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THE EFFECTS OF THE LOWERED MAXIMUM SPEED LIMIT AND FUEL SHORTAGE ON HIGHWAY SAFETY IN NORTH CAROLINA

Andrew F. Seila

Donald W. Reinfurt

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ATTENTION

The enclosed report is a reprint of the original technical report which has recently gone out of print. Its content does not differ in any way from the original report. The format differs slightly due to time restrictions in the reprinting process.

We hope that this report will fulfill your interests. We appreciate your continued concern in highway safety.

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16. Abstract

This is an interim report on the effects of the lowered maximum speed limit and other fuel conservation measures which were instituted during the fuel shortage from November 1973 to March 1974. Comparisons made between the first four months of 1974 and the same period a year earlier indicate that accidents decreased 9.5 percent, fatal accidents decreased 21.0 percent, and injury accidents decreased 12.0 percent in North Carolina. The severity of accidents was decreased during the fuel shortage, and gross exposure decreased an estimated 3.2 percent. The fatality and serious injury rates per hundred million vehicle miles dropped by 17.7 and 19.0 percent, respectively. These changes were attributed to the lowered maximum speