	Weekend	16597	10369	14073	-37.52	-15.21
U.S.	Weekday	5065	4806	5058	- 5.11	- 0.14
	Weekend	5013	4279	4712	-14.64	- 6.00
N.C.	Weekday	2357	2135	2106	- 9.42	-10.65
	Weekend	2663	2201	2296	-17.35	-13.78
Rural Paved Roads	Weekday	1817	1557	1668	-14.31	- 8.20
	Weekend	1663	1341	1451	-19.36	-12.75

[1]City streets

[2]Interstate, U.S., N.C., and rural paved roads

[3] $+0.26 = \frac{12761-12728}{12728} \times 100$

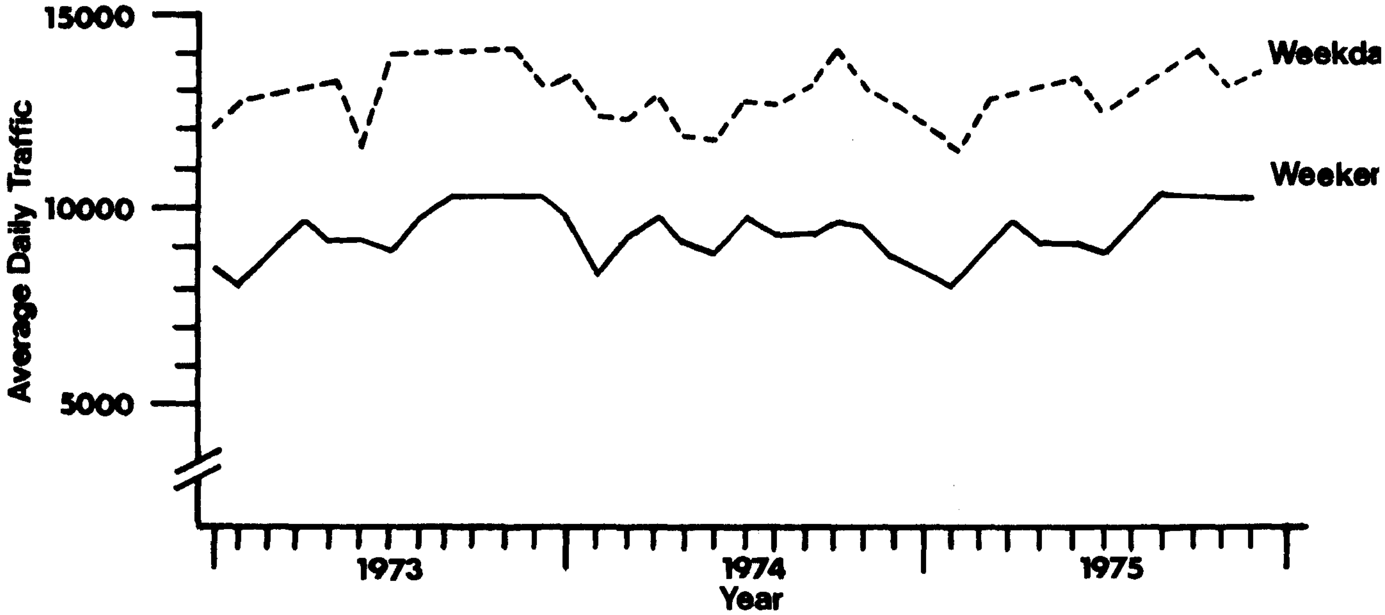

Figure 2.3. Monthly average daily traffic volume - City Streets.

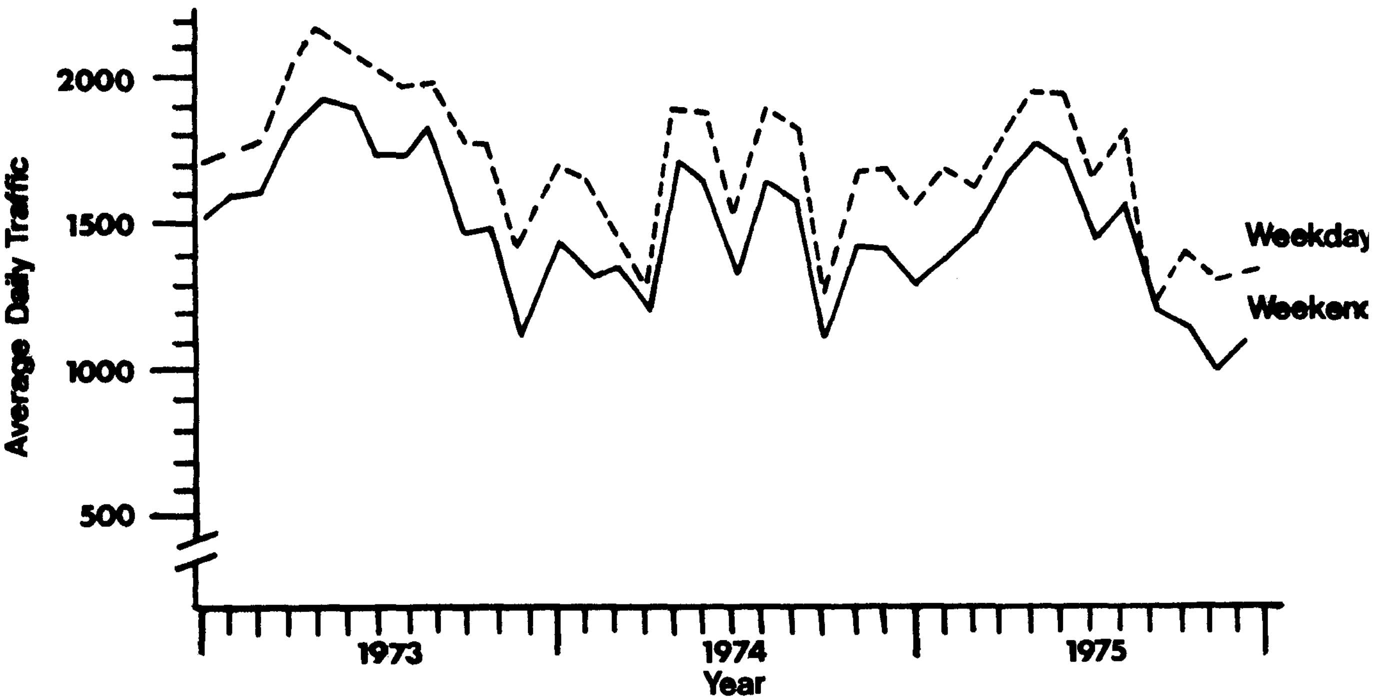

Figure 2.4. Monthly average daily traffic volume - Rural paved roads

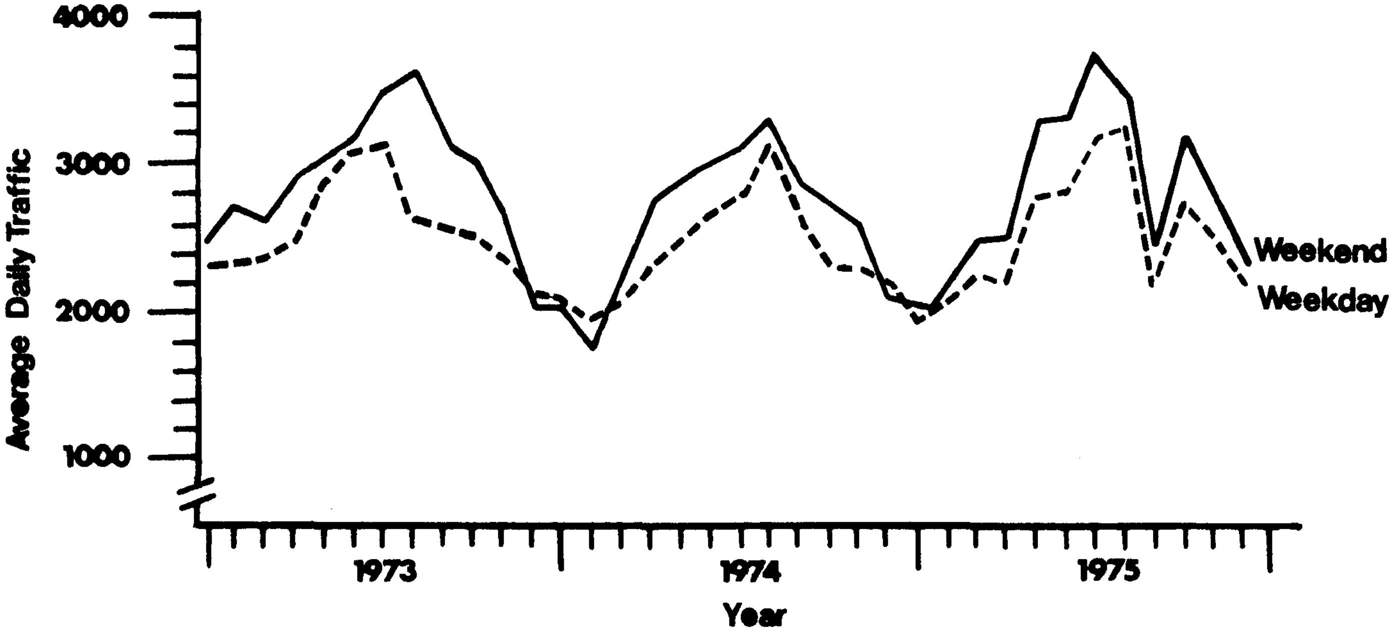

Figure 2.5. Monthly average daily traffic volume - NC highways

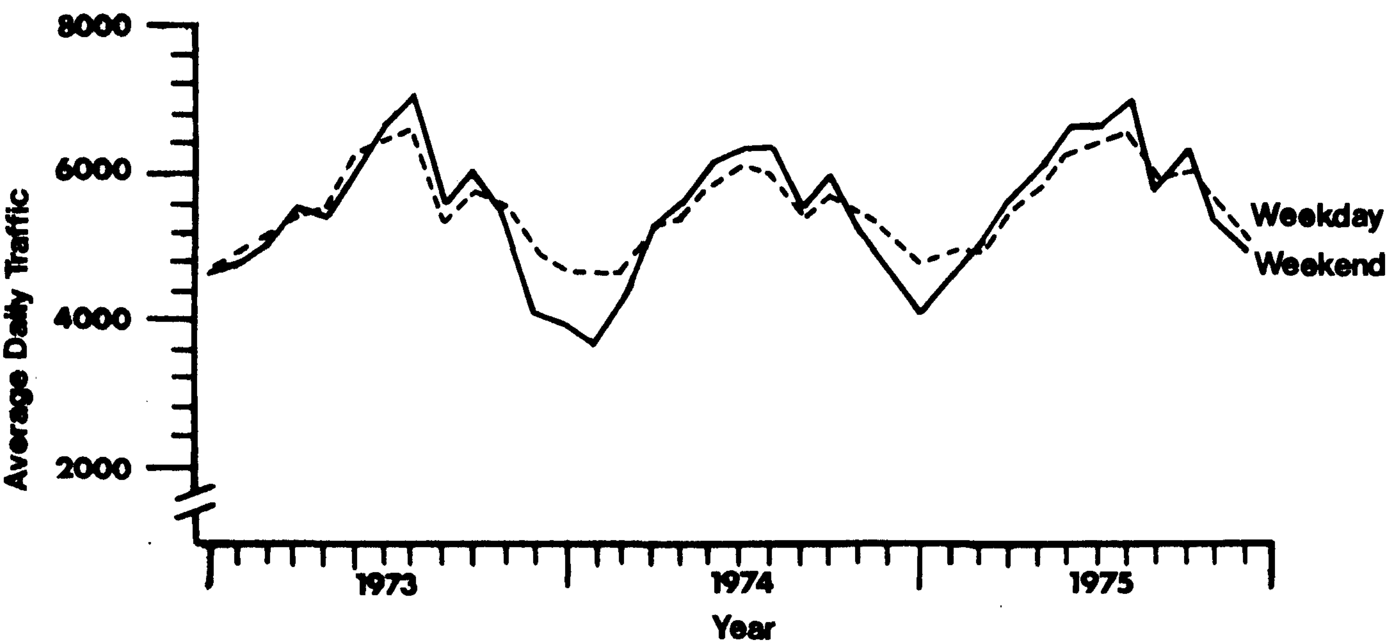

Figure 2.6. Monthly average daily traffic volume - U.S. highways

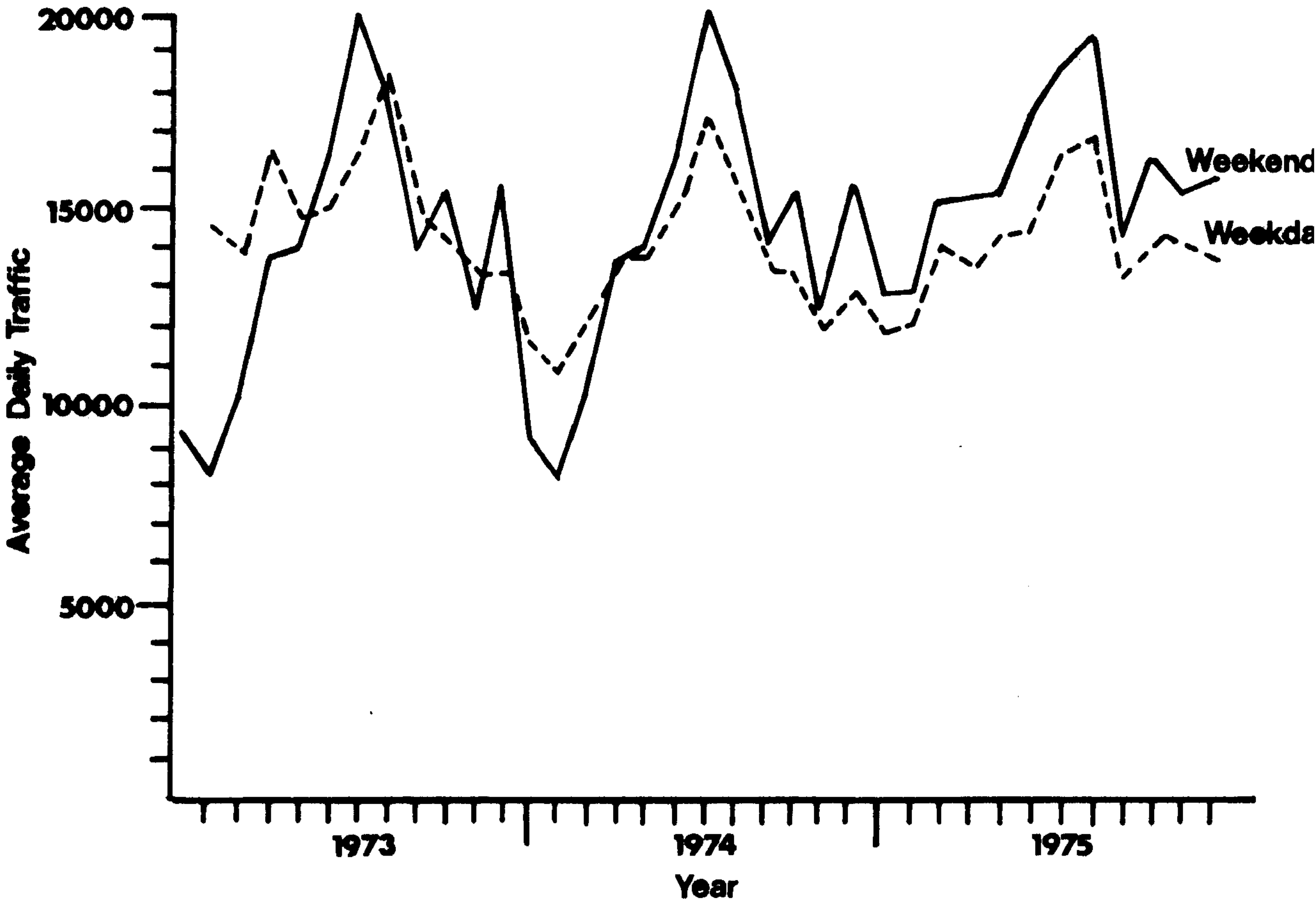

Figure 2.7. Monthly average daily traffic volume - Interstates

3) Rural volumes decreased more than urban volumes.

4) Volume decreases in 1974 for Interstate highways were greater than for other roads.

5) Urban weekday volumes experienced a slight increase in 1974, while a decrease in both weekday and weekend volumes was observed for rural roads.

6) In 1975, volumes on N.C. and rural paved roads experienced smaller increases than volumes on other roads.

7) Volumes on rural paved roads in N.C. seemed to experience a decreasing trend from 1973 through 1975, while volumes on other highways did not seem to experience any discernible trends.

2.1.3 Vehicle speeds.

Data on vehicle speeds were extracted from the report, Rural Speeds on Primary Highways and Secondary Roads, which is published annually by the Planning and Research Branch of the N.C. Division of Highways. This data consists of speed observations collected at 36 stations on rural primary and paved secondary roads, during the months of April or May of each year. Observations are made during weekday daylight hours, using radar units concealed in unmarked cars. The speeds of free-flowing vehicles are recorded, along with information on highway class and vehicle type. Approximately 6,000 - 7,000 observations are made each year, and all observations during a particular year are made by the same team of data collectors. In addition to these annual speed surveys, additional surveys were made in December 1973, November 1974, and September 1975.

For the current study, vehicles were classified into two categories: passenger cars and commercial vehicles. Commercial vehicles included all vehicles other than passenger cars, motorcycles, and buses, and were composed primarily of single and dual tire trucks and tractor-trailer combinations. While buses were not included in the commercial vehicle category, bus speeds were included when all vehicles were considered.

Roads were also classified into two categories: Interstate highways and main routes not in Interstate corridors. Data on main routes in

Interstate corridors and paved secondary roads were not included in either of these classifications; however, this data was included in tables depicting all highways. Unfortunately, urban speed data was not available.

Four parameters of the speed distribution were estimated from the data: 1) mean speeds; 2) 80 percent speed interval; 3) 85th percentile speeds; and 4) the percentage of vehicles traveling above 55 mph. The 80 percent speed interval is the interval (S_1, S_2) such that ten percent of the vehicles in the sample were observed traveling below speed S_1 and ten percent above speed S_2. The 85-th percentile speed is the speed below which 85 percent of the vehicles were observed traveling.

Changes in Mean Speeds

The observed mean speeds taken over all vehicles and all highways for the years 1963 through 1975 are shown in Figure 2.8. (The actual data is presented in Table B.1 of Appendix B). For comparability, only the observations made in April or May of the year are included in the figure.

Figure 2.8 indicates that the mean speeds remained constant from 1964 through 1969. In 1970, there was an increase of 1.5 mph, and from 1971 through 1975 there appears to have been a decreasing trend in mean speeds. In particular, there was a large decrease (2.6 mph) from 1971 to 1972 and another decrease (1.6 mph) from 1973 to 1974. (The observations for 1974 were made in April and therefore fall into the January through April energy crisis period.) The speed observations made in December 1973, after the 55 mph speed limit was put into effect in North Carolina, are very similar to those made in April 1974. By April 1975, however, the mean speed had increased to the pre-energy crisis level of 52.3 mph (see Table B.1). Finally, Figure 2.8 shows that decreases in mean speeds for passenger cars between 1970 and 1975 were greater than decreases for commercial vehicles.

Tables B.2 and B.3 of Appendix B contain speed data for passenger cars and commercial vehicles classified into two highway types, Interstate and main routes, for the years 1968 through 1975. Data on

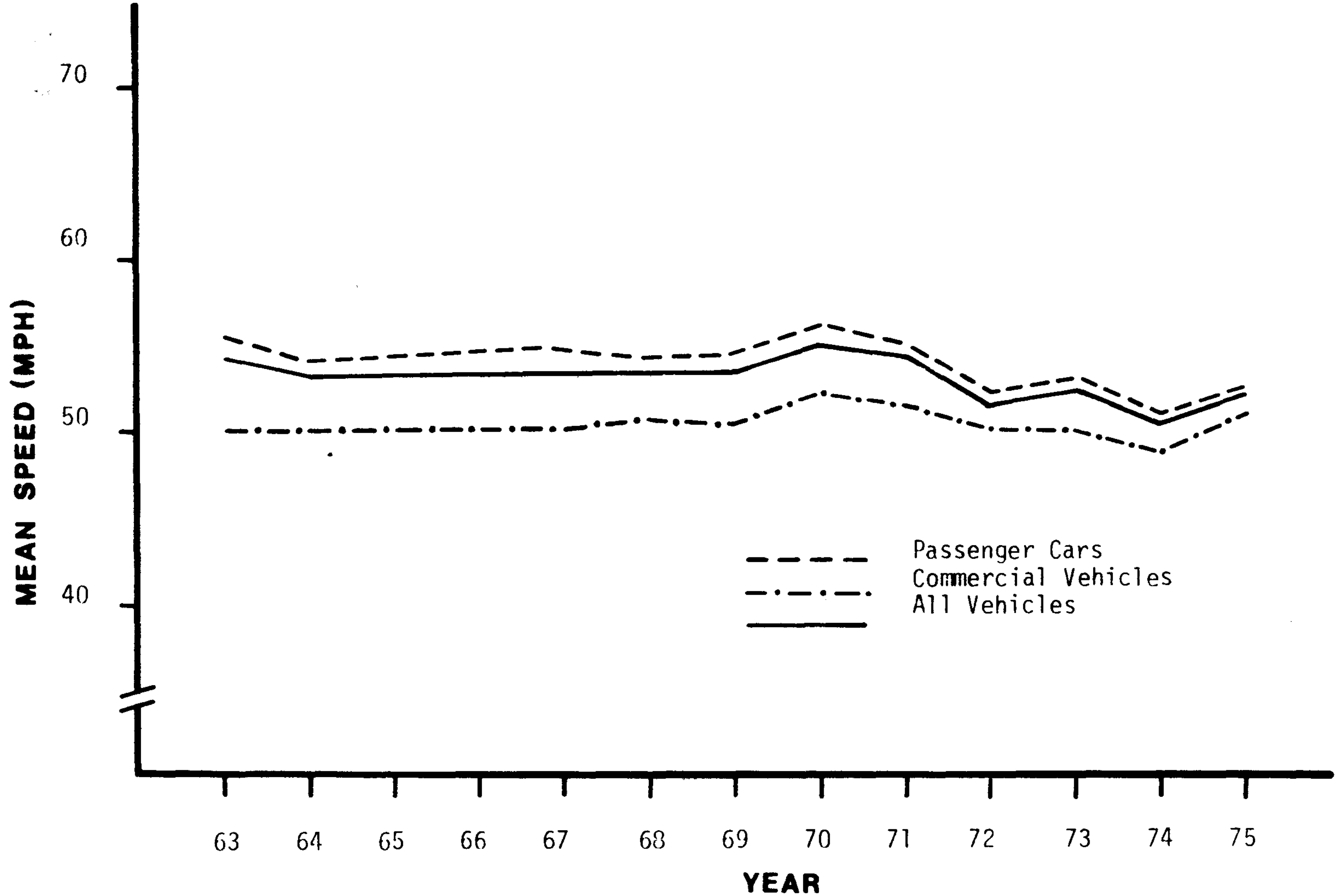

Figure 2.8 Mean speeds for passenger cars, commercial vehicles and all vehicles, across all highway classes. (1963 through 1975).

mean speeds from these tables are plotted in Figure 2.9. These plots exhibit the same characteristic increase in mean speeds in 1970, followed by a generally decreasing trend from 1971 through 1975 for passenger cars and commercial vehicles. It is immediately apparent, however, that the decrease in mean speed in 1974 is much greater on Interstate highways than on main routes, both for passenger cars and commercial vehicles. It should be noted that on main routes, the 1975 mean speed had virtually returned to the 1973 level; however, on Interstate highways, the mean speeds in 1975 were still below the 1973 levels.

The fact that speed changes were greater on Interstate highways than on main routes may be due to the fact that the decrease in the speed limit was greater on these highways (65 mph or more to 55 mph) than on main routes (either 60 mph to 55 mph, or no change at 55 mph). Table 2.3 contains mean speeds for passenger cars and for commercial vehicles, classified by posted speed limit. This table reveals that speeds decreased in 1974 both on those roads where the speed limit was changed and on those roads where the speed limit remained unchanged. However, the decrease on the Interstate highways was about 8 mph, while the decrease on the other roads was never more than 2.3 mph. In 1975, mean speeds remained 4 mph below the level of 1973 on Interstate roads, while on the other roads -- both those which experienced a decrease in speed limit and those which did not -- the mean speeds returned essentially to their 1973 levels.

<u>Changes in the 80-Percent Interval</u>[1]

The variances of the speed observations were not given in the reports from which the speed data were taken; however, the percentage of vehicles traveling above a given speed was given for the speeds 35, 40, 50, 55,

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[1]If the speed observations were normally distributed, then the width of this "observed" 80-percent tolerance interval would be proportional to the standard deviation, and then a confidence interval for the mean speed could be computed (see Dixon and Massey, <u>Introduction to Statistical Analysis</u>, (1957) p. 130). For each of the years examined, the 99 percent confidence interval for the mean speed has a width of 2 mph or less.

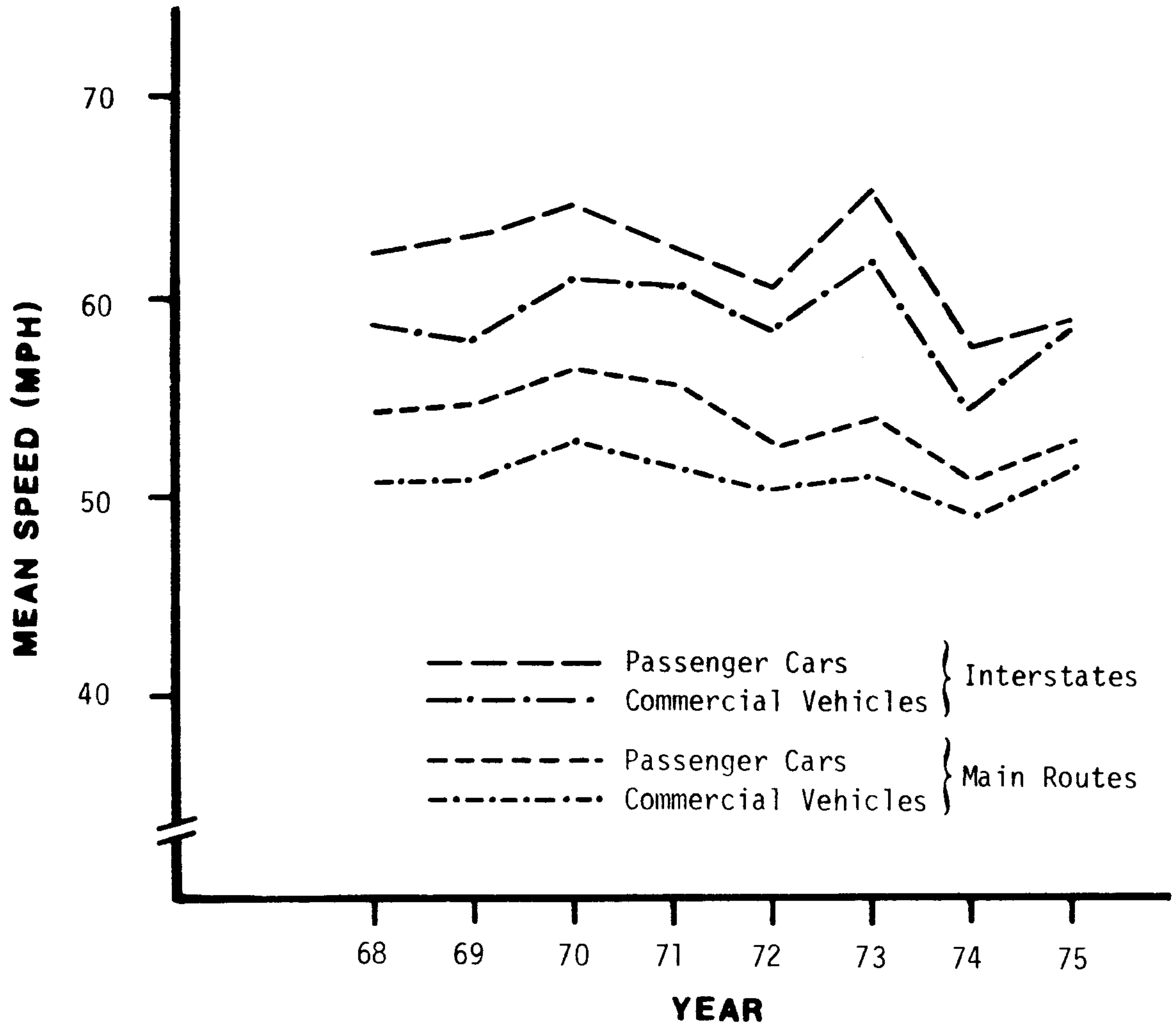


Figure 2.9. Mean speeds for passenger cars and commercial vehicles by highway class (1968-1975).

Table 2.3 - Mean speeds (MS) and posted speed limits (PSL) by year and vehicle type.

Year	Vehicle Type	Interstate MS (PSL)	Main Routes MS (PSL)	 MS (PSL)	Rural Secondary MS (PSL)
1968	Passenger cars	62.1 (65)	56.3 (60)	50.7 (55)	48.7 (55)
	Commercial vehicles	58.5 (65)	52.0 (50)	49.0 (45)	46.0 (45)
1969	Passenger cars	63.0 (65)	56.4 (60)	52.6 (55)	48.3 (55)
	Commercial vehicles	58.0 (65)	51.8 (50)	49.2 (45)	44.7 (45)
1970	Passenger cars	64.6 (65)	58.4 (60)	55.2 (55)	51.4 (55)
	Commercial vehicles	60.9 (65)	53.8 (50)	51.4 (45)	47.3 (45)
1971	Passenger cars	62.2 (65)	57.1 (60)	54.3 (55)	49.2 (55)
	Commercial vehicles	60.7 (65)	52.3 (50)	50.5 (45)	46.2 (45)
1972	Passenger cars	60.8 (65)	52.6 (60)	49.8 (55)	44.8 (55)
	Commercial vehicles	58.2 (65)	50.4 (50)	48.3 (45)	41.9 (45)
1973	Passenger cars	65.4 (65)	54.2 (60)	51.1 (55)	47.3 (55)
	Commercial vehicles	62.0 (65)	51.0 (50)	47.1 (45)	44.4 (45)
1974	Passenger cars	57.4 (55)	52.0 (55)	48.8 (55)	46.1 (55)
	Commercial vehicles	54.4 (55)	49.8 (50)	46.3 (45)	44.5 (45)
1975	Passenger cars	58.9 (55)	53.6 (55)	51.2 (55)	48.2 (55)
	Commercial vehicles	58.1 (55)	51.7 (50)	48.8 (45)	45.6 (45)

60, and 65 mph. The lower and upper ends of the 80-percent interval were computed by linearly interpolating between the percentages given to find the speed above which 90 percent of the vehicles were traveling and the speed above which 10 percent of the vehicles were traveling.

Tables B.1 - B.3 show the 80-percent speed intervals for passenger cars and commercial vehicles on all highways, Interstates, and main routes, respectively. As was observed with mean speeds, vehicles traveling on Interstate routes experienced the greatest decrease in speeds, and this decrease generally remained in 1975. It should also be noted that the width of the 80-percent interval on Interstate highways was nearly constant, whereas on main routes, the width decreased by 4.1 mph from 1973 to 1974, a decrease which was maintained in 1975.

Changes in the 85-th Percentile Speed and the Percent Above 55

The graphs and tables presented thus far have indicated that the changes in the highway environment have had a greater effect on high speeds than on low speeds. To investigate this hypothesis further, the 85-th percentile speeds and the percent of vehicles traveling above 55 mph were calculated. Both of these parameters are measures of the extreme speeds that are likely to be observed.

Table B.1 gives the data for all vehicles on all highways. The 85-th percentile speeds (rounded to the nearest whole mph) for 1963 through 1975 are plotted Figure 2.10. Comparison of this plot with Figure 2.8 reveals that the 85-th percentile speed has indeed changed more than mean speeds. From 1973 to 1974, the mean speed decreased 1.6 mph while the 85-th percentile speed decreased 3 mph.

Figure 2.10 reveals that in 1974, the 85-th percentile speed for both passenger cars and commercial vehicles dropped substantially, and remained down in 1975. In addition, one can observe a decrease in the difference between the 85-th percentile speed for passenger cars and that for commercial vehicles. From 1964 through 1975, the 85-th percentile speed for commercial vehicles gradually increased (except in 1974) while for passenger cars it remained relatively constant.

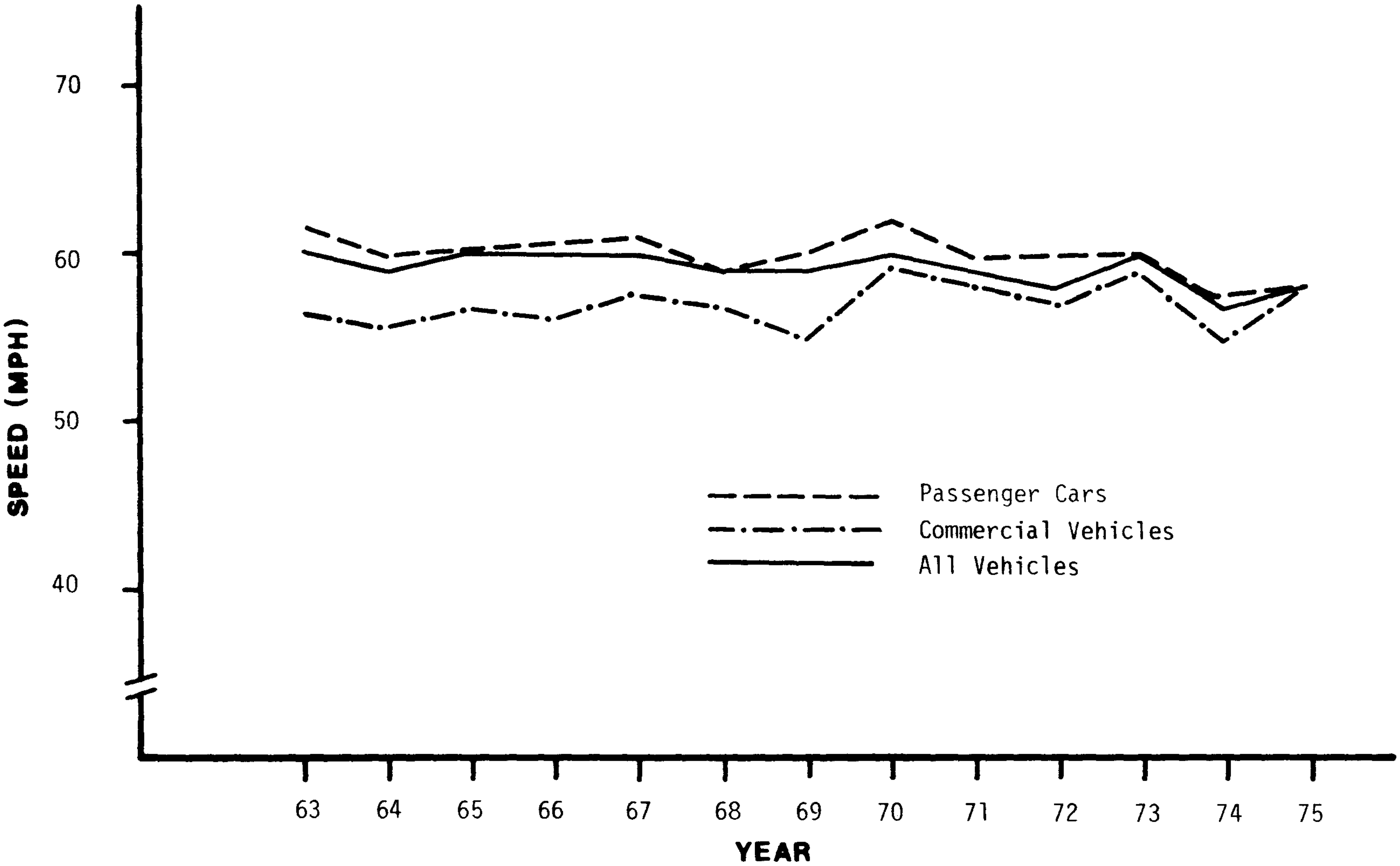


Figure 2.10. 85-th percentile speed, all highways, all vehicles.

Figure 2.11 displays the 85-th percentile speed data given in Tables B.2 and B.3. From these plots, it is clear that Interstate highways experienced greater changes in higher speeds than main routes, especially for passenger cars. Figure 2.11 also shows that through 1973, over 85 percent of the passenger cars were exceeding the speed limit on Interstate highways, while commercial vehicles were traveling somewhat slower.

Figure 2.12 is a graph of the percent of vehicles traveling over 55 mph for all vehicles on all highway types (see also Table B.1), while Figure 2.13 gives the corresponding graphs for Interstate highways and main routes. Speeds were relatively constant from 1964 through 1969, followed by an increase in 1970 and a generally decreasing trend from 1970 through 1975, with 1974 being the lowest year. Note the dramatic but expected drop on Interstates in 1974!

Conclusions: Vehicle Speeds

The foregoing analysis leads to the following conclusions concerning vehicle speeds from 1962 through 1975:

1) From 1964 through 1969, the vehicle speed distribution was virtually constant; however, during the years 1970 through 1975, there have been substantial changes in vehicle speeds.

2) In 1973, speeds were generally greater than in the immediately preceding years. Therefore, some reduction in speeds in 1974 might be expected even without the effects of the fuel shortage.

3) From 1970 through 1975, passenger car speeds have generally been experiencing a decreasing trend while commercial vehicle speeds have been increasing somewhat.

4) From 1970 through 1975, differences in speeds between passenger cars and commercial vehicles have been decreasing.

5) Changes in vehicle speeds that have been observed between 1970 and 1975 (especially changes from 1973 to 1975) have been primarily at the higher speeds. Fewer vehicles were observed traveling at speeds that were substantially higher than the mean speed.

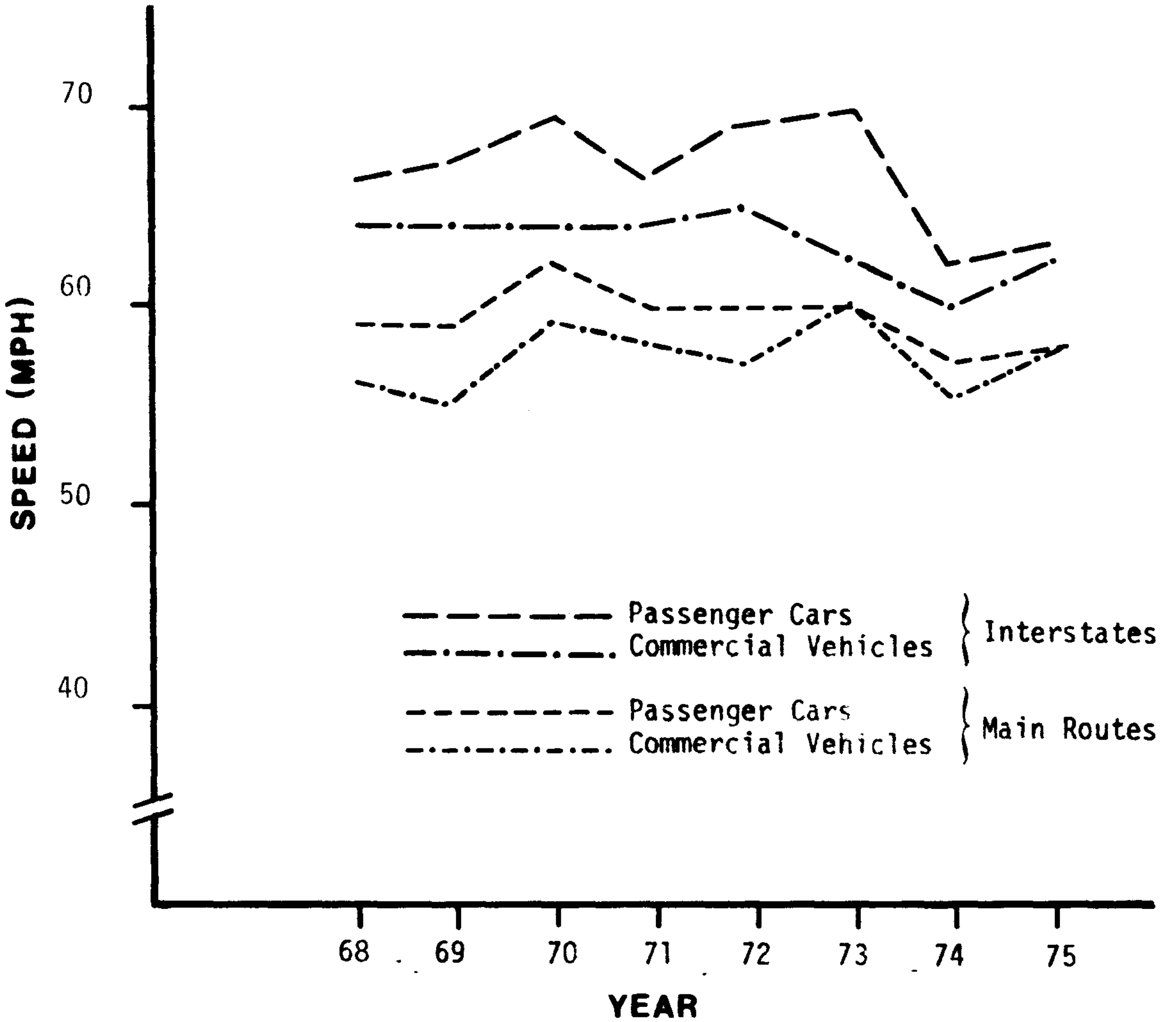


Figure 2.11. 85th percentile speed, interstate highways, main routes.

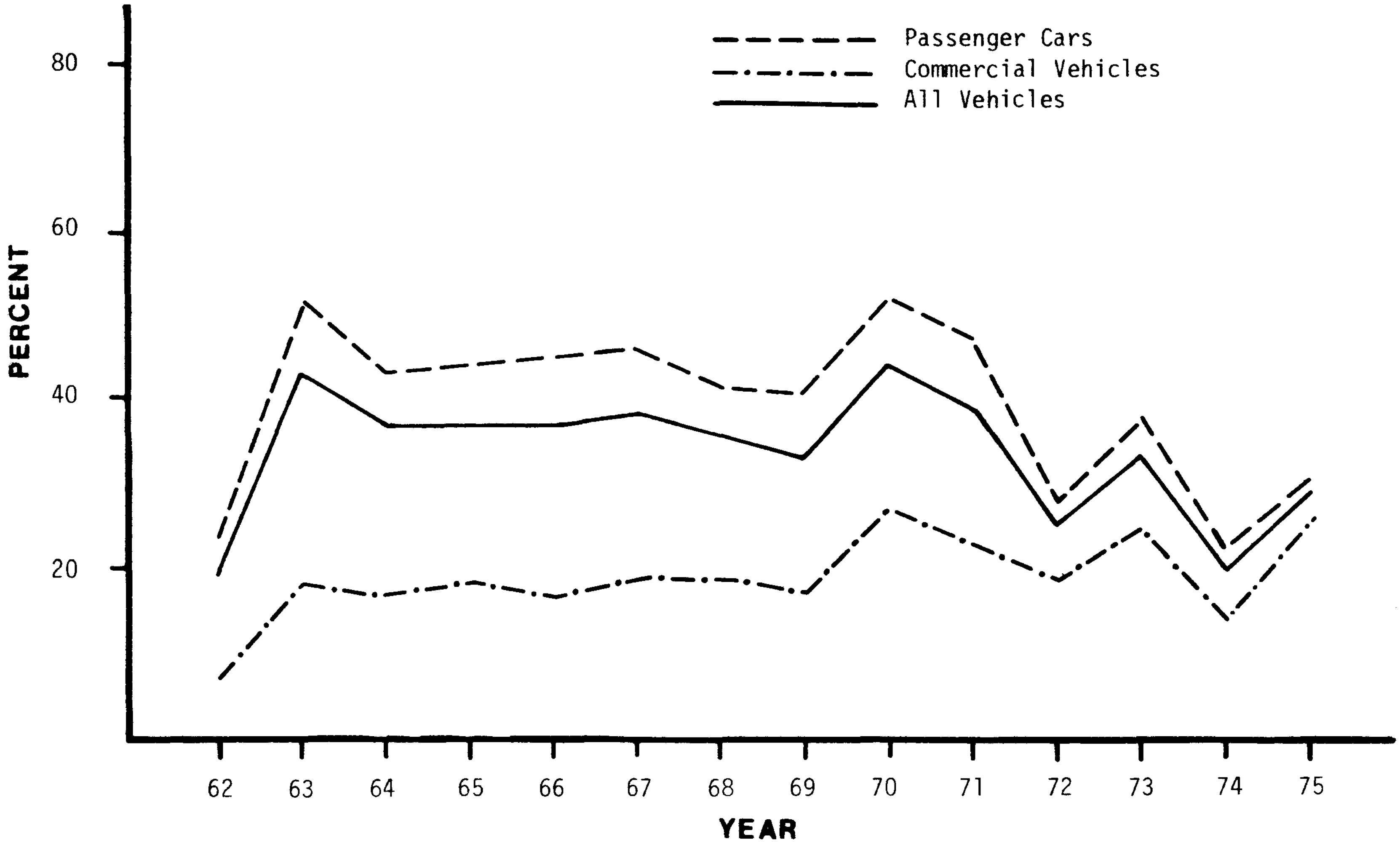


Figure 2.12. Percent above 55 mph, all highways.

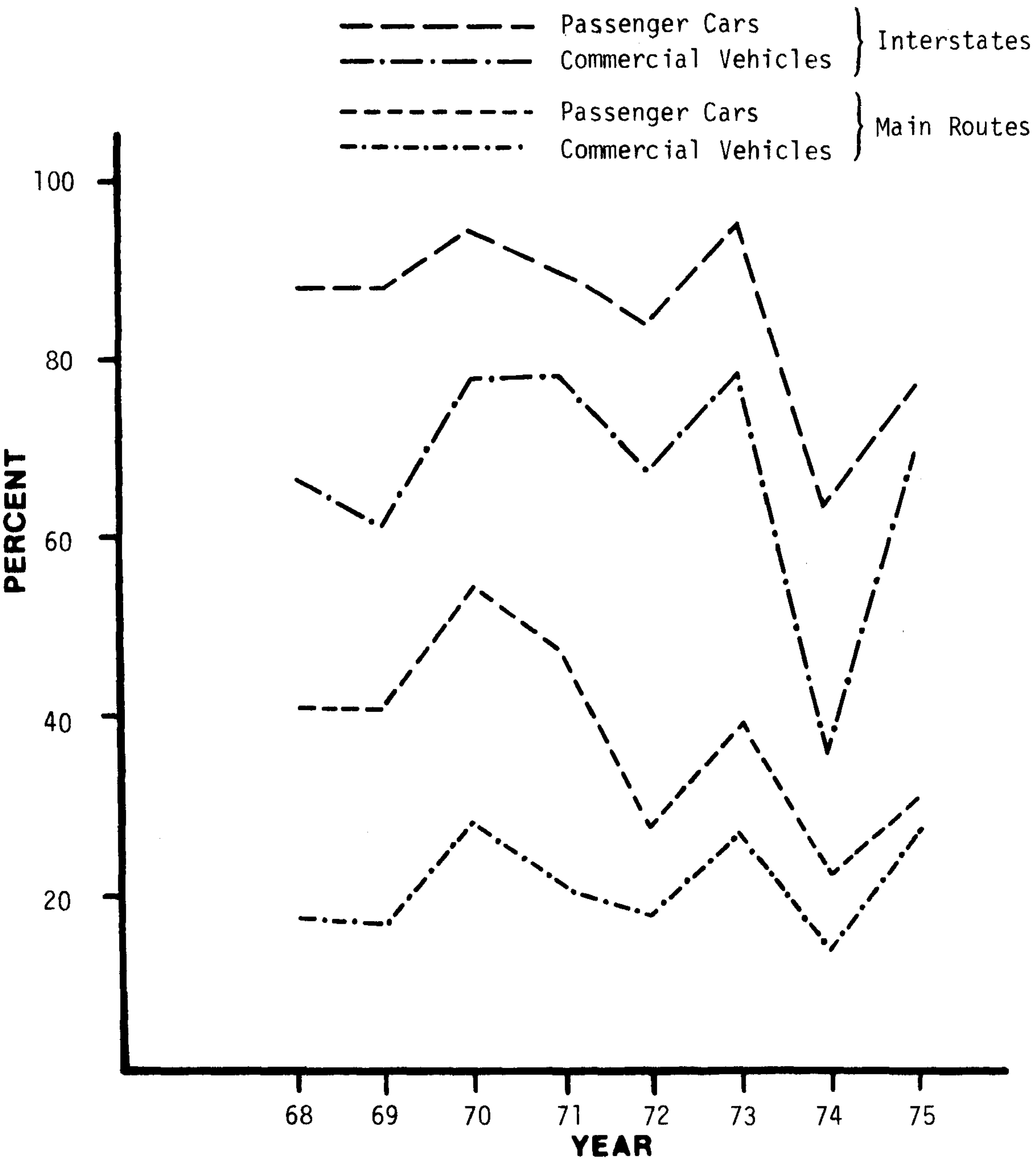


Figure 2.13. Percent above 55 mph, Interstate highways, main routes.

6) Speed changes that have been observed among passenger cars have been greater in magnitude than changes observed among commercial vehicles.

7) On Interstate highways, the mean speed experienced a sizable decrease from 1973 to 1974, while the speed variability remained relatively constant. On main routes, the mean speeds experienced a relatively smaller decrease, while the speed variability experienced a substantial decrease.

8) The changes that occurred during 1974 have remained in 1975 to a greater extent on Interstate highways than on main routes and among passenger cars than among commercial vehicles.

9) There was a decrease in 1974 in mean speeds on roads which did not experience a speed limit change as well as those which did; however, this decrease did not remain in 1975 except on the Interstates where the speed limit had been lowered.

2.2 Changes in the Accident Scene

In addition to effecting changes in the vehicle and driving populations on the road, the events surrounding the energy crisis also contributed to changes in the accident scene itself. In particular, the period of the energy crisis was characterized by a shift in the number and severity of accidents, and in the types of individuals involved in accidents along with the specific violations they appear to have committed. All of these areas will be explored in greater detail in the sections that follow.

2.2.1 Changes in number of accidents.

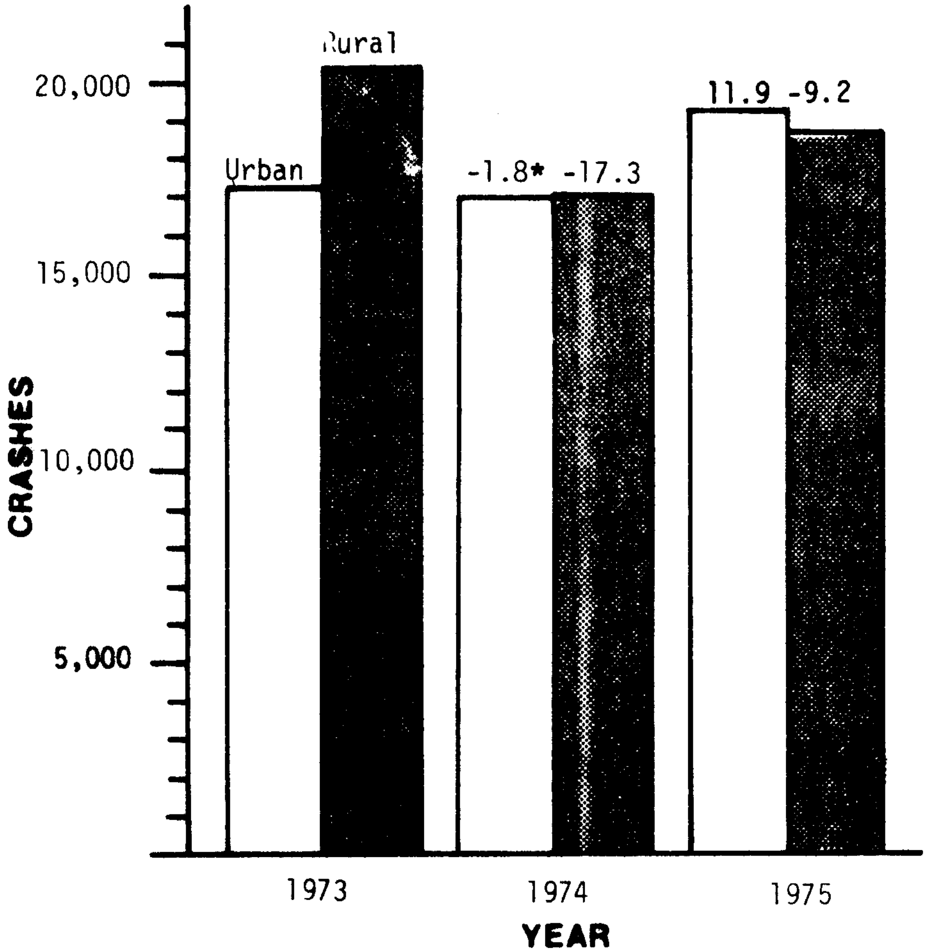
Data on the number of reportable crashes occurring in North Carolina by type of road, injury severity, and other factors were obtained from the North Carolina Traffic Accident Summary. The data are taken from accident reports submitted by the investigating officer (see Appendix A) and include all reportable accidents in North Carolina, where a reportable accident is one which involves at least $200 in property damage or one in which a person is injured. Each report is published 60 days or more after the end of the month for which data are being collected. During this time, if crash victims succumb to injuries, the corresponding change is made on the accident file. Therefore, data concerning injuries is typically quite accurate. A study by House et al. (1974) indicates that North Carolina accident records are rather complete. The study showed that at least 84.6 percent of the accident cases which should have been found in the North Carolina accident files were indeed found. In addition, the study showed that more severe crashes (in terms of injuries) were more likely to be reported, and that virtually all fatal crashes were reported.

Total Crashes

The total number of crashes which occurred in North Carolina during the period January through April for the years 1973, 1974, and 1975 are presented in Table B.4, and plotted in Figures 2.14 through 2.17. For the purposes of this study, urban crashes are defined to be those crashes where the road type given on the accident report form is "city street." Rural Crashes are those which occur on rural highways, namely Interstate, U.S., N.C., rural paved roads, and rural unpaved roads. Crashes which occurred on private property are omitted. Weekend crashes are defined here to be those crashes which occurred between 6:00 p.m. Friday and 8:00 a.m. Monday, and weekday crashes are all crashes which are not weekend crashes.

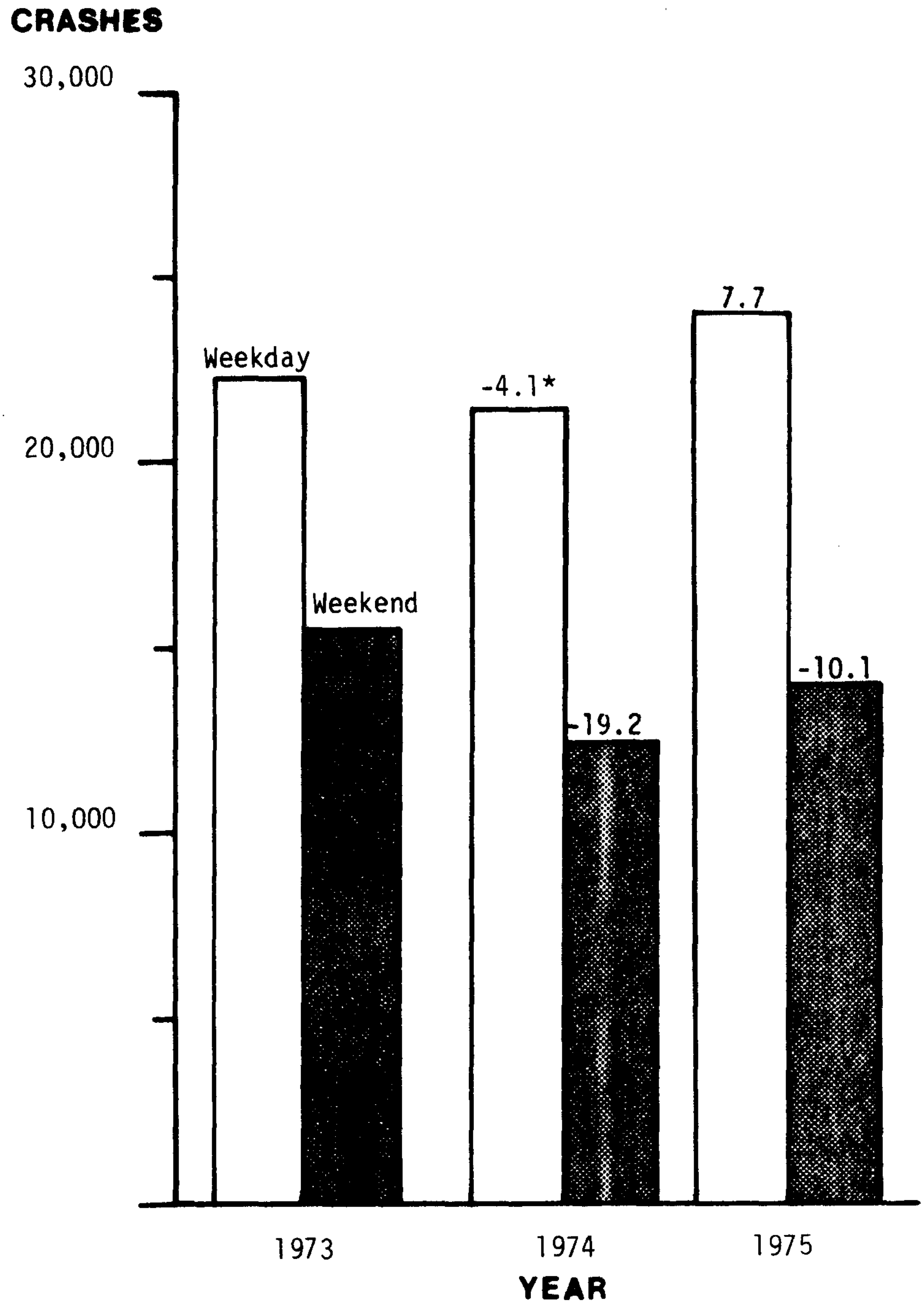
The data presented in Table B.4 represent only the crashes for which both time (weekday/weekend) and location (urban/rural) were reported. Roughly 1.5 percent of the total number of crashes for each year did not have time information available. However, if one assumes that the distribution of occurrence times of these crashes is the same as that for crashes where the time was reported, then the crashes with unknown occurrence times can be ignored without introducing any significant error. The remainder of the discussion in this section is based on this assumption.

Total urban and rural crashes in North Carolina for the time period under consideration are plotted in Figure 2.14. Of the decrease that was observed in the total number of crashes between 1973 and 1974, 92 percent was attributable to a decrease in rural crashes and only



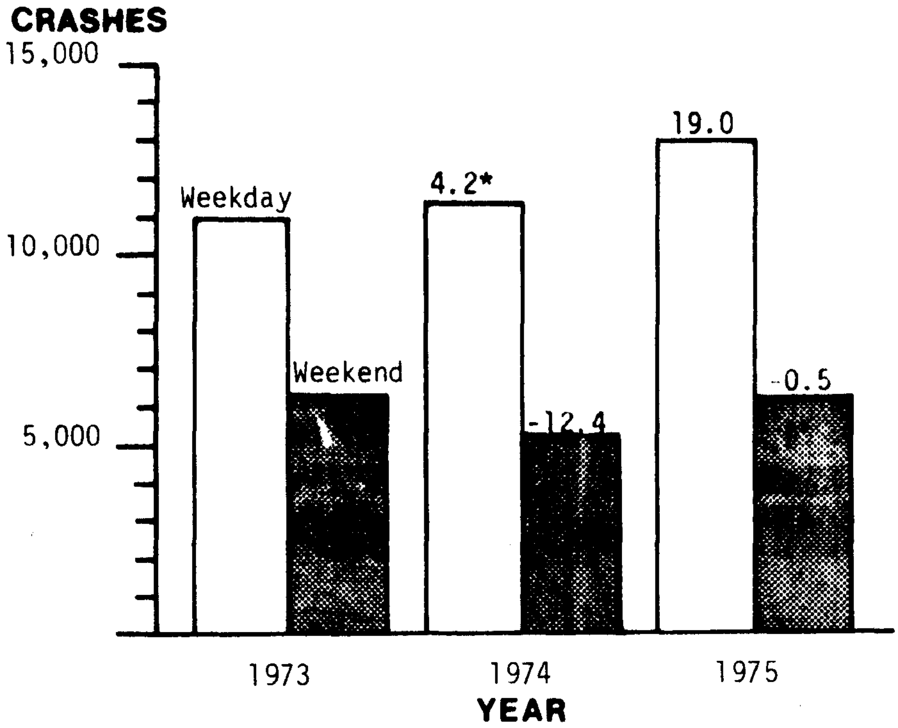
*Percent Change from 1973.

Figure 2.14 Total Crashes in North Carolina - by Location (January through April)



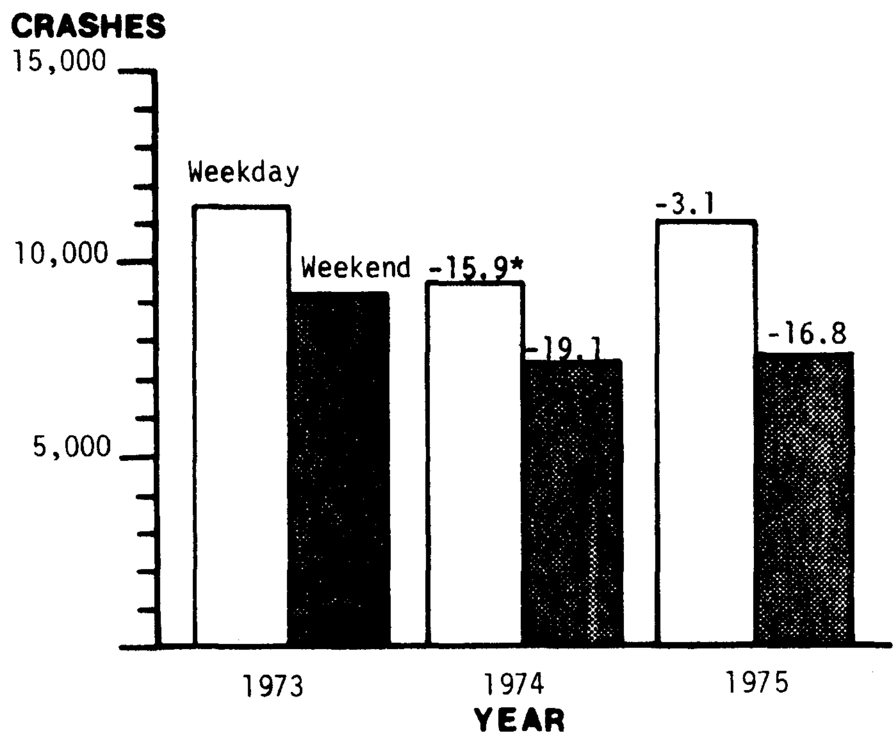
*Percent Change from 1973.

Figure 2.15 Total Crashes in North Carolina - by Time of Week (January through April)



*Percent Change from 1973.

Figure 2.16 Urban Crashes in N.C. (January through April) -Time of Week



*Percent Change from 1973.

Figure 2.17 Rural Crashes in N.C. (January through April) -Time of Week

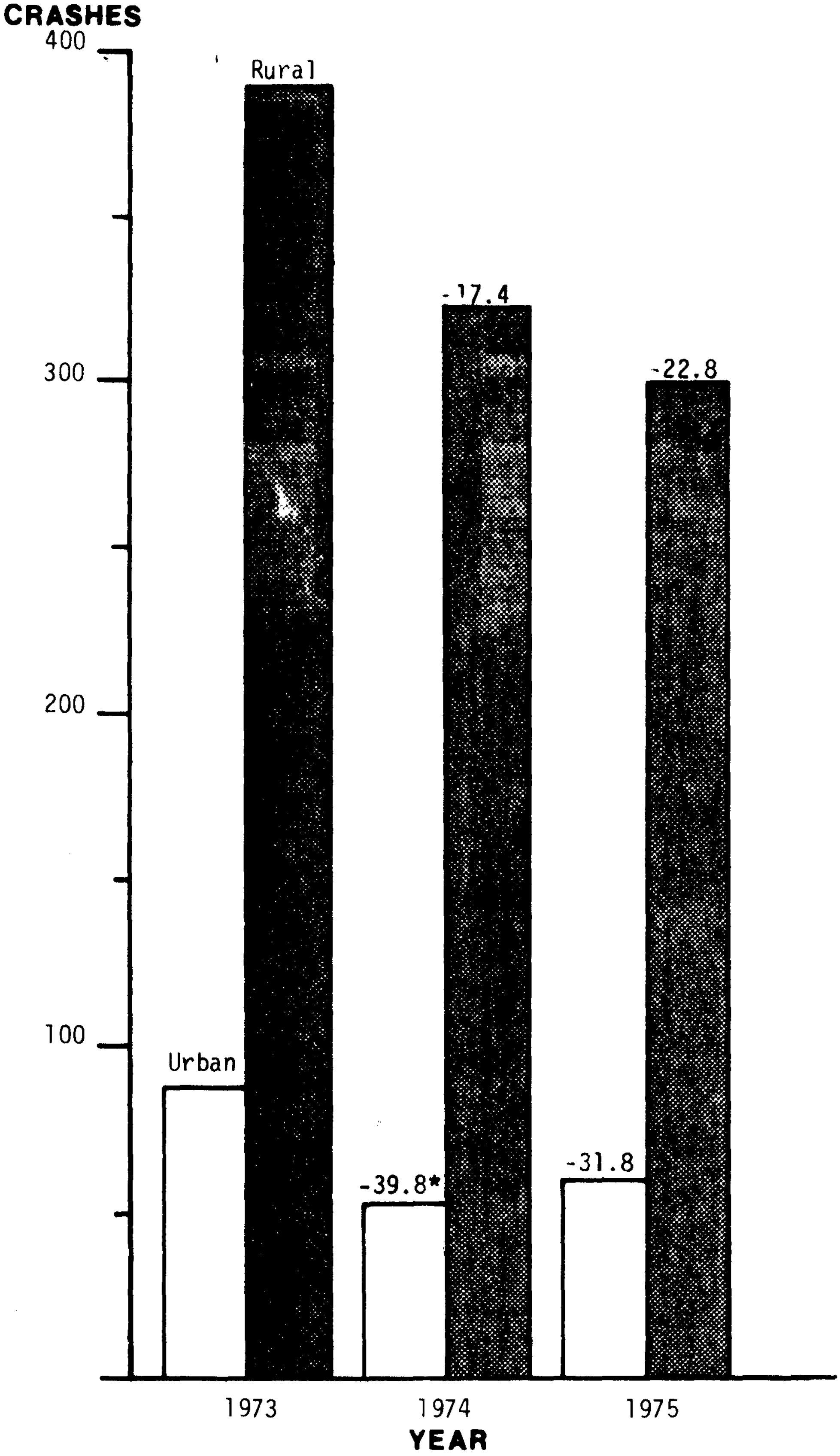
8 percent was due to a decrease in urban crashes. Between 1973 and 1975, the number of urban crashes increased considerably, but was offset by a corresponding decrease in the number of rural crashes, resulting in no significant change in the total number of crashes over the two year period.

Figure 2.15 shows both weekday and weekend crashes for North Carolina. In 1974 there was a decrease in both weekday and weekend crashes; however, of the total decrease, approximately 76 percent was due to a decline in weekend crashes. From 1974 to 1975, there were sizable increases in both weekday and weekend crashes. This resulted in a net increase in weekday crashes between 1973 and 1975, while weekend crashes remained substantially below the 1973 level.

Figures 2.16 and 2.17 display a breakdown of total crashes by location-time categories. It can readily be seen that urban weekday crashes experienced a small increase in 1974, while urban weekend and all rural crashes decreased substantially. As noted earlier, the decrease in rural crashes accounted for 92 percent of the decline in total crashes in 1974, with roughly 46 percent coming from each of the rural weekday and rural weekend categories. Between 1974 and 1975, total crashes increased considerably in all four categories except rural weekend crashes where only a minor increase was experienced. Hence, a large net increase was experienced in urban weekday crashes between 1973 and 1975 while a large net decrease was observed in rural weekend crashes. The other two categories experienced only a small net change from 1973.

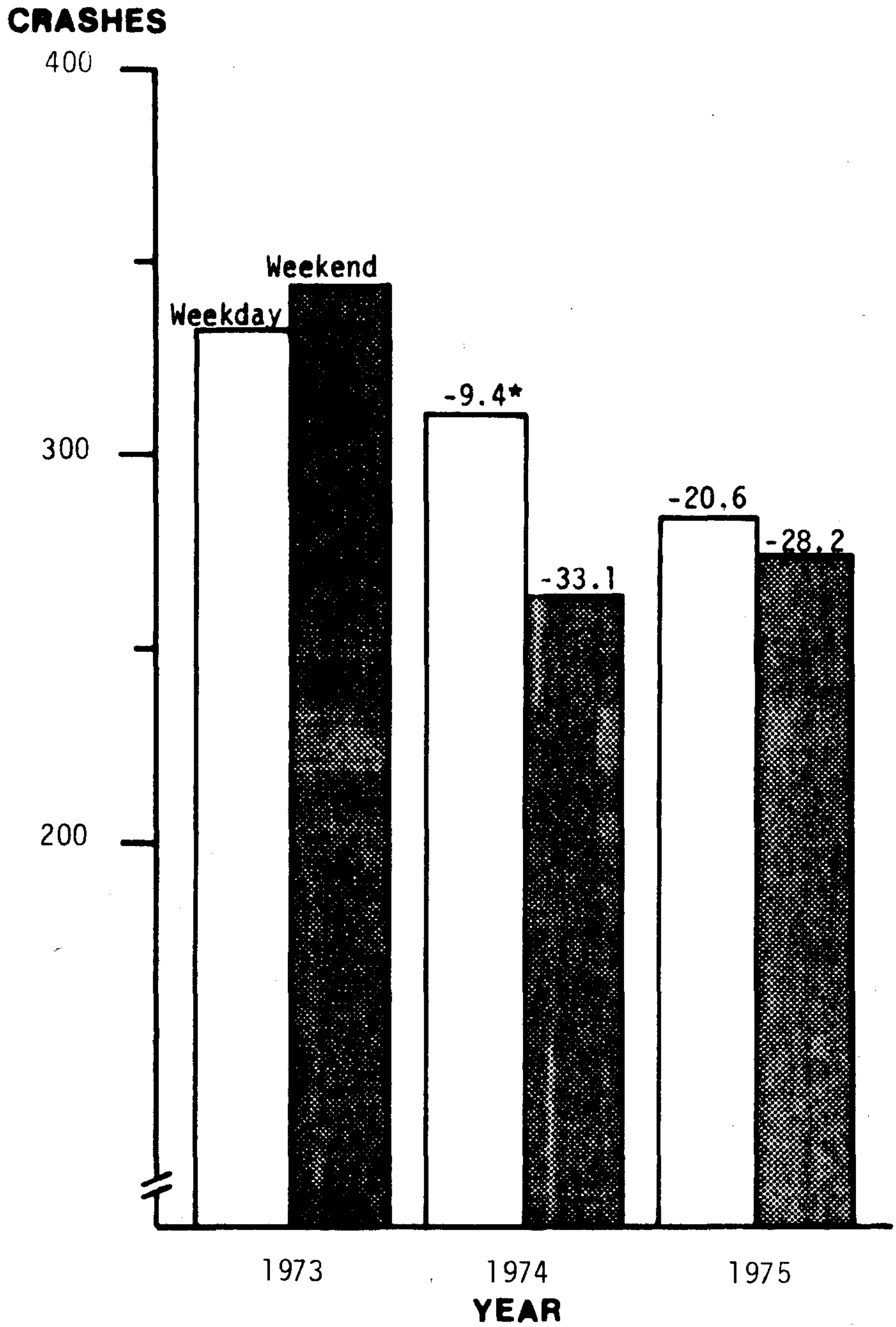
Fatal Crashes

A fatal crash is defined to be any crash in which at least one fatality is indicated on the accident report form. Fatal crashes occurring in North Carolina during the first four months of 1973, 1974, and 1975 are given in Table B.5 and displayed graphically in Figures 2.18 through 2.21. In 1974, sizable decreases were observed in both urban and rural categories resulting in a decline of 22 percent in the number of fatal crashes. However, because rural fatal crashes are more numerous, 66 percent of the decrease in 1974 is attributable to rural crashes and



*Percent change from 1973.

Figure 2.18 Fatal crashes in North Carolina - by Location (January through April)



*Percent Change from 1973.

Figure 2.19 Fatal Crashes in North Carolina - by time.
(January through April)

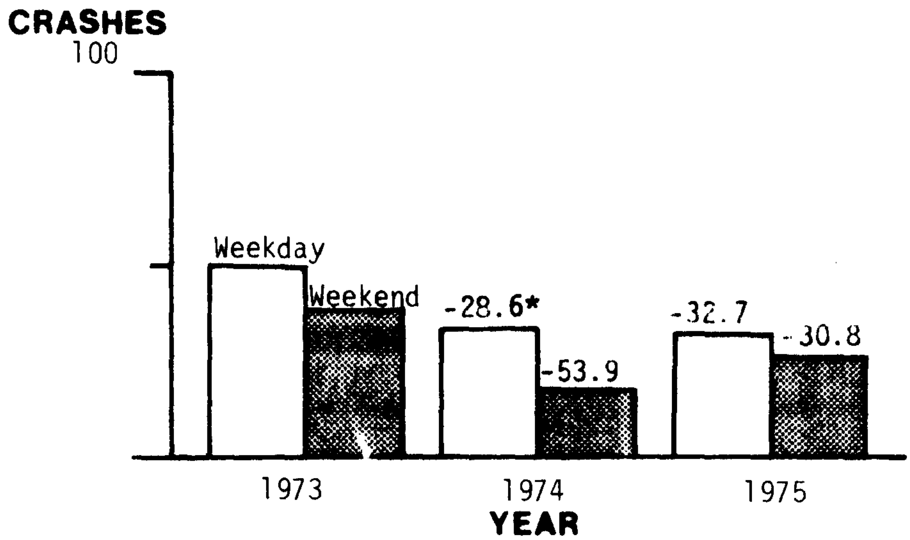
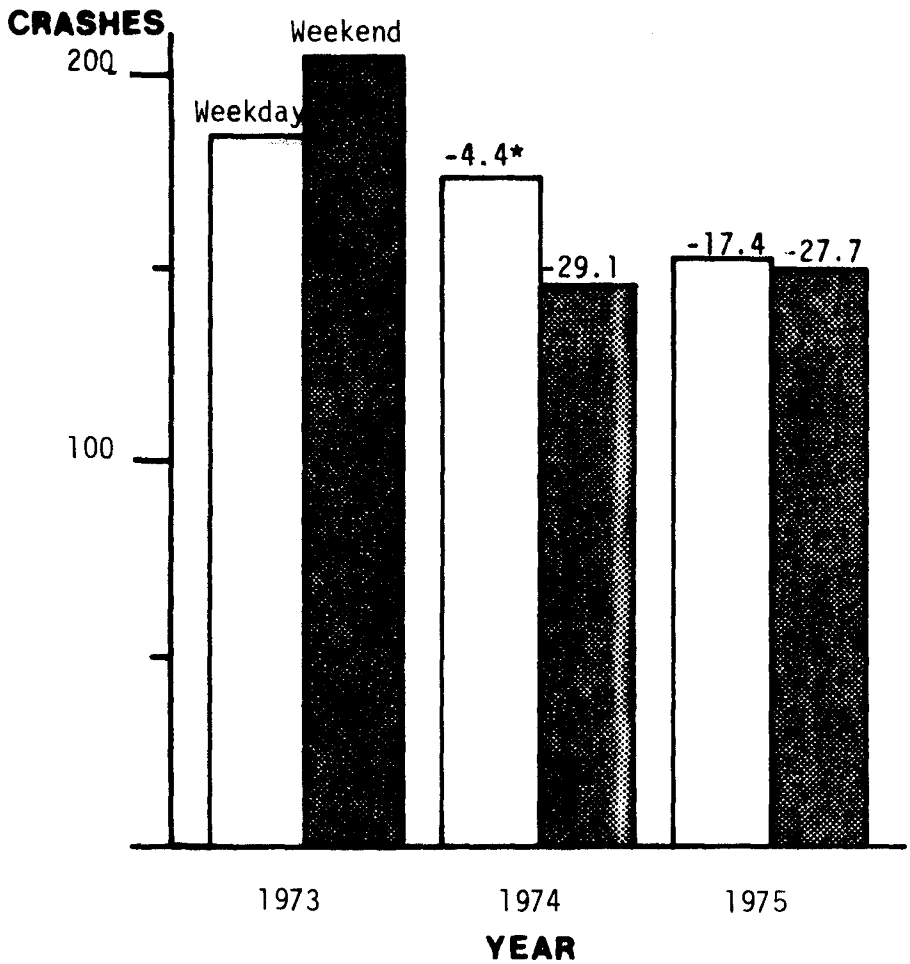


Figure 2.20 Urban Fatal Crashes in North Carolina - by Time (January through April)



*Percent change from 1973.

Figure 2.21 Rural Fatal Crashes in North Carolina - by Time (January through April)

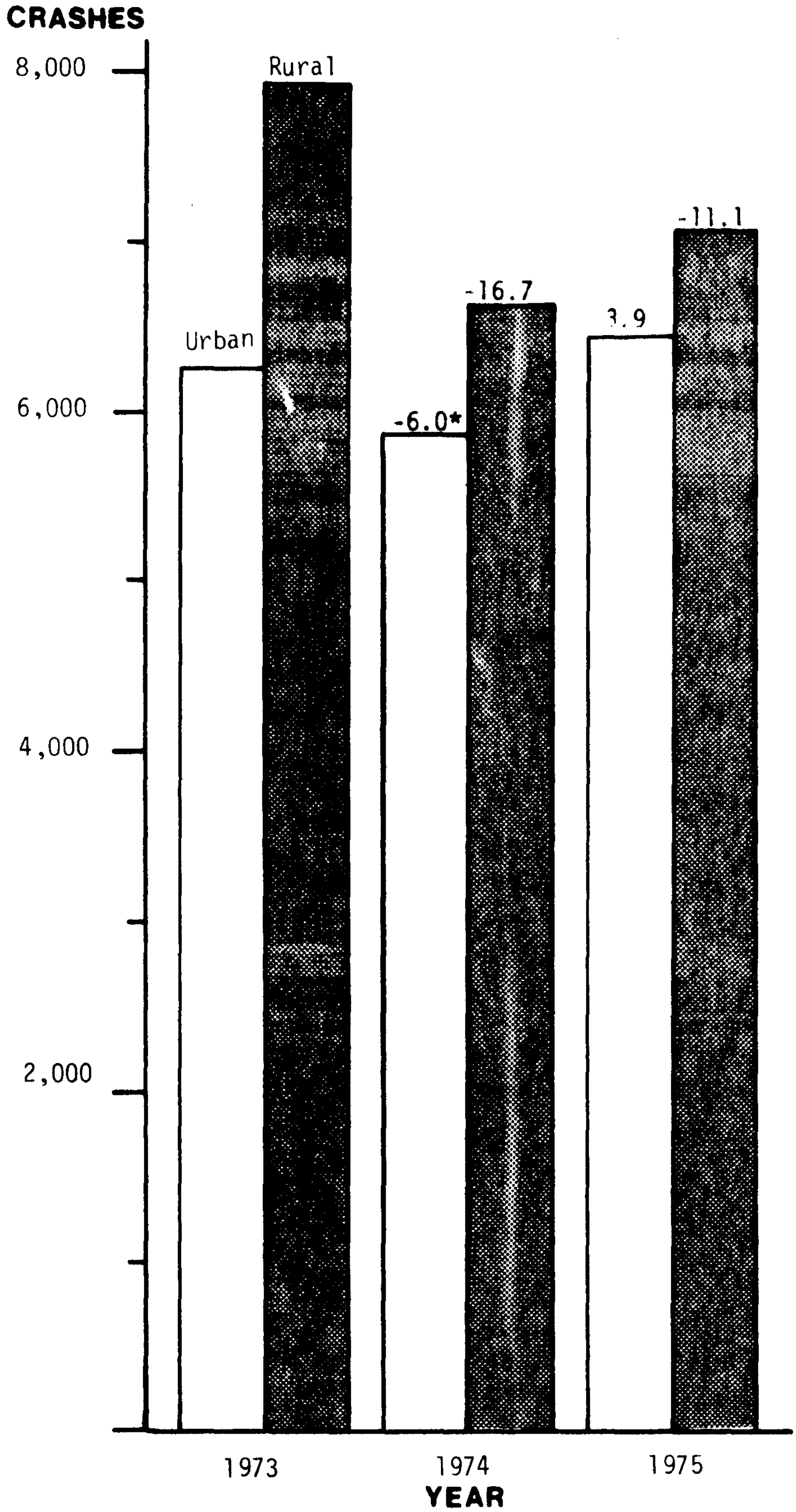
34 percent is due to the decline in urban crashes. In 1975, the number of rural fatal crashes continued to fall while the number of urban crashes increased somewhat over 1974. Despite this increase, both urban and rural fatal crashes remained substantially below 1973 levels.

Of the total decrease in fatal crashes in 1974, approximately 79 percent is due to a decline in the number of fatal crashes occurring on the weekend, with the other 21 percent coming from a decrease in the number of weekday fatal crashes. In 1975, there was a further decrease in fatal crashes occurring on weekdays, but a slight increase was observed in the number of weekend fatal crashes. The net change between 1973 and 1975 left both the number of weekday and weekend fatal crashes considerably below the levels in 1973.

Figures 2.20 and 2.21 show a breakdown of fatal crashes by location and time. All of the location-time categories experienced sizable decreases in 1974, except rural weekday crashes where only a small decline was observed. Over half of the decrease in fatal crashes in 1974 came from a drop in rural weekend crashes. The decrease in fatal crashes in 1975 shifted from rural weekend crashes to rural weekday crashes. It is notable that rural weekend crashes remained 28 percent below the figure for 1973 despite a minor increase between 1974 and 1975. Notice that although urban weekday fatal crashes experienced a 50 percent increase between 1974 and 1975, this category only represents a small proportion of the total number of fatal crashes. Of particular interest is the fact that in 1975, the number of fatal crashes in all location-time categories remained substantially below the corresponding figures for 1973.

Injury Crashes

An injury crash is defined to be any crash in which an injury of any type is reported on the accident report form. Thus, injury crashes also include fatal crashes. Table B.6 gives the number of injury crashes in North Carolina classified by urban and rural locations (see also Figure 2.22). Total injury crashes decreased by 12 percent in 1974, with the decline in rural crashes accounting for the major portion. In



*Percent change from 1973.

Figure 2.22 Injury Crashes in North Carolina - by Location.
(January through April)

1975, injury crashes remained below the level for 1973; however, urban injury crashes rose slightly above the 1973 level while rural crashes rose also but remained well below the 1973 figure.

Note: It could be argued that the changes observed during the energy crisis were simply a result of random variation in the processes that govern crash occurrence and crash severity. To better understand whether previous behavior was indeed interrupted, the total crash series (total number of crashes in North Carolina per month from 1962 through 1975) was analyzed by means of a time series model (see Appendix C). The same type of analysis was performed for the fatal crash series. As a result of this analysis, it can be concluded that changes observed in crashes during the energy crisis were not likely to be due to random variation.

Conclusions: Changes in the Number of Accidents

The following is a summary of observations that can be made from the data presented in this section:

1) There was a substantial reduction (10 percent) in the total number of crashes in North Carolina between 1973 and 1974.

2) The percentage decrease in fatal crashes (22 percent) during the energy crisis was greater than either the percentage decrease in total crashes (10 percent) or the percentage decrease in injury crashes (12 percent).

3) Comparing 1974 with 1973, rural crashes decreased more than urban crashes and weekend crashes decreased more than weekday crashes.

4) Of the decrease in fatal crashes between 1973 and 1974, the decrease in rural fatal crashes contributed more than the decrease in urban fatal crashes. The same is true of weekend fatal crashes as compared with weekday fatal crashes.

5) Decrements in both total and fatal crashes during the energy crisis were primarily due to respective declines in rural weekend crashes.

6) In urban areas, weekday crashes increased during the energy crisis while in rural areas, they decreased.

7) After the energy crisis (1975 compared with 1974), total crashes increased in all categories: urban, rural, weekday, and weekend; however, net decreases from 1973 remained in rural and weekend crashes, while net increases from 1973 persisted in urban and weekday crashes. Total crashes in 1975 were at the level of 1973.

8) Fatal crashes continued to decline from 1974 to 1975 -- urban and weekend fatal crashes increased somewhat, but rural and weekday crashes decreased considerably.

9) The number of injury crashes rose after the energy crisis; however, rural injury crashes increased less than urban injury crashes. This left a net increase in urban injury crashes in 1975 (as compared to 1973) and a net decrease in rural injury crashes in 1975 (as compared to 1973).

2.2.2 Changes in number of persons injured.

Data concerning the number of persons injured or killed in traffic accidents was again obtained from the North Carolina Traffic Accident Summary. During the investigation of a crash, the police officer classifies the injuries to the occupants as being O (none), C (slight), B (moderate), A (severe), or K (fatal). On January 1, 1973, a change in the definition of an A injury was introduced and this change produced a large decrease in the number of A injuries that were reported. However, since this time, there have been no substantial changes in the North Carolina accident report system, and therefore, comparisons of Injuries for the first four months of 1973, 1974, and 1975, respectively, are valid.

Table 2.4 gives the number of persons killed or injured in highway crashes in North Carolina in 1973, 1974, and 1975 by urban and rural location. As can be seen from the table, fatalities (K) decreased during the energy crisis by 114 (20 percent) throughout North Carolina. This trend continued through 1975 resulting in a total reduction of 27 percent between 1973 and 1975. The major portion of this reduction is attributable to a decrease in rural fatalities. However, it is interesting to note that there was no significant[1] change in the urban-rural distribution of fatal crashes during this period.

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[1]Because the information used includes all the crashes reported in North Carolina for 1973, 1974 and 1975, statistical tests are meaningful only in the sense that such a collection of crashes is assumed to represent a probabilistic sample taken from a larger population of crashes.

Table 2.4 Persons killed or injured in traffic accidents in North Carolina (January through April) by year and location.

Injury Severity	Population	Number of Persons 1973	1974	1975	Percent Change 73-74	74-75	73-75
K	All	560	446	407	-20.36[1]	- 8.74	-27.32
	Urban	99	60	67	-39.39	11.67	-32.32
	Rural	461	386	340	-16.27	-11.92	-26.25
	P[2]				0.068	0.218	0.620
A+K	All	4749	3621	3470	-23.75	- 4.17	-26.93
	Urban	1394	947	971	-32.07	2.53	-30.34
	Rural	3355	2674	2499	-20.30	- 6.54	-25.51
	P				0.001	0.083	0.175
Any Injury	All	22558	19319	21251	-14.36	10.00	- 5.79
	Urban	9588	8745	9927	- 8.79	13.52	3.54
	Rural	12970	10574	11324	-18.47	7.09	-12.69
	P				0.000	0.003	0.000

[1] Percent change: $\frac{446-560}{560} \times 100 = -20.36$

[2] P-value associated with the corresponding χ^2 (1 d.f.)

The number of fatal or serious injuries (K or A) occurring in highway crashes in North Carolina is also given in Table 2.4. A similar pattern is evident as was the case with persons killed, with the exception that between 1973 and 1974 there was a significant change in the location distribution. This change is a consequence of the smaller percentage of urban fatal or serious injuries in 1974.

Total injuries of any severity (K,A,B, or C) are presented at the bottom of Table 2.4. These results are very similar to those in Table B.6, which reports on the number of injury crashes. Thus, changes in total injuries were very similar to changes in total crashes in 1974 and 1975. At this level of conglomeration significant changes in the urban-rural distribution are observed for both periods 1973-1974 and 1974-1975.

In conclusion, the following can be said concerning changes in the number of persons injured:

1) Fatalities experienced continuing decreases in 1974 and 1975.

2) Serious injuries experienced a pattern of decreases very similar to that of fatalities.

3) Total injuries showed a small net decrease from 1973 to 1975. This was a result of a substantial decrease in rural injuries and a small increase in urban injuries.

2.2.3 Changes in crash severity.

To determine the extent of changes in crash severity, three measures of crash severity were examined:

a) Driver Injury:

For each vehicle involved in a crash, the driver's injury is coded by the investigating police as K, A, B, C, or O. The distribution of driver injury is a measure of crash severity which is insensitive to vehicle occupancy changes, but which is sensitive to changes in the types of crashes that occur.

b) Most Severe Injury:

The second measure of crash severity to be considered is the most severe injury sustained in the crash. MSI will be used to denote "most severe injury." If the crash involves more than one vehicle, a bicyclist, or a pedestrian, then all persons involved are considered in determining the most severe injury. Driver injury is a vehicle-oriented severity measure, whereas MSI is a crash-oriented measure. In the HSRC accident files, MSI is coded: 0 (uninjured), C (slight injury), A or B (severe or moderate injury), or K (fatal injury).

c) TAD Severity:

The TAD (Traffic Accident Data) severity index is a measure of the amount of deformation to the body of a passenger car which is caused by the crash. The index takes on the values 1, 2, 3, 4, 5, 6 or 7, where a value of 1 indicates very slight deformation and a value of 7 indicates extensive damage to the vehicle. During the period 1973 through 1975, the TAD severity index was being coded and placed on the accident report form by all highway patrol officers and many city police.

Table 2.5 gives the distribution of driver injuries for all crashes (urban and rural) in North Carolina during the first four months of 1973, 1974, and 1975. A reduction in the number of crashes can be observed from 1973 to 1975 -- both overall and within urban and rural categories. These reductions resulted from a large reduction between 1973 and 1974 and a partial "recovery" between 1974 and 1975.

For a more precise examination of this data, a ridit analysis (see Bross, 1958) was utilized. From the year-by-year mean ridits, one can see a statistically significant change from 1974 to 1975). This "shift" in severity appears to be a partial contradiction to the observed trend of decreasing fatalities (both for urban and rural crashes) over the three-year period due to the decrease in property damage only accidents. However, looking at the within-year percent distributions of driver injury severity (conditional probabilities), it is clear that these percentages have changed differentially from 1973 to 1975, depending on the severity level. Reduction in the property damage only (0) level is much more sizable in terms of the overall proportion than reductions in A and K level injuries. Notice that these reductions are, as expected, accompanied by corresponding increases in levels B and C. In summary

Table 2.5 Number of drivers by year, location, and injury severity.

Driver Injury Severity	Population	Number of Drivers			Change in Distribution		
		1973	1974	1975	73-74	74-75	73-75
O	All	62937	51716	56399	- 1.40[1]	0.23	- 1.17
	Urban	30855	27799	30097	- 1.40	0.00	- 1.40
	Rural	32082	23917	26302	- 1.89	0.50	- 1.39
C	All	5399	4797	5450	0.45	0.33	0.78
	Urban	2622	2563	2910	0.49	0.38	0.87
	Rural	2777	2234	2540	0.37	0.30	0.67
B	All	4904	4784	5180	1.07	- 0.03	1.04
	Urban	1840	2111	2242	1.28	- 0.12	1.16
	Rural	3064	2673	2938	1.09	0.05	1.14
A	All	2623	2130	1994	- 0.10	- 0.46	- 0.56
	Urban	779	609	567	- 0.32	- 0.26	- 0.58
	Rural	1844	1521	1427	0.37	- 0.70	- 0.33
K	All	392	311	291	- 0.02	- 0.07	- 0.09
	Urban	62	39	43	- 0.05	0.00	- 0.05
	Rural	330	272	248	0.07	- 0.15	- 0.08
Total	All	76255	63738	69314	-16.41[2]	8.75	- 9.10
	Urban	36158	33121	35859	- 8.40	8.27	- 0.83
	Rural	40097	30617	33455	-23.64	9.27	-16.56
Mean Ridit	All	0.4962	0.5031	0.5013	0.00[3]	0.28	0.00
	Urban	0.4956	0.5025	0.5022	0.00	0.87	0.00
	Rural	0.4951	0.5048	0.5014	0.00	0.14	0.00

[1] $\frac{51716}{63738} \times 100 - \frac{62937}{76255} \times 100 = -1.40$

[2]Percent change: $\frac{63738 - 76255}{76255} \times 100 = -16.41$

[3]P-value for the corresponding differences of mean ridits (normal approximation).

there was a net reduction in K, A, and 0 levels with a corresponding increase in the B and C categories, resulting in a tightening or narrowing of the injury distribiton.

The distributions of MSI for all crashes (urban and rural) in North Carolina during the first four months of 1973, 1974 and 1975 are presented in Table 2.6. An analysis of this information basically reinforces the conclusions already drawn from the analysis of driver injury severity.

Table 2.7 gives the TAD severity distribution for that subset of crashes in North Carolina (first four months of 1973, 1974 and 1975) for which the TAD index was reported. The ridit analysis of this vehicle-oriented measure of severity shows a statistically significant reduction over all three years for the total and rural categories. The urban category indicates a significant increase in severity from 1973 to 1974 coupled with a significant decrease from 1974 to 1975, resulting in a non-significant net difference between 1973 and 1975.

Closer examination of Table 2.7 reveals an enormous (571%) increase in the number of urban crashes for which TAD severity was reported. A large proportion of this increase between 1973 and 1975 is due to an increase in the number of city police officials using the TAD index. Since the difference between new and established TAD users may be a source of distributional changes quite independent of the energy crisis, it is suggested that one exercise caution when considering any conclusions drawn from the analysis of the urban TAD distribution.

In summary, driver injury severity and most severe injury both indicate the 1974 distributions to be more concentrated in the intermediate severity levels than the 1973 distributions. No significant changes occurred in these distributions between 1974 and 1975. The third measure, TAD severity, exhibits a general shift toward lower levels of vehicle damage severity.

2.2.4 Changes in driver characteristics.

Age and Sex

It has been suggested that the energy crisis reduced pleasure driving, and thus the number of teenage drivers on the road. A reduction

Table 2.6 Number of crashes by year, location, and most severe injury (MSI).

Most Severe Injury	Population	Number of Crashes 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
O	All	29751	24397	26808	- 1.84[1]	0.42	-1.42
	Urban	13834	12383	13358	- 1.90	-0.28	-2.18
	Rural	15917	12014	13450	- 2.20	1.13	-1.07
C	All	5391	4723	5347	0.48	0.47	0.95
	Urban	2662	2542	2874	0.52	0.62	1.14
	Rural	2729	2181	2473	0.27	0.35	0.62
A or K	All	8133	7365	7732	1.39	-0.77	0.62
	Urban	2938	2971	3153	1.50	-0.34	1.16
	Rural	5195	4394	4579	1.78	-1.22	0.56
K	All	465	380	364	- 0.03	-0.13	-0.16
	Urban	74	47	51	- 0.12	0.00	-0.12
	Rural	391	333	313	0.15	-0.26	-0.11
Total	All	43740	36865	40251	-15.72[2]	9.18	-7.98
	Urban	19508	17943	19436	- 8.02	8.32	-0.37
	Rural	24232	18922	20815	-25.11	13.59	-8.16
Mean Ridit	All	0.4950	0.5045	0.5013	0.000[3]	0.119	0.002
	Urban	0.4932	0.5032	0.5039	0.000	0.818	0.000
	Rural	0.4950	0.5068	0.4997	0.000	0.015	0.085

[1] $\frac{24397}{36865} \times 100 - \frac{29751}{43740} \times 100 = -1.84$

[2] Percent change: $\frac{36865 - 43740}{43740} \times 100 = -15.72$

[3] P-value for the corresponding difference of mean ridits (normal approximation).

Table 2.7 Number of cars with TAD rating by year, location, and TAD severity.

TAD	Population	Number of Cars with TAD 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
1	All	7998	6867	11121	2.43[1]	1.57	4.00
	Urban	654	2222	4006	- 5.22	2.09	-3.13
	Rural	7344	4645	7115	2.28	1.20	3.48
2	All	7349	5936	9317	0.65	0.54	1.19
	Urban	426	1916	3295	3.06	0.51	3.57
	Rural	6923	4020	6022	- 0.03	0.48	0.45
3	All	5680	4316	6635	- 0.64	0.01	-0.63
	Urban	222	1179	2053	2.09	0.52	4.61
	Rural	5458	3137	4582	- 0.22	-0.12	-0.34
4	All	4304	3282	4645	- 0.44	-1.08	-1.52
	Urban	285	998	1516	- 1.87	-1.37	-3.24
	Rural	4019	2284	3129	- 0.31	-0.94	-1.25
5	All	2174	1573	2280	- 0.57	-0.38	-0.95
	Urban	81	460	692	1.90	-0.69	1.21
	Rural	2093	1113	1588	- 0.63	-0.19	-0.82
6	All	1647	1106	1565	- 0.80	-0.37	-1.17
	Urban	96	331	462	- 0.70	-0.79	-1.49
	Rural	1551	775	1103	- 0.77	-0.15	-0.92
7	All	985	626	853	- 0.63	-0.30	-0.93
	Urban	58	140	204	- 1.25	-0.26	-1.51
	Rural	927	486	649	- 0.32	-0.27	-0.59
Total	All	30137	23706	36416	-21.34[2]	53.62	20.83
	Urban	1822	7246	12228	297.70	68.76	571.13
	Rural	28315	16460	24188	-41.87	46.95	-14.58
Mean Ridit	All	0.5190	0.4988	0.4850	0.00[3]	0.00	0.00
	Urban	0.4962	0.5120	0.4935	0.04	0.00	0.70
	Rural	0.5135	0.4967	0.4864	0.00	0.00	0.00

[1] $\frac{6867}{23706} \times 100 - \frac{7998}{30137} \times 100 = 2.43$

[2] Percent change: $\frac{23706 - 30137}{30137} \times 100 = -21.34$

[3] P-value for the corresponding differences of mean ridits (normal approximation).

in young male drivers might account in part for reduced accidents and fatalities during the crisis. As no data regarding the population at risk is available, an analysis was made of the age and sex of drivers involved in accidents before, during, and after the energy crisis to identify changes in the accident driver population.

Table 2.8 shows the distribution of accident-involved drivers by age and sex for the first four months of 1973, 1974 and 1975, respectively. Examination of the total figures for all drivers indicates a 16 percent reduction in the number of drivers involved in accidents from 1973 to 1974. However, an increase in this figure in 1975 led to a net reduction of 7 percent for the period 1973 to 1975. This resulted from different patterns of change by sex. The reduction of female drivers involved in crashes in North Carolina from 1973 to 1974 was almost exactly compensated for by an increase from 1974 to 1975. For male drivers, more than half of the original 1974 reduction remained by 1975. Also, while there was a greater proportion of male drivers in accidents in all three periods, there was a statistically significant ($p < .001$) shift toward a greater proportion of female drivers involved in accidents (29.4 percent in 1973, 30.9 percent in 1974, and 31.8 percent in 1975). Whether this is a result of the energy crisis, or is indicative of a long term shift reflecting cultural and economic changes in the status of women is impossible to determine.

Comparing the 1973 and 1974 overall age distributions, one finds a significant difference between the mean ages (33.35 vs 33.57, respectively). This shift is statistically significant for females but non-significant for males (at $\alpha = 0.05$). There is no significant change in mean ages from 1974 to 1975.

In addition, in 1973, 7.20 percent of all crashes involving male drivers were single vehicle crashes in which the driver's age was under 30; in 1974 the figure was 6.41 percent and in 1975 it was 7.63 percent. This suggests that there was a tendency to discourage frivolous travel by young drivers, and this discouragement probably accounted for some of the reduction in fatalities.

Table 2.8 Number of drivers involved in accidents in North Carolina by year, age, and sex. (January through April)

Age	Population	Number of Drivers 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
16-25	All	33235	27425	30280	- 0.61[1]	-0.10	- 0.71
	Male	23922	19370	21039	- 0.48	-0.26	- 0.74
	Female	9313	8055	9241	- 0.78	0.33	- 0.45
26-35	All	16642	14156	16140	0-34	0.66	1.00
	Male	11437	9458	10797	0.21	0.94	1.15
	Female	5205	4698	5343	0.54	-0.01	0.53
36-45	All	10611	8593	9158	- 0.45	-0.49	- 0.94
	Male	7084	5715	5884	- 0.19	-0.73	- 0.92
	Female	3527	2878	3274	- 1.15	0.00	- 1.15
46-55	All	8623	7442	7812	0.34	-0.59	- 0.25
	Male	6064	5029	5263	0.14	-0.47	- 0.33
	Female	2559	2413	2549	0.78	-0.86	- 0.08
56-65	All	5578	4730	5439	0.09	0.28	0.37
	Male	4066	3323	3774	- 0.01	0.29	0.28
	Female	1512	1407	1665	0.37	0.28	0.63
66-75	All	2471	2175	2507	0.16	0.14	0.30
	Male	1867	1602	1816	0.16	0.13	0.29
	Female	604	573	691	0.20	0.17	0.37
76+	All	646	619	758	0.12	0.10	0.22
	Male	525	502	601	0.16	0.11	0.27
	Female	121	117	157	0.05	0.10	0.15
Total	All	77806	65140	72094	-16.28[2]	10.68	- 7.34
	Male	54965	44999	49174	-18.13	9.28	-10.54
	Female	22841	20141	22920	-11.82	13.80	0.35
Mean Ridit	All	33.35	33.57	33.58	.007[3]	.901	.004
	Male	33.40	33.58	33.61	.060	.777	.027
	Female	33.24	33.54	33.51	.033	.842	.047

[1] $\frac{33235}{77806} \times 100 - \frac{27425}{65140} \times 100 = -0.61$

[2] Percent change: $\frac{65140 - 77806}{77806} \times 100 = -16.28$

[3] P-value for the corresponding differences of mean values (normal approximation)

Thus, it appeared that during the energy crisis there was a sligh; shift toward older drivers. Also, there was a shift (not necessarily affected by the energy crisis) toward an increasing proportion of female drivers -- at least in accidents.

Driver Violations by Sex

HSRC accident files were used to obtain frequencies for traffic violations of accident-involved drivers (including bicyclists) as noted by the investigating officers. Table B.7 presents these frequencies for the first violation noted (usually the worst) for the first four months of 1973, 1974, and 1975. Table 2.9 (extracted from Table B.7) presents the most prevalent violation categories.

While the tables show relatively slight differences in the distributions for the three years, Chi-square tests comparing 1973 and 1974, 1973 and 1975, and all three years combined indicate differences in the three distributions. Referring to Table B.7, it can be observed that all violations decreased numerically from 1973 to 1974 with the exception of 'speeding 65-75', 'improper turn', 'drinking', and 'improper lights and brakes'. However, just as with the severity distributions of the previous section, if one examines the within-year percent distributions of driver violations, it is clear that these percentages have changed differentially depending on the violation. Examination of the violation categories presented in Table 2.9 indicates a relative decrease (in terms of overall proportion) in all categories except 'didn't look', where there was a corresponding proportional increase (despite a numerical decrease in frequency). Overall, there was a 13.9 percent reduction in the number of total violations of accident-involved drivers from 1973 to 1974.

Of interest is the decrease in the number of drivers speeding over 75. Although speeding over 75 accounts for only a very small proportion of total violations and therefore the distributional change was minor, the decrease in frequency represents a 38 percent reduction. This reduction is not surprising as North Carolina law provides an especially stiff penalty for speeding more than 15 mph over the posted limit. Thus, the 55 mph limit would probably cause many drivers in the over 75 mph

Table 2.9 Violations of accident involved drivers in North Carolina (January through April).

Violation	Population	Number of Violations 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
Speeding	Total	8881	7227	7345	- 1.36[1]	-1.77	-3.12
	Male	6915	5622	5669	- 0.78	-1.98	-2.70
	Female	1720	1324	1351	- 2.34	-1.58	-3.92
Failed to Yield	Total	4682	3719	3988	- 1.01	-0.30	-1.37
	Male	2962	2266	2411	- 0.99	-0.26	-1.20
	Female	1664	1388	1531	- 0.99	-0.45	-1.44
Driving Wrong Side	Total	3049	2341	2608	- 0.92	0.09	-0.82
	Male	2235	1651	1872	- 1.02	0.30	-0.72
	Female	716	554	605	- 0.94	-0.24	-1.18
Following too Close	Total	2807	2134	3078	- 0.91	2.13	1.22
	Male	2034	1541	2174	- 0.75	2.09	1.34
	Female	744	555	859	- 1.22	2.41	1.19
Didn't Look	Total	7923	7833	9496	3.24	2.56	5.80
	Male	5299	4996	6094	2.59	2.73	5.32
	Female	2530	2670	3257	5.17	2.41	7.58
Other Violations	Total	8839	7910	7770	0.95	-2.72	-1.77
	Male	6299	5480	5304	0.95	-2.87	-1.92
	Female	2119	1900	1912	0.32	-2.55	-2.23
Total	Total	36181	31164	34285	-13.87[2]	10.01	-5.24
	Male	25744	21556	23524	-16.27	9.13	-8.62
	Female	9493	8391	9515	-11.61	13.40	0.23

[1] $\frac{7227}{31164} \times 100 - \frac{8881}{36181} \times 100 = -1.36$

[2] Percent change: $\frac{31164-36181}{36181} \times 100 = -13.87$

category to move into the 65-75 mph category, accounting for the increase in the number of violations observed in that category in 1974.

From 1974 to 1975 the trend was reversed, with the number of violations increasing in all categories except 'improper turn'. Despite these numerical increases, Table 2.9 indicates that 'speeding' and 'failed to yield' categories continued to decline in proportion of total violations. Overall, the total number of violations increased by 10.0 percent between 1974 and 1975, resulting in a net reduction of 5.2 percent over 1973.

'Following too closely' exhibited a large increase in 1975 to effect a net increase over 1973. This behavior may reflect the reduced speed and traffic densities of 1974 (contributing to a low incidence of 'following too closely'), followed by the return of a larger volume of vehicles in 1975 still traveling at reduced speeds. This latter combination would increase traffic density, with following-too-closely accidents being a likely consequence of the increased density.

It is evident from Tables B.7 and 2.9 (which include bicyclists) that much of the 1974 reduction in total violations was due to reductions in the number of males cited (down 16.3 percent). It should be noted that 2.7 times as many males were cited for violations in 1973 as females. This ratio decreased slightly in 1974 to 2.6 and in 1975 to 2.5, as might be expected from the increase in the percentage of accident-involved drivers whowere female.

Aside from the large difference in proportion of male and female drivers cited for violations, Table 2.9 indicates that the patterns of distributional changes for each subpopulation were very similar to that for the total population. That is, in 1974 decreases can be observed in most violation categories for both males and females. Likewise, in 1975 increases occurred in most categories for both subpopulations. The net result for both males and females was a lower incidence of 'speeding', 'failed to yield', and 'driving on the wrong side' violations, while the number of 'following too closely' and 'didn't look' violations exceeded 1973 figures.

Conclusions: Driver Characteristics

The analyses in this section lead to the following conclusions about changes in accident driver characteristics and violations in North Carolina during the energy crisis:

1) There was a slight shift toward older drivers during the three year period, and an increase in the proportion of females.

2) The number of drivers speeding between 65-75 mph increased, probably due to the decrease in the number speeding over 75. The number speeding under 65 also decreased.

3) The proportion of 'following too closely' and 'didn't look' accidents increased.

3. FURTHER ANALYSIS OF CHANGES

In the previous chapter, it was shown that the highway environment experienced substantial changes during and after the energy crisis. Vehicle volumes and speeds decreased, crashes decreased, and the nature of the drivers in accidents changed. In this chapter, these changes will be examined in more detail in order to better understand some of the factors that were responsible for the changes observed. Since data on exposure is not available, it is impossible to compare changes in the accident population with those in the vehicle population. Nevertheless, it seems appropriate to study in a more detailed manner changes in accident characteristics and to examine their implications in terms of possible causative factors.

In Section 3.1, crash rates are considered and analyzed, while in Section 3.2, changes in accident severity are studied using a variety of severity measures. In Section 3.3, changes by type of road are considered. Specifically, Interstate roads are examined for possibly distinctive characteristics. Trucks and bus crashes are presented and analyzed in Section 3.4. Finally, in Section 3.5, other changes of interest are examined.

3.1 Crash Rates

It has been observed in Chapter 2 that fewer drivers were on the highways during the fuel shortage period. This decrease in vehicle volume would account for some of the decrease in crashes and fatalities. In this section, crash rates per 100 million vehicle miles and per unit traffic volume will be examined to determine if there were changes in addition to those that would be expected from decreasing traffic volumes.

3.1.1 Crash rates per 100 million vehicle miles.

In this section total, fatal and injury crash rates based on vehicle mileage are examined. These rates were obtained by dividing the corresponding accident counts by the estimated mileage for the entire state. As indicated in Section 2.1.1, the mileage estimates must be considered with caution as they are computed on the basis of average miles per gallon of fuel sold. Any lag in the time at which gasoline sales are reported and the actual consumption of the fuel may distort the monthly mileage figures. Furthermore, 1974 witnessed a shift to more fuel-efficient vehicles, and any underestimation (or overestimation) of the actual miles per gallon achieved would also result in erroneous mileage figures. Thus, any crash rates based on these estimates should be viewed with caution. Even with these limitations, however, the analysis that follows should still provide some insight into the manner in which crash rates were changing before, during, and after the energy crisis.

Figure 3.1 displays a plot of total, fatal, and injury (including fatal) crash rates for the first four months of the years 1962 through 1975. Notice that the ordinate on the left applies to total and injury crash rates, while the ordinate on the right corresponds to the fatal crash rate. All figures represent crashes per 100 million vehicle miles. With the exception of a drop in 1967 (following a large increase the year before), the total crash rate exhibits an upward trend between 1962 and 1971. In 1972, this rate dropped 14.4 percent from the previous year and continued to fall in 1973. It is interesting to note that the upward trend in the total crash rate was interrupted two years before the energy crisis.

An examination of the fatal crash rate does not reveal any obvious changes that might be directly related to the energy crisis. The fatal crash rate has decreased in a roughly linear fashion since 1966, with a 13.1 percent drop between 1973 and 1974. This downward trend is no doubt responsible for a large portion of the rate reduction during the energy crisis. The injury crash rate also appears to have decreased steadily after 1966. However, this trend appears to have been displaced upwards in 1973, a full year before the energy crisis.

In order to further examine the trends in the total and fatal crash rates, monthly rates were computed for the years 1968 through 1975. Both series were smoothed using a six term moving average so that trends would not be obscured by month-to-month variation. The resulting series for the period April, 1968 through October, 1975 are displayed in Figures 3.2 and 3.3. These plots tend to confirm the

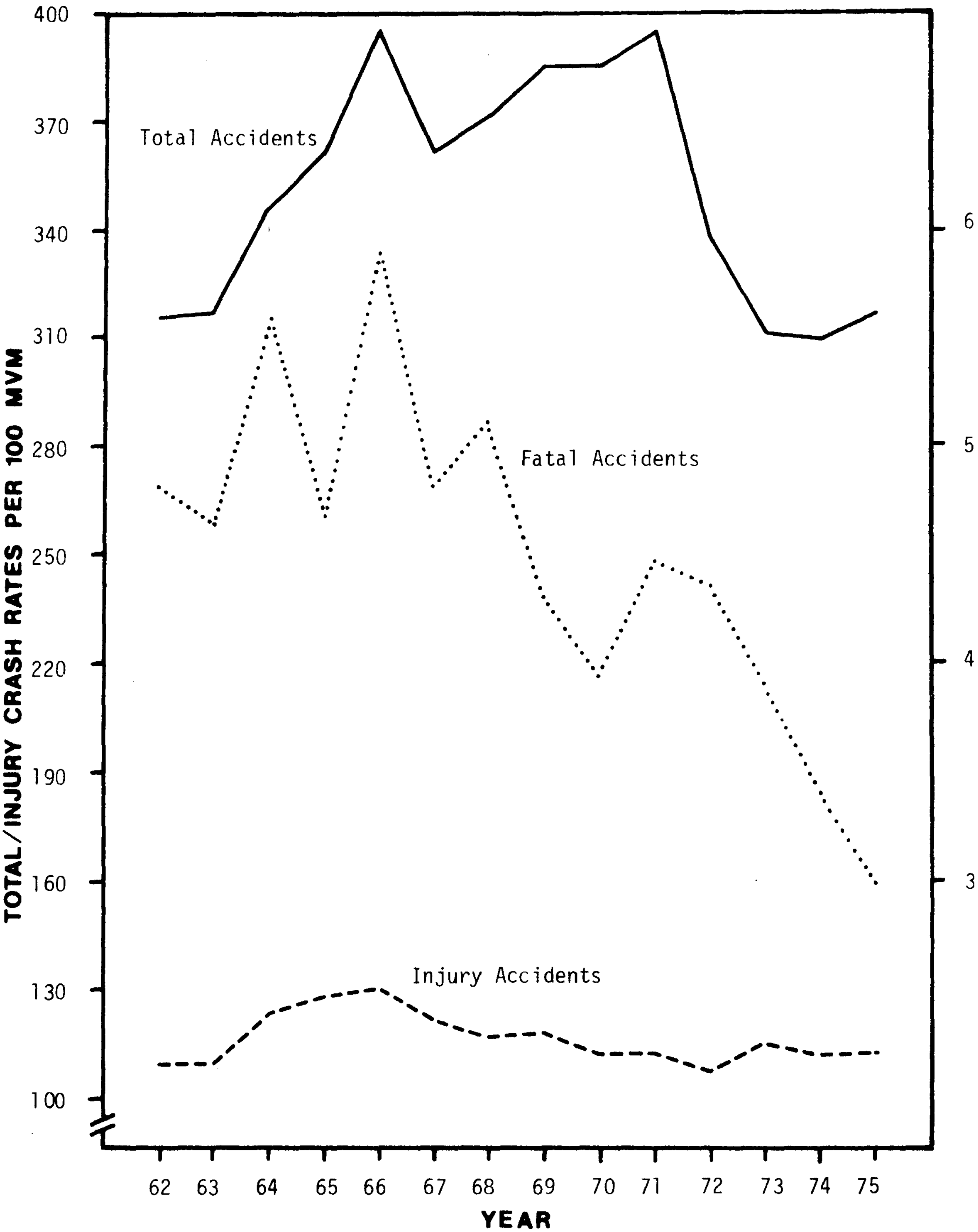


Figure 3.1. Crash rates per 100 MVM (January through April).

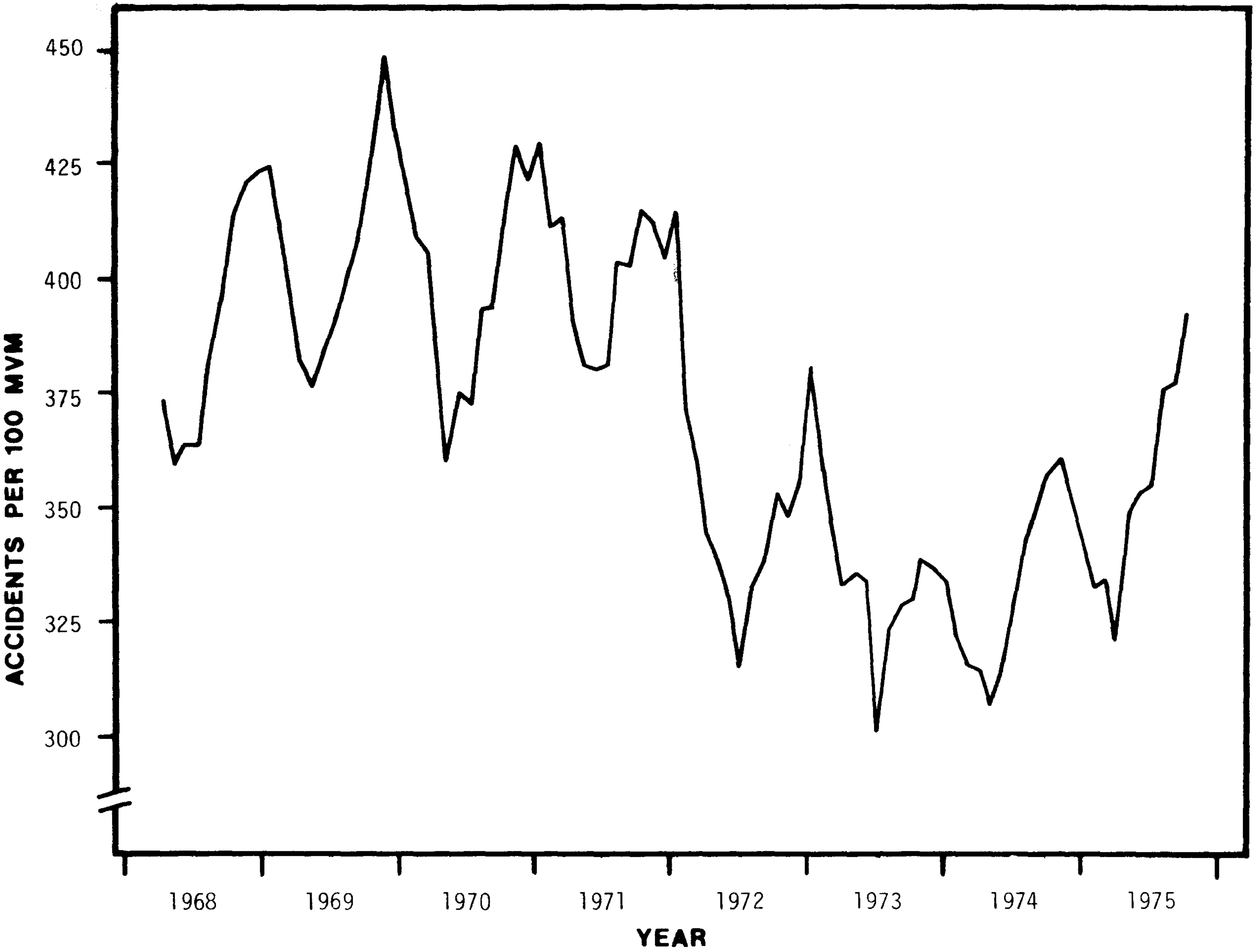
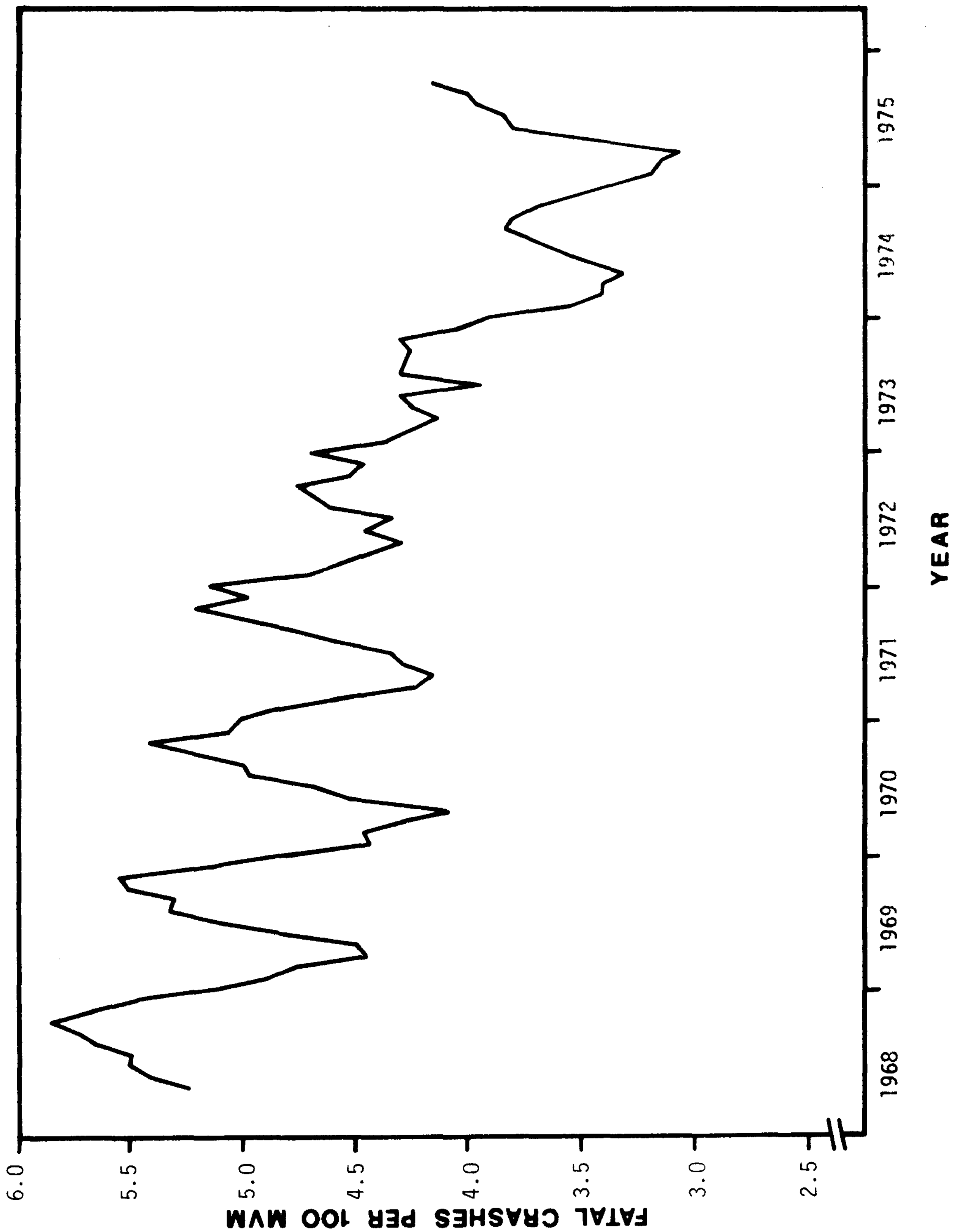


Figure 3.2. Smoothed total crash rate per 100 MVM.


FATAL CRASHES PER 100 MVM
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
YEAR
1968
1969
1970
1971
1972
1973
1974
1975

earlier observations, namely, that the upward climb of the total crash rate was interrupted early in 1972, and that the fatal crash rate has been decreasing in a linear fashion since at least 1968.

The observations presented above tend to suggest that there has been a decrease in the crash rates for various severity levels throughout most of the years between 1968 and 1975. Furthermore, due to the time at which changes were observed (often one or two years prior to the gas shortage), they also suggest the presence of factors in addition to the energy crisis.

3.1.2 Ratio of crashes to traffic counts.

A second measure of the crash rate is the ratio of crashes to average daily traffic counts (ADT). The assumption will be made that the ADT figures presented in Section 2.1.2 are representative of traffic volumes for their respective time periods and roadways in North Carolina. Although the actual value of the ratio will not be meaningful in an absolute sense, the ratio will be proportional to the actual crash rate if this assumption holds, and comparisons can be made between 1973, 1974 and 1975. Since ADT data is available on a more accurate and specific basis than vehicle mileage data, more specific inferences can be made concerning the crash rates for various time periods and roadways. Unfortunately, ADT data is not available for the years prior to 1973, thereby preventing the examination of any long-term trends in these ratios. Thus, while the rates presented in this section will be discussed in terms of percentage change from year to year, the reader must keep in mind that based on the analysis of crash rates per 100 vehicle miles, downward trends had already been established. This implies that changes occurring during 1974 may not necessarily be related only to the energy crisis, but rather partially a continuation of previous patterns.

Table 3.1 presents the ratios of total and fatal crashes to ADT for several different time/location categories. As was the case in the previous section, the overall total crash rate dipped slightly during the fuel shortage, and then increased 6.6 percent in 1975. The rural-weekend total crash rate experienced a substantial increase in 1974,

Table 3.1. Ratio of crashes to average daily traffic counts.

Population		Crash Rate			Percent Change		
		1973	1974	1975	73-74	74-75	73-75
Overall	Total	5.65	5.59	5.96	- 1.06[2]	6.62	5.49
	Fatal[1]	7.07	6.13	5.61	-13.30	- 8.48	-20.65
Urban	Total	1.47	1.50	1.73	2.04	15.33	17.69
	Fatal	0.75	0.47	0.54	-37.33	14.89	-28.00
Rural	Total	3.59	3.33	3.39	- 7.24	1.80	- 5.57
	Fatal	6.79	6.33	5.43	- 6.77	-14.22	-20.03
Weekday	Total	3.24	3.29	3.63	1.54	10.33	12.04
	Fatal	3.38	3.24	2.79	- 4.14	-13.89	-17.46
Weekend	Total	2.36	2.31	2.31	- 2.12	0.00	- 2.12
	Fatal	3.72	3.03	2.92	-18.55	- 3.63	-21.51
Urban-Weekday	Total	0.86	0.89	1.05	3.49	17.98	22.09
	Fatal	0.38	0.27	0.27	-28.95	0.00	-28.95
Urban-Weekend	Total	0.61	0.60	0.71	- 1.64	18.33	16.39
	Fatal	0.38	0.20	0.31	-47.37	55.00	-18.42
Rural-Weekday	Total	1.99	1.80	1.99	- 9.55	10.56	0.00
	Fatal	3.21	3.31	2.73	3.12	-17.52	-14.95
Rural-Weekend	Total	1.57	2.01	1.39	28.03	-30.85	-11.46
	Fatal	3.53	3.12	2.71	-11.61	-13.14	-23.23

[1] All fatal crash rates have been multiplied by 100.

[2] Percent change: $\frac{5.59-5.65}{5.65} \times 100 = -1.06$

which is opposite to what one might have expected for this category. In 1975, increases can be observed in the total crash rates for all categories except rural, weekend, and rural-weekend.

The overall fatal crash ratio is also consistent with that presented in the previous chapter in that a decrease occurred for both 1974 and 1975. With the exception of the rural-weekday fatal crash rate, all other categories experienced decreases during 1974, with the largest reductions occurring on urban roads. In 1975, the urban-weekend fatal crash ratio rose substantially, while the rates for rural roads declined.

It has been assumed in other studies that when the fatal crash rate for a particular population experienced a greater percentage decrease than the corresponding total crash rate, a decrease in accident severity could be noted for that population. Based on that assumption, it is apparent from Table 3.1 that rural-weekday accidents became more severe during the energy crisis period, while urban-weekday, urban-weekend and rural-weekend accidents increased in severity following the fuel shortage.

3.2 Crash Severity

In Section 2.2.3, it was observed that changes have occurred in crash severity. Changes in crash severity were further suggested in the preceding section on crash rates. This section presents a more detailed analysis of these changes in crash severity, using the following four measures (or indicators) of severity:

a) Driver Injury
b) Most Severe Injury (MSI)
c) TAD Severity
d) Estimated Speed Prior to Impact (ESPI)

3.2.1 Driver injury.

The decrease in the maximum speed limit from 60 and 55 mph to 55 mph in North Carolina would presumably have a lasting effect only on those roads where the posted speed limit (PSL) actually changed. Therefore, to examine the effect of the decrease in the maximum speed limit, it would be useful to examine separately characteristics of crashes on roads which experienced a change in the PSL and roads on which there was no change in the PSL. Unfortunately, the data available do not allow one to determine whether a crash occurred on a stretch of road where the PSL was changed.

Table 3.2 shows the driver injury distribution for three classes of rural roads: Interstate, PSL greater than or equal to 55; rural primary, PSL greater than or equal to 55; and rural primary, PSL less than 55, where rural primary roads are defined to be U.S. and N.C. highways. This table indicates that a significant increase in severity (as measured by driver injury) occurred between 1973 and 1974 on rural primary highways with PSL greater than or equal to 55. The majority of the increased severity is due to a large reduction in the number of uninjured drivers accompanied by an increase in the proportion of intermediate level injuries. This initial increase reverted back in 1975 to the net result of a tighter or narrower injury distribution.

3.2.2 Most severe injury.

Table 3.3 is analogous to Table 3.2 except that the most severe injury occurring in the crash is used as the measure of crash severity. The distributional changes for most severe injury are quite similar to those for the driver injury distribution. Rural primary roads with PSL greater than or equal to 55 exhibit a significant (at $\alpha = 0.10$) increase in MSI from 1973 to 1974, followed by a similar decrease in severity in 1975. As with driver injury, this change is explained in large part by a reduction in the proportion uninjured and an increase in the proportion of B or A level injuries.

3.2.3 TAD severity.

In Section 2.2.3, TAD as a measure of accident severity was discussed and the TAD severity distributions by road type were examined. In this section, TAD distributions are presented for Interstate and rural primary highways, and the distributions of driver injuries (conditional on the TAD levels) are examined. As before, rural primary roads are defined to be U.S. and N.C. highways.

Table 3.2 Driver injury distributions for three classes of rural roads.

ver ury	Population	Injury Distribution			Percent Change		
		1973	1974	1975	73-74	74-75	73-75
O	Interstate, PSL[1]≥55	77.71[2]	74.68	77.94	- 3.90[3]	4.37	0.30
	Rural Primary, PSL≥55	77.78	76.23	76.93	- 1.98	0.92	- 1.09
	Rural Primary, PSL<55	84.42	83.76	83.61	- 0.78	- 0.18	- 0.96
C	Interstate, PSL≥55	7.17	9.87	7.45	37.66	-24.52	3.91
	Rural Primary, PSL≥55	7.77	8.07	8.39	3.86	3.97	7.98
	Rural Primary, PSL<55	6.76	7.01	6.89	3.70	- 1.71	1.92
B	Interstate, PSL≥55	7.94	8.58	9.02	8.06	5.13	13.60
	Rural Primary, PSL≥55	8.12	8.98	9.21	10.59	2.56	13.42
	Rural Primary, PSL<55	5.56	5.73	6.50	3.06	13.44	16.91
A	Interstate, PSL≥55	5.87	4.72	4.31	-19.59	- 8.69	-26.58
	Rural Primary, PSL≥55	5.31	5.59	4.56	5.27	-18.43	-14.12
	Rural Primary, PSL<55	2.78	3.02	2.53	8.63	-16.23	- 8.99
K	Interstate, PSL≥55	1.30	2.15	1.27	65.38	-40.93	- 2.31
	Rural Primary, PSL≥55	1.01	1.13	0.91	11.88	-19.47	- 9.90
	Rural Primary, PSL<55	0.48	0.48	0.48	0.00	0.00	0.00
tal	Interstate, PSL≥55	1687	932	1020	-44.75	9.44	-39.54
	Rural Primary, PSL≥55	14296	10122	11382	-29.20	12.45	-20.38
	Rural Primary, PSL<55	8891	7142	7358	-19.67	3.02	-17.24
an dit	Interstate, PSL≥55	.4973	.5105	.4948	.26[4]	.23	.83
	Rural Primary, PSL≥55	.4967	.5047	.4999	.03	.23	.37
	Rural Primary, PSL<55	.4977	.5011	.5017	.46	.89	.38

[1]Posted speed limit

[2]Column percent

[3]Percent change: $\frac{74.68-77.71}{77.71} \times 100 = -3.90$

[4]P-value for corresponding difference of mean ridits (normal approximation)

Table 3.3 Most severe injury (MSI) distribution for three classes of rural roads.

MSI	Population	MSI Distribution 1973	1974	1975	Percent Change 73-74	74-75	73-75
O	Interstate, PSL[1]≥55	62.34[2]	60.10	65.78	- 3.59[3]	9.45	5.52
	Rural Primary, PSL≥55	62.78	61.28	62.71	- 2.39	2.33	- 0.11
	Rural Primary, PSL<55	70.22	68.92	68.63	- 1.85	- 0.42	- 2.26
C	Interstate, PSL≥55	11.33	14.69	11.06	29.65	24.71	- 2.38
	Rural Primary, PSL≥55	12.21	12.50	12.47	2.38	- 0.24	2.13
	Rural Primary, PSL<55	12.08	12.82	12.80	6.13	- 0.16	5.96
B or A	Interstate, PSL≥55	23.57	21.54	20.35	- 8.61	- 5.53	-13.66
	Rural Primary, PSL≥55	22.98	24.05	22.97	4.66	- 4.49	- 0.04
	Rural Primary, PSL<55	16.66	17.32	17.62	3.96	1.73	6.24
K	Interstate, PSL≥55	2.76	3.67	2.80	32.97	-23.71	1.45
	Rural Primary, PSL≥55	2.03	2.17	1.85	6.90	-14.75	- 8.87
	Rural Primary, PSL<55	1.04	0.95	0.94	- 8.65	- 1.05	- 9.62
Total	Interstate, PSL≥55	1086	599	678	-44.84	13.19	-37.57
	Rural Primary, PSL≥55	8518	6178	6977	-27.49	12.93	-18.09
	Rural Primary, PSL<55	4718	3800	3921	-19.46	3.18	-16.89
Mean Ridit	Interstate, PSL≥55	.5033	.5109	.4850	.60[4]	.11	.20
	Rural Primary, PSL≥55	.4978	.5058	.4976	.10	.10	.96
	Rural Primary, PSL<55	.4957	.5018	.5034	.33	.80	.22

[1]Posted speed limit

[2]Column percent

[3]Percent change: $\frac{60.10-62.34}{62.34} \times 100 = -3.59$

[4]P-value for corresponding difference of mean ridits (normal approximation)

As indicated by the ridit analysis in Section 2.2.3, TAD severity decreased uniformly for rural roads between 1973 and 1975 (see Table 2.7). Table 3.4 clearly confirms this pattern for rural primary roads. Notice that while there was no significant reduction in crash severity for Interstate highways as measured by the difference of mean ridits from 1973 to 1974 and from 1974 to 1975, the total shift from 1973 to 1975 was significant at the 0.05 level. This is consistent with the findings of Council et al. (1975).

The downward trend in TAD severity should allay suspicions that the driver injury patterns might be due entirely to changes in automobile construction rather than reduced accident severity. Indeed, as Figure 3.4 indicates, the conditional probability of a driver being killed given a particular TAD severity has remained quite constant over the three time periods. Note that a log transformation was used, as this yielded a linear scatter diagram. Due to the small number of deaths in the lower TAD categories, a similar plot was produced for the probability of serious injury or death (see Figure 3.5). This figure also shows a relatively constant distribution over the three year period.

To summarize, the data presented in this section tends to support the conclusion that TAD severity declined slightly over the three year period, at least on rural primary roads.

3.2.4 Estimated speed prior to impact.

Estimated speed prior to impact (ESPI) is a subjective judgement made by the investigating officer at the scene of an accident. The officer may consider such things as skid marks, injuries, damage, statements by witnesses, etc., in estimating the speed. Thus, one expects a high correlation between ESPI and other severity indicators (e.g., injury or TAD). In considering the following analysis, one must keep in mind the possibility that changes in ESPI distributions, especially if they are not consistent with other severity indicators, may be due more to the effect of the energy crisis on officers' expectations of public driving habits than to an actual effect on driving and accident patterns.

Table 3.4 TAD severity distribution for three classes of roads.

TAD	Population	TAD Distribution 1973	1974	1975	Percent Change 73-74	74-75	73-75
1	Interstate, PSL[1]≥55	22.76[2]	26.67	25.29	17.18[3]	- 5.17	11.12
	Rural Primary, PSL≥55	23.14	25.06	27.20	8.30	8.54	17.55
	Rural Primary, PSL<55	29.29	31.93	34.45	9.01	7.89	17.62
2	Interstate, PSL≥55	21.29	20.49	25.80	- 3.75	25.91	21.18
	Rural Primary, PSL≥55	23.49	24.02	24.11	2.26	0.38	2.64
	Rural Primary, PSL<55	26.69	25.83	26.31	- 3.22	1.86	- 1.42
3	Interstate, PSL≥55	18.69	16.54	16.86	-11.50	1.94	- 1.94
	Rural Primary, PSL≥55	19.22	19.92	19.38	3.64	- 2.71	0.83
	Rural Primary, PSL<55	17.74	17.50	18.03	- 1.35	3.03	3.03
4	Interstate, PSL≥55	16.42	16.05	13.32	- 2.25	-17.01	-18.88
	Rural Primary, PSL≥55	15.18	14.54	13.84	- 4.22	- 4.81	- 8.83
	Rural Primary, PSL<55	13.48	12.57	11.38	- 6.75	- 9.47	-15.58
5	Interstate, PSL≥55	8.38	8.15	7.59	- 2.74	- 6.87	- 9.43
	Rural Primary, PSL≥55	8.40	7.48	7.32	-10.95	- 2.14	-12.86
	Rural Primary, PSL<55	6.19	5.68	4.86	- 8.24	-14.44	-21.49
6	Interstate, PSL≥55	8.15	6.17	6.07	-24.29	- 1.62	-25.52
	Rural Primary, PSL≥55	6.71	5.35	4.78	-20.27	-10.65	-28.76
	Rural Primary, PSL<55	4.28	4.12	3.44	- 8.47	-16.50	-19.63
7	Interstate, PSL≥55	4.30	5.93	5.06	37.90	-14.67	17.67
	Rural Primary, PSL≥55	3.86	3.63	3.36	- 5.96	- 7.43	-12.95
	Rural Primary, PSL<55	2.34	2.38	1.53	17.09	-35.71	-34.62
Total	Interstate, PSL≥55	883	405	593	-54.13	46.42	-32.84
	Rural Primary, PSL≥55	10778	5682	8510	-47.28	49.77	-21.04
	Rural Primary, PSL<55	4882	3326	4709	-31.87	41.58	- 3.54
Mean Ridit	Interstate, PSL≥55	.5137	.4967	.4819	.33[4]	.43	.04
	Rural Primary, PSL≥55	.5160	.4967	.4819	.00	.00	.00
	Rural Primary, PSL<55	.5172	.5027	.4803	.03	.00	.00

[1]Posted speed limit

[2]Column percent

[3]Percent change: $\frac{26.67-22.76}{22.76} \times 100 = 17.18$

[4]P-value for corresponding difference of mean ridits (normal approximation)

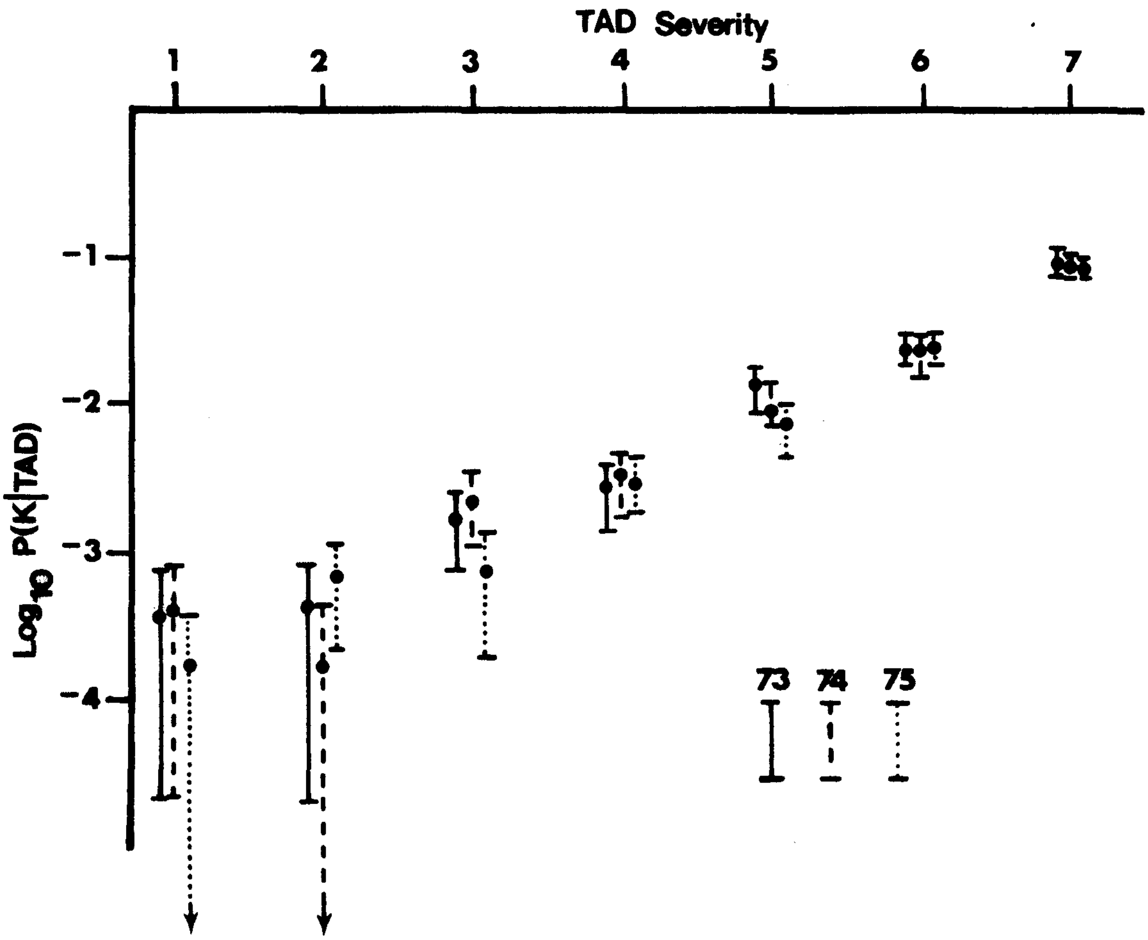


Figure 3.4. Log of probability of driver fatality within TAD severity level (90 percent confidence intervals).

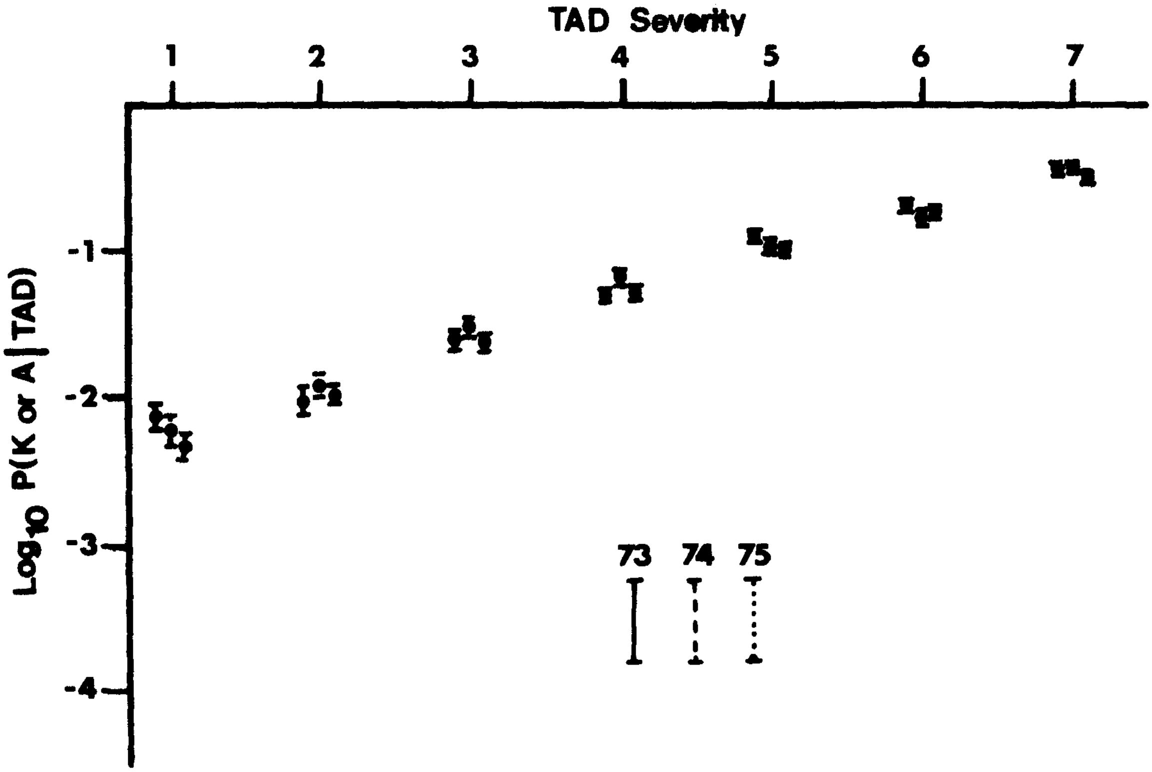


Figure 3.5. Log of probability of driver seriously injured or killed within TAD severity level (90 percent confidence intervals).

ESPI was examined for fatal and fatal or serious driver injuries. The data was tabulated primarily in 10 mph intervals for the three years on three road classifications: posted speed limit (PSL) less than 55, PSL greater than or equal to 55, and all roads together. Table 3.5 indicates a 20.6 percent reduction in the total number of drivers killed from 1973 to 1974 followed by a modest increase (2.0%) in 1975. This trend holds for most of the roads with the higher speed limits. However, a t-test for the difference of means in the ESPI distributions for each year failed to indicate any significant change. Indeed, an examination of the distributional changes reveals no definite pattern in ESPI over the three year period.

Because of the small number of driver fatalities, one must exercise a great deal of caution when forming conclusions from the results presented in Table 3.5. For this reason, a similar analysis was performed for drivers killed or seriously injured, where the sample size was considerably larger. The results are presented in Table 3.6. The conclusions are similar to those for driver fatalities: important reductions in the absolute frequencies between 1973 and 1974 (again with the majority of the decrease occurring on roads where the PSL $\geq$ 55), and no significant changes in mean ESPI. As before, no definite upward or downward shifts emerged in the distributions of ESPI.

The data presented here lead to the following conclusions about ESPI as reported in North Carolina during the energy crisis:

1) Approximately 77 percent of the reduction in driver fatalities between 1973 and 1974 occurred on roads where the PSL was greater than or equal to 55.

2) Approximately 62 percent of the reduction in driver fatalities or serious injuries between 1973 and 1974 occurred on roads where the PSL was greater than or equal to 55.

3) There was no significant change in mean ESPI over the three years being examined.

Table 3.5 Number of drivers killed by ESPI[1], PSL and year.

ESPI[1]	Road Type	Distribution 1973	Distribution 1974	Distribution 1975	Percent Change 73-74	Percent Change 74-75	Percent Change 73-75
≤35	All	17.51[2]	20.59	22.12	17.59[3]	7.43	26.33
	PSL<55	33.33	35.56	40.00	6.69	12.49	20.01
	PSL≥55	13.00	16.35	15.69	25.77	- 4.04	20.69
36-45	All	14.79	15.20	8.66	2.77	-43.03	-41.44
	PSL<55	15.79	17.78	18.18	12.60	2.25	15.14
	PSL≥55	14.50	14.47	5.23	- 0.21	-63.86	-63.93
46-55	All	21.40	24.51	28.37	14.53	15.75	32.57
	PSL<55	15.79	15.56	7.27	- 1.46	-53.28	-53.96
	PSL≥55	23.00	27.04	35.95	17.57	32.95	56.30
56-65	All	14.40	11.76	11.06	-18.33	- 5.95	-23.19
	PSL<55	15.79	4.44	9.09	-71.88	104.73	-42.43
	PSL≥55	14.00	13.84	11.76	- 1.14	-15.03	-16.00
66-75	All	14.78	10.78	13.46	-27.06	24.86	- 8.93
	PSL<55	12.28	8.89	7.27	-27.61	-18.22	-40.80
	PSL≥55	15.50	11.32	15.69	-26.97	38.60	1.23
76-85	All	8.56	3.43	9.61	-59.93	180.17	12.27
	PSL<55	0.00	6.67	14.54	--	117.99	--
	PSL≥55	11.00	2.52	7.84	-77.09	211.11	-28.73
>85	All	8.56	13.72	6.73	60.28	-50.95	-14.86
	PSL<55	7.02	11.11	3.63	58.26	-67.33	-48.29
	PSL≥55	9.00	14.47	7.84	60.78	-45.82	-12.89
Total	All	257	204	208	-20.62	1.96	-19.07
	PSL<55	57	45	55	- 5.26	22.22	- 3.51
	PSL≥55	200	159	153	-20.50	- 3.77	-23.50
Mean Speed	All	55.5	54.7	54.6	0.74[4]	0.95	0.67
	PSL<55	47.7	49.1	46.7	0.79	0.66	0.83
	PSL≥55	57.7	56.3	57.4	0.58	0.68	0.90

[1]Estimated speed prior to impact (mph)

[2]Column percent

[3]Percent change: $\frac{20.59-17.51}{17.51} \times 100 = 17.59$

[4]P-value for corresponding difference of mean speeds (normal approximation)

Table 3.6 Number of drivers killed or seriously injured by ESPI, PSL and year.

ESPI[1]	Road Type	Distribution 1973	Distribution 1974	Distribution 1975	Percent Change 73-74	Percent Change 74-75	Percent Change 73-75
≤35	All	35.04[2]	33.18	33.55	- 5.30[3]	1.12	- 4.25
	PSL<55	61.00	58.99	57.08	- 3.30	- 3.24	- 6.43
	PSL≥55	18.58	16.72	18.88	-10.01	12.92	1.61
36-45	All	17.17	19.91	19.06	15.96	- 4.27	11.01
	PSL<55	19.44	20.37	20.48	4.78	0.54	5.35
	PSL≥55	16.61	19.61	18.18	18.06	- 7.29	9.45
46-55	All	22.25	24.21	24.93	8.81	2.97	12.04
	PSL<55	8.70	9.99	10.80	14.83	8.11	24.14
	PSL≥55	30.84	33.28	33.74	7.91	1.38	9.40
56-65	All	12.21	9.90	9.10	-18.92	- 8.08	-25.47
	PSL<55	5.80	5.59	5.89	- 3.62	5.37	1.56
	PSL≥55	16.27	12.65	11.10	-22.25	-12.25	-31.78
66-75	All	6.88	6.18	7.27	-10.17	17.64	5.67
	PSL<55	2.90	1.86	2.24	-35.86	20.43	-22.76
	PSL≥55	9.39	8.83	10.40	- 5.96	17.78	10.76
76-85	All	3.13	2.70	3.23	-43.00	19.63	3.19
	PSL<55	.97	1.33	1.96	37.54	47.37	102.69
	PSL≥55	4.49	3.57	4.02	-20.49	12.61	-10.47
>85	All	2.79	3.47	2.85	24.37	-17.87	2.15
	PSL<55	1.18	1.86	1.54	57.63	-17.20	30.51
	PSL≥55	3.81	5.35	3.67	40.42	-31.40	- 3.67
Total	All	2400	1929	1857	-19.63	- 3.73	-22.63
	PSL<55	931	751	713	-19.33	- 5.06	-23.42
	PSL≥55	1469	1178	1144	-19.81	- 2.89	-22.12
Mean Speed	All	44.7	45.1	44.9	0.52[4]	0.73	0.78
	PSL<55	34.6	34.9	35.9	0.73	0.36	0.18
	PSL≥55	51.1	54.6	50.5	0.51	0.18	0.45

[1]Estimated speed prior to impact (mph)

[2]Column percent

[3]Percent change: $\frac{33.18-35.04}{35.04} \times 100 = -5.30$

[4]P-value for corresponding difference of mean speeds (normal approximation)

3.3 Analysis by Road Type

In this section, changes in the number of crashes and changes in traffic volume for several different road categories are examined. Since almost all speed limit reductions in North Carolina occurred on Interstate and U.S. highways, it is likely that any changes peculiar to these two road systems would be a result of the lowered speed limit. Therefore, particular attention will be paid to examining such changes.

3.3.1 Changes in the number and severity of crashes by road type.

Table 3.7 gives the number of fatal, non-fatal injury, and property damage only (PDO) crashes for the following road classifications: Interstate (I), U.S. highways (US), N.C. highways (NC), rural paved roads (RPR), and city streets (CS). Also presented are the proportions of total crashes for each road type that fall into each of the three injury categories. These proportions are estimates of the conditional probabilities of sustaining a particular injury severity given that a crash has occurred on the particular road type. The data for this table were derived from the North Carolina Traffic Accident Summary, and represent crashes occurring during the first four months of each year.

Note that between 1973 and 1974, decreases in the actual number of crashes were observed in all severity categories on all types of roads except city streets where the number of non-injury crashes increased. In 1975, the number of fatal crashes continued to fall on all rural roads except N.C. highways, where they remained constant.

Perhaps of greatest interest is the manner in which the conditional probabilities of sustaining a particular injury level changed over the two years. These changes are presented in the last three columns of Table 3.7. Specifically, the probability of sustaining a fatal crash (given that a crash occurred) increased for Interstate highways between 1973 and 1974, while there were only slight changes in the proportions of fatal crashes on each of the other road classifications during this period. Interstate, N.C., and rural paved highways all experienced slight increases in the probability of non-fatal injury crashes, while

Table 3.7. Crashes by severity and road type.

Road Type	Crash Severity	Number of Crashes 1973 Freq.	1973 $\hat{p}$[1]	1974 Freq.	1974 $\hat{p}$	1975 Freq.	1975 $\hat{p}$	Change in Proportion 73-74	74-75	73-75
I	Fatal	26	.033	19	.043	16	.031	.011[2]	-.012	-.001
	Injury	286	.360	164	.374	164	.321	.014	-.053	-.039
	PDO[3]	482	.607	255	.582	331	.648	-.025	.066	.041
	Total	794		438		511				
US	Fatal	118	.019	84	.018	77	.016	-.001	-.002	-.004
	Injury	2222	.366	1645	.357	1746	.360	-.009	.003	-.006
	PDO	3727	.614	2875	.624	3027	.624	.010	.000	.010
	Total	6067		4604		4850				
NC	Fatal	100	.023	77	.021	77	.019	-.001	-.002	-.004
	Injury	1662	.375	1398	.383	1534	.377	.008	-.007	.002
	PDO	2670	.602	2171	.595	2462	.604	-.007	.009	.002
	Total	4432		3646		4073				
RPR	Fatal	140	.016	137	.018	127	.015	.002	-.003	-.001
	Injury	3192	.362	2888	.370	3147	.361	.008	-.009	-.001
	PDO	5475	.622	4776	.612	5433	.624	-.010	.012	.002
	Total	8807		7801		8707				
CS	Fatal	90	.005	55	.003	61	.003	-.002	.000	-.002
	Injury	6254	.352	5881	.335	6496	.330	-.018	-.005	-.022
	PDO	11402	.643	11630	.662	13127	.667	.019	.005	.024
	Total	17746		17566		19684				

[1] Estimate of the conditional probability of sustaining corresponding injury severity given that crash has occurred.

[2] Change in corresponding proportion (i.e., conditional probability)

[3] PDO - property damage only

U.S. highways and city streets saw a reduction in this category. Between 1974 and 1975, the probability of a fatal crash decreased on all road types except city streets, where no change occurred. As before, these changes were greatest for Interstate roads, partly because they had a much higher proportion of fatalities initially (.033 on Interstates compared with .023 on N.C. highways and .005 on city streets). Also, the proportion of non-fatal injury crashes decreased appreciably for Interstates in 1975.

The net result was that little change was noted between 1973 and 1975 in the probability of sustaining a fatal crash on any road type, given that a crash occurred. The chance of being involved in a non-fatal injury crash decreased substantially over the three year period for Interstates and city streets. On other road types, however, there was once again little change.

In an effort to determine whether the changes noted above were due to actual changes in the processes governing the proportion of fatal crashes or merely to random sampling fluctuation, 0.95 interval estimates were computed for the difference of corresponding proportions. Treating the number of fatal crashes occurring on a particular road type as a binomial random variable, calculation of confidence intervals for the difference of the proportions follows in a straightforward manner[1]. Interval estimates for differences between fatal proportions for the two periods 1973 to 1974 and 1973 to 1975 are displayed in Figure 3.6. Notice that if the difference for a particular highway class is positive, this implies an increase in the probability of fatality given that a crash occurred, and hence an increase in severity for that type of highway. Also, if an interval estimate includes zero, one concludes that there is no significant change (at the 0.05 level) in the proportion of fatal crashes during the period of interest.

Examination of Figure 3.6 reveals that, with the exception of city streets, all other highways experienced no statistically significant

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[1]See Hogg and Craig, "Introduction to Mathematical Statistics," (1970), p. 201.

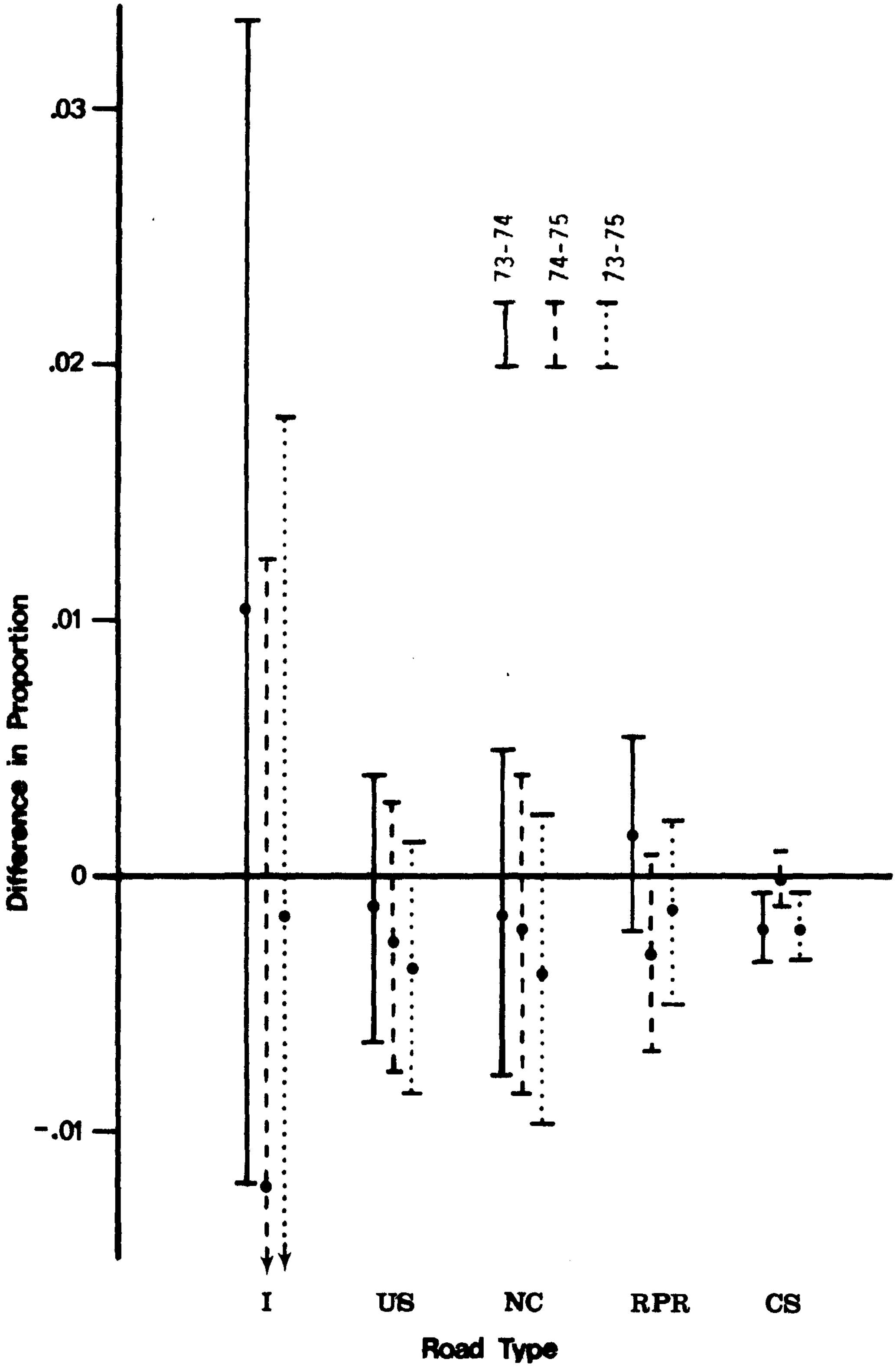


Figure 3.6. 0.95 interval estimates for difference of proportions of fatal crashes.

changes in the proportion of fatal crashes for either of the two periods of interest. Thus, despite minor decreases in the conditional probability of sustaining a fatal crash, there was no significant decrease in crash severity on any rural road during the energy crisis. In fact, severity appeared to increase (although not in a statistically significant sense) on Interstate highways during 1974. This is opposite to what one might have expected since the largest speed limit changes occurred on these roads.

3.3.2 Changes in volume by road type.

Table 3.8 gives average daily traffic (ADT) counts for the same road categories that were presented in Table 3.7. It can be observed that traffic volume decreased on all types of roads during the energy crisis, with Interstate highways experiencing the largest percentage decrease. This is not unexpected since the curtailment of non-essential driving (e.g., long trips) would tend to have a greater effect on Interstate roadways than on the other highways which carry more local traffic. In 1975, volumes increased on all rural roads, but continued to decline on city streets. The net result in 1975 left traffic volumes below 1973 levels on all roads, with Interstate highways still maintaining the largest reduction.

Table 3.8 Average daily traffic by road type.

Road Type	ADT			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
Interstate	15713	11656	13284	-25.82[1]	13.97	-15.46
U.S.	5051	4658	4959	- 7.78	6.46	- 1.82
N.C.	2441	2154	2161	-11.76	0.32	-11.47
Rural Paved	1774	1496	1606	-15.67	7.35	- 9.47
City Street	12052	11743	11365	- 2.56	-3.22	- 5.70

[1]Percent change: $\frac{11656-15713}{15713} \times 100 = -25.82$

It has been suggested that the reduced traffic volume rather than the lowered speed limit was largely responsible for the drop in total crashes during and following the energy crisis. If one assumes that the relationship between volume and total crashes is such that a percentage change in volume results in roughly the same percentage change in total crashes, then the plausibility of this theory for North Carolina data can be examined.

Figure 3.7 displays the percentage decrease in ADT plotted against the percentage decrease in total crashes for the periods 1973-1974 and 1973-1975. If the points tend to scatter near the given 45 degree line, this would be an indication that the changes in accidents are predicted by the volume changes under the hypothesized relationship. It appears that for Interstate and U.S. highways, the percentage decrease in total crashes was somewhat larger than what would have been expected from the reduced traffic volume, while the changes for other rural roads were roughly the same in magnitude. This difference for Interstate and U.S. highways strongly suggests the presence of other factors, in addition to traffic volume, that exhibited a significant influence on the reduction in total crashes. Furthermore, because Interstate and U.S. highways were most affected by the decrease in posted speed limit in North Carolina, one is led to conclude that, while reduced traffic volume was no doubt responsible for a large portion of the decrease in total crashes, other factors, including the lowered speed limit, played a significant role.

One must remember that this discussion is based on the hypothesized relationship between ADT and total crashes that was put forth above. Council et al. (1975) present a series of "predicted" regression lines for percent change in ADT and total accidents for several different road classifications and geographic areas. These lines are quite similar to the assumed relationship represented by the 45 degree line in Figure 3.7. implying that the suggested hypothesis is certainly reasonable.

It was stated in Section 3.1.2 that, under mild assumptions, the ratio of total crashes to ADT is reflective of the total crash rate.

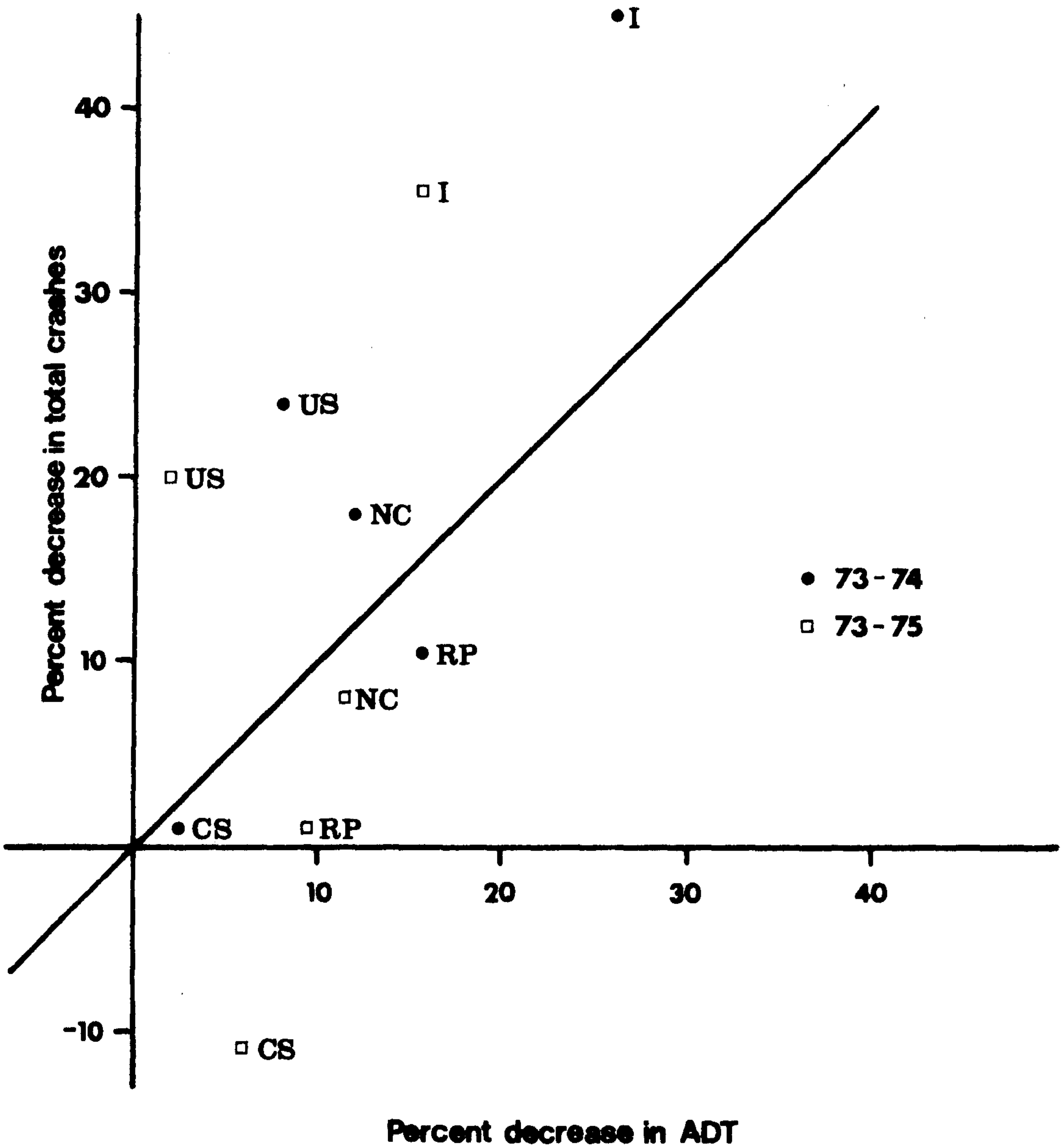


Figure 3.7 Percentage decrease in average daily traffic by percentage decrease in total crashes for U.S., N.C., and rural paved roads and city streets.

Since ADT data are available for different types of highways, it would be worthwhile to examine how these ratios changed during the period 1973 to 1975. Table 3.9 presents both total and fatal crash rates (based on ADT) for the four rural highway types. (The rates for urban roads were discussed in Section 3.1.2, and will not be reported here.) One may recall from the earlier discussion that the total crash rate for rural roads (as indicated by the ratio of crashes to ADT) dropped in 1974, but rose slightly in 1975. Table 3.9 implies that Interstate and U.S. roadways were responsible for much of the 1974 reduction. During 1975, the total crash rates remained relatively unchanged for all rural roads with the exception of N.C. highways, where an increase was observed. With the exception of rural paved roads, fatal crash rates experienced an even greater decrease over the three year period. However, since the fatal crash rate had been experiencing a downward trend for several years, it is not surprising to observe this pattern for the rural roads.

Table 3.9 Ratio of crashes to average daily traffic counts (×100) for rural highways.

Population		Crash Rate			Percent Change		
		1973	1974	1975	73-74	74-75	73-75
Interstate	Total	5.05	3.76	3.85	-25.54[1]	2.39	-23.76
	Fatal	.17	.16	.12	- 5.88	-25.00	-29.41
U.S.	Total	120.11	98.84	97.80	-17.71	- 1.05	-18.57
	Fatal	2.34	1.80	1.55	-23.08	-13.89	-33.76
N.C.	Total	181.56	169.27	188.48	- 6.77	11.35	3.81
	Fatal	4.10	3.57	3.56	-12.93	- 0.28	-13.17
Rural Paved	Total	496.45	521.46	542.15	5.04	3.97	9.21
	Fatal	7.89	9.16	7.91	16.10	-13.65	0.25

[1]Percent change: $\frac{3.76-5.05}{5.05} \times 100 = -25.54$

Conclusions: Road Types

From the data presented in Sections 3.3.1 and 3.3.2, it seems clear that the events of the energy crisis had different effects on the various types of roads that were examined. Table 3.10 presents a summary of the changes in the severity and rate measures examined in these sections.

Although not statistically significant, the evident increase in crash severity for Interstate highways during the energy crisis (1973-1974) is of particular interest since the largest speed limit changes occurred on these roads. In Chapter 2, it was observed that all highways experienced decreases in mean vehicle speeds, speed variance and vehicle volumes, with the largest reductions occurring on Interstates. One would have expected, then, a reduction in crash severity for Interstate accidents. Crash severity, however, is not only a function of these speed and volume variables but also accident type, belt usage, vehicle type, and many other factors. Differences among these factors for Interstate crashes may at least partially account for the lack of a decrease in crash severity.

Table 3.10 Trends in crash severity and total crash rate.

Road Type	1973-1974		1974-1975	
	Crash Rate	Crash Severity	Crash Rate	Crash Severity
Interstate	decrease*	increase	increase	decrease
U.S.	decrease*	decrease	decrease	decrease
N.C.	decrease	decrease	increase*	decrease
Rural Paved	increase	increase	increase	decrease
City Streets	increase	decrease**	increase*	no change

* Change greater than 10 percent

** Change significant at .05 level

3.4 Truck (and Bus) Speeds and Accidents

This section will examine changes in accidents involving trucks and, to a limited extent, buses during the energy crisis. The bus accidents will only be examined indirectly through involvement in truck accidents. This is because buses represent an extremely small percentage of the overall vehicle mix, and information on bus accidents is therefore most limited. Also, since no mileage information is available by particular type of vehicle, the presentation of changes in the highway environment for trucks will be restricted to a discussion of tractor trailer/semi-trailer speeds during the three year period surrounding the energy crisis, and an analysis of two-vehicle accidents involving trucks.

3.4.1 Truck speeds.

Tractor trailer/semi-trailer (TTST) speed data were obtained from "Rural Speeds on Primary Highways and Secondary Roads", a North Carolina Department of Transportation publication discussed in Section 2.1.3. Table B.10 shows mean speeds, 85-th percentile speeds, and 80 percent intervals and widths for TTST's on Interstate highways and main routes. As in section 2.1.3, the 85-th percentile speed is the speed which 85 percent of the traffic does not exceed. The 80 percent interval is determined by the speed which 90 percent of the TTST's exceed and the speed which 10 percent exceed. As Figures 3.8 and 3.9 indicate, TTST mean and 85-th percentile speeds did not deviate by more than 1 mph from the overall commercial vehicle speeds during the period 1968 through 1974. Since the commercial vehicle speeds were discussed in Section 2.1.3, that discussion will not be repeated here. However, it is interesting to note that both the mean and 85-th percentile speeds dropped considerably in 1974 on Interstate highways, while the changes on main routes appear to be relatively minor. This is most likely due to the fact that Interstate highways experienced a greater change in speed limits than main routes. In 1975, TTST mean and 85-th percentile speeds increased considerably more than either passenger car or commercial vehicle speeds. In fact, TTST mean and 85-th percentile speeds equalled or exceeded those for passenger cars on both Interstate highways and main routes for the first time in 1975. Considering the arguments presented by the trucking

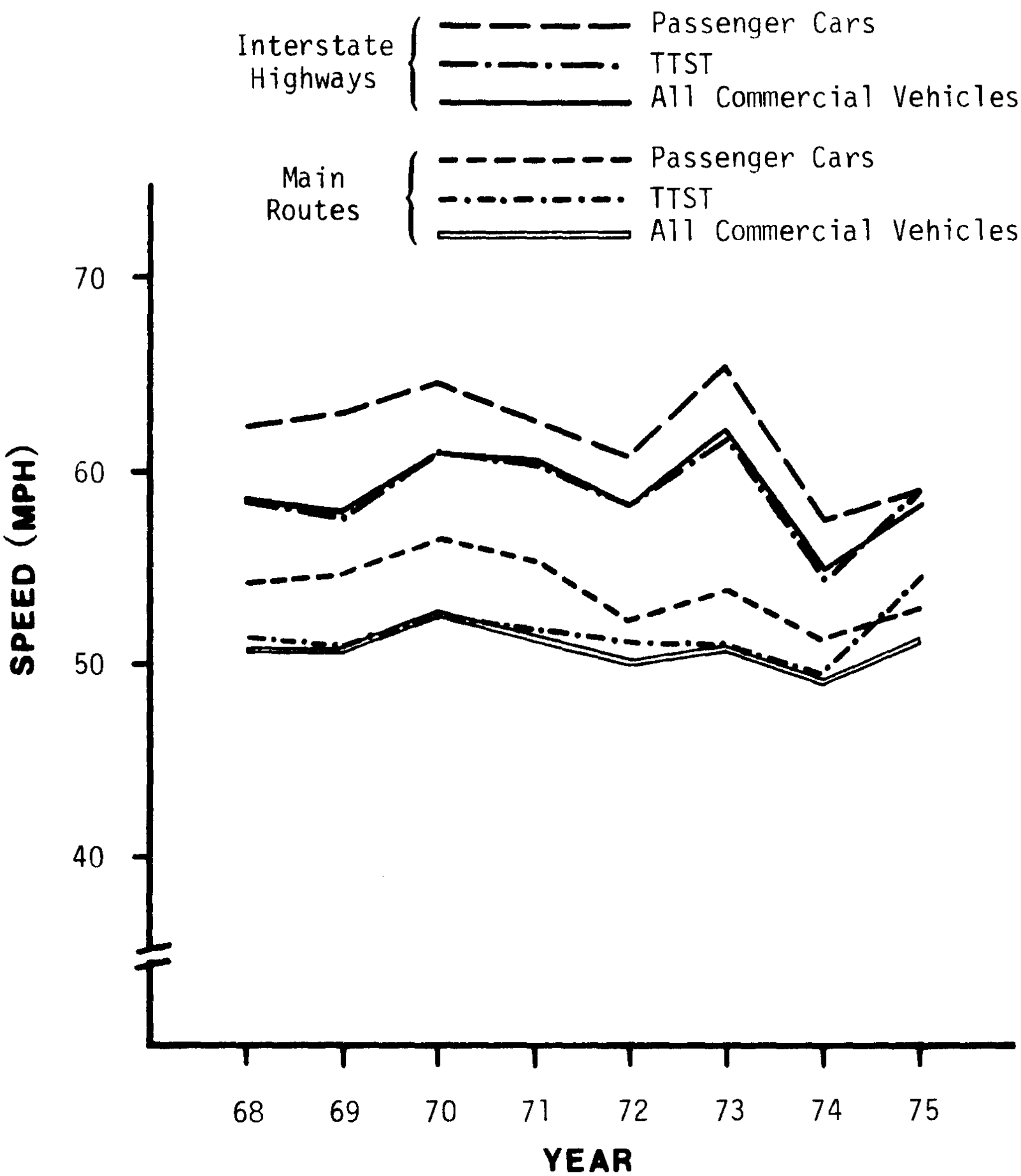


Figure 3.8. Mean speeds: Interstate highways and main routes.

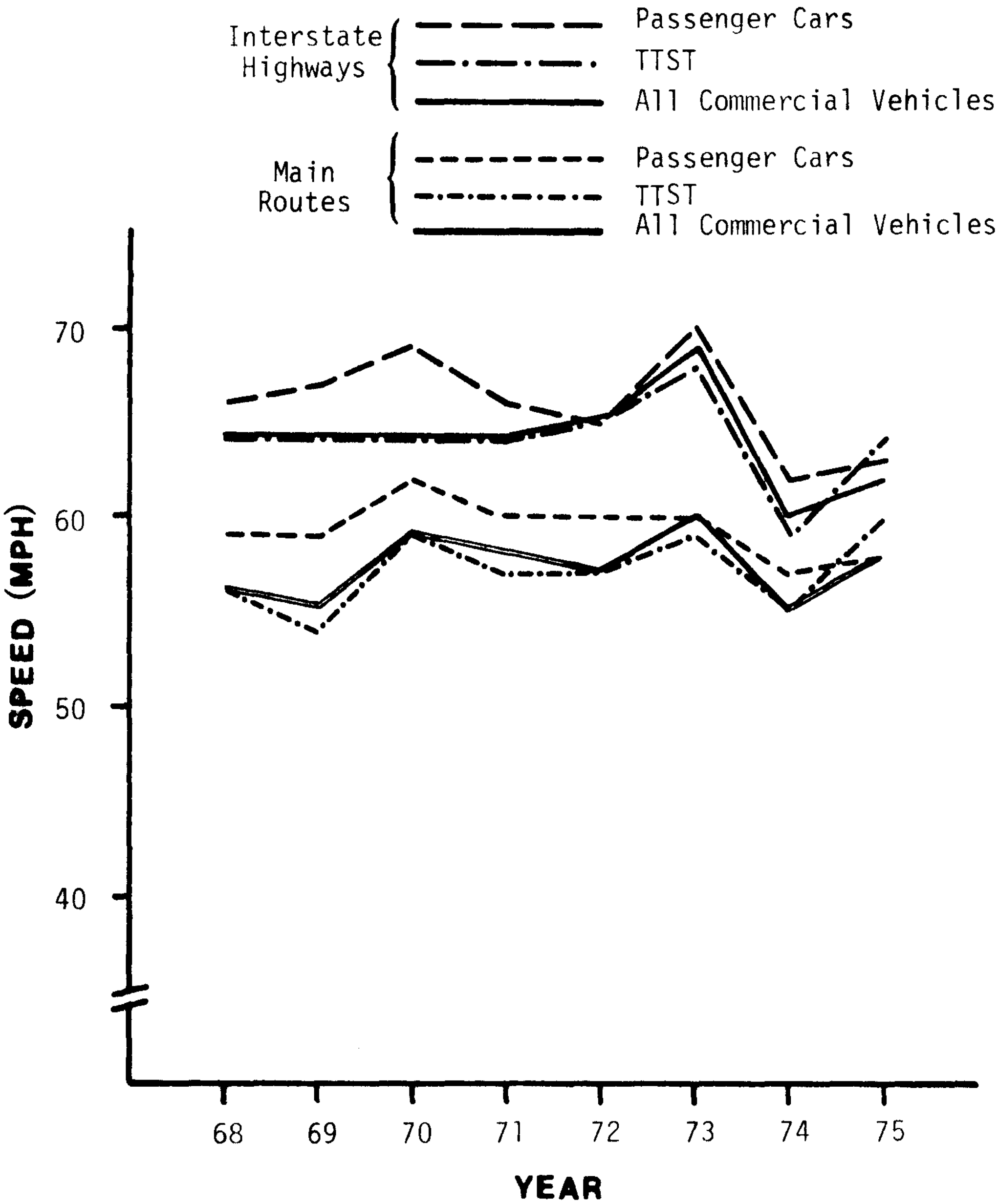


Figure 3.9. 85-th percentile speeds: Interstate highways and main routes.

industry against the 55 mph speed limit, it is not surprising that this population of drivers is exceeding the lower limit by a larger margin than many other drivers.

The speed variance for TTST's as indicated by the 80 percent interval width is consistently less than that for all commercial vehicles, as should be expected since TTST's represent a more homogeneous group of vehicles. However, TTST speed variance was generally greater than that for passenger cars. In 1974, the TTST 80 percent interval width was noticeably reduced from pre-crisis levels, and remained down in 1975. Thus, while 1974 witnessed a sizable dip in mean speeds for TTST followed by an increase in 1975, speed variance dropped in 1974 and remained down in 1975. (A similar observation was also noted for passenger cars in Section 2.1.3.) This apparent relationship between the lowered speed limit and reduced speed variance is noteworthy since a smaller variance is generally associated with fewer accidents.

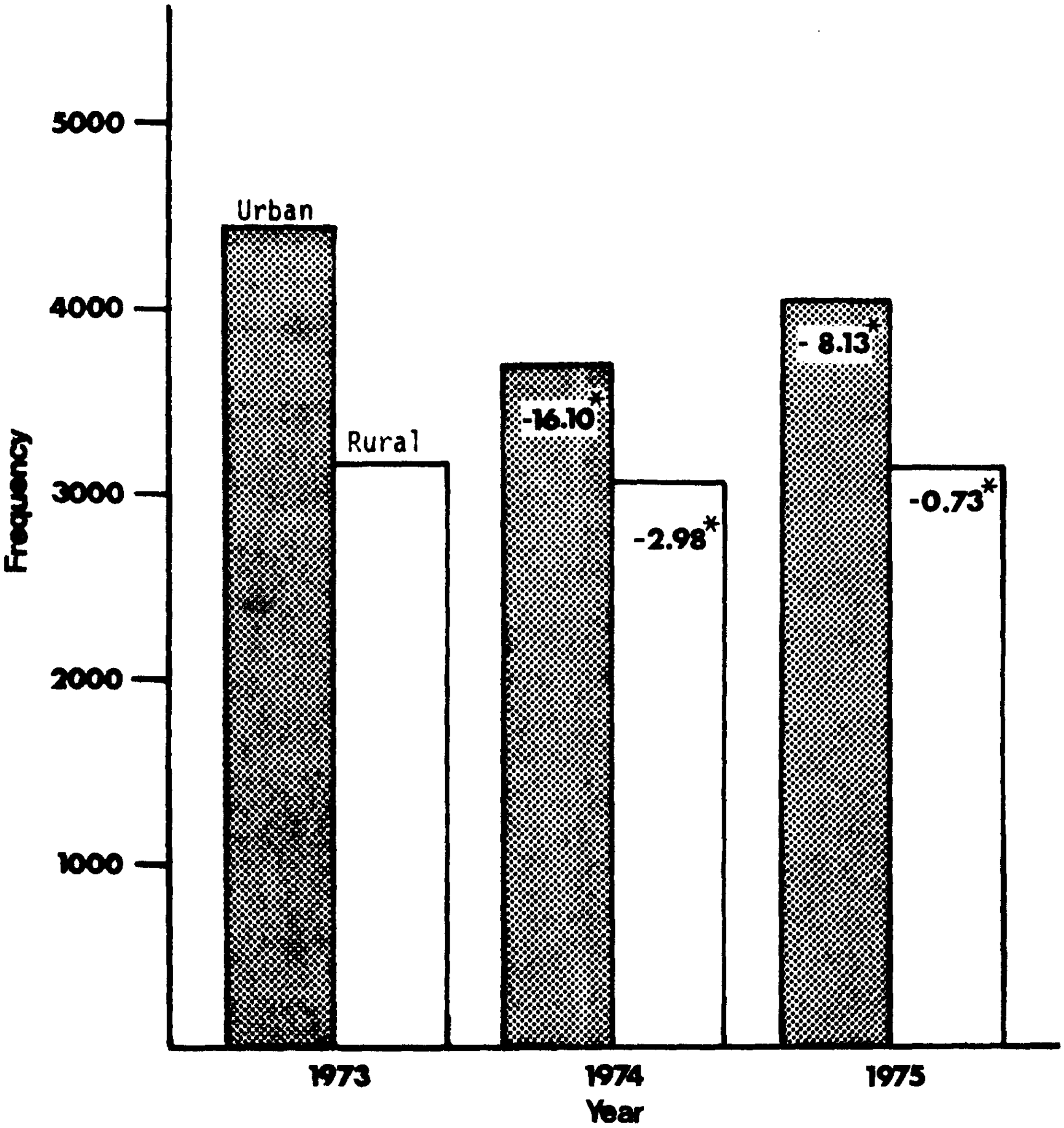
3.4.2 Two vehicle truck accidents.

Truck accident data were obtained from the North Carolina accident tapes which are prepared by the Division of Motor Vehicles. Total two vehicle truck crashes for the three time periods are shown in Figure 3.10. As was the case for total crashes for all vehicles, a majority of the observed decrease from 1973 to 1974 was due to a reduction in rural crashes. Unlike the accident data for all vehicles, the number of truck accidents in 1975 did not return to 1973 levels; however, the 1974 reduction was partially recovered.

Accident Characteristics

Table 3.11 presents a breakdown of truck accidents by road type. Of particular interest is the fact that the proportion of truck accidents occurring on Interstate and U.S. highways not only fell during the crisis period, but continues to decline in 1975. The remaining roads experienced proportional increases in the number of truck accidents during either 1974, 1975, or both years.

Recalling that most speed limit changes occurred on only Interstate and U.S. highways in North Carolina, it seems likely that the proportional



*Percent Change from 1973.

Figure 3.10. Number of two-vehicle crashes involving trucks (January thru April).

Table 3.11. Distribution of truck accidents by road type.

Road Type	Distribution 1973	Distribution 1974	Distribution 1975	Percent Change 73-74	Percent Change 74-75	Percent Change 73-75
Interstate	3.10[1]	2.39	2.30	-22.90[2]	-3.77	-25.81
U.S.	21.20	19.78	18.29	-6.70	-7.53	-13.73
N.C.	12.34	11.56	12.53	-6.32	8.39	1.54
Rural Paved	17.30	15.71	16.21	-9.19	3.18	-6.30
Rural Unpaved	1.29	1.42	1.56	10.08	9.86	20.93
City Streets	41.66	45.23	43.55	8.57	-3.71	4.54
Private Property	3.10	3.92	5.56	26.45	41.84	79.35
Total	7571	6766	7189	-10.63	6.25	-5.05

H_0: No change in distribution between corresponding years.	$\chi^2(6)$	34.97 (p=0.00)	29.97 (p=0.00)	84.20 (p=0.00)

[1]Column percent.

[2]Percent change: $\frac{2.39-3.10}{3.10} \times 100 = -22.90$

decreases in truck accidents on these roads were a result of these speed limit changes rather than any large shifts in traffic volumes. As pointed out in the previous section, the mean speed for all commercial vehicles in 1975 had returned to the pre-crisis level for main routes (U.S. and N.C. highways). Since the percentage of truck accidents occurring on these roads also fell steadily over the three year period, this suggests that reduced speeds are not entirely responsible for the distributional shifts.

A Chi-Square test on the data presented in Table 3.12 indicates that the accident type distribution varied significantly ($p \leq .02$) over the three time periods, although the actual yearly distributions vary only slightly. Ran-off-road and head-on accidents experienced the largest relative distributional decreases in 1974. While one might argue that the reduced speeds during this period would allow a driver more time to react and thus avoid many accidents of this type, the argument could also be applied to those accidents where the percentage of truck crashes increased (e.g., sideswipe/angle and turning). For this reason, the changes in accident type for truck crashes do not appear to be obviously related to energy crisis factors.

Examination of the type of vehicle involved in accidents with trucks (Table 3.13) reveals large relative increases in the proportion of buses and motorcycles accompanied by a decrease in the percentage of passenger cars from 1973 to 1974. In light of the scarcity and high cost of fuel during this period, these changes suggest a probable shift in vehicle mix toward more mileage-efficient vehicles as a result of the fuel crisis.

The number of occupants, both of the trucks and of the cars involved in two-vehicle truck accidents, is of interest because it should affect severity estimates and death rates. From the occupancy distributions presented in Table 3.14, one can observe a tendency for both cars and trucks to carry progressively more occupants over the three year period. Using a value of five for the category labelled "5 or more", mean occupancies were computed for each year and are displayed at the bottom of Table 3.14. A t-test was used to investigate differences

Table 3.12. Accident type distribution for truck accidents.

Accident Type	Distribution			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
Sideswipe/Angle	32.55[1]	33.15	35.06	1.84	5.76	7.71
Turning	26.07	26.58	25.43	1.96	- 4.33	- 2.45
Rear End	20.98	21.16	21.15	0.86	- 0.05	0.81
Hit Fixed Object	7.94	7.53	6.64	- 5.16	-11.82	-16.37
Backing	5.77	6.31	6.12	9.36	- 3.01	6.07
Ran-Off-Road	3.49	3.09	3.12	-11.46	0.97	-10.60
Head-on	2.91	1.91	2.36	-34.36	23.56	-18.90
Non-Collision	0.30	0.28	0.12	- 6.67	-57.14	-60.00
Total	7331	6404	6700	-12.64	4.62	- 8.61

Ho: No change in distribution between corresponding years.	$\chi^2(7)$	18.89 (p=0.01)	16.42 (p=0.02)	26.69 (p=0.00)

[1]Column percent.

Table 3.13. Distribution of second (or other) vehicle type in two vehicle truck accidents.

Second Vehicle Type	Distribution			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
Car	85.76[1]	84.80	85.22	-1.12	0.50	-0.63
Truck	10.02	10.27	10.48	2.50	2.04	4.59
Bus	0.94	1.27	1.12	35.11	-11.81	19.15
Motorcycle	0.62	1.05	0.58	69.35	-44.76	-6.45
Other	2.66	2.61	2.59	-1.88	-0.77	-2.63
Total	7632	6785	7213	-11.10	6.31	-5.49

H_o: No change in distribution between corresponding years.	$\chi^2(4)$	12.22 (p=0.02)	10.16 (p=0.04)	2.18 (p=0.70)

[1]Column percent.

Table 3.14. Occupancy distributions for cars and trucks involved in two vehicle truck accidents.

Number of Occupants	Population[1]	Distribution			Percent Change		
		1973	1974	1975	73-74	74-75	73-75
0	Car	9.93[2]	8.32	9.13	-16.21	9.74	- 8.06
	Truck	10.38	7.31	8.78	-29.58	20.11	-15.41
1	Car	58.43	58.90	55.54	0.80	-5.70	- 4.95
	Truck	67.96	70.08	66.46	3.12	-5.17	- 2.21
2	Car	19.37	20.52	21.62	5.94	5.36	11.62
	Truck	15.37	16.29	17.34	5.99	6.45	12.82
3	Car	6.86	7.16	7.79	4.37	8.80	13.56
	Truck	4.72	4.63	5.17	- 1.91	11.66	9.53
4	Car	3.35	3.18	3.60	- 5.07	13.21	7.46
	Truck	1.06	1.18	1.53	11.32	29.66	44.34
5 or More	Car	2.06	1.91	2.33	- 7.28	21.99	13.11
	Truck	0.51	0.52	0.72	1.96	38.46	41.18
Total Vehicles	Car	6545	5754	6147	-12.09	6.83	- 6.08
	Truck	7632	6785	7213	-11.10	6.31	- 5.49
Mean Occupancy	Car	1.4145	1.4371	1.4817	.212[3]	.017	.000
	Truck	1.1965	1.2448	1.2637	.000	.150	.000

[1]The tabled occupancy distributions are for cars involved in (truck/car) accidents and trucks involved in (truck/any vehicle) accidents.

[2]Column percent.

[3]P-value for test comparing difference of means.

between successive years with the following results: mean occupancy for passenger cars increased significantly ($p = .017$) following the energy crisis, while mean truck occupancy increased significantly ($p < .001$) between 1973 and 1974 (i.e., during the energy crisis). Considering the high price of fuel during and after the crisis period and the increasing emphasis on conservation measures such as carpooling, the rise in mean occupancy for cars is not surprising. The same argument might also apply to trucks, although probably to a lesser extent. Whatever the reasons, increased occupancy would result in more injuries -- all other factors held constant. This would probably cause accident severity estimates based on injury to rise.

Accident Severity Measures

The use of driver injury, most severe injury (MSI) and TAD as indices of accident severity was discussed in Section 2.2.3 of this report. Table 3.15 gives the distribution of injuries to the drivers of passenger cars involved in truck/car crashes. Although ridit analyses suggested a slight upward trend in accident severity as indicated by this measure, none of the differences were found to be statistically significant.

Deaths were investigated by grouping all non-fatal injuries into one category and testing (1) over the three years using a Chi-square test, and (2) for significant changes between any two years using a test for differences of binomial proportions. Neither test indicated any significant differences at the five percent level, suggesting that the observed variation is a result of random fluctuation.

The distributions of MSI in truck/car accidents are shown in Table 3.16. Again, ridit analysis failed to indicate any statistically significant change in severity. However, the MSI distribution is occupant-sensitive; therefore, taking the increase in mean occupancy into consideration might admit the possibility of a slight decrease in accident severity.

TAD distributions for cars involved in truck/car accidents are presented in Table 3.17. Unlike the previous two measures of severity, TAD experienced a downward trend during the three year period, although again

Table 3.15. Distribution of car driver injuries in truck/car accidents.

Driver Injury	Distribution			Percent Change		
	1973	1974	1975	73-74	74-74	73-75
0	84.57[1]	83.89	83.41	-0.80	-0.57	-1.37
C	7.00	7.70	7.66	10.00	-0.52	9.43
B	4.95	5.27	6.01	6.46	14.04	21.41
A	3.00	2.54	2.52	-15.33	-0.79	-16.00
K	0.49	0.61	0.39	24.49	-36.07	-20.41
Total	6143	5276	5587	-14.11	5.89	-9.05
Mean ridit	.4973	.5003	.5027	.583[2]	.664	.314

Table 3.16. Distribution of overall accident severity (most severe injury) for truck/car accidents.

Accident Severity	Distribution			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
0	76.78[1]	75.94	75.69	-1.09	-0.33	-1.42
C	10.59	11.33	11.26	6.99	-0.62	6.33
A or B	11.96	11.88	12.42	0.67	4.55	3.85
K	0.68	0.85	0.64	25.00	-24.71	-5.88
Total	6339	5498	5783	-13.27	5.18	-8.77
Mean ridit	.4971	.5010	.5023	.464[2]	.808	.320

[1]Column percent.

[2]P-value for corresponding difference of mean ridits.

Table 3.17. Distribution of TAD severity for cars in truck/car accidents.

TAD Severity	Distribution			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
1	23.43[1]	24.53	25.90	4.69	5.58	10.54
2	25.07	24.97	26.02	-0.40	4.21	3.79
3	19.29	20.60	20.20	6.79	-1.94	4.72
4	14.42	14.47	13.84	0.35	-4.35	-4.02
5	7.56	6.75	6.24	-10.71	-7.56	-17.46
6	6.27	5.47	4.98	-12.76	-8.96	-20.57
7	3.97	3.22	2.82	-18.89	-12.42	-28.97
Total	2872	2267	3332	-21.07	46.98	16.02
Mean ridit	.5141	.5014	.4868	.118[2]	.063	.000

[1]Column percent.

[2]P-value for corresponding difference of mean ridits.

the year-to-year change was not statistically significant (at $\alpha = 0.05$). As pointed out in Section 2.2.3, the number of urban crashes for which TAD was reported rose substantially during this period. It is quite possible that the reduced severity is merely a result of the increased usage of TAD for urban crashes (which tend to be less severe than rural crashes due to the generally lower speeds involved).

Based on this investigation, the following may be concluded about two-vehicle truck accidents in North Carolina:

(1) The number of truck crashes decreased in 1974 and partially recovered in 1975.

(2) There is some indication that the lowered speed limit is partially responsible for the reduced number of truck accidents.

(3) Accident type distribution changed in both 1974 and 1975, but the changes do not appear to be directly related to the energy crisis.

(4) Changes in the vehicle-struck (car) distribution are due to the increased number of motorcycles and buses involved in 1974.

(5) Occupancy shows an upward trend.

(6) Accident severity exhibits no notable and consistent change.

3.5 Other Changes

The changes in the highway safety environment that occurred during the energy crisis were many and complex, and it would be impossible to examine all changes. In this final section, changes in accident characteristics that have not been presented elsewhere, and which could illuminate basic changes in accident patterns will be examined briefly. In Section 3.5.1, the vehicle occupancy distribution will be investigated; in Section 3.5.2, the distribution of accident types will be presented; in Section 3.5.3, changes in the time of day/week at which accidents occurred will be examined; and the changes in the vehicle size mix that have been observed in crashes are presented in Section 3.5.4. All data presented were obtained from the North Carolina accident files, and pertain to reportable crashes which occurred in North Carolina during the four month period January through April of each year.

3.5.1 Vehicle occupancy distributions.

The distributions of the number of occupants per accident-involved vehicle for each of the years 1973, 1974 and 1975 are given in Table 3.18. For obvious reasons pedestrians, bicycles and parked cars are not included in this table. Assuming the occupancy of accident-involved vehicles is similar to that of other vehicles, one can make inferences concerning overall vehicle occupancy in North Carolina based on the data presented in the table.

Examination of the distributional changes between 1973 and 1974 indicates an increase in the proportion of vehicles having only one occupant, while the proportions in all other categories except "9 or more" experienced decreases. This may reflect a cutback in the amount of non-essential driving such as for vacations or recreation. In 1975, the pattern essentially reverses with a dramatic reduction in the proportion of single occupant vehicles, accompanied by a corresponding increase in the number of vehicles having two or more occupants. This may well be a result of a general increase in the use of carpools when driving to and from work.

The mean number of occupants was computed using a value of nine for the category labeled "9 or more", and is presented at the bottom of Table 3.18. Consistent with the above discussion, mean occupancy dipped slightly during the energy crisis and rose immediately afterward to a level greater than that observed for 1973. A t-test for the difference of means indicated that these changes were statistically significant ($p \leq .002$) for each of the three periods.

Because many factors were indeed changing at the same time, the shift in mean occupancy in a perhaps unexpected direction further complicates the task of trying to distinguish between major effects contributing to the reduction in fatalities.

Table 3.18. Occupancy distribution for accident-involved vehicles.

Number of Occupants	Distribution 1973	Distribution 1974	Distribution 1975	Change in Distribution 73-74	Change in Distribution 74-75	Change in Distribution 73-75
1	64.80[1]	65.68	62.41	0.88	-3.27	-2.39
2	21.58	21.27	22.87	- 0.31	1.60	1.29
3	7.46	7.23	8.13	- 0.23	0.90	0.67
4	3.62	3.44	3.85	- 0.18	0.41	0.23
5	1.37	1.27	1.47	- 0.10	0.20	0.10
6	0.66	0.57	0.60	- 0.09	0.03	-0.06
7	0.16	0.13	0.16	- 0.03	0.03	0.00
8	0.05	0.04	0.08	- 0.01	0.04	0.03
9 or More	0.31	0.37	0.43	0.06	0.06	0.12
Total Vehicles	72348	63374	69180	-12.40[2]	9.16	-4.38
Mean Occupancy	1.60	1.58	1.64	.002[3]	.000	.000
Std. Dev.	1.07	1.06	1.11			

[1]Column percent.

[2]Percent change.

[3]P-value for testing corresponding differences of means.

3.5.2 Accident distributions.

Accidents were classified (according to the first harmful event) into one of the following categories:

1. Ran-off-road
2. Non-collision (e.g., roll-over in road)
3. Hit fixed object (e.g., hit utility pole)
4. Hit pedestrian
5. Hit bicycle
6. Rear-end
7. Turning (at least one vehicle turning)
8. Head-on
9. Sideswipe, angle
10. Backing

Categories 1, 2, and 3 are single vehicle crashes, while categories 6 through 10 involve two or more vehicles and categories 4 and 5 involve one or more motor vehicles and either a pedestrian or a bicycle.

Table 3.19 presents the distributions of urban, rural, and all accidents in North Carolina for the first four months of 1973, 1974 and 1975, for the ten accident types listed above.

Due to large sample sizes, Chi-square tests indicate that the distribution of all accidents has changed significantly with each succeeding year, while the actual distributional changes were very minor in most categories. Between 1973 and 1974, the most notable proportional decreases occurred in the following accident categories: ran-off-road, rear-end, head-on, and sideswipe, angle. In 1975, there were reductions from the level in 1974 in the incidence of all crash types except ran-off-road and rear-end accidents. The net results were that ran-off-road and sideswipe, angle crashes increased in prevalence as compared to 1973, while the proportion of rear-end and head-on accidents decreased. The remaining accident categories experienced only minor distributional changes.

These results are not easily interpreted in terms of accident severity; however, it is significant that head-on crashes were down, as these tend to be rather severe in terms of the probability of a fatality or serious injury.

Table 3.19. Distributions of accident types.

Accident Type	Population	Number of Accidents 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
Ran off road	All	10893	9165	10320	- 0.12	0.66	0.54
	Urban	2245	2094	2384	0.15	0.51	0.66
	Rural	8648	7071	7936	1.49	0.66	2.15
Non-collision	All	411	428	442	0.21	-0.07	0.15
	Urban	104	124	113	0.15	-0.11	0.04
	Rural	307	304	329	0.33	-0.03	0.30
Hit fixed object	All	3832	3216	3493	- 0.07	-0.08	- 0.14
	Urban	2285	2013	2125	- 0.49	-0.33	- 0.82
	Rural	1547	1203	1368	- 0.05	0.20	0.14
Hit pedestrian	All	753	666	670	0.08	-0.14	- 0.07
	Urban	445	419	431	0.05	-0.13	- 0.08
	Rural	308	247	239	0.03	-0.16	- 0.13
Hit bicycle	All	221	367	300	0.48	-0.25	0.23
	Urban	132	240	195	0.64	-0.33	0.31
	Rural	89	127	105	0.30	-0.16	0.13
Rear end	All	8221	6814	7215	- 0.37	-0.61	- 0.98
	Urban	3897	3563	3728	- 0.13	-0.76	- 0.89
	Rural	4324	3251	3487	- 0.73	-0.46	- 1.19
Turning	All	8099	6907	7441	0.15	-0.31	- 0.16
	Urban	4439	4006	4445	- 0.43	0.40	- 0.03
	Rural	3660	2901	2996	0.16	-0.95	- 0.80
Head on	All	844	537	586	- 0.47	-0.01	- 0.47
	Urban	231	183	189	- 0.16	-0.05	- 0.2
	Rural	613	354	397	- 0.66	0.03	- 0.6
Sideswipe, angle	All	10169	8516	9765	- 0.22	1.04	0.8
	Urban	5637	5181	5860	- 0.04	1.07	1.0
	Rural	4532	3335	3905	- 1.14	1.07	- 0.0
Backing	All	1296	1219	1235	0.33	-0.24	0.0
	Urban	731	721	728	0.26	-0.28	- 0.0
	Rural	565	498	507	0.28	-0.20	0.0
Total	All	44739	37835	41467	-15.43[1]	9.60	- 7.3
	Urban	20146	18544	20198	- 7.95	8.92	0.2
	Rural	24593	19291	21269	-21.56	10.25	-13.5
P-value	All				.000[2]	.000	.00
	Urban				.000	.003	.00
	Rural				.000	.004	.00

[1]Percentage change

[2]P-value for corresponding χ^2(9 d.f.).

Table 3.19 also gives the accident distributions for both urban and rural crashes. Again, while Chi-square tests indicate that these distributions changed significantly during the three years, the proportional changes were rather slight and mixed. Perhaps of most interest is the fact that between 1973 and 1975, rear-end, turning, and head-on crashes experienced the largest proportional decreases for rural crashes, while the incidence of ran-off-road accidents increased. It seems reasonable that the reduction in rear-end accidents is related to the lowered speed limit.

3.5.3 Time of day/week distribution.

Among other things, the energy crisis should have affected the times at which accidents occurred. To investigate this hypothesis, the week was partitioned into four time periods:

1. Commuting hours: 6 a.m. to 9 a.m. and 4 p.m. to 7 p.m., Monday through Friday.
2. Working hours: 9 a.m. to 4 p.m., Monday through Friday.
3. Weekday night hours: 7 p.m. to 12 midnight, Monday through Thursday and 12 midnight to 6 a.m., Tuesday through Friday.
4. Weekend: 7 p.m. Friday to 6 a.m. Monday.

Table 3.20 gives the distribution of all crashes occurring during these times for the first four months of 1973, 1974 and 1975. Chi-square tests show significant differences in the distributions for the three years, largely because weekend crashes were down substantially in 1974. This is not unexpected, as a good portion of non-essential travel probably took place during weekends prior to the energy crisis. The reduced availability and increased prices for fuel in 1974 forced much of the public to curtail non-essential driving, and as a result, fewer accidents occurred during the weekend hours.

Although rising slightly, weekend crashes continued to decrease proportionally in 1975. Furthermore, a drop in the proportion of accidents occurring while driving to and from work can also be noted for this

Table 3.20 Distribution of all accident times.

Time	Number of Accidents			Change in Distribution		
	1973	1974	1975	73-74	74-75	73-75
To and From Work	12080 (26.97)	10269 (27.68)	10869 (26.46)	0.71	-1.22	-0.51
Weekday Working Hours	11451 (25.57)	9870 (26.61)	11558 (28.14)	1.04	1.53	2.57
Weekday Nights	4452 (9.94)	4292 (11.57)	4783 (11.65)	1.63	0.07	1.71
Weekends	16803 (37.52)	12662 (34.14)	13861 (33.75)	- 3.38	-0.39	-3.77
Total	44786	37093	41071	-17.18[1]	10.72	-8.30
P-value				.000[2]	.000	.000

[1]Percentage change

[2]P-value for corresponding χ^2(3 d.f.)

year. Perhaps this is another indication of the increased usage of carpools suggested by the results of Section 3.5.1. Since weekend crashes tend to be more severe than crashes occurring at other times, the distributional shift away from these crashes is significant.

3.5.4 Vehicle size distribution.

Table 3.21 gives the vehicle size distribution of all vehicles involved in reportable crashes in North Carolina during the first four months of 1973, 1974 and 1975. In 1974 there were notable increases in the proportion of subcompact (domestic) and imported cars involved in accidents, while the frequency of involvement decreased for larger vehicles (luxury, medium, and standard). The percentage of subcompacts in accidents continued to rise in 1975, accompanied by a further reduction

Table 3.21. Vehicle size distribution - all roads.

Size	Number of Vehicles			Change in Distribution		
	1973	1974	1975	73-74	74-75	73-75
Luxury	2694	1867	2462	- 0.34	0.35	0.01
Medium	4818	3356	4172	- 0.56	0.12	-0.44
Standard	12880	8616	10004	- 2.37	-1.10	-3.47
Intermediate	11688	8801	10914	0.25	0.26	0.52
Compact	7541	5613	6855	0.00	-0.04	-0.04
Subcompact	1847	1697	2471	0.79	0.78	1.57
Specialty	78	48	53	- 0.02	-0.01	-0.04
Imported	4335	3478	4243	0.62	-0.04	0.58
Multi-purpose	1508	1580	2447	1.12	1.02	2.14
Truck or Semi	592	622	658	0.44	-0.21	0.24
Truck Size Unknown	6954	5198	5803	0.06	-1.13	-1.07
Total	54935	40876	50082	-25.59[1]	22.52	-8.83
P-value				.000[2]	.000	.000

[1]Percentage change

[2]P-value for the corresponding χ^2(10 d.f.)

in the proportion of standard-sized cars. Chi-square tests indicate that these distributional changes were statistically significant for all three years. It is interesting to note the small proportional increases for luxury and medium-sized vehicles during 1975, perhaps indicating a relaxation of public concern for the energy crisis.

To better understand the nature of these distributional changes, a ridit analysis was performed for domestic, passenger cars only (i.e., luxury through subcompact). This also indicated a significant shift towards smaller vehicles over the three year period. Since crash severity tends to be greater for smaller cars, this shift would imply that if all other factors were the same, then crash severity should have increased. The combination of factors (reduced speed and a greater proportion of smaller cars) may have interacted to yield a shift in the injury and accident severity distributions away from the extremes (i.e., K or A and PDO).

4. SUMMARY AND DISCUSSION

In this report, a variety of North Carolina data concerning the highway environment, accident characteristics, severity measures and many other traffic related factors have been examined in an effort to describe some of the changes that occurred during the peak of the energy crisis. Of all the observed changes, perhaps of primary interest is the fact that highway fatalities and overall accidents experienced dramatic reductions during this period, with fatalities continuing to remain below expected levels well after the peak of the crisis period.

There have been published studies that have attempted to determine what proportions of the reduction in the number of accidents or number of fatalities could be attributed to the various changes that were observed during that period. In most studies, the two major contributing factors were found to be the lowered maximum speed limit and the reduction in traffic volume. While this report does not present any strong evidence that would refute these arguments, it does suggest that attempts to quantify and compare these effects should be examined cautiously. The reasoning for this is twofold. First, because there were so many factors (both known and unknown) that were changing simultaneously, and because of the interactive nature of variables such as speed, traffic volumes, driver characteristics, vehicle type shifts, exposure changes, etc., it is virtually impossible to single out and estimate the effect of any specific factor. Indeed, some of the changes described in this report did not always present a consistent picture of what was taking place during and after the energy crisis in North Carolina.

Secondly, the available data for some variables were quite often crude and subjective, while crucial exposure data were almost nonexistant. One of the most unfortunate examples of this for North Carolina was the lack of accurate vehicle mileage estimates (e.g., three widely varying DOH mileage figures for 1974), an essential factor if one is attempting to investigate the effect of reduced traffic volumes.

Despite these shortcomings, it is well worthwhile to examine the changes associated with the crisis period in an attempt to at least identify some of those factors that may have been responsible for the accident reductions. The analyses conducted in this report have provided some insight into the nature of the changes that have taken place. The remainder of this chapter will be devoted to a summary and discussion of the major findings.

There was a clear alteration in the driving environment in North Carolina during the energy crisis, with various changes remaining, to a somewhat lesser extent, in the "post-crisis" period. Prior to 1974, overall vehicle mileage had been increasing in a linear fashion. Forecasts obtained from a time series model indicate that observed vehicle mileages for the first four months of 1974 and 1975 were 13.7 and 11.3 percent below expectation, respectively.

From average daily traffic counts, which were available on a much more detailed and accurate basis than vehicle mileage, it was found that weekend volumes decreased substantially more than weekday volumes on all road systems during the first four months of 1974. Furthermore, rural volumes dropped more than urban volumes during the same period. Since the scarcity and increased price of fuel forced a cutback in the amount of non-essential travel, the last two results come as no surprise.

In December of 1973, the 55 mph speed limit was imposed in an attempt to conserve dwindling fuel supplies. This did not result in as much change in North Carolina as in other states since the vast majority of highways already had posted speed limits of 55 mph or less. Furthermore, on those roadways where the limit did decrease, the change generally was no greater than 5 mph. The one exception was the Interstate system where speed limit changes were fairly substantial. One must keep in mind, however, the fact that North Carolina has relatively few miles of Interstate highway when compared with many other states. Therefore, one should expect the direct impact of the lowered speed limit to be somewhat smaller in North Carolina than in other states.

Interestingly enough, while the mean speed on Interstate highways did fall substantially during 1974, decreases in mean speeds were also observed on roads where there was no change in posted speed limits. By 1975, mean speeds on all non-Interstate roads had returned to their original levels. Interstate speeds did increase somewhat in 1975 but remained below the pre-crisis level.

Of considerable significance is the fact that speed variability decreased substantially on main highways during the energy crisis and remained down even with mean speeds increasing in the following year. It is well-known that the rate of accident involvement is related to speed variability, therefore suggesting a partial explanation of the lower accident frequencies observed during and after the energy crisis.

As noted earlier, the decrease observed in the number of crashes during this period is of primary concern. In 1974, total crashes fell 10 percent from the previous year while fatal crashes dropped 22 percent. Reductions in both total and fatal crashes during the energy crisis were primarily due to decreases in rural, weekend accidents. In 1975, the number of total crashes returned to the pre-crisis level; however, the number of fatal crashes continued to fall resulting in a net decrease of 24 percent as compared with 1973. Injury crashes exhibited the same pattern as total crashes, but did not completely return to pre-crisis levels in 1975.

When overall and fatal crashes were examined by individual road systems, some unexpected results became apparent. Statistical analysis indicated that the probability of a crash being fatal appeared to increase for Interstate highways between 1973 and 1974, though not significantly. This is surprising since it was on this road system where the largest reductions in posted speed limits and mean speeds were observed. All other types of rural roads witnessed decreases in this probability, although again, none of the changes were statistically significant. Urban roads, on the other hand, did experience a significant reduction in the chance of an accident being fatal.

The results discussed in the preceeding paragraph are representative of accident severity. More direct measures of accident severity are provided by the distributions of driver injury, most severe injury in an accident and TAD (indicating vehicle crush). It was found that driver injury and most severe injury in the accident experienced significant shifts in severity between 1973 and 1974 for both urban and rural roads.

Much of this increase was a result of distributional shifts out of the no injury category into the intermediate levels. Unlike the previous measures, TAD severity decreased significantly in both 1974 and 1975 for rural roads.

More specifically, both driver injury and most severe injury changed significantly between 1973 and 1974 on rural primary highways with posted speed limits orginally greater than or equal to 55 mph. No changes were observed for Interstate highways or rural primary roads with posted speed limits less than 55 mph. TAD severity decreased significantly in both 1974 and 1975 for all rural primary roads. Interstates, on the other hand, did not reveal any substantial decreases from year to year for TAD, but the combined change for both years was significant.

There was no noticeable change in the estimated travelling speed prior to an accident either during the crisis period or afterwards, despite the large reductions in fatalities and injuries. This suggests that perhaps the slightly lower mean speeds may have enabled some drivers to avoid potential accident situations, but that those drivers who were involved continued to crash at approximately similar speeds during the three year period. If this were the case, then there is no reason to expect any large decreases in the accident severity measures.

Crash rates based on vehicle mileage also failed to reveal any dramatic interruptions during the crisis period. The total crash rate had been following an upward trend since 1962, but then dropped 14.4 percent between 1971 and 1972, two years before the fuel shortage. The rate leveled off in 1973 and 1974, and then rose in 1975. The fatal crash rate had been decreasing linearly since 1966 and the 13.1 percent decrease in 1974 appears to be mainly only a continuation of this trend.

These observations suggest that the severity of accidents has decreased rather steadily since 1968. Based on these results, one might conclude that the reduced amount of travel was largely responsible for the lower number of accidents. However, a comparison of the percentage change in average daily traffic volume and total crashes revealed that a substantial portion of the reduction in total crashes for Interstate and U.S.

highways was not "predicted" by decreased volume. Since it was these two road systems that were affected most by the speed limit changes, it appears that other factors, in addition to volume changes, had a sizeable impact on accident frequency.

In addition to the observations presented above, there were a variety of other changes that came about as a result of the fuel shortage. The mean number of occupants of accident-involved vehicles dropped significantly during 1974 but then rose substantially in 1975. There was a slight shift toward older drivers during the three years. The percentage of accidents occurring on weekends fell considerably during 1974. Finally, there was a definite shift from larger cars to smaller cars in accidents during both 1974 and 1975. While most of these observations are not surprising, they are important since each factor certainly contributed to the shift in the number of total and fatal accidents.

The results presented in this report more than anything else, convey the complex and interactive nature of the changes that took place in the highway environment during and after the energy crisis. The lack of detailed exposure data, which would have shown in what way the characteristics of the driving population and the vehicles, routes, and trip purposes have changed, prevents one from being more definitive about the exact causes of the reduced number of fatalities. It is gratifying to see that there are plans for gathering exposure data on a regular basis within the framework of the National Accident Sampling System.

Furthermore, this report has produced a few results that are not exactly what was anticipated before the project began. For example, mean travelling speed did drop somewhat on rural North Carolina highways following implementation of the 55 mph speed limit, and as expected, was accompanied by a significant reduction in TAD severity. However, driver injury and most severe injury did not decrease significantly, even on Interstate highways where speed reductions were greatest. Because of the complex nature of the problem and the absence of crucial data, it does not appear possible to adequately explain this finding; however, perhaps one possible explanation should be considered. Figure 4.1 presents two different hypothesized relationships between the probability of death or serious injury and speed prior to impact. The absence of accurate speed estimates in the past has prevented researchers from defining the exact relationship between these two variables. However, the form of the curves in Figure 4.1 is intuitively appealing since it is known that the chance of serious injury rises exponentially with speed, and that above some speed virtually all passengers will be killed. The critical issue is the shape of the curve in the 55 to 70 mph range. If the upper curve represents the true situation, decreasing travelling speeds from the 65 to 70 mph range down to the 55 to 60 mph range would substantially increase the likelihood of escaping an accident without serious injury. On the other hand, if the lower curve is closer to reality, the same speed reductions would not produce any significant change in the probability of surviving an accident. It is possible that the lower curve is more representative of the situation in North Carolina. This could explain the reason why driver injury and most severe injury did not undergo any significant changes on rural roads. Furthermore, if a shift in TAD levels is more likely in this speed range, this would explain the downward shift that was observed. Council et al. (1975) also suggested this possibility in their study of North Carolina data.

It would appear from several of the results presented earlier that reduced travel rather than the lowered speed limit was largely responsible for the decrease in total and fatal crashes in North Carolina. However, the lower speed limit cannot be dismissed for two important reasons. First, the percentage decrease in total crashes was substantially greater than would have been expected as a result of volume decreases for the two roads systems that were most affected by the lower speed limit, namely Interstate and U.S. highways. Second, and perhaps of greater importance, was the reduction in speed variance that appeared in 1974 and remained even after mean speeds on most rural roads had returned to pre-crisis levels. Although the exact relationship between the lowered speed limit and the speed variance is not known, it is conceivable that a return to older, higher limits would increase this variance. Since speed variance is related to accident frequency, it appears that rather than a large direct effect, the lowered speed limit may have resulted in a significant indirect effect in North Carolina.

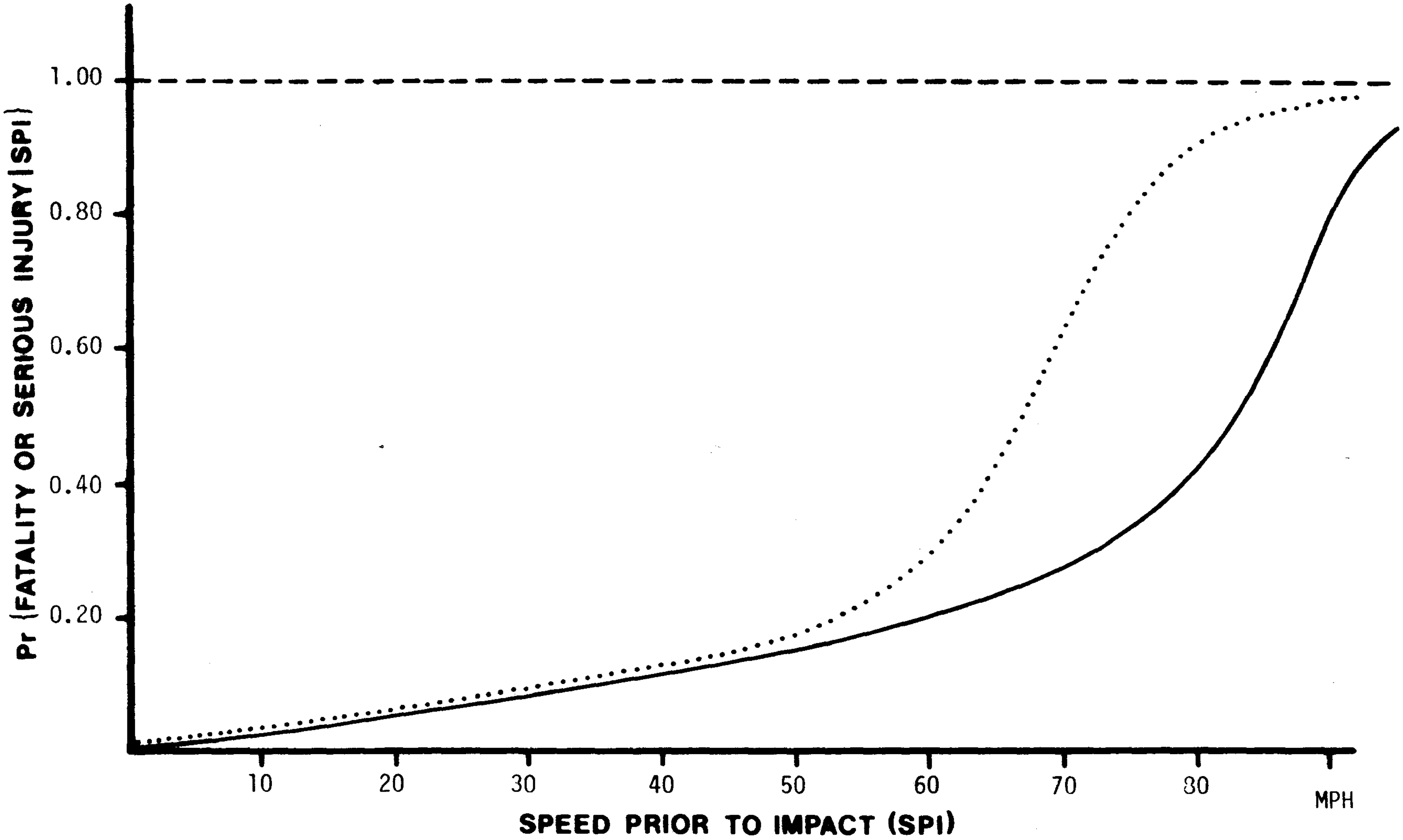


Figure 4.1 Hypothesized relationship between probability of death or serious injury and speed before impact.

Among the many variables examined in this study, one that has not been mentioned previously is a factor that will be referred to as "driver awareness". During the energy crisis and afterwards, the public was under constant pressure to conserve fuel. Drivers were urged to change old, inefficient driving habits such as quick stopping and starting, and to keep their vehicles in better running condition. In addition to various advertising campaigns, the 55 mph speed limit and the substantially higher price of gasoline also served as a constant reminder that times had changed. Perhaps an unintended, but desirable effect of this increase in awareness was a driving population that was more safety conscious. For example, drivers were urged to increase their gas mileage by checking tires regularly and maintaining proper air pressure. It would be impossible to measure, but there is little doubt that this action prevented a number of accidents due, for example, to blowouts that would have otherwise occurred. Although this heightened sense of awareness may have eroded to a certain extent over time, it likely remained in effect long after the peak of the energy crisis had past.

One final comment concerns the basically univariate approach taken in this study which ignores effects due to variable interactions. Obviously interactions among variables are important. Appendix D represents a self-contained study which examines the relative effects on serious and fatal injuries of certain variables for which data were available and which should be highly associated with the likelihood of serious injury. These include: year, driver age and sex, belt usage, time of day, day of week, road type, occupancy of vehicle and estimated speed prior to impact (ESPI). In short, the analysis identifies those variables (ESPI, belt usage, year, etc.) most associated with likelihood of serious injury or death to control for in the next analysis stage; obtains predicted rates (and standard errors) using weighted least squares procedures for categorical data; and finally derives a series of indices showing percentage reductions under a variety of assumptions. The upshot is that there could have been a hypothetical reduction of 28.3 percent in serious injuries to belted drivers in 1973 that would have been realized if the 1973 accident type distribution of belted driver accidents with respect to ESPI, time and road type and the 1973 injury rates for ESPI × time × road type combinations had been the same as their observed counterparts in 1974. For unbelted drivers, the corresponding reduction could have been 9.4 percent. (See Appendix D for full details.)

In conclusion, this study illustrates the complex, interrelated and sometimes surprising nature of the changes that took place in the North Carolina driving environment during and after the energy crisis. It further demonstrates the need to collect more comprehensive and accurate data on the highway environment, driver exposure and accidents. While several factors certainly contributed in some minor way to the lower number of fatal accidents, there can be little doubt that the reduction in travel played a major role in North Carolina. Perhaps unlike other areas of the country, the lowered speed limit appears to have had more of an indirect, but nevertheless important, impact on accident frequency. Regardless of the magnitude of the individual effects, the overall effects of the energy crisis on highway safety in North Carolina were indeed substantial.

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APPENDIX A

North Carolina Accident Report Form

In filling out these items on the back use the following examples:

1. LOCALITY
   1. Business
   2. Residential
   3. School & playground
   4. Open country
2. SPEED LIMIT
3. ROAD FEATURE
   1. Bridge or underpass
   2. Driveway
   3. Alley intersection
   4. Intersection of two roadways
   5. Non-intersection median crossover
   6. End or beginning of divided highway
   7. Other
4. ROAD SURFACE
   1. Concrete
   2. Smooth asphalt
   3. Coarse asphalt
   4. Gravel
   5. Dirt or sand
   6. Other
5. ROAD DEFECTS
   1. Loose material on surface
   2. Holes, deep ruts
   3. Low shoulders
   4. Soft shoulders
   5. Other defects
   6. Road under construction
   7. No defects
6. ROAD CONDITION
   1. Dry
   2. Wet
   3. Oily
   4. Muddy
   5. Snowy
   6. Icy
7. LIGHT CONDITION
   1. Daylight
   2. Dusk
   3. Dawn
   4. Darkness (street lighted)
   5. Darkness (street not lighted)
8. WEATHER
   1. Clear
   2. Cloudy
   3. Raining
   4. Snowing
   5. Fog
   6. Sleet or hail
9. TRAFFIC CONTROL
   1. Stop sign
   2. Yield sign
   3. Stop and go signal
   4. Flashing signal with stop sign
   5. Flashing signal without stop sign
   6. R. R. gate and flasher
   7. R. R. flasher
   8. Officer
   9. Other device
   10. No control present
10. OBJECT STRUCK (first only)
   1. Tree
   2. Utility pole
   3. Fence or fence post
   4. Guardrail or guardpost in median
   5. Guardrail or guardpost on shoulder
   6. Bridge
   7. Underpass
   8. Traffic island, curb, or median
   9. Sign or sign post
   10. Animal
   11. Ditch bank
   12. Parked vehicle
   13. Pedestrian
   14. Other object
   15. None
11. SOBRIETY
   1. Had not been drinking
   2. Drinking-ability impaired
   3. Drinking-unable to determine impairment
   4. Unknown
12. PHYSICAL CONDITION
   1. Ill
   2. Fatigued
   3. Asleep
   4. Other physical impairment
   5. Restriction not complied with
   6. Normal
   7. Condition not known
13. CHEMICAL TEST
14. PEDESTRIAN ACTION
   1. Crossing at intersection
   2. Crossing not at intersection
   3. Coming from behind parked vehicle
   4. Walking with traffic
   5. Walking against traffic
   6. Getting on or off vehicle
   7. Standing in road
   8. Working in road
   9. Playing in road
   10. Lying in road
   11. Other
   12. Not in road
15. VEHICLE MANEUVER
   1. Stopped in travel lane
   2. Parked out of travel lanes
   3. Parked in travel lanes
   4. Going straight ahead
   5. Changing lanes or merging
   6. Passing
   7. Making right turn
   8. Making left turn
   9. Making U turn
   10. Backing
   11. Slowing or stopping
   12. Starting in roadway
   13. Parking
   14. Leaving parked position
   15. Other
16. VEHICLE DEFECTS (List one or more)
   1. Defective brakes
   2. Defective headlights
   3. Defective rear lights
   4. Defective steering
   5. Defective tires
   6. Other defects
   7. Not known if defective
   8. No defects detected

TRAFFIC ACCIDENT REPORT

N. C. Department of Motor Vehicles DMV-349 (Rev. 1-1-73)

LOCATION

Date of Accident ________ 19 ____ Day of Week ________ Hour ____ A.M. ☐ P.M. ☐

Do not write in this space

Accident Occurred In ________ County ☐ In ☐ Near City or Town of ________

Outside City or Town ____ Miles ☐ N ☐ E ☐ S ☐ W of ☐ Limits ☐ Center

Patrol Area

On ________ Hwy. No. (I., U.S., N.C., R.P., R.U.) If No., or within corporate limits, identify by name

☐ Miles ☐ Feet (0 Ft. if Intersec.) ☐ N ☐ E ☐ S ☐ W At or From ________ Hwy. No., or Adjacent County Line Toward ________ Hwy. No., City, or Adjacent County Line

ACCIDENT TYPE

Ran off Road			Non-Collision in Road		Collision of Motor Vehicle in Road With:						
1. Right	2. Left	3. Straight Ahead	4. Overturn	5. Other in Road	6. Pedestrian	7. Parked Vehicle	8. Train	9. Bicycle	10. Animal	11. Fixed Obj.	12. Other Obj.

Collision of M.V. in Road With Another M. V.

13. Rear End Slow or Stop	14. Rear End Turn	15. Left Turn Same Roadway	16. Left Turn Cross Traffic	17. Right Turn Same Roadway	18. Right Turn Cross Traffic	19. Head On	20. Sideswipe	21. Angle	22. Backing

VEHICLE NO. 1	VEHICLE NO. 2 or PEDESTRIAN
No. of Vehicles Involved ☐	
Driver: First ____ Middle ____ Last Name ____	Driver: First ____ Middle ____ Last Name ____
Address:	Address:
City: ____ State: ____	City: ____ State: ____
Is above address same as on Driver's License? Yes ☐ No ☐	Is above address same as on Driver's License? Yes ☐ No ☐
Race/Sex: ____ Driver's Lic: ____ State: ____	Race/Sex: ____ Driver's Lic. ____ State: ____
Date of Birth: Month Day Year ____ Specify Restriction: ____	Date of Birth: Month Day Year ____ Specify Restriction: ____
Member of Armed Forces Yes ☐ No ☐ Veh. Year: ____ Veh. Make: ____ Veh. Type: ____	Member of Armed Forces Yes ☐ No ☐ Veh. Year: ____ Veh. Make: ____ Veh. Type: ____
Lic. Plate No. ____ State: ____ Year: ____	Lic. Plate No. ____ State ____ Year: ____
VIN ____ ODOM. _ _ _ _ _ . _	VIN ____ ODOM. _ _ _ _ _ . _
Owner:	Owner:
Address:	Address:
City: ____ State: ____	City: ____ State: ____
Parts Damaged (TAD) ____ Amount of Damage $ ____	Parts Damaged (TAD) ____ Amount of Damage $ ____
Drivable: Yes ☐ No ☐ Vehicle Removed to: ____	Drivable: Yes ☐ No ☐ Vehicle Removed to: ____
By: ____ Authority: ____	By: ____ Authority: ____

Other Property Damaged ________ Amt. of Dam. $ ____ Owner and Address ________

INJURY SECTION INSTRUCTIONS

Give injury class, restraint used, race, sex and age of all occupants in the space corresponding to the seat occupied. Names and addresses are necessary for persons who were injured. For type of Restraint (Res.) used: N – None, L – Lap Belt, LS – Lap and Shoulder, S – Shoulder Belt only, YR – Child Restraint System.

K=Killed	A=Incapacitating	B=Nonincapacitating – Injury other than K or A evident at the scene	C=No visible sign of injury but complaint of pain, momentary unconsciousness	O=No injury

SEAT	Inj cl	Res usd	Race, sex	Age	INJURED NAMES AND ADDRESSES First Name / Last	SEAT	Inj cl	Res usd	Race sex	Age	INJURED NAMES AND ADDRESSES First Name / Last
Left Front					DRIVER 1	Left Front					DRIVER 2 OR PEDESTRIAN
Center Front						Center Front					
Right Front						Right Front					
Left Rear						Left Rear					
Center Rear						Center Rear					
Right Rear						Right Rear					
Total No. Occupants					Total No. Inj.	Total No. Occupants					Total No. Inj.

Injured taken to: ________

WIT- Name ________ Address ________ Phone No. ________

NESSES Name ________ Address ________ Phone No. ________

Arrests: Name ________ Charge(s) ________ (Cit. No.) ________

Name ________ Charge(s) ________ (Cit. No.) ________

Sign Here ________ Officer's Rank and Name ________ Number ________ Department ________ Date of Report

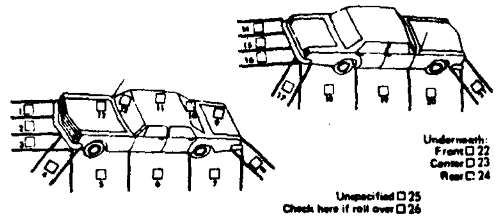
ADDED BY ________ (Initial)

MARKS

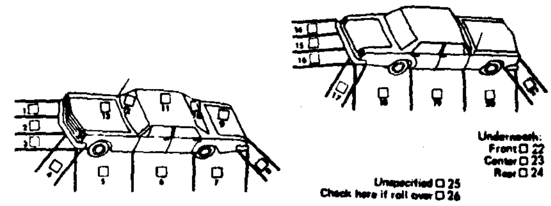
In filling out these items on the back use the following examples:

1. LOCALITY
   1. Business
   2. Residential
   3. School & playground
   4. Open country
2. SPEED LIMIT
3. ROAD FEATURE
   1. Bridge or underpass
   2. Driveway
   3. Alley intersection
   4. Intersection of two roadways
   5. Non-intersection median crossover
   6. End or beginning of divided highway
   7. Other
4. ROAD SURFACE
   1. Concrete
   2. Smooth asphalt
   3. Coarse asphalt
   4. Gravel
   5. Dirt or sand
   6. Other
5. ROAD DEFECTS
   1. Loose material on surface
   2. Holes, deep ruts
   3. Low shoulders
   4. Soft shoulders
   5. Other defects
   6. Road under construction
   7. No defects
6. ROAD CONDITION
   1. Dry
   2. Wet
   3. Oily
   4. Muddy
   5. Snowy
   6. Icy
7. LIGHT CONDITION
   1. Daylight
   2. Dusk
   3. Dawn
   4. Darkness (street lighted)
   5. Darkness (street not lighted)
8. WEATHER
   1. Clear
   2. Cloudy
   3. Raining
   4. Snowing
   5. Fog
   6. Sleet or hail
9. TRAFFIC CONTROL
   1. Stop sign
   2. Yield sign
   3. Stop and go signal
   4. Flashing signal with stop sign
   5. Flashing signal without stop sign
   6. R. R. gate and flasher
   7. R. R. flasher
   8. Officer
   9. Other device
   10. No control present
10. OBJECT STRUCK (first only)
    1. Tree
    2. Utility pole
    3. Fence or fence post
    4. Guardrail or guardpost in median
    5. Guardrail or guardpost on shoulder
    6. Bridge
    7. Underpass
    8. Traffic island, curb, or median
    9. Sign or sign post
    10. Animal
    11. Ditch bank
    12. Parked vehicle
    13. Pedestrian
    14. Other object
    15. None
11. SOBRIETY
    1. Had not been drinking
    2. Drinking-ability impaired
    3. Drinking-unable to determine impairment
    4. Unknown
12. PHYSICAL CONDITION
    1. Ill
    2. Fatigued
    3. Asleep
    4. Other physical impairment
    5. Restriction not complied with
    6. Normal
    7. Condition not known
13. CHEMICAL TEST
14. PEDESTRIAN ACTION
    1. Crossing at intersection
    2. Crossing not at intersection
    3. Coming from behind parked vehicle
    4. Walking with traffic
    5. Walking against traffic
    6. Getting on or off vehicle
    7. Standing in road
    8. Working in road
    9. Playing in road
    10. Lying in road
    11. Other
    12. Not in road
15. VEHICLE MANEUVER
    1. Stopped in travel lane
    2. Parked out of travel lanes
    3. Parked in travel lanes
    4. Going straight ahead
    5. Changing lanes or merging
    6. Passing
    7. Making right turn
    8. Making left turn
    9. Making U turn
    10. Backing
    11. Slowing or stopping
    12. Starting in roadway
    13. Parking
    14. Leaving parked position
    15. Other
16. VEHICLE DEFECTS (List one or more)
    1. Defective brakes
    2. Defective headlights
    3. Defective rear lights
    4. Defective steering
    5. Defective tires
    6. Other defects
    7. Not known if defective
    8. No defects detected

VEHICLE 1 POINT OF INITIAL CONTACT



VEHICLE 2 POINT OF INITIAL CONTACT



					VEHICLE 1	VEHICLE 2
1. Locality	9. Traffic Control	Not Operating ☐	Not Visible ☐			
2. Speed Limit	10. Object Struck			15. Veh. Maneuver		
3. Road Feature		DRIVER 1	DRIVER 2 or PED.	16. Veh. Defects		
4. Road Surface	11. Sobriety			17. Estimated Speed		
5. Road Defects	12. Physical Cond.			18. Tire Impressions(ft)		
6. Road Condition	13. Chem. Test	YES ☐ NO ☐	YES ☐ NO ☐	19. Distance Traveled After Impact (ft.)		
7. Light Condition						
8. Weather	14. Ped. Action					

INDICATE NORTH

Vehicle 1 was Traveling ☐ N ☐ E ☐ S ☐ W on ______ Vehicle 2 was Traveling ☐ N ☐ E ☐ S ☐ W on ______

DESCRIBE WHAT HAPPENED:

Vehicle 1 2 — VIOLATION INDICATED

- ☐ ☐ 1. No. Violation Indicated
- ☐ ☐ 2. Excessive Speed
- ☐ ☐ 3. Yield Violation
- ☐ ☐ 4. Left of Center
- ☐ ☐ 5. Passing Violation
- ☐ ☐ 6. Stop S. or Yield S. Vio.
- ☐ ☐ 7. Traffic Signal Vio.
- ☐ ☐ 8. Safe Movement Vio.
- ☐ ☐ 9. Too Close
- ☐ ☐ 10. Improper Turn
- ☐ ☐ 11. Improper or No Signal
- ☐ ☐ 12. Improper Parking Location
- ☐ ☐ 13. Other Improper Driving

(describe) ______

EMERGENCY ASSISTANCE INFORMATION

INVESTIGATOR NOTIFIED ______ ☐ a.m. ☐ p.m.

BY ______

INVESTIGATOR ARRIVED ______ ☐ a.m. ☐ p.m.

AMBULANCE ARRIVED ______ ☐ a.m. ☐ p.m.

OTHER COMMENTS: ______

RESERVED FOR STATE USE:

20.	21.	22.	23.	24.
25.	26.	27.	28.	29.

RESERVED FOR CITY OR OTHER USE:

APPENDIX B

Supplementary Tables

Table B.1 Vehicle Speeds, All Highways

Year	Vehicle	Mean Speed	85% Speed	80% Interval	80% Width	Percent Above 55	Sample Size
1963	All	54.2	60	(42.7 61.0)	18.3	42.7	NA[1]
	Pasgr. Cars	55.7	62	(45.2 61.6)	16.4	52.0	NA
	Comm. Vehicle	50.3	56	(40.2 57.7)	17.5	18.3	NA
1964	All	53.2	59	(42.2 60.1)	17.9	36.6	NA
	Pasgr. Cars	54.2	60	(43.4 60.5)	17.1	43.3	NA
	Comm. Vehicle	50.1	55.5	(40.5 57.2)	16.7	16.6	NA
1965	All	53.3	60	(41.9 60.4)	18.5	36.9	NA
	Pasgr. Cars	54.5	60	(43.5 60.9)	17.4	43.9	NA
	Comm. Vehicle	50.3	56.6	(40.1 57.9)	17.8	18.4	NA
1966	All	53.6	60	(42.3 60.6)	18.3	37.2	NA
	Pasgr. Cars	54.9	60	(44.5 61.1)	16.6	44.7	NA
	Comm. Vehicle	50.3	56	(40.4 57.6)	17.2	16.9	NA
1967	All	53.7	60	(41.8 60.8)	19.0	38.6	NA
	Pasgr. Cars	55.0	61	(43.7 61.4)	17.7	46.2	NA
	Comm. Vehicle	50.5	58	(39.4 58.0)	18.6	18.6	NA

[1] NA - data not available.

(Continued)

Table B.1 Vehicle Speeds, All Highways

Year	Vehicle	Mean Speed	85% Speed	80% Interval	80% Width	Percent Above 55	Sample Size
1968	All	53.6	59	(42.3 60.2)	17.9	35.8	4962
	Pasgr. Cars	54.5	59	(43.5 60.7)	17.2	42.1	3583
	Comm. Vehicle	51.0	57	(40.7 57.9)	17.2	18.8	1342
1969	All	53.5	59	(42.9 60.3)	17.4	33.7	4901
	Pasgr. Cars	54.7	60	(44.7 61.0)	16.3	41.3	3347
	Comm. Vehicle	50.8	55	(41.0 57.4)	16.4	16.7	1524
1970	All	55.0	60	(44.7 61.4)	16.7	44.2	4881
	Pasgr. Cars	56.4	62	(46.3 62.0)	15.7	52.0	3313
	Comm. Vehicle	52.3	59	(42.0 59.3)	17.3	27.2	1544
1971	All	54.3	59	(44.0 61.6)	17.6	39.9	5014
	Pasgr. Cars	55.4	60	(45.5 62.6)	17.1	47.3	3500
	Comm. Vehicle	51.9	58	(41.8 58.6)	16.8	22.8	1476

Table B.1 Vehicle Speeds, All Highways

Year	Vehicle	Mean Speed	85% Speed	80% Interval	80% Width	Percent Above 55	Sample Size
1972	All	51.7	58	(41.6 59.1)	17.5	25.3	4171
	Pasgr. Cars	52.4	60	(42.6 59.4)	16.8	28.2	2883
	Comm. Vehicle	50.3	57	(40.3 58.2)	17.9	18.9	1268
1973	All	52.3	60	(40.4 61.4)	21.0	33.9	4471
	Pasgr. Cars	53.3	60	(41.4 62.1)	20.7	37.9	3070
	Comm. Vehicle	50.4	59	(38.3 59.6)	21.3	25.2	1381
1974	All	50.7	57	(41.6 58.0)	16.4	20.1	4361
	Pasgr. Cars	51.5	57	(42.7 58.4)	15.7	22.6	2937
	Comm. Vehicle	49.2	55	(40.5 56.9)	16.4	14.9	1412
1975	All	52.3	58	(42.9 59.3)	16.4	29.6	4442
	Pasgr. Cars	52.8	58	(44.2 59.4)	15.2	31.0	3092
	Comm. Vehicle	51.2	58	(41.2 58.9)	17.7	26.6	1322

Table B.2 Vehicle Speeds: Interstate Highways

Year	Vehicle	Mean Speed	Sample Size	85% Speed	80% Interval	80% Width	Percent Above 55	Percent Above 65
1968	Pasgr. Cars	62.1	793	66	(54.1 66.3)	12.2	88.4	20.1
	Comm. Vehicles	58.3	319	64	(47.0 63.9)	16.9	66.8	4.1
1969	Pasgr. Cars	63.0	782	67	(54.2 67.3)	13.1	88.6	27.9
	Comm. Vehicles	57.8	331	64	(47.0 63.8)	16.8	61.6	4.5
1970	Pasgr. Cars	64.6	786	69	(56.2 68.7)	12.5	94.8	37.4
	Comm. Vehicles	60.8	335	64	(51.0 65.5)	14.5	77.9	13.7
1971	Pasgr. Cars	62.6	1102	66	(55.0 66.6)	11.6	90.1	22.6
	Comm. Vehicles	60.6	486	64	(50.8 65.3)	14.8	78.8	11.9
1972	Pasgr. Cars	60.8	1156	65	(52.9 65.2)	12.3	84.3	11.2
	Comm. Vehicles	58.2	550	65	(48.8 64.0)	15.2	67.3	5.1
1973	Pasgr. Cars	65.4	1098	70	(56.5 70.1)	13.6	95.4	44.1
	Comm. Vehicles	61.9	463	69	(50.8 67.7)	16.9	78.8	25.3
1974	Pasgr. Cars	57.4	1036	62	(50.5 63.0)	12.5	63.3	3.6
	Comm. Vehicles	54.4	570	60	(46.7 59.6)	12.9	35.4	0.5

(Continued)

Table B.2 Vehicle Speeds: Interstate Highways

Year	Vehicle	Mean Speed	Sample Size	85% Speed	80% Interval	80% Width	Percent Above 55	Percent Above 65
1975	Pasgr. Cars	58.9	986	63	(52.0 63.9)	11.9	77.2	5.1
	Comm. Vehicles	58.1	561	62	(50.9 63.5)	12.6	69.2	4.5

Table B.3 Speed data: Main routes

Year	Vehicle	Mean Speed	Sample Size	85% Speed	80% Interval	80% Width	Percent Above 55	Percent Above 65
1968	Pasgr. Cars	54.2	2958	59	(43.5 61.3)	17.8	40.3	12.8
	Comm. Vehicles	50.8	1065	56	(40.7 57.5)	16.8	16.9	3.1
1969	Pasgr. Cars	54.6	2761	59	(44.9 62.0)	17.1	41.0	14.6
	Comm. Vehicles	50.8	1229	55	(41.1 57.3)	16.2	16.2	2.8
1970	Pasgr. Cars	56.3	2763	62	(46.2 63.5)	17.3	54.2	22.0
	Comm. Vehicles	52.5	1215	59	(42.1 59.5)	17.4	28.1	7.9
1971	Pasgr. Cars	55.4	2876	60	(45.4 62.6)	17.2	47.2	17.2
	Comm. Vehicles	51.6	1199	58	(41.5 58.4)	16.9	21.4	4.5
1972	Pasgr. Cars	52.3	2680	60	(42.5 59.5)	17.0	27.9	7.8
	Comm. Vehicles	50.1	1179	57	(40.1 58.0)	18.1	17.6	5.1
1973	Pasgr. Cars	53.7	2556	60	(42.3 62.2)	19.9	39.3	14.6
	Comm. Vehicles	50.8	1173	60	(39.1 59.9)	20.8	26.9	9.7
1974	Pasgr. Cars	51.2	2701	57	(42.4 58.2)	15.8	21.1	4.0
	Comm.	49.0	1300	55	(40.4 56.6)	16.2	13.8	1.8

(Continued)

Table B.3 Speed Data: Main routes

Year	Vehicle	Mean Speed	Sample Size	85% Speed	80% Interval	80% Width	Percent Above 55	Percent Above 65
1975	Pasgr. Cars	52.7	2801	58	(44.1 59.3)	15.2	30.6	6.9
	Comm.	51.3	1211	58	(41.2 58.9)	17.7	26.8	5.2

Table B.4 Total crashes in North Carolina (January through April).

Variables	Number of Crashes 1973	1974	1975	Percent Change 73-74	74-75	73-75
Entire state	37832	33946	37979	-10.27[1]	11.88	0.39
Urban	17236 (45.56)[2]	16919 (49.84)	19278 (50.76)	- 1.84 (4.28)[3]	13.94 (0.92)	11.85 (5.20)
Rural	20596 (54.44)	17027 (50.16)	18701 (49.24)	-17.33 (-4.28)	9.83 (-0.92)	-9.20 (-5.20)
Weekday	22336 (59.04)	21422 (63.11)	24055 (63.34)	- 4.09 (4.07)	12.29 (0.23)	7.70 (4.30)
Weekend	15496 (40.96)	12524 (36.89)	13924 (36.66)	-19.18 (-4.07)	11.18 (-0.23)	-10.14 (-4.30)
Urban-Weekday	10928 (28.89)	11390 (33.55)	13002 (34.23)	4.23 (4.67)	14.15 (0.68)	18.98 (5.35)
Urban-Weekend	6308 (16.67)	5529 (16.29)	6276 (16.52)	-12.35 (-0.39)	13.51 (0.24)	- 0.51 (-0.15)
Rural-Weekday	11408 (30.15)	9594 (28.26)	11053 (29.10)	-15.90 (-1.89)	15.21 (0.84)	- 3.11 (-1.05)
Rural-Weekend	9188 (24.29)	7433 (21.90)	7648 (20.14)	-19.10 (-2.39)	2.89 (-1.76)	-16.76 (-4.15)

[1] Percent change: $-10.27 = \frac{33946-37832}{37832} \times 100.$

[2] Percent of column total.

[3] Difference in column percentages (e.g., 4.28 = 49.84 - 45.56).

Table B.5 Fatal crashes in North Carolina (January through April).

Variables	Number of Fatal Crashes 1973	1974	1975	Percent Change 73-74	74-75	73-75
Entire state	478	375	361	-21.55[1]	- 3.73	-24.48
Urban	88 (18.41)[2]	53 (14.13)	60 (16.62)	-39.77 (-4.28)[3]	13.21 (2.49)	-31.82 (-1.79)
Rural	390 (81.59)	322 (85.87)	301 (83.38)	-17.44 (4.28)	- 6.52 (-2.49)	-22.82 (1.79)
Weekday	233 (48.74)	211 (56.27)	185 (51.25)	- 9.44 (7.52)	-12.32 (-5.02)	-20.60 (2.50)
Weekend	245 (51.26)	164 (43.73)	176 (48.75)	-33.06 (-7.52)	7.32 (5.02)	-28.16 (-2.50)
Urban-Weekday	49 (10.25)	35 (9.33)	33 (9.14)	-28.57 (-0.92)	- 5.71 (-0.19)	-32.65 (-1.11)
Urban-Weekend	39 (8.16)	18 (4.80)	27 (7.48)	-53.85 (-3.36)	50.00 (2.68)	-30.77 (-0.68)
Rural-Weekday	184 (38.49)	176 (46.93)	152 (42.11)	- 4.35 (8.44)	-13.64 (-4.83)	-17.39 (3.61)
Rural-Weekend	206 (43.10)	146 (38.93)	149 (41.27)	-29.13 (-4.16)	2.05 (2.34)	-27.67 (-1.82)

[1] Percent change: $-21.55 = \frac{375-478}{478} \times 100.$

[2] Percent of column total.

[3] Difference in column percentages (e.g., -4.28 = 14.13 - 18.41).

Table B.6 Injury crashes in North Carolina (January through April).

Variable	Number of Injury Crashes			Percent Change		
	1973	1974	1975	73-74	74-75	73-75
Entire state	14214	12515	13570	-11.95	8.43	- 4.53
Urban	6254	5881	6495	- 5.96	10.44	3.85
Rural	7960	6634	7075	-16.66	6.65	-11.12

Table B.7 Violations of accident-involved drivers in North Carolina (January through April).

Violation	Population	Number of Violations			Change in Distribution		
		1973	1974	1975	73-74	74-75	73-75
Speeding < 65	Total	7592	6083	6127	- 1.46[1]	-1.65	-3.11
	Male	5815	4652	4642	- 1.01	-1.85	-2.85
	Female	1621	1254	1279	- 2.13	-1.50	-3.63
Speeding 65-75	Total	777	827	884	0.51	-0.08	0.43
	Male	653	698	736	0.70	-0.11	0.59
	Female	74	55	61	- 0.12	-0.01	-0.14
Speeding > 75	Total	512	317	334	- 0.40	-0.04	-0.44
	Male	447	272	291	- 0.47	-0.02	-0.50
	Female	25	15	11	- 0.08	-0.06	-0.15
Failed to Yield	Total	4682	3719	3988	- 1.01	-0.30	-1.31
	Male	2962	2266	2411	- 0.99	-0.26	-1.26
	Female	1664	1388	1531	- 0.99	-0.45	-1.44
Driving Wrong Side	Total	3049	2341	2608	- 0.92	0.09	-0.82
	Male	2235	1651	1872	- 1.02	0.30	-0.72
	Female	716	554	605	- 0.94	-0.24	-1.18
Improper Passing	Total	1056	786	848	- 0.40	-0.05	-0.45
	Male	819	594	610	- 0.43	-0.16	-0.59
	Female	220	164	198	- 0.36	0.13	-0.24
Ran Stop Sign	Total	1399	1170	1229	- 0.11	-0.17	-0.28
	Male	933	740	777	- 0.19	-0.13	-0.32
	Female	445	399	419	0.07	-0.35	-0.28
Ran Traffic Signal	Total	1159	1019	1281	0.07	0.47	0.53
	Male	753	620	794	- 0.05	0.50	0.45
	Female	393	382	466	0.41	0.35	0.76
Following too Close	Total	2807	2134	3078	- 0.91	2.13	1.22
	Male	2034	1541	2174	- 0.75	2.09	1.34
	Female	744	555	859	- 1.22	2.41	1.19
Improper Turn	Total	1152	1169	545	0.57	-2.16	-1.59
	Male	755	746	325	0.53	-2.08	-1.55
	Female	383	400	203	0.73	-2.63	-1.90
Improper Signal	Total	404	256	268	- 0.30	-0.04	-0.33
	Male	288	187	191	- 0.25	-0.06	-0.31
	Female	111	62	73	- 0.43	0.03	-0.40
Improper Parking	Total	310	221	256	- 0.15	0.04	-0.11
	Male	116	83	91	- 0.07	0.002	-0.06
	Female	26	24	29	0.01	0.02	0.03

Table B.7 (Continued).

Violation	Population	Number of Violations 1973	1974	1975	Change in Distribution 73-74	74-75	73-75
Drinking	Total	1185	1246	1277	0.72	-0.27	0.45
	Male	1063	1102	1160	0.98	-0.18	0.80
	Female	104	117	100	0.30	-0.34	-0.04
Reckless Driving	Total	513	494	506	0.17	-0.11	0.06
	Male	444	416	418	0.21	-0.15	0.05
	Female	54	55	65	0.09	0.03	0.11
Didn't Look	Total	7923	7833	9496	3.24	2.56	5.80
	Male	5299	4996	6094	2.59	2.73	5.32
	Female	2530	2670	3257	5.17	2.41	7.58
Improper Lights and Brakes	Total	332	340	367	0.17	-0.02	0.15
	Male	235	247	249	0.23	-0.09	0.15
	Female	93	92	115	0.12	0.11	0.23
Other	Total	1329	1209	1193	0.21	-0.40	-0.19
	Male	893	745	689	- 0.01	-0.53	-0.54
	Female	290	205	244	- 0.61	0.12	-0.49
Total	Total	36181	31164	34285	-13.87[2]	10.01	-5.24
	Male	25744	21556	23524	-16.27	9.13	-8.62
	Female	9493	8391	9515	-11.61	13.40	0.23

1 $\frac{6083 \times 100}{31164} - \frac{7592 \times 100}{36181} = -1.46$

2 $\frac{31164 - 36181}{36181} \times 100 = -13.87$

Table B.8 Probability that driver is seriously injured (incapacitated) or killed as a function of TAD severity ($Pr\{I \geq A|TAD\}$).

TAD	1973		1974		1975	
	$\hat{p}$[1]	$\log_{10}(\hat{p})$	$\hat{p}$	$\log_{10}(\hat{p})$	$\hat{p}$	$\log_{10}(\hat{p})$
1	.00769 (60)[2]	-2.11	.00619 (43)	-2.21	.00462 (51)	-2.34
2	.00936 (67)	-2.03	.01230 (74)	-1.91	.01012 (94)	-1.99
3	.02444 (136)	-1.61	.02915 (129)	-1.53	.02277 (150)	-1.64
4	.04765 (201)	-1.32	.05058 (171)	-1.30	.05003 (232)	-1.30
5	.12120 (259)	-0.92	.10098 (165)	-0.99	.09528 (216)	-1.02
6	.19502 (313)	-0.71	.15432 (175)	-0.81	.17495 (271)	-0.76
7	.33679 (325)	-0.47	.35047 (225)	-0.46	.28790 (245)	-0.54

[1]$\hat{p}$ = estimate of $Pr\{I \geq A|TAD\}$

[2]actual number of drivers seriously injured or killed.

Table B.9 Probability that driver is killed as a function of TAD severity (Pr{K|TAD}).

TAD	1973		1974		1975	
	$\hat{p}$[1]	$\log_{10}(\hat{p})$	$\hat{p}$	$\log_{10}(\hat{p})$	$\hat{p}$	$(\log_{10}(\hat{p})$
1	.00038 (3)[2]	-3.41	.00043 (3)	-3.36	.00018 (2)	-3.74
2	.00042 (3)	-3.38	.00017 (1)	-3.78	.00065 (6)	-3.19
3	.00162 (9)	-2.79	.00226 (10)	-2.65	.00076 (5)	-3.12
4	.00261 (11)	-2.58	.00325 (11)	-2.49	.00302 (14)	-2.52
5	.01310 (28)	-1.88	.00918 (15)	-2.04	.00706 (16)	-2.15
6	.02368 (38)	-1.63	.02205 (25)	-1.66	.02389 (37)	-1.62
7	.09119 (88)	-1.04	.08411 (54)	-1.08	.07991 (68)	-1.10

[1] $\hat{p}$ = estimate of Pr{K|TAD}

[2] actual number of drivers killed

Table B.10. Tractor trailer/semi-trailer speed data for Interstate highways and main routes.[1]

Year	Road Type	Mean Speed	85-th Percentile	80% Interval	Interval Width
1968	Int.	58.1	64	(47.4, 63.6)	16.2
	Main	51.2	56	(41.4, 57.4)	16.0
1969	Int.	57.5	64	(48.2, 63.3)	15.1
	Main	50.8	54	(41.8, 56.4)	14.6
1970	Int.	60.8	64	(51.6, 65.0)	13.4
	Main	52.4	59	(42.6, 59.2)	16.6
1971	Int.	60.4	64	(51.4, 65.5)	14.1
	Main	51.8	57	(43.1, 57.9)	14.8
1972	Int.	58.3	65	(49.2, 64.1)	14.9
	Main	51.0	57	(41.5, 58.6)	17.1
1973	Int.	61.6	68	(51.4, 67.7)	16.3
	Main	50.9	59	(40.2, 59.7)	19.5
1974	Int.	54.2	59	(46.4, 59.4)	13.0
	Main	49.5	55	(40.6, 56.7)	16.1
1975	Int.	58.6	64	(51.1, 64.1)	13.0
	Main	54.1	60	(44.2, 60.0)	15.8

[1]Source: "Rural Speeds on Primary Highways and Secondary Roads;" Planning and Research Section of the North Carolina Division of Highways.

APPENDIX C

Time Series Analysis

Time series analysis is that branch of statistics concerned with the analysis of sequences of dependent observations on some random variable. Quite often when observations of a variable are plotted against time, certain patterns such as seasonality trends become apparent. Using time series techniques, one can develop models based on samples of observations that not only provide some insight into the nature of the relationships between observations, but can also be used to predict future behavior taking into account these within-period trends.

In this report, such an approach has been used to investigate total vehicle mileage, total crashes, and fatal crashes on a monthly basis from 1962 through 1975. The major reason for doing this was to develop models based on the series of observations from January, 1962 through December, 1973; use these models to predict monthly values for 1974 and 1975; and then compare these expected figures with the actual observations. In this way, the impact of the energy crisis period on these three variables can be examined.

Figure 2.1 in Section 2.1.1 is a time series plot of the estimated monthly vehicle mileage in North Carolina for 1962 through 1975. It is immediately apparent that the series is increasing in a linear fashion between 1962 and 1973, and exhibits a seasonal component with a period of approximately 12 months. Following the procedures for non-stationary, seasonal behavior suggested by Box and Jenkins (1970), a multiplicative integrated moving average model was found to provide the best fit to the series between January, 1962 and December, 1973. The theoretical form of this model is as follows:

$$\nabla\nabla_{12} Z_t = (1-\theta B)(1-\Phi B^{12})a_t \qquad (C.1)$$

where Z_t is the estimated vehicle mileage in month t (t=1 for January, 1962); $\{a_t\}$ is a sequence of independent, identically distributed normal random variables with mean zero and constant variance S_a^2; B is the backward shift operator such that

$$B^K F_t = Z_{t-K}, \quad \text{where} \quad B = B' ;$$

and ∇ is the difference operator defined by

$$\nabla^K = 1-B^K, \quad \text{where} \quad \nabla = \nabla' \quad .$$

Upon writing out the left side of (C.1), it is clear that mileage in any particular month depends to a large extent upon the mileage observed 12 months earlier plus the mileage due to the increasing trend over a one year period. Once these two components are incorporated in the model, the remaining behavior is accounted for by the appropriate combination of random shocks as indicated by the expression on the right side of (C.1). The least squares estimates of the two parameters were $\hat{\theta} = 0.99$ and $\hat{\Phi} = 0.03$. Using these values in the model (C.1) and the expected value of zero for the unknown shocks after December, 1973, predicted values of vehicle mileage for 1974 and 1975 were computed. These forecasts and their implications are discussed in Section 2.1.1 of this report.

Figures C.1 and C.2 present the total and fatal crash series for the period January, 1962 through December, 1975. As with vehicle mileage, both of these series seem to be experiencing a linearly, increasing trend prior to 1974. The total crash series appears to be leveling off somewhat in 1973, but the fatal series definitely indicates some type of interruption in 1974. Also, both series exhibit seasonal behavior with a period of 12 months.

In Section 2.2.1, it was suggested that these apparent departures from past behavior might fall within the range of random variation. To investigate this possibility, both series through November, 1973 were analyzed by fitting time series models. It was found that model (C.1) was adequate for describing the behavior of both total and fatal crashes. This is not surprising since the behavior of these two variables is quite similar to that of estimated vehicle mileage. Table C.1 presents the parameter estimates followed by their standard errors, an estimate of the residual standard deviations, and goodness-of-fit information.

Predicted total crashes based on the fitted model for the 25 month period December, 1973 through December, 1975 along with upper and lower

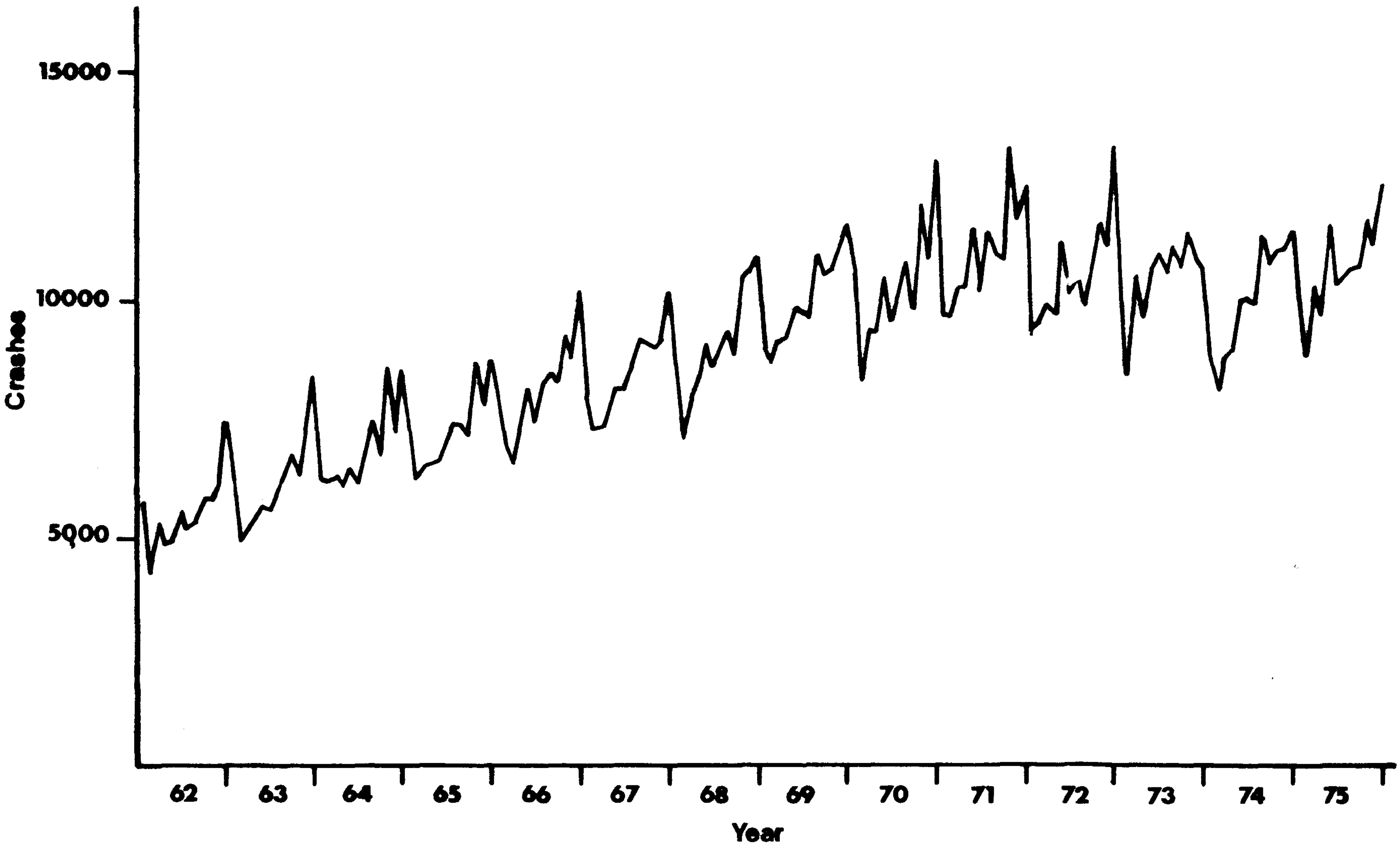


Figure C.1 Total crashes per month in N.C. (1962 through 1975).

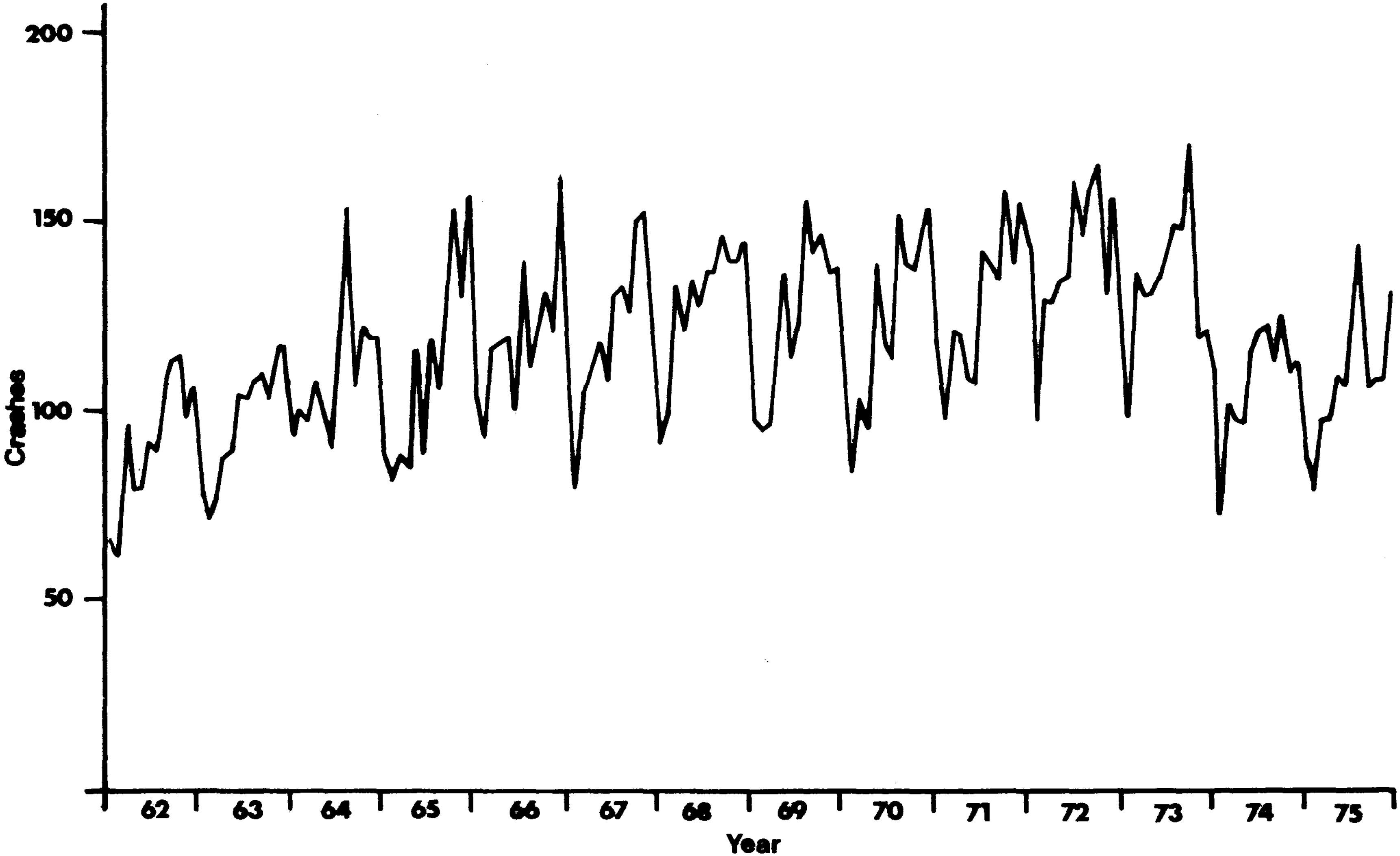


Figure C.2 Fatal crashes per month in N.C. (1962 through 1975).

Table C.1 Summary of parameter estimates for model (C.1) for total and fatal crashes in North Carolina.

Parameter	Estimate: Total Crashes	Estimate: Fatal Crashes
θ	$.82 \pm .10$	$.89 \pm .09$
Φ	$.65 \pm .15$	$.75 \pm .13$
$\hat{\sigma}_a$	575	14
$\chi^2(34)$	26.84 (p=.80)	34.07 (p=.40)

90 percent confidence limits and the observed number of crashes are plotted in Figure C.3. From this plot it is apparent that total crashes for December, 1973 through March, 1974 are considerably below what would normally have been expected; however, after March, 1974, the series appears to return to the previous pattern of behavior.

Predicted fatal crashes, upper and lower 90 percent confidence limits, and observed fatal crashes for the same 25 month period are displayed in Figure C.4. This plot illustrates that the observed fatal accidents were uniformly below predicted values for the entire 25 month period, and for 22 of the 25 months, observed values fell below the lower 90 percent confidence limit for the predicted values. Thus, fatal crashes not only decreased during the energy crisis, but there is rather conclusive evidence that the number of fatal crashes continued to fall below previous trends long after the height of the crisis had passed. Since traffic volume returned to pre-crisis levels in 1975, this analysis suggests that the lowered speed limit may very well be directly responsible for much of the reduced number of fatal crashes.

This investigation indicates that differences observed during the energy crisis in total and fatal crashes were not likely to be due to random variation. Furthermore, Figure C.4 implies that the number of fatal accidents appears to have undergone a significant, downward displacement, since there is no indication that fatal crashes are reverting to their predicted levels in 1975. Moreover, the fact that fatal crashes decreased somewhat more than total crashes suggests that there has been a general decrease in accident severity in North Carolina. However, one must realize that this approach is limited to an examination of rather gross effects. Since there were a large number of factors interacting during this period, a more detailed analysis was necessary to examine the nature of the general changes described above (see Chapter 3).

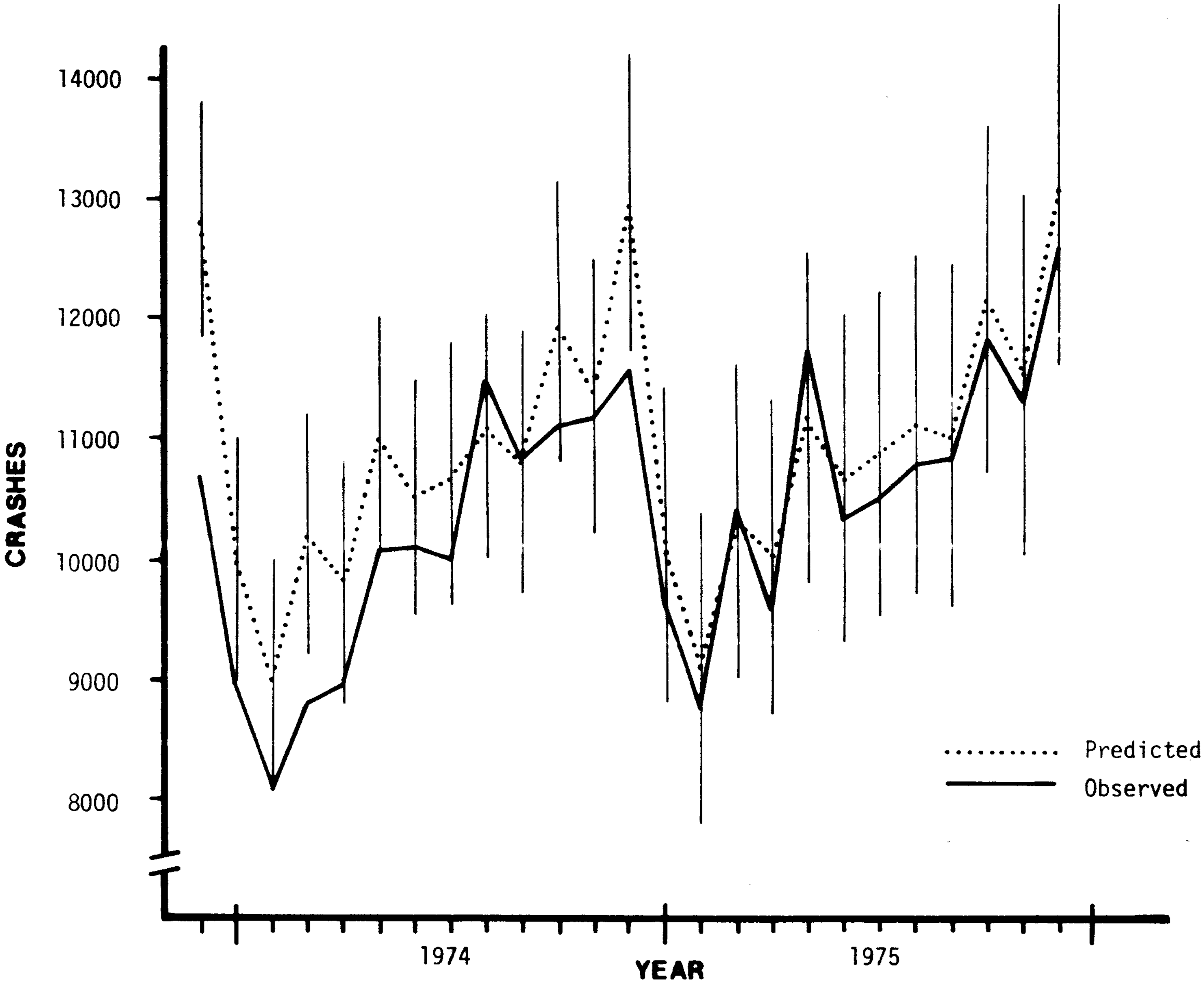


Figure C.3. Observed and predicted <u>total</u> crashes and 90 percent confidence limits.

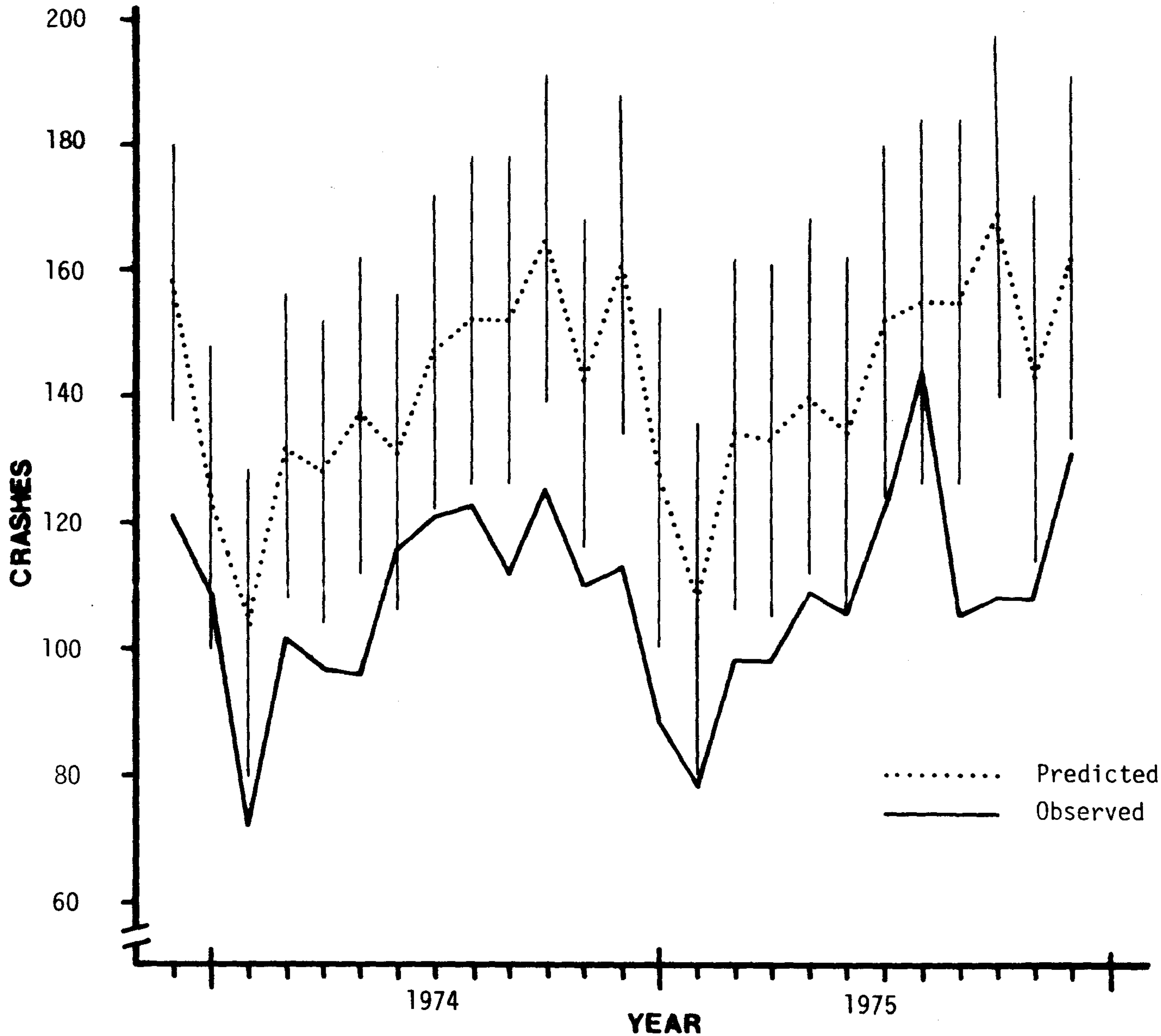


Figure C.4. Observed and predicted <u>fatal</u> crashes and 90 percent confidence limits.

APPENDIX D

A Multivariate Analysis of the Changes in the Driver Injury Distribution Associated with the Energy Crisis

Introduction

The accident data available for this analysis consists of all reported accidents occurring in North Carolina from January - April in 1973 and correspondingly in 1974. As indicated in the main text, if one assumes that this data represents a random sample taken from a large population of interest, then a variety of techniques of statistical inference can be applied. In this case, a variable selection or screening process was carried out, followed by modeling using categorical data techniques and finally the construction of appropriate indices for comparison purposes.

The variable selection or screening process was required in order to reduce the dimensionality of the final contingency table used in the weighted least squares modeling at the next step of the analysis. Various criteria are utilized in the selection process. Accident year is essentially chosen a priori since differences in driver injury distributions for the two accident years is the basic question of interest. As for the remaining independent variables, they are selected primarily in the order of and on the basis of their strength of association with driver injury. Where two variables have essentially a similar degree of association with driver injury (e.g., road type vs time of day), that variable (time of day) with fewer levels is selected as this effects a greater reduction in the dimensionality of the final contingency table.

The weighted least squares analysis of categorical data procedure was chosen for the modeling because it represents a convenient procedure for characterizing the relationship between the dependent variable "injury" and the various independent variables selected during screening. It also allows for models to be developed in terms of the proportions themselves (as opposed to log-linear transformations), and provides a goodness-of-fit statistic for the model at each stage.

Finally, the derived regression coefficients obtained from the modeling process are then incorporated into a set of indices for deriving estimates of the serious injury reduction attributable to various energy crisis-related factors.

Screening Process

Eight basic variables were selected as factors affected by the energy crisis and associated with driver injury rates. The marginal distributions of these variables for the periods of interest in 1973 and 1974 are displayed in Table D.1. Along with the substantial reduction in the total number of vehicles involved in accidents in North Carolina, one should note the percentage reductions in weekend accidents, high speed accidents and rural (both Interstate and non-Interstate) accidents.

Table D.2 shows the injury distributions for the same period according to three dichotomizations of interest. The percent of serious or

Table D.2 Distribution of fatal (K), serious or fatal (A+K), and any injury (I) to drivers involved in North Carolina accidents occurring during the first four months of 1973 and 1974, respectively.

Driver Injury	1973 No.[1]	1973 %[2]	1974 No.	1974 %	Total
K	398	0.5	314	0.5	712
$\overline{K}$[3]	77,294	99.5	64,267	99.5	142,273
A+K	3,079	4.0	2,465	3.8	5,544
$\overline{A+K}$	74,613	96.0	62,116	96.2	136,729
I	13,561	17.5	12,152	18.8	25,713
$\overline{I}$	64,131	82.5	52,429	81.2	116,560
Total	77,692		64,581		142,273

[1]Missing: 6808 in 1973; 7453 in 1974

[2]Within column percent (excluding missing values)

[3]$\overline{K}$ = not killed

Table D.1 Marginal distribution of selected variables for North Carolina accidents occurring during the first four months of 1973 and 1974, respectively.

Variable	Level	1973 No.[1]	1973 %[2]	1974 No.	1974 %	Total
Driver Age	≤20 yrs.	19,094	24.1	16,056	24.1	35,150
	21-35 yrs.	31,850	40.2	26,578	40.0	58,428
	≥36 yrs.	28,249	35.7	23,851	35.9	52,100
Driver Sex	Male	56,356	70.7	46,371	69.1	102,727
	Female	23,395	29.3	20.747	30.9	44,142
Belt Usage	Unbelted	54,732	86.0	50,457	86.7	105,189
	Belted	8,878	14.0	7,758	13.3	16,636
Occupancy	1	46,938	64.8	41,627	65.6	88,565
	>1	25,492	35.2	21,782	34.4	47,274
ESPI	≤30 mph.	50,289	65.4	46,517	68.2	96,806
	31-55 mph.	22,349	29.1	19,287	28.3	41,636
	≥56 mph.	4,248	5.5	2,452	3.2	6,700
Road Type	Urban	39,221	48.6	36,194	53.1	75,415
	Rural, Non-Int.	39,261	48.7	30,768	45.2	70,029
	Rural, Interstate	2,185	2.7	1,176	1.7	3,361
Time of Day	Day	58,609	70.5	48,986	69.6	107,595
	Night	24,495	29.5	21,349	30.4	45,844
Time of Week	Weekday	58,615	69.4	52,226	72.5	110,841
	Weekend	25,885	30.6	19,808	27.5	45,693
Total		84,500		72,034		156,534

[1]Missing observations can be obtained from the overall totals.

[2]Within column percent (excluding missing values).

fatal (A+K) injuries is shown to have decreased slightly in 1974, while the percent of any injury (I) has increased. This is consistent with the findings in Chapter 3, namely that an apparent increase in driver injury severity was due to a reduction in both the percent of seriously injured and in the percent of non-injured thereby resulting in an increase in B and C level injuries.

Due mainly to sample size considerations, the major portion of this Appendix deals with the (A+K) vs. $(\overline{A+K})$ representation of driver injury. The first step in selecting the most important independent variable (i.e., that variable most associated with the likelihood of serious injury) is to consider the $\chi_p^2/(\text{d.f.})$ statistics for <u>each</u> of the eight variables identified in Table D.1 vs. serious driver injury. Also included as a candidate independent variable is accident year. As shown in Table D.3, the most important variable appears to be ESPI, followed by Time of Day, Road Type and Belt Usage. ESPI is also strongly associated with accident year (see Table D.4).

To determine which of the remaining variables is the next most important with respect to serious driver injury (after adjusting for ESPI), Pearson Chi-squares are generated within each level of ESPI (for <u>each</u> of the remaining variables) and then summed to yield the termination statistic (Q) shown in Table D.5. For details, see Higgins and Koch (1975). An alternative criterion examined is the Pearson Chi-square per degree of freedom for each three-way table (e.g., time of week × ESPI × driver injury).

From Table D.5 in terms of $\chi_p^2/(\text{d.f.})$, Belt Usage and Occupancy appear to be of similar importance, but the termination statistics show that, within levels of ESPI, the importance of Occupancy is non-significant whereas Belt Usage remains strongly associated with serious driver injury.

As mentioned in the previous section, Year is a variable that, because of the nature of the study, is desired in the model even if its statistical association with serious driver injury is marginal. Accordingly, Table D.6 presents detailed information on the various four-way combinations including Year.

Table D.3 Examination of association of selected variables with drivers incurring serious injury.

Variable	Level	No. Drivers Involved[1]	A + K No.	A + K %	$\chi_p^2/(d.f.)$	d.f.
Driver Age	≤20 yrs.	33,791	1,550	4.6	44.16	2
	21-35 yrs.	56,388	2,059	3.7		
	≥36 yrs.	50,295	1,687	3.4		
Driver Sex	Male	54,822	2,193	4.0	14.76	1
	Female	22,496	865	3.8		
Belt Usage	Unbelted	16,177	218	1.3	228.97	1
	Belted	101,001	3,688	3.7		
Occupancy	1	88,520	2,888	3.3	0.79	1
	>1	47,223	1,584	3.4		
ESPI	≤30 mph.	85,155	1,995	2.3	1667.08	2
	31-55 mph.	41,225	2,198	5.3		
	≥56 mph.	6,547	1,044	16.2		
Road Type	Urban	70,257	1,525	2.2	556.23	2
	Rural, Non-Int.	67,857	3,785	5.6		
	Rural, Interstate	3,281	199	6.1		
Time of Day	Day	99,329	3,083	3.1	617.85	1
	Night	40,404	2,406	6.0		
Time of Week	Weekday	101,142	3,608	3.6	101.11	1
	Weekend	41,131	1,936	4.7		
Year	1973	77,692	3,079	4.0	1.97	1
	1974	64,581	2,465	3.8		

[1]Missing cases excluded.

Table D.4 Examination of association of selected variables with accident period.

Variable	Level	No. Drivers Involved[1]	1973 (%)[2]	1974 (%)	χ_p^2/(d.f.)	d.f.
Driver Age	≤20 yrs.	35,150	24.1	24.1	0.48	2
	21-35 yrs.	58,428	40.2	40.2		
	≥36 yrs.	52,100	35.7	35.9		
Driver Sex	Male	102,727	70.7	69.1	43.00	1
	Female	44,142	29.3	30.9		
Belt Usage	Unbelted	105,189	86.0	86.7	10.19	1
	Belted	16,636	14.0	13.3		
Occupancy	1	88,565	64.8	65.6	10.57	1
	>1	47,274	35.2	34.4		
ESPI	≤30 mph.	96,806	65.4	68.2	107.64	2
	31-55 mph.	41,636	29.1	28.2		
	≥56 mph.	6,700	5.5	3.6		
Road Type	Urban	75,415	48.6	53.1	201.18	2
	Rural, Non-Int.	70,029	48.7	45.2		
	Rural, Interstate	3,361	2.7	1.7		
Time of Day	Day	107,595	29.5	30.4	13.98	1
	Night	45,844	70.5	69.6		
Time of Week	Weekday	110,841	69.4	72.5	184.75	1
	Weekend	45,693	30.6	27.5		

[1]Missing cases excluded.

[2]Column percent.

Table D.5 Examination of association of remaining variables with drivers incurring serious injury, controlling for ESPI.

Variable	Level	ESPI = 1 No. Drivers Involved	ESPI = 1 % (A+K)	ESPI = 2 No. Drivers Involved	ESPI = 2 % (A+K)	ESPI = 3 No. Drivers Involved	ESPI = 3 % (A+K)	χ_P^2/(d.f.) Q^1	d.f.
Driver Age	≤20 yrs.	18,574	3.4	10,969	4.7	2,324	14.9	463.25	8
	21-35 yrs.	32,262	1.5	17,428	5.3	2,924	17.0	210.76	6
	≥36 yrs.	33,145	2.0	12,511	5.9	1,096	16.7		
Driver Sex	Male	56,420	2.3	31,110	5.0	5,661	16.2	684.92	5
	Female	28,348	2.3	10,021	6.3	743	17.0	25.59	3
Belt Usage	Unbelted	59,248	1.4	30,887	5.8	30,887	17.4	201.79	3
	Belted	9,604	0.6	4,974	2.3	682	6.0	913.26	5
Occupancy	1	52,953	1.3	25,918	5.5	3,866	15.9	966.35	5
	>1	27,226	1.3	14,714	5.0	2,553	16.5	4.75	3
Road Type	Urban	53,560	1.7	10,093	3.9	343	18.7	456.80	8
	Rural, Non-Int.	30,120	3.5	29,550	5.8	5,329	16.8	361.68	6
	Rural, Interstate	849	3.5	1,432	4.9	772	10.8		
Time of Day	Day	64,003	2.0	25,915	4.9	2,674	14.1	690.37	5
	Night	19,371	3.6	14,834	6.1	3,750	17.6	201.01	3
Time of Week	Weekday	63,066	2.2	27,650	5.2	3,598	16.3	670.37	5
	Weekend	22,089	2.7	13,575	5.6	2,859	16.0	24.49	3
Year	1973	44,940	1.3	22,171	5.3	4,128	14.6	682.71	5
	1974	40,215	1.0	19,054	5.4	2,329	18.9	29.22	3

[1] Q = Termination statistic = $\sum_{i=1}^{3} \chi_P^2(\mathrm{ESPI}=i)$

Table D.6 Examination of association of remaining variables with drivers incurring serious injury, controlling for Belt Usage, ESPI, and Year.

Variable	Belt Usage	ESPI	1973 No.	1973 $\underline{p}$	1973 χ^2_p	1974 No.	1974 $\underline{p}$	1974 χ^2_p	Q	d.f.
Driver Age	B	1	4,879[1]	(0.9, 0.7, 0.7)[2]	0.25	4,653	(0.4, 0.4, 0.6)	0.76		
		2	2,646	(1.3, 2.0, 2.8)	3.39	2,301	(3.1, 1.8, 2.7)	2.90	13.45	12
		3	490	(5.5, 5.0, 8.2)	1.55	188	(1.7, 6.1, 12.9)	4.60		
	U	1	29,693	(1.4, 1.2, 1.8)	15.70	29,066	(1.5, 1.2, 1.3)	2.27		
		2	16,116	(5.4, 5.5, 6.3)	4.80	14,554	(4.6, 6.2, 6.3)	15.09	50.46	12
		3	3,097	(14.9, 16.4, 15.0)	1.30	1,867	(16.8, 22.0, 25.3)	11.30		
Driver Sex	B	1	4,894	(0.6, 1.1)	2.65	4,690	(0.4, 0.5)	0.06		
		2	2,657	(1.8, 3.5)	5.46	2,314	(1.8, 4.7)	1.67	10.74	6
		3	493	(5.5, 9.1)	0.89	189	(5.6, 10.0)	0.01		
	U	1	29,834	(1.4, 1.6)	2.21	29,253	(1.2, 1.5)	3.98		
		2	16,181	(5.3, 7.0)	15.83	14,658	(5.8, 5.8)	0.00	22.73	6
		3	3,119	(15.6, 16.4)	0.12	1,888	(20.6, 17.6)	0.59		
Occupancy	B	1	4,899	(0.8, 0.7)	0.01	4,691	(0.4, 0.6)	0.37		
		2	2,655	(2.4, 1.6)	1.53	2,316	(2.1, 3.0)	1.47	4.08	6
		3	492	(5.2, 7.5)	0.70	189	(6.2, 5.1)	0.00		
	U	1	29,830	(1.5, 1.4)	0.73	29,292	(1.3, 1.3)	0.08		
		2	16,180	(6.0, 5.2)	4.26	14,672	(6.0, 5.4)	2.34	7.47	6
		3	3,124	(15.6, 15.7)	0.00	1,896	(19.9, 20.5)	0.06		
Road Type	B	1	4,849	(0.6, 1.0, 0.9)	2.91	4,688	(0.3, 0.7, 1.5)	4.86		
		2	2,648	(1.6, 2.1, 4.6)	5.78	2,315	(2.2, 2.6, 1.4)	0.81	16.63	12
		3	493	(5.0, 6.5, 5.4)	0.26	189	(0.0, 6.0, 10.5)	0.01		
	U	1	20,574	(1.0, 2.0, 2.0)	51.97	29,229	(0.9, 2.0, 2.5)	61.92		
		2	16,121	(4.8, 6.0, 4.4)	8.41	14,661	(3.9, 6.4, 6.5)	32.29	174.30	12
		3	3,118	(26.4, 16.0, 11.0)	18.00	1,898	(15,5, 20.5, 20.9)	1.71		
Time of Day	B	1	4,816	(1.2, 0.6)	3.50	4,568	(1.0, 0.3)	6.06		
		2	2,624	(1.8, 2.3)	0.51	2,288	(2.9, 2.2)	0.73	11.74	6
		3	491	(7.3, 4.9)	0.87	188	(5.7, 5.9)	0.07		
	U	1	49,446	(1.7, 1.4)	3.25	28,617	(1.7, 1.2)	6.49		
		2	16,048	(6.3, 5.4)	4.56	14,514	(6.9, 5.1)	18.92	41.14	6
		3	3,111	(17.1, 13.9)	5.47	1,891	(21.3, 18.2)	2.45		
Time of Week	B	1	4,908	(0.8, 0.5)	0.60	4,696	(0.4, 0.7)	0.78		
		2	2,658	(2.4, 1.6)	1.45	2,316	(2.1, 3.3)	2.01	5.32	6
		3	493	(6.5, 5.4)	0.09	189	(7.1, 3.9)	0.39		
	U	1	29,908	(1.5, 1.5)	0.00	29,340	(1.3, 1.4)	0.92		
		2	16,201	(5.8, 5.6)	0.44	14,686	(5.3, 6.8)	13.57	16.21	6
		3	3,125	(15.5, 15.9)	0.05	1,901	(21.2, 19.0)	1.23		

A careful analysis of the different vectors ($\underline{p}$) of injury rates and corresponding χ_p^2's in Table D.6 shows that the rates of serious driver injury are dramatically different between belt usage categories. Whereas Time of Day shows some explanatory potential for both levels of belt usage, Road Type and Age appear important only within the unbelted driver category. Thus, Time of Day is the next variable selected for the subsequent modeling task.

At this point, the cell frequencies become rather minimal for the belted categories. Thus, since also the rates are so different between the belt usage groups, the remainder of the variable selection process along with the subsequent modeling is carried out within belt usage categories.

In Table D.7, the five-way combinations for belted drivers is presented, and clearly Road Type emerges as the final variable in the model for belted drivers. Similarly, Table D.8 shows information on six-way combinations for unbelted drivers, with a clear indication that Driver Age should be included as the final variable in the model for unbelted drivers.

Beyond this point, the data becomes too sparse and/or the dimensionality of the contingency tables too great to add any additional variables to either model.

Mathematical Modeling

Linear categorical models for serious injury (A+K) rates.

From the results discussed in the previous section, it is obvious that models related to belted drivers will be different from the models related to unbelted drivers. The first should involve ESPI, Year, Time of Day, and Road Type whereas the second should involve ESPI, Year, Time of Day, Road Type, and Driver Age. The basic data is given in Table D.9. The table also includes the serious injury rates estimated by using the models subsequently developed along with their standard errors.

The initial design matrices $\underset{\sim}{X}$ for the six ESPI × Year modules within the belted driver category and for the four Year × Time modules within the three unbelted × ESPI groups are given at the top of page 179.

Table D.7 Examination of association of remaining variables with belted drivers incurring serious injury, controlling for Time of Day, Year, and ESPI.

Time of Day	Year	ESPI	Driver Age N	Driver Age χ^2_P (df=2)	Driver Sex N	Driver Sex χ^2_P (df=1)	Occupancy N	Occupancy χ^2_P (df=1)	Road Type N	Road Type χ^2_P (df=2)	Time of Week N	Time of Week χ^2_P (df=1)
D	1973	1	3737	0.36	3749	1.31	3754	0.04	3716	2.85	3762	2.32
		2	1744	2.21	1749	4.00	1747	3.69	1742	6.06	1749	4.29
		3	244	1.88	245	2.00	244	0.29	245	0.96	245	1.13
	1974	1	3547	1.36	3575	0.15	3575	0.00	3575	4.53	3580	5.58
		2	1510	0.65	1516	10.92	1517	3.48	1516	3.71	1517	5.21
		3	70	1.13	70	1.42	70	0.31	70	1.26	70	0.05
N	1973	1	1050	0.03	1053	1.93	1054	0.24	1041	0.59	1054	0.00
		2	868	1.30	874	0.32	874	0.25	872	0.78	874	0.54
		3	244	2.06	246	0.07	246	3.04	246	0.75	246	0.02
	1974	1	979	0.59	988	3.24	988	0.03	985	8.27	988	1.38
		2	763	4.18	770	0.64	771	0.28	771	3.67	771	0.03
		3	117	10.98	118	0.00	118	0.00	118	3.20	118	1.05
Q				26.73		25.99		11.66		36.64		21.60

Table D.8 Examination of association of remaining variables with unbelted drivers incurring serious injury, controlling for Road Type, Time of Day, Year, and ESPI.

Road Type	Time of Day	Year	ESPI	Driver Age N	Driver Age X_p^2 (df=2)	Driver Sex N	Driver Sex X_p^2 (df=1)	Occupancy N	Occupancy X_p^2 (df=1)	Time of Week N	Time of Week X_p^2 (df=1)
U	D	1973	1	12831	1.66	12885	2.54	12896	0.03	12924	0.18
			2	2043	0.15	2055	0.79	2050	3.36	2056	0.05
			3	24	3.20	24	0.83	23	0.08	24	2.15
		1974	1	13823	2.44	13916	2.83	13947	0.49	13970	0.80
			2	2128	1.47	2148	0.69	2150	0.35	2151	0.03
			3	28	2.31	28	0.20	28	0.15	28	0.01
	N	1973	1	3708	2.05	3729	0.04	3734	11.84	3746	11.84
			2	1190	1.03	1199	0.02	1199	2.45	1201	2.45
			3	95	0.84	94	1.68	95	1.08	95	1.08
		1974	1	4128	0.02	4158	0.02	4168	0.03	4174	0.03
			2	1324	1.79	1346	0.07	1352	1.76	1352	1.76
			3	83	7.91	84	0.00	84	0.22	84	0.22
R	D	1973	1	9297	10.19	9337	0.95	9232	0.00	9344	0.05
			2	7921	1.67	7948	12.55	7947	0.28	7956	0.00
			3	1130	3.37	1139	0.25	1139	0.01	1139	0.15
		1974	1	7777	1.06	7816	4.02	7820	1.51	7826	0.13
			2	6536	6.33	6569	0.07	6573	1.34	6577	9.92
			3	602	1.16	608	0.00	610	0.33	611	0.08
	N	1973	1	2792	1.89	2809	0.07	2808	1.05	2816	2.92
			2	4358	6.90	4371	6.07	4376	0.57	4379	2.78
			3	1403	0.54	1414	0.11	1419	0.12	1419	0.00
		1974	1	2321	0.10	2340	0.23	2338	1.89	2344	0.01
			2	3925	17.24	3947	0.11	3947	0.52	3953	2.83
			3	1078	8.67	1090	2.54	1095	0.71	1099	0.69
I	D	1973	1	219	2.79	222	0.12	220	1.30	222	0.25
			2	256	6.18	259	2.37	258	1.04	259	0.85
			3	226	1.35	227	2.73	227	0.37	227	1.13
		1974	1	148	0.77	149	0.37	148	0.30	149	0.11
			2	262	0.92	266	0.77	266	0.00	267	0.28
			3	21	3.78	22	0.24	22	0.00	22	0.12
	N	1973	1	59	0.51	60	0.42	60	1.18	60	1.18
			2	117	1.63	117	0.31	117	0.19	117	0.13
			3	198	0.28	200	0.11	200	0.00	200	2.05
		1974	1	44	1.91	44	0.01	44	0.08	44	0.04
			2	186	1.57	188	1.18	188	0.51	188	0.37
			3	44	4.32	44	0.08	44	0.00	44	0.48
Q					44.99		111.00		32.21		35.14

Table D.9 Observed and predicted serious driver injury rates and their corresponding standard errors.

A. Belted

ESPI	Year	Time	Road	Number Drivers	Number (A+K)	Observed (A+K) Rate	Estimated s.e.	Predicted (A+K) Rate	Predicted s.e.
1	73	N	U	628	7	0.011	0.0042	0.009	0.0022
1	73	N	R	393	6	0.015	0.0062	0.014	0.0024
1	73	N	I	20	0	0.000	0.0341	0.016	0.0061
1	73	D	U	2245	10	0.004	0.0014	0.004	0.0012
1	73	D	R	1380	12	0.009	0.0024	0.009	0.0017
1	73	D	I	91	1	0.011	0.0109	0.011	0.0059
1	74	N	U	710	6	0.008	0.0034	0.007	0.0021
1	74	N	R	265	3	0.011	0.0065	0.012	0.0025
1	74	N	I	10	1	0.100	0.0947	0.014	0.0061
1	74	D	U	2437	5	0.002	0.0009	0.002	0.0008
1	74	D	R	1085	7	0.006	0.0024	0.007	0.0017
1	74	D	I	53	0	0.000	0.0132	0.009	0.0058
2	73	N	U	200	4	0.020	0.0099	0.021	0.0028
2	73	N	R	609	10	0.016	0.0051	0.026	0.0025
2	73	N	I	63	2	0.032	0.0221	0.028	0.0060
2	73	D	U	346	5	0.014	0.0064	0.016	0.0025
2	73	D	R	1288	30	0.023	0.0042	0.021	0.0023
2	73	D	I	108	6	0.056	0.0220	0.023	0.0059
2	74	N	U	199	9	0.045	0.0147	0.019	0.0028
2	74	N	R	524	13	0.025	0.0068	0.024	0.0027
2	74	N	I	48	0	0.000	0.0145	0.026	0.0061
2	74	D	U	404	4	0.010	0.0049	0.014	0.0024
2	74	D	R	1022	27	0.026	0.0050	0.019	0.0024
2	74	D	I	90	2	0.022	0.0155	0.021	0.0059
3	73	N	U	9	0	0.000	0.0724	0.056	0.009
3	73	N	R	174	13	0.075	0.0199	0.061	0.009
3	73	N	I	63	5	0.079	0.0341	0.063	0.0099
3	73	D	U	10	1	0.100	0.0949	0.051	0.009
3	73	D	R	150	8	0.053	0.0183	0.056	0.009
3	73	D	I	85	3	0.035	0.0200	0.058	0.0099
3	74	N	U	10	0	0.000	0.0657	0.054	0.009
3	74	N	R	96	5	0.052	0.0227	0.059	0.009
3	74	N	I	12	2	0.167	0.1076	0.061	0.010
3	74	D	U	9	0	0.000	0.0724	0.049	0.009
3	74	D	R	54	4	0.074	0.0356	0.054	0.009
3	74	D	I	7	0	0.000	0.0911	0.056	0.010

Table D.9 Continued.

B. Unbelted (ESPI $\leq$ 30 mph)

Year	Time	Road	Age	Number Drivers	Number (A+K)	Observed (A+K) Rate	Estimated s.e.	Predicted (A+K) Rate	Predicted s.e.
73	N	U	1	1019	12	0.012	0.0034	0.013	0.0014
73	N	U	2	1506	12	0.008	0.0023	0.011	0.0013
73	N	U	3	1183	16	0.014	0.0034	0.014	0.0014
73	N	R	1	748	19	0.025	0.0058	0.023	0.0016
73	N	R	2	1075	24	0.022	0.0045	0.021	0.0015
73	N	R	3	969	31	0.032	0.0057	0.024	0.0016
73	N	I	1	10	0	0.000	0.0657	0.020	0.0060
73	N	I	2	29	1	0.034	0.0339	0.018	0.0059
73	N	I	3	20	1	0.050	0.0487	0.022	0.0060
73	D	U	1	2549	26	0.010	0.0020	0.010	0.0012
73	D	U	2	4958	45	0.009	0.0013	0.008	0.0009
73	D	U	3	5324	62	0.012	0.0015	0.011	0.0010
73	D	R	1	2040	32	0.016	0.0028	0.020	0.0013
73	D	R	2	3432	51	0.015	0.0021	0.018	0.0012
73	D	R	3	3825	93	0.024	0.0025	0.021	0.0012
73	D	I	1	34	1	0.029	0.0290	0.018	0.0059
73	D	I	2	89	0	0.000	0.0079	0.015	0.0058
73	D	I	3	96	3	0.031	0.0178	0.019	0.0059
74	N	U	1	1073	12	0.011	0.0032	0.012	0.0014
74	N	U	2	1719	20	0.012	0.0026	0.010	0.0012
74	N	U	3	1336	15	0.011	0.0029	0.013	0.0013
74	N	R	1	691	16	0.023	0.0057	0.022	0.0016
74	N	R	2	898	20	0.022	0.0049	0.020	0.0015
74	N	R	3	732	18	0.025	0.0057	0.023	0.0016
74	N	I	1	8	0	0.000	0.0807	0.020	0.0060
74	N	I	2	23	2	0.087	0.0588	0.017	0.0060
74	N	I	3	13	0	0.000	0.0514	0.021	0.0060
74	D	U	1	2595	29	0.011	0.0021	0.009	0.0012
74	D	U	2	5343	38	0.007	0.0011	0.007	0.0009
74	D	U	3	5885	52	0.009	0.0012	0.010	0.0009
74	D	R	1	1778	34	0.019	0.0032	0.019	0.0014
74	D	R	2	2804	47	0.017	0.0024	0.017	0.0012
74	D	R	3	3195	65	0.020	0.0025	0.020	0.0012
74	D	I	1	22	0	0.000	0.0311	0.017	0.0059
74	D	I	2	68	2	0.029	0.0205	0.015	0.0059
74	D	I	3	58	1	0.017	0.0171	0.018	0.0059

Table D.9 Continued.

C. Unbelted (30 < ESPI $\leq$ 55)

Year	Time	Road	Age	Number Drivers	Number (A+K)	Observed (A+K) Rate	Estimated s.e.	Predicted (A+K) Rate	Predicted s.e.
73	N	U	1	403	20	0.050	0.0108	0.052	0.0042
73	N	U	2	536	35	0.065	0.0107	0.052	0.0042
73	N	U	3	251	15	0.060	0.0150	0.064	0.0048
73	N	R	1	1385	70	0.051	0.0059	0.063	0.0029
73	N	R	2	1868	121	0.065	0.0057	0.063	0.0029
73	N	R	3	1105	84	0.076	0.0080	0.076	0.0036
73	N	I	1	26	0	0.000	0.0264	0.031	0.0080
73	N	I	2	43	2	0.047	0.0321	0.031	0.0080
73	N	I	3	48	3	0.063	0.0349	0.044	0.0084
73	D	U	1	583	24	0.041	0.0082	0.039	0.0039
73	D	U	2	887	35	0.039	0.0065	0.039	0.0039
73	D	U	3	573	25	0.044	0.0085	0.052	0.0041
73	D	R	1	2080	123	0.059	0.0052	0.051	0.0025
73	D	R	2	3210	172	0.054	0.0040	0.051	0.0025
73	D	R	3	2631	161	0.061	0.0047	0.064	0.0030
73	D	I	1	33	3	0.091	0.0500	0.019	0.0077
73	D	I	2	108	1	0.009	0.0092	0.019	0.0077
73	D	I	3	115	8	0.070	0.0237	0.031	0.0080
74	N	U	1	399	17	0.043	0.0101	0.035	0.0042
74	N	U	2	630	35	0.056	0.0091	0.048	0.0038
74	N	U	3	295	11	0.037	0.0110	0.048	0.0038
74	N	R	1	1223	60	0.049	0.0062	0.061	0.0034
74	N	R	2	1718	144	0.084	0.0067	0.074	0.0032
74	N	R	3	984	89	0.090	0.0091	0.074	0.0032
74	N	I	1	36	5	0.139	0.0576	0.061	0.0034
74	N	I	2	88	6	0.068	0.0269	0.074	0.0032
74	N	I	3	62	6	0.097	0.0375	0.074	0.0032
74	D	U	1	550	18	0.033	0.0076	0.023	0.0039
74	D	U	2	922	34	0.037	0.0062	0.036	0.0034
74	D	U	3	656	17	0.026	0.0062	0.036	0.0034
74	D	R	1	1700	79	0.046	0.0051	0.049	0.0031
74	D	R	2	2614	154	0.059	0.0046	0.061	0.0026
74	D	R	3	2222	145	0.065	0.0052	0.061	0.0026
74	D	I	1	43	1	0.023	0.0230	0.049	0.0031
74	D	I	2	117	5	0.043	0.0187	0.061	0.0026
74	D	I	3	102	6	0.059	0.0233	0.061	0.0026

Table D.9 Continued.

D. Unbelted (ESPI > 55 mph)

Year	Time	Road	Age	Number Drivers	Number (A+K)	Observed (A+K) Rate	Estimated s.e.	Predicted (A+K) Rate	Predicted s.e.
73	N	U	1	32	9	0.281	0.0795	0.258	0.0245
73	N	U	2	47	12	0.255	0.0636	0.258	0.0245
73	N	U	3	16	6	0.375	0.1210	0.258	0.0245
73	N	R	1	596	98	0.164	0.0152	0.174	0.0093
73	N	R	2	647	113	0.175	0.0149	0.174	0.0093
73	N	R	3	160	30	0.188	0.0309	0.174	0.0093
73	N	I	1	48	4	0.083	0.0399	0.090	0.0192
73	N	I	2	97	9	0.093	0.0295	0.090	0.0192
73	N	I	3	53	6	0.113	0.0435	0.090	0.0192
73	D	U	1	9	3	0.333	0.1571	0.092	0.0256
73	D	U	2	6	0	0.000	0.1045	0.092	0.0256
73	D	U	3	9	1	0.111	0.1048	0.092	0.0256
73	D	R	1	395	48	0.122	0.0164	0.152	0.0072
73	D	R	2	485	80	0.165	0.0169	0.152	0.0072
73	D	R	3	250	35	0.140	0.0219	0.152	0.0072
73	D	I	1	50	8	0.160	0.0518	0.152	0.0072
73	D	I	2	102	11	0.108	0.0307	0.152	0.0072
73	D	I	3	74	7	0.095	0.0340	0.152	0.0072
74	N	U	1	38	2	0.053	0.0362	0.092	0.0256
74	N	U	2	41	9	0.220	0.0646	0.174	0.0281
74	N	U	3	4	2	0.500	0.2500	0.255	0.0364
74	N	R	1	448	80	0.179	0.0181	0.152	0.0072
74	N	R	2	514	120	0.233	0.0187	0.234	0.0134
74	N	R	3	116	34	0.293	0.0423	0.315	0.0268
74	N	I	1	11	2	0.182	0.1163	0.152	0.0072
74	N	I	2	23	4	0.174	0.0790	0.234	0.0134
74	N	I	3	10	5	0.500	0.1581	0.315	0.0268
74	D	U	1	13	1	0.077	0.0739	0.092	0.0256
74	D	U	2	9	1	0.111	0.1048	0.092	0.0256
74	D	U	3	6	2	0.333	0.1925	0.092	0.0256
74	D	R	1	245	41	0.167	0.0238	0.152	0.0072
74	D	R	2	259	53	0.205	0.0251	0.152	0.0072
74	D	R	3	98	18	0.184	0.0391	0.152	0.0072
74	D	I	1	5	2	0.400	0.2191	0.152	0.0072
74	D	I	2	11	1	0.091	0.0867	0.152	0.0072
74	D	I	3	5	0	0.000	0.1226	0.152	0.0072

$$\underset{6\times 4}{\underset{\sim}{X}} = \begin{array}{cccc} & \text{Time} & \text{Road} & \\ \end{array}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Preliminary model for ESPI x Year modules within Belted

b_1 = Predicted value for (N, U)

b_2 = Increment for Day

b_3 = Increment for Rural or Interstate

b_4 = Additional Increment for Interstate

$$\underset{9\times 5}{\underset{\sim}{X}} = \begin{array}{ccc} & \text{Road} & \text{Age} \\ \end{array}\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Preliminary model for Year x Time modules within Unbelted x ESPI groups

b_1 = Predicted value for (U, Age=1)

b_2 = Increment for Rural or Interstate

b_3 = Additional Increment for Interstate

b_4 = Increment for Age = 2 or 3

b_5 = Additional Increment for Age = 3

A. Belted

		Parameters $\hat{b}$ and (s.e.($\hat{b}$))					Test Statistics			
ESPI[1]	Year	Mean	Time	Road			Time (d.f.=1)	Road (d.f.=2)	Model (d.f.=3)	Fi (d.f
1	1973	0.0112 (0.0036)	-0.0067 (0.0037)	0.0042 (0.0027	0.0029 (0.0107)	χ^2 (p)[2]	3.37 (0.07)	2.83 (0.24)	6.51 (0.09)	0. (0.
1	1974	0.0082 (0.0031)	-0.0062 (0.0032)	0.0042 (0.0024)	0.0046 (0.0132)	χ^2 (p)	3.81 (0.05)	3.38 (0.18)	7.69 (0.05)	0 (0
2	1973	0.0129 (0.0067)	0.0045 (0.0057)	0.0049 (0.0063)	0.0236 (0.0159)	χ^2 (p)	0.64 (0.43)	3.06 (0.22)	3.49 (0.32)	1 (0
2	1974	0.0178 (0.0078)	-0.0048 (0.0070)	0.0112 (0.0064)	-0.0109 (0.0114)	χ^2 (p)	0.47 (0.50)	3.43 (0.18)	4.68 (0.20)	5 (0
3	1973	0.0797 (0.0581)	-0.0261 (0.0220)	-0.0024 (0.0593)	-0.0113 (0.0224)	χ^2 (p)	1.41 (0.24)	0.27 (0.88)	2.03 (0.57)	0 (0
3	1974	0.0449 (0.0515)	0.0109 (0.0374)	0.0103 (0.0527)	0.0468 (0.0729)	χ^2 (p)	0.09 (0.77)	0.48 (0.78)	0.62 (0.89)	0 (0

[1] ESPI = 1 corresponds to ESPI $\leq$ 30 mph

ESPI = 2 corresponds to 30 < ESPI $\leq$ 55 mph

ESPI = 3 corresponds to ESPI > 55 mph

[2] p = p-value corresponding to the calculated χ^2.

The goodness-of-fit test statistics ($0.04 \leq \chi_f^2 \leq 5.06$, with df=2) for the models for <u>belted</u> drivers suggest that perhaps similar models can be fit across some of these modules. Proceeding in that direction, one finally obtains the additive model shown on page 181. This has an excellent fit ($\chi_f^2 = 18.40$ with df=29) and shows that the most important factor is ESPI ($\chi_c^2 = 48.35$, df=2) followed by Road Type ($\chi_f^2 = 8.74$, df=2) and Time ($\chi_c^2 = 5.71$, df=1). The increment in the injury rate for increasing levels of ESPI are both positive and significant in their own right. The decrease for Year is statistically non-significant while the decrease from night to day is statistically significant. Finally, the increment for Rural or Interstate (vs. Urban) is significant but the additional increment for Interstate is not.

For <u>unbelted</u> drivers with ESPI = 1, the modeling process was very similar to that previously described for the <u>belted</u> drivers resulting in the model given on page 183. In this case, the most important factors are Road Type ($\chi_c^2 = 85.68$, df=2), Driver Age ($\chi_c^2 = 10.66$, df=2), and Time of Day ($\chi_c^2 = 6.25$, df=1). The comments on Year, Time of Day, and Road Type made with respect to <u>belted</u> drivers hold also for <u>unbelted</u> drivers with ESPI = 1. The additional increment in the serious injury rate for the oldest age group is more important than the reduction for the two other age groups combined.

For the four modules within <u>unbelted</u> drivers with ESPI = 2, the additive models differ widely in their goodness of fit (see page 182) resulting in a more complex model (see page 184) in order to allow for some forms of interaction of Road Type and Age with Year. Reductions for Year and Time of Day are both significant. The significant increment for Rural or Interstate in 1973 is combined with a significant reduction for Interstate in 1973. This situation is mainly due to the behavior observed in the 1973 day module. In 1974, both modules -- night and day -- show similar patterns: significant increment for Rural or Interstate and non-significant additional increment for Interstate.

For <u>unbelted</u> drivers with ESPI = 3, the model building process was even more involved, and, as shown on page 185, some parameters of the

A. <u>Belted</u>

$$\underset{36\times 7}{\underset{\sim}{X}} = \begin{array}{c} \begin{array}{ccccccc} & \text{ESPI} & & \text{Year} & \text{Time} & \text{Road} & \end{array} \\ \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 0 & 1 & 1 & 0 \\
1 & 0 & 0 & 0 & 1 & 1 & 1 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 1 \\
1 & 0 & 0 & 1 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 1 & 0 \\
1 & 0 & 0 & 1 & 1 & 1 & 1 \\
1 & 1 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 0 & 1 & 1 & 0 \\
1 & 1 & 0 & 0 & 1 & 1 & 1 \\
1 & 1 & 0 & 1 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 1 \\
1 & 1 & 0 & 1 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 1 & 1 & 0 \\
1 & 1 & 0 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 0 & 1 & 1 & 0 \\
1 & 1 & 1 & 0 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1
\end{bmatrix} \end{array}$$

$$\underset{\sim}{b} = \begin{bmatrix} 0.0092 \pm 0.0022 \\ 0.0119 \pm 0.0023 \\ 0.0352 \pm 0.0093 \\ -0.0020 \pm 0.0013 \\ -0.0050 \pm 0.0021 \\ 0.0048 \pm 0.0017 \\ 0.0018 \pm 0.0059 \end{bmatrix}$$

b_1 = Predicted rate for (ESPI = 1, 1973,N,U)

b_2 = Increment for ESPI = 2 or 3

b_3 = Additional increment for ESPI = 3

b_4 = Increment for 1974

b_5 = Increment for Day

b_6 = Increment for Rural or Interstate

b_7 = Additional increment for Interstate

Source of Variation	Hypothesis	df	χ^2
ESPI	$b_2 \hat{=} b_3 \hat{=} 0$	2	48.35**
Year	$b_4 \hat{=} 0$	1	2.22
Time	$b_5 \hat{=} 0$	1	5.71*
Road Type	$b_6 \hat{=} b_7 \hat{=} 0$	2	8.74*
Model		6	111.31**
Residual		29	18.40

*Means significant at $\alpha = 0.05$

**Means significant at $\alpha = 0.01$

Unbelted (ESPI=1)[1]

Year	Time	Parameters $\hat{b}$ and (s.e.($\hat{b}$)): Mean	Road		Age			Test Statistics: Road (d.f.=2)	Age (d.f.=2)	Model (d.f.=4)	Fit (d.f.=4)
1973	N	0.0114	0.0153	0.0153	-0.0036	0.0066	χ^2	20.91	3.66	25.67	0.36
		(0.0030)	(0.0034)	(0.0258)	(0.0036)	(0.0035)	(p)[2]	(0.00)	(0.16)	(0.00)	(0.99)
1973	D	0.0094	0.0079	-0.0001	-0.0011	0.0046	χ^2	23.36	7.72	29.95	5.56
		(0.0017)	(0.0016)	(0.0071)	(0.0020)	(0.0017)	(p)	(0.00)	(0.02)	(0.00)	(0.23)
1974	N	0.0112	0.0119	0.0354	0.0002	0.0001	χ^2	12.87	0.01	12.87	0.51
		(0.0029)	(0.0035)	(0.0350)	(0.0036)	(0.0034)	(p)	(0.00)	(1.00)	(0.01)	(0.97)
1974	D	0.0106	0.0100	0.0036	-0.0035	0.0020	χ^2	34.67	3.60	40.17	0.88
		(0.0018)	(0.0017)	(0.0122)	(0.0020)	(0.0015)	(p)	(0.00)	(0.17)	(0.00)	(0.93)

ESPI=2

Year	Time	Parameters $\hat{b}$ and (s.e.($\hat{b}$)): Mean	Road		Age			Test Statistics: Road (d.f.=2)	Age (d.f.=2)	Model (d.f.=4)	Fit (d.f.=4)
1973	N	0.0473	0.0035	-0.0228	0.0150	0.0079	χ^2	1.72	8.30	10.12	0.97
		(0.0078)	(0.0077)	(0.0180)	(0.0071)	(0.0085)	(p)	(0.42)	(0.02)	(0.04)	(0.91)
1973	D	0.0430	0.0161	-0.0350	-0.0062	0.0092	χ^2	21.68	3.34	28.48	6.22
		(0.0057)	(0.0051)	(0.0091)	(0.0055)	(0.0052)	(p)	(0.00)	(0.19)	(0.00)	(0.18)
1974	N	0.0287	0.0265	0.0073	0.0272	-0.0024	χ^2	14.53	15.11	27.70	8.85
		(0.0074)	(0.0071)	(0.0209)	(0.0075)	(0.0087)	(p)	(0.00)	(0.00)	(0.00)	(0.06)
1974	D	0.0240	0.0258	-0.0155	0.0103	-0.0001	χ^2	29.49	4.28	32.51	5.40
		(0.0053)	(0.0048)	(0.0126)	(0.0055)	(0.0054)	(p)	(0.00)	(0.12)	(0.00)	(0.25)

ESPI=3

Year	Time	Parameters $\hat{b}$ and (s.e.($\hat{b}$)): Mean	Road		Age			Test Statistics: Road (d.f.=2)	Age (d.f.=2)	Model (d.f.=4)	Fit (d.f.=4)
1973	N	0.2727	-0.1081	-0.0805	-0.0086	0.0195	χ^2	18.78	0.97	19.00	0.59
		(0.0475)	(0.0471)	(0.0234)	(0.0192)	(0.0280)	(p)	(0.00)	(0.62)	(0.00)	(0.96)
1973	D	0.1236	0.0066	-0.0340	0.0279	-0.0220	χ^2	2.04	1.86	3.61	4.64
		(0.0689)	(0.0679)	(0.0238)	(0.0216)	(0.0234)	(p)	(0.36)	(0.39)	(0.46)	(0.33)
1974	N	0.0815	0.0903	-0.0068	0.0647	0.0782	χ^2	6.92	14.12	25.70	5.56
		(0.0319)	(0.0344)	(0.0619)	(0.0241)	(0.0440)	(p)	(0.03)	(0.00)	(0.00)	(0.23)
1974	D	0.0987	0.0700	-0.0742	0.0320	-0.0106	χ^2	2.38	0.95	3.26	3.56
		(0.0589)	(0.0600)	(0.0700)	(0.0329)	(0.0435)	(p)	(0.30)	(0.62)	(0.52)	(0.47)

[1] ESPI = 1 corresponds to ESPI $\leq$ 30 mph

ESPI = 2 corresponds to 31 $\leq$ ESPI $\leq$ 55 mph

ESPI = 3 corresponds to ESPI > 55 mph

[2] p = p-value corresponding to the calculated χ^2.

B. Unbelted [ESPI = 1]

$$
\underset{36\times 7}{\underset{\sim}{X}} = \begin{array}{c}
\begin{array}{ccccccc} & \text{Year} & \text{Time} & \text{Road} & & \text{Age} & \end{array} \\
\left[\begin{array}{ccccccc}
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 1 \\
1 & 0 & 0 & 1 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 1 & 0 \\
1 & 0 & 0 & 1 & 1 & 1 & 1 \\
1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 1 \\
1 & 0 & 1 & 1 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 1 & 0 \\
1 & 0 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 1 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 1 \\
1 & 1 & 0 & 1 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 1 & 1 & 0 \\
1 & 1 & 0 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 1 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1
\end{array}\right]
\end{array}
$$

$$
\underset{\sim}{b} = \left[\begin{array}{c}
0.0129 \pm 0.0014 \\
-0.0009 \pm 0.0009 \\
-0.0029 \pm 0.0012 \\
0.0099 \pm 0.0011 \\
-0.0023 \pm 0.0059 \\
-0.0021 \pm 0.0012 \\
0.0033 \pm 0.0010
\end{array}\right]
$$

b_1 = Predicted rate for (1973, N, U, Age = 1)

b_2 = Increment for 1974

b_3 = Increment for Day

b_4 = Increment for Rural or Interstate

b_5 = Additional increment for Interstate

b_6 = Increment for Age = 2 or 3

b_7 = Additional Increment for Age = 3

Source of Variation	Hypothesis	df	χ^2
Year	$b_2 \hat{=} 0$	1	0.97
Time	$b_3 \hat{=} 0$	1	6.25*
Road Type	$b_4 \hat{=} b_5 \hat{=} 0$	2	85.68**
Age	$b_6 \hat{=} b_7 \hat{=} 0$	2	10.66*
Model		6	104.87**
Residual		29	19.95

*Means significant at $\alpha = 0.05$

**Means significant at $\alpha = 0.01$

C. Unbelted [ESPI = 2]

$$
\underset{36\times 7}{\underset{\sim}{X}} = \begin{array}{ccccccc}
 & \text{Year} & \text{Time} & \multicolumn{2}{c}{\text{1973 Road}} & \text{1974 Road} & \text{Age} \\
\end{array}
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 1 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 1 \\
1 & 0 & 0 & 1 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 0 & 1 \\
1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 0 & 1 \\
1 & 0 & 1 & 1 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 0 & 1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 0 & 1 \\
1 & 1 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 & 1 \\
1 & 1 & 0 & 0 & 0 & 0 & 1 \\
1 & 1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 0 & 1 \\
1 & 1 & 1 & 0 & 0 & 0 & 1 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 1 & 0 & 0 & 1 & 1
\end{bmatrix}
$$

$$
\underset{\sim}{b} = \begin{bmatrix}
0.0515 \pm 0.0042 \\
-0.0161 \pm 0.0051 \\
-0.0122 \pm 0.0028 \\
0.0118 \pm 0.0043 \\
-0.0325 \pm 0.0079 \\
0.0254 \pm 0.0039 \\
0.0127 \pm 0.0029
\end{bmatrix}
$$

b_1 = Predicted rate for (1973, N, U, Age = 1)

b_2 = Increment for 1974

b_3 = Increment for Day

b_4 = Increment for Rural or Interstate in 1973

b_5 = Additional increment for Interstate in 1973

b_6 = Increment for Rural or Interstate in 1974

b_7 = Increment for Age = 3 in 1973 or for Age = 2 or 3 in 1974

Source of Variation	Hypothesis	df	χ^2
Year	$b_2 \hat{=} 0$	1	10.18 **
Time	$b_3 \hat{=} 0$	1	19.30 **
1973 Road	$b_4 \hat{=} b_5 \hat{=} 0$	2	21.83 **
1974 Road	$b_6 \hat{=} 0$	1	42.03 **
Age	$b_7 \hat{=} 0$	1	19.87 **
Model		6	102.69 **
Residual		29	38.38

* Means significant at α=0.05.

** Means significant at α=0.01.

D. Unbelted [ESPI = 3]

$$
\underset{36\times5}{\underset{\sim}{X}} = \begin{array}{c}
\begin{array}{ccccc} & \begin{matrix}1973\\ \text{Day or}\\ 1974\end{matrix} & \begin{matrix}1973\\ \text{Night}\\ \text{Road}\end{matrix} & \begin{matrix}1973\\ \text{Day or}\\ 1974\\ \text{Road}\end{matrix} & \text{Age}\end{array}\\
\begin{bmatrix}
1 & 0 & 0 & 0 & 0\\
1 & 0 & 0 & 0 & 0\\
1 & 0 & 0 & 0 & 0\\
1 & 0 & 1 & 0 & 0\\
1 & 0 & 1 & 0 & 0\\
1 & 0 & 1 & 0 & 0\\
1 & 0 & 2 & 0 & 0\\
1 & 0 & 2 & 0 & 0\\
1 & 0 & 2 & 0 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 0 & 1\\
1 & 1 & 0 & 0 & 2\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 1\\
1 & 1 & 0 & 1 & 2\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 1\\
1 & 1 & 0 & 1 & 2\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 0 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0\\
1 & 1 & 0 & 1 & 0
\end{bmatrix}
\end{array}
$$

$$
\underset{\sim}{b} = \begin{bmatrix}
0.2576 \pm 0.0245\\
-0.1651 \pm 0.0354\\
-0.0838 \pm 0.0199\\
0.0600 \pm 0.0263\\
0.0811 \pm 0.0143
\end{bmatrix}
$$

Source of Variation	Hypothesis	df	χ^2
1973 Day or 1974 Increment	$\hat{b}_2 = 0$	1	21.73 **
Road	$\hat{b}_3 = \hat{b}_4 = 0$	2	22.85 **
Age	$b_5 = 0$	1	32.17 **
Model		4	55.22 **
Residual		31	29.84

** Means significant at α=0.01.

final model do not lead themselves to simple interpretation and/or comparisons.

The "regression" models obtained up to this point will be used in the final section to provide the "injury rate structure" involved in the construction of the indices presented therein.

Linear categorical models for fatality (K) rates.

Proceeding as before with (A+K) rates, various models are fit to the fatality rates for belted drivers and for unbelted drivers (at each level of ESPI). The main difference between these two problems is (as shown in Table D.10) the necessity of a rather stringent collapsing to provide appropriate cell sizes. The analysis of some preliminary models (shown in Table D.11) produced the collapsing displayed in Table D.10.

The final models for belted drivers and for unbelted (ESPI = 1) drivers (see page 193) were additive on ESPI and on Year, Road Type and Age, respectively. The final models for unbelted drivers with ESPI = 2 and ESPI = 3 (see pages 194 and 195) were both additive on Year, Time of Day and Road Type with Driver Age nested within Rural non-Interstate. All of the predicted values given by these models are listed in Table D.10.

Table D.10 Observed and predicted driver fatality rates and their corresponding standard errors.

Belted Fatalities

ESPI	Year	Time	Road	Number Drivers Involved	Number (K)	Observed K-rate	Estimated s.e.	Predicted K-rate	Predic s.e
1	73	N	U	628	0	.000	.0001	.000	.00
1	73	N	R	393	0				
1	73	N	I	20	0				
1	73	D	U	2245	0				
1	73	D	R	1380	0				
1	73	D	I	91	0				
1	74	N	U	710	0				
1	74	N	R	265	0				
1	74	N	I	10	1				
1	74	D	U	2437	0				
1	74	D	R	1085	0				
1	74	D	I	53	0				
2	73	N	U	200	0	.001	.0004	.001	.0
2	73	N	R	609	1				
2	73	N	I	63	0				
2	73	D	U	346	0				
2	73	D	R	1288	0				
2	73	D	I	108	0				
2	74	N	U	199	0				
2	74	N	R	524	0				
2	74	N	I	48	0				
2	74	D	U	404	0				
2	74	D	R	1022	2				
2	74	D	I	90	0				
3	73	N	U	9	0	.007	.0033	.007	.0
3	73	N	R	174	2				
3	73	N	I	63	1				
3	73	D	U	10	0				
3	73	D	R	150	0				
3	73	D	I	85	0				
3	74	N	U	10	0				
3	74	N	R	96	1				
3	74	N	I	12	0				
3	74	D	U	9	0				
3	74	D	R	54	1				
3	74	D	I	7	0				

Table D.10 Continued.

Unbelted Fatalities (ESPI ≤ 30 mph)

Year	Road	Age	Time	Number Drivers Involved	Number (K)	Observed K-rate	Estimated s.e.	Predicted K-rate	Predicted s.e.
73	U	1	N	1019	0				
73	U	1	D	2549	0				
73	U	2	N	1506	0				
73	U	2	D	4958	0				
73	U	3	N	1183	1				
73	U	3	D	5323	1				
						.000	.0001	.000	.0001
73	I	1	N	10	0				
73	I	1	D	34	0				
73	I	2	N	29	0				
73	I	2	D	89	0				
73	I	3	N	20	0				
73	I	3	D	96	0				
73	R	1	N	748	0				
73	R	1	D	2040	4	.001	.0004	.001	.0003
73	R	2	N	1075	1				
73	R	2	D	3432	2				
73	R	3	N	969	3	.004	.0010	.004	.0007
73	R	3	D	3825	18				
74	U	1	N	1073	1				
74	U	1	D	2595	2				
74	U	2	N	1719	1				
74	U	2	D	5343	0				
74	U	3	N	1336	0				
74	U	3	D	5885	0				
						.000	.0001	.000	.0001
74	I	1	N	8	0				
74	I	1	D	22	0				
74	I	2	N	23	2				
74	I	2	D	68	0				
74	I	3	N	13	0				
74	I	3	D	58	1				
74	R	1	N	691	2				
74	R	1	D	1778	5	.001	.0005	.001	.0003
74	R	2	N	898	1				
74	R	2	D	2804	0				
74	R	3	N	732	4	.003	.0010	.004	.0007
74	R	3	D	3195	9				

Table D.10 Continued.

Unbelted Fatalities (30 < ESPI ≤ 55 mph)

Year	Time	Road	Age	Number Drivers Involved	Number K	Observed K Rate	Estimated s.e.	Predicted Rate	Predicted s.e.
73	N	U	1	403	1				
73	N	U	2	536	2				
73	N	U	3	251	0	.003	.0015	.004	.0009
73	N	I	1	26	0				
73	N	I	2	43	0				
73	N	I	3	48	1				
73	N	R	1	1385	8	.006	.0020	.004	.0009
73	N	R	2	1868	10	.005	.0017	.006	.0010
73	N	R	3	1105	12	.011	.0031	.010	.0013
73	D	U	1	583	0				
73	D	U	2	887	2				
73	D	U	3	573	5	.003	.0012	.003	.0008
73	D	I	1	33	1				
73	D	I	2	108	0				
73	D	I	3	115	0				
73	D	R	1	2080	8	.004	.0014	.003	.0009
73	D	R	2	3210	13	.004	.0011	.005	.0008
73	D	R	3	2631	20	.008	.0017	.009	.0012
74	N	U	1	399	1				
74	N	U	2	630	1				
74	N	U	3	295	0	.004	.0016	.003	.0009
74	N	I	1	36	0				
74	N	I	2	88	1				
74	N	I	3	62	3				
74	N	R	1	1223	2	.002	.0012	.003	.0008
74	N	R	2	1718	16	.009	.0023	.005	.0010
74	N	R	3	984	8	.008	.0029	.009	.0013
74	N	U	1	550	0				
74	N	U	2	921	1				
74	N	U	3	655	1	.002	.0009	.002	.0007
74	N	I	1	43	0				
74	N	I	2	117	1				
74	N	I	3	102	2				
74	N	R	1	1700	4	.002	.0012	.002	.0008
74	N	R	2	2614	9	.003	.0011	.004	.0008
74	N	R	3	2222	22	.010	.0021	.008	.0012

Table D.10 Continued.

lted Fatalities (ESPI >55 mph)

Time	Road	Age	Number Drivers Involved	Number K	Observed K Rate	Estimated s.e.	Predicted K Rate	Predicted s.e.
N	U	1	32	1				
N	U	2	47	2				
N	U	3	16	4	.038	.0111	.033	.0067
N	I	1	48	2				
N	I	2	97	0				
N	I	3	53	2				
N	R	1	596	18	.030	.0070	.026	.0050
N	R	2	647	25	.039	.0076	.041	.0053
N	R	3	160	9	.056	.0182	.059	.0096
D	U	1	9	0				
D	U	2	6	0				
D	U	3	9	1	.016	.0079	.021	.0063
D	I	1	50	1				
D	I	2	102	1				
D	I	3	74	1				
D	R	1	395	7	.018	.0066	.015	.0048
D	R	2	485	13	.027	.0073	.029	.0052
D	R	3	250	11	.044	.0130	.047	.0092
N	U	1	38	0				
N	U	2	41	2				
N	U	3	4	0	.039	.0173	.035	.0077
N	I	1	11	0				
N	I	2	23	2				
N	I	3	10	1				
N	R	1	448	10	.022	.0070	.029	.0049
N	R	2	514	23	.045	.0091	.043	.0057
N	R	3	116	9	.078	.0248	.061	.0100
N	U	1	13	0				
N	U	2	9	0				
N	U	3	6	1	.061	.0342	.024	.0078
N	I	1	5	1				
N	I	2	11	1				
N	I	3	5	0				
N	R	1	245	4	.016	.0081	.017	.0054
N	R	2	259	10	.039	.0120	.031	.0062
N	R	3	98	5	.051	.0222	.050	.0099

Analysis of Fatal Injury Data

$$\underset{6\tilde{x}4}{X} = \begin{array}{c} \begin{matrix} & \text{ESPI} & & \text{Year} \end{matrix} \\ \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 \end{bmatrix} \end{array}$$

Preliminary model for belted drivers (after collapsing across Time and Road type)

b_1 = Predicted value for ESPI = 1, 1973

b_2 = Increment for ESPI = 2

b_3 = Increment for ESPI = 3

b_4 = Increment for 1974

$$\underset{20\tilde{x}7}{X} = \begin{array}{c} \begin{matrix} & \text{Year} & \text{Time} & \text{Road} & & \text{Age} & \end{matrix} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

Preliminary model for unbelted drivers (after collapsing across Age within U and I)

b_1 = Predicted value for 1973, N, U, Age = 1

b_2 = Increment for 1974

b_3 = Increment for Day

b_4 = Increment for Rural Non-Interstate

b_5 = Increment for Interstate

b_6 = Increment for Age = 2

b_7 = Additional Increment for Age = 3

Table D.11 Estimated parameters, standard errors and tests of significance for preliminary model analysis of fatal injury data.

Belted Drivers

$$\underset{\sim}{b} = \begin{bmatrix} .0001 \pm .0001 \\ .0004 \pm .0003 \\ .0064 \pm .0032 \\ .0002 \pm .0002 \end{bmatrix}$$

Source	Hypothesis	df	χ^2
Speed	$\hat{b}_2 = \hat{b}_3 = 0$	2	5.72
Year	$\hat{b}_4 = 0$	1	0.42
	Model	3	6.09
	Residual	2	0.52

Unbelted Drivers
ESPI = 1

$$\underset{\sim}{b} = \begin{bmatrix} .0003 \pm .0002 \\ .0001 \pm .0001 \\ -.0002 \pm .0002 \\ .0015 \pm .0006 \\ .0036 \pm .0028 \\ -.0013 \pm .0006 \\ .0033 \pm .0007 \end{bmatrix}$$

Source	Hypothesis	df	χ^2
Year	$\hat{b}_2 = 0$	1	0.19
Time	$\hat{b}_3 = 0$	1	1.37
Road	$\hat{b}_4 = \hat{b}_5 = 0$	2	8.55*
Age: Rural	$\hat{b}_6 = \hat{b}_7 = 0$	2	26.07**
	Model	6	40.94**
	Residual	13	8.84

Jnbelted Drivers
ESPI = 2

$$\underset{\sim}{b} = \begin{bmatrix} .0029 \pm .0008 \\ -.0011 \pm .0007 \\ -.0008 \pm .0007 \\ .0011 \pm .0008 \\ .0054 \pm .0030 \\ .0016 \pm .0010 \\ .0042 \pm .0013 \end{bmatrix}$$

Source	Hypothesis	df	χ^2
Year	$\hat{b}_2 = 0$	1	2.52
Time	$\hat{b}_3 = 0$	1	1.22
Road	$\hat{b}_4 = \hat{b}_5 = 0$	2	4.39
Age: Rural	$\hat{b}_6 = \hat{b}_7 = 0$	2	19.42**
	Model	6	45.37**
	Residual	13	13.24

Inbelted Drivers
ESPI = 3

$$\underset{\sim}{b} = \begin{bmatrix} .0395 \pm .0131 \\ .0013 \pm .0053 \\ -.0098 \pm .0048 \\ -.0134 \pm .0132 \\ -.0156 \pm .0144 \\ .0142 \pm .0056 \\ .0180 \pm .0099 \end{bmatrix}$$

Source	Hypothesis	df	χ^2
Year	$\hat{b}_2 = 0$	1	0.06
Time	$\hat{b}_3 = 0$	1	4.20*
Road	$\hat{b}_4 = \hat{b}_5 = 0$	2	1.20
Age: Rural	$\hat{b}_6 = \hat{b}_7 = 0$	2	14.28**
	Model	6	22.05**
	Residual	13	8.14

ans significant at $\alpha = 0.05$
ans significant at $\alpha = 0.01$

Final Models for Fatal Injury Data

A. Belted

$$
\begin{array}{cc}
 & \text{ESPI} \\
\underset{3\tilde{x}3}{X} = & \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}
\end{array}
\qquad
\underset{\sim}{b} = \begin{bmatrix} 0.0001 \pm 0.0001 \\ 0.0005 \pm 0.0004 \\ 0.0068 \pm 0.0033 \end{bmatrix}
$$

b_1 = Predicted rate for ESPI = 1

b_2 = Increment for ESPI = 2

b_3 = Additional increment for ESPI = 3

B. Unbelted (ESPI = 1)

$$
\begin{array}{cc}
 & \begin{array}{cccc} & \text{Year} & \text{Road} & \text{Age} \end{array} \\
\underset{6\tilde{x}4}{X} = & \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}
\end{array}
\qquad
\underset{\sim}{b} = \begin{bmatrix} 0.0001 \pm 0.0001 \\ 0.0003 \pm 0.0002 \\ 0.0009 \pm 0.0003 \\ 0.0027 \pm 0.0007 \end{bmatrix}
$$

b_1 = Predicted rate for 1973, U or I, any age

b_2 = Increment for 1974

b_3 = Increment for Rural Non-Interstate

b_4 = Additional increment for Age 3 in Rural Non-Interstate

Source of Variation	Hypothesis	df	χ^2
Year	$\hat{b}_2 = 0$	1	2.46
Road Type	$\hat{b}_3 = 0$	1	8.73**
Age: Rural	$\hat{b}_4 = 0$	1	14.13**
Model		3	40.98**
Residual		2	1.10

** Means significant at $\alpha = 0.01$

Unbelted (ESPI = 2)

$$
\begin{array}{c}
\\
6 =
\end{array}
\begin{array}{cccccc}
 & \text{Year} & \text{Time} & \text{Road} & \text{Age} & \\
\end{array}
$$

$$
= \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 \\
1 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 \\
1 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 1 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 \\
1 & 1 & 1 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 1 & 1 & 0 & 1
\end{bmatrix}
$$

$$
\underset{\sim}{b} = \begin{bmatrix}
0.0040 \pm 0.0009 \\
-0.0008 \pm 0.0007 \\
-0.0010 \pm 0.0008 \\
-0.0001 \pm 0.0009 \\
0.0017 \pm 0.0010 \\
0.0059 \pm 0.0013
\end{bmatrix}
$$

b_1 = Predicted rate for 1973, N, U or I, any age

b_2 = Increment for 1974

b_3 = Increment for Day

b_4 = Increment for Rural Non-Interstate, Age 1

b_5 = Additional Increment for Age 2 in Rural Non-Interstate

b_6 = Additional Increment for Age 3 in Rural Non-Interstate

Source of Variation	Hypothesis	df	χ^2
Year	$\hat{b}_2 = 0$	1	1.13
Time	$\hat{b}_3 = 0$	1	1.56
Road Type	$\hat{b}_4 = 0$	1	0.01
Age: Rural	$\hat{b}_5 = \hat{b}_6 = 0$	2	20.06**
Model		5	27.64**
Residual		10	9.43

** means significant at $\alpha = 0.01$

Unbelted (ESPI = 3)

$$\underset{16\times 6}{\underset{\sim}{X}} = \begin{array}{c} \begin{array}{cccc} \text{Year} & \text{Time} & \text{Road} & \text{Age} \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

$$\underset{\sim}{b} = \begin{bmatrix} 0.0329 \pm 0.0067 \\ 0.0024 \pm 0.0052 \\ -0.0017 \pm 0.0049 \\ -0.0065 \pm 0.0071 \\ 0.0142 \pm 0.0056 \\ 0.0327 \pm 0.0097 \end{bmatrix}$$

b_1 = Predicted rate for 1973, N, U or I, any age

b_2 = Increment for 1974

b_3 = Increment for Day

b_4 = Increment for Rural Non-Interstate, Age 1

b_5 = Additional Increment for Age 2 in Rural Non-Interstate

b_6 = Additional Increment for Age 3 in Rural Non-Interstate

Source of Variation	Hypothesis	df	X^2
Year	$\hat{b}_2 = 0$	1	0.22
Time	$\hat{b}_3 = 0$	1	5.77*
Road Type	$\hat{b}_4 = 0$	1	0.84
Age: Rural	$\hat{b}_5 = \hat{b}_6 = 0$	2	14.59**
Model		5	20.20**
Residual		10	4.31

* means significant at $\alpha = 0.05$

** means significant at $\alpha = 0.01$

Predicted Serious Driver Injury Rates
Under a Variety of Assumptions

This section is concerned with the construction of indices derived from the results given in the previous two sections which reflect the extent to which various aspects of the 1974 accident type distribution and the corresponding serious injury rate structure would have hypothetically implied a smaller total number of serious injuries in 1973 than actually occurred if they had indeed been the underlying parameters for the 1973 data. In this sense, they may be regarded as operational measures of the impact of the change between 1973 and 1974 in the risks of various types of motor vehicle accidents and correspondingly serious injury.

Let

$n_{hi_1i_2i_3i_4i_5j}$ = the observed frequency of the j-th injury category during the h-th year for accident types with the i_1-th driver belt usage status, the i_2-th ESPI status, the i_3-th time of day, the i_4-th road type, and the i_5-th driver age (D.1)

where

h = 1 1973
2 1974

i_1 = 1 Belted
2 Unbelted

i_2 = 1 ESPI $\leq$ 30 mph
2 30 < ESPI $\leq$ 55
3 ESPI > 55

i_3 = 1 Night
2 Day

i_4 = 1 Urban
2 Rural
3 Interstate

i_5 = 1 $\leq$ 20 years
2 21-35
3 $\geq$ 36

j = 1 Serious (A+K) injury
2 Not serious injury

Then

$$N_{hi_1} = \sum_{i_2=1}^{3} \sum_{i_3=1}^{2} \sum_{i_4=1}^{3} \sum_{i_5=1}^{3} \sum_{j=1}^{2} n_{hi_1i_2i_3i_4i_5j} \tag{D.2}$$

= the total number of accidents during the h-th year for drivers with the i_1-th belt usage status.

$$N_{hi_1i_2} = \sum_{i_3=1}^{2} \sum_{i_4=1}^{3} \sum_{i_5=1}^{3} \sum_{j=1}^{2} n_{hi_1i_2i_3i_4i_5j} \tag{D.3}$$

= the total number of accidents during the h-th year for drivers with the i_1-th belt usage status and the i_2-th ESPI.

$$N_{hi_1i_2i_3i_4i_5} = \sum_{j=1}^{2} n_{hi_1i_2i_3i_4i_5j} \tag{D.4}$$

= the total number of accidents during the h-th year with the i_1-th driver belt usage status, the i_2-th ESPI status, the i_3-th time of day, the i_4-th road type and the i_5-th driver age.

$$m_{i_1i_2i_3i_4i_5} = \left(\frac{N_{1i_1}}{N_{2i_1}}\right) N_{2i_1i_2i_3i_4i_5} \tag{D.5}$$

= the number of accidents which would have been expected in 1973 with the i_1-th driver belt usage status, the i_2-th ESPI status, the i_3-th time of day, the i_4-th road type, and the i_5-th driver age if the 1973 accidents with the i_1-th driver belt usage status had the same distribution with respect to (i_2, i_3, i_4, i_5) as the 1974 accidents.

$$f_{i_1i_2i_3i_4i_5} = \left(\frac{N_{1i_1}}{N_{2i_1}}\right)\left(\frac{N_{2i_1i_2}}{N_{1i_1i_2}}\right) N_{1i_1i_2i_3i_4i_5} \tag{D.6}$$

= the number of accidents which would have been expected in 1973 with the i_1-th driver belt usage status, the i_2-th ESPI status, the i_3-th time of day, the i_4-th road type, and the i_5-th driver age if the 1973 accidents with the i_1-th driver belt usage status had the same distribution with respect to i_2 (ESPI) as the 1974 accidents but otherwise had the same conditional distribution of (i_3, i_4, i_5) given i_2 as 1973; i.e., the 1973 accident type distribution is left intact except for the re-allocation of the marginal ESPI distribution in accordance with 1974.

$$\hat{p}_{hi_1i_2i_3i_4i_5} = \sum_{k=1}^{t} b_k \, x_{hi_1i_2i_3i_4i_5k} \tag{D.7}$$

= predicted values from the regression models in the previous section for the probability of serious injury for accidents corresponding to the h-th year, i_1-th driver belt usage status, i_2-th ESPI status, i_3-th time of day, i_4-th road type and i_5-th driver age.

Thus

$$M_{hi_1g} = \sum_{k=1}^{t} \left\{ \sum_{i_2=1}^{3} \sum_{i_3=1}^{2} \sum_{i_4=1}^{3} \sum_{i_5=1}^{3} U_{gi_1i_2i_3i_4i_5} x_{hi_1i_2i_3i_4i_5k} \right\} b_k \tag{D.8}$$

$$= \sum_{k=1}^{t} c_{hgk} b_k$$

= the predicted value for the number of accidents involving serious injury for 1973 based on the predicted injury rate structure for the h-th year from (D.7) and the g-th projected 1973 accident type distributions

where

$$U_{1i_1i_2i_3i_4i_5} = N_{1i_1i_2i_3i_4i_5} ,$$

$$U_{2i_1i_2i_3i_4i_5} = m_{i_1i_2i_3i_4i_5} ,$$

$$U_{3i_1i_2i_3i_4i_5} = f_{i_1i_2i_3i_4i_5} .$$

Since the quantities M_{hi_1g} are linear functions of the estimated parameter vectors $\underset{\sim}{b}$, they may be computed together with corresponding standard errors by using appropriate matrix operators. Thus, indices of the type

$$R_{hi_1g} = \frac{(M_{1i_11} - M_{hi_1g})}{M_{1i_11}}$$

can be constructed to reflect the extent to which various aspects of the 1974 accident type distribution and/or its corresponding serious injury rate structure would have hypothetically implied a smaller total number of serious injuries in 1973.

To illustrate the computations using the data in Table D.12, consider M_{hi_1g} for h=2, i_1=1, and j=2; i.e., the predicted number of serious

Table D.12 Distribution of drivers by ESPI, Belt Usage, and Accident Year.

Number of Drivers Involved

	Belted		Unbelted	
ESPI	1973	1974	1973	1974
1	4757	4560	28906	28241
2	2614	2287	15885	14361
3	491	188	3075	1856
Total	7862	7035	47866	44458

driver injuries for 1973 belted drivers, based on the predicted injury structure for 1974 and the projected 1973 accident distribution obtained from $m_{1i_2i_3i_4} = N_{11} \dfrac{N_{21i_2i_3i_4}}{N_{21}}$ since i_5=0 (i.e., no age component in the linear categorical model for belted drivers).

In Table D.13, the left hand side shows the computation of $m_{1i_2i_3i_4}$ for all combinations of i_2(ESPI), i_3(Time of Day) and i_4(Road Type). Note that $N_{21i_2i_3i_4}$ is the corresponding entry in column 5 of Table D.9. The $m_{1i_2i_3i_4}$ represent the reallocation of the N_{11} (1973) drivers according to the 1974 belted driver accident distribution.

The right hand side of Table D.13 reproduces the 1974 sections of the design matrix ($\underset{\sim}{X}$) of the final model for belted drivers (see page 181).

The components of M_{212} are derived from Table D.13 and $\underset{\sim}{b}$ obtained from the final model for belted drivers as follows:

$$M_{212} = \underset{\sim}{c}'\underset{\sim}{b} = \sum_{k=1}^{7} c_k b_k = 86.04$$

where

$$\underset{\sim}{c}' = (c_k) = \underset{\sim}{m}'\underset{\sim}{X}$$

$$\text{with} \qquad \underset{\sim}{m} = (m_{1i_2i_3i_4})$$

The $\underset{\sim}{c}'$ for belted and also unbelted drivers within ESPI are given in Table D.14. Finally, the predicted M_{hi_1g} and their standard errors along with the estimated injury reduction indices (R_{hi_1g}) and their standard errors are given in Table D.15.

Thus, it can be seen that the index $R_{212} = 0.283$ corresponds to a 28.3% hypothetical reduction in serious injury among belted drivers for 1973 which could have been potentially realized if the 1973 accident type distribution of belted driver accidents with respect to ESPI, Time, and Road Type and the 1973 injury rates for ESPI × Time × Road Type combinations had been effectively the same as their observed counterparts in 1974. Similarly, $R_{222} = 0.094$ corresponds to an analogously defined 9.4% hypothetical reduction for unbelted drivers. The other R_{hi_1g} reflect hypothetical reductions which pertain to the implied and/or results associated either with modifying the injury rate structure and/or

Table D.13 Basic computations for obtaining M_{212}.

$m_{1i_2i_3i_4}$				$\underset{\sim}{X}$			
		ESPI		Year	Time	Road Type	
$m_{1111} = (710/7035)7862 = 793.464$	1	0	0	1	0	0	0
$m_{1112} = (265/7035)7862 = 296.152$	1	0	0	1	0	1	0
$m_{1113} = (10/7035)7862 = 11.176$	1	0	0	1	0	1	1
$m_{1121} = (2437/7035)7862 = 2723.482$	1	0	0	1	1	0	0
$m_{1122} = (1085/7035)7862 = 1212.547$	1	0	0	1	1	1	0
$m_{1123} = (53/7035)7862 = 59.230$	1	0	0	1	1	1	1
$m_{1211} = (199/7035)7862 = 222.393$	1	1	0	1	0	0	0
$m_{1212} = (524/7035)7862 = 585.599$	1	1	0	1	0	1	0
$m_{1213} = (48/7035)7862 = 53.643$	1	1	0	1	0	1	1
$m_{1221} = (404/7035)7862 = 541.492$	1	1	0	1	1	0	0
$m_{1222} = (1022/7035)7862 = 1142.141$	1	1	0	1	1	1	0
$m_{1223} = (90/7035)7862 = 100.580$	1	1	0	1	1	1	1
$m_{1311} = (10/7035)7862 = 11.176$	1	1	1	1	0	0	[illegible]
$m_{1312} = (96/7035)7862 = 107.285$	1	1	1	1	0	1	[illegible]
$m_{1313} = (12/7035)7862 = 13.411$	1	1	1	1	0	1	[illegible]
$m_{1321} = (9/7035)7862 = 10.058$	1	1	1	1	1	0	[illegible]
$m_{1322} = (54/7035)7862 = 60.348$	1	1	1	1	1	1	[illegible]
$m_{1323} = (7/7035)7862 = 7.823$	1	1	1	1	1	1	
$c_k =$	7862	2766	210	7862	5767	3650	2
$b_k =$	.0092	.0119	.0352	-.0020	-.0050	.0048	.0
$c_k b_k =$	77.330	32.915	7.392	-15.724	-28.835	17.520	0.

$$M_{212} = \sum_{k=1}^{7} c_k b_k = 86.04$$

Table D.14 Values of c for various combinations of 1973 projected accident distributions (g) and injury rates (h) by Belt Usage and ESPI.

	g	h	c_1	c_2	c_3	c_4	c_5	c_6	c_7
	1	1	7862.00	3105.00	491.00	0.00	5703.00	4424.00	430.00
	1	2	7862.00	3105.00	491.00	7862.00	5703.00	4424.00	430.00
ielted	2	1	7861.61	2765.81	210.09	0.00	5767.42	3649.76	245.85
	2	2	7861.61	2765.81	210.09	7861.61	5767.42	3649.76	245.85
	3	1	7862.24	2766.07	210.10	0.00	5789.11	4242.39	349.45
	3	2	7862.24	2766.07	210.10	7862.24	5789.11	4242.39	349.45
	1	1	28906.00	0.00	22347.00	12367.00	278.00	22506.00	11417.00
	1	2	28906.00	28906.00	22347.00	12367.00	278.00	22506.00	11417.00
ibelted	2	1	30404.26	0.00	23413.90	11078.21	206.71	23764.87	12078.38
ESPI=1	2	2	30404.26	30404.26	23413.90	11078.21	206.71	23764.87	12078.38
	3	1	30406.22	0.00	23506.81	13008.85	292.43	23674.06	12009.54
	3	2	30406.22	30404.26	23506.81	13008.85	292.43	23674.06	12009.54
	1	1	15885.00	0.00	10220.00	12652.00	373.00	0.00	4723.00
	1	2	15885.00	15885.00	10220.00	0.00	0.00	12652.00	11375.00
	2	1	15461.05	0.00	9609.73	11744.63	482.32	0.00	4651.99
ESPI=2	2	2	15461.05	15461.05	9609.73	0.00	0.00	11744.63	11207.41
	3	1	15462.46	0.00	9948.14	12315.46	363.08	0.00	4597.37
	3	2	15462.46	15462.46	9948.14	0.00	0.00	12315.46	11072.43
	1	1	3075.00	1379.00	1799.00	1355.00	0.00	NA	NA
	1	2	3075.00	3075.00	0.00	2956.00	1249.00	NA	NA
	2	1	1998.17	700.87	1255.32	670.72	0.00	NA	NA
ESPI=3	2	2	1998.17	1998.17	0.00	1878.67	902.19	NA	NA
	3	1	1998.14	896.07	1168.99	880.48	0.00	NA	NA
	3	2	1998.14	1998.14	0.00	1920.81	811.60	NA	NA

where NA = not applicable

the ESPI distribution structure and/or the complete accident type distribution.

Table D.15 Predicted M_{hi_1g} and their s.e.'s along with the injury reduction indices (R_{hi_1g}) and their s.e.'s for various combinations of 1974 projected accident distributions (J) and injury rates (H) by belt usage categories.

		Predicted Values M_{hi_1g} and their s.e.'s		Injury Reduction Indices (R_{hi_1g}) and their s.e.'s	
		Belted	Unbelted	Belted	Unbelted
1	1	120.5 ± 9.8	1804.3 ± 39.4	NA	NA
1	2	104.7 ± 9.4	1858.4 ± 42.6	0.131 ± 0.082	-0.030 ± 0.031
2	1	102.2 ± 8.9	1616.9 ± 37.1	0.152 ± 0.021	0.104 ± 0.004
2	2	86.4 ± 8.2	1635.1 ± 38.5	0.283 ± 0.075	0.094 ± 0.028
3	1	105.1 ± 9.0	1628.9 ± 36.9	0.128 ± 0.019	0.097 ± 0.003
3	2	89.3 ± 8.4	1657.6 ± 39.0	0.258 ± 0.077	0.081 ± 0.028
Actual observed total number of serious injuries		123	1811		

NA = not applicable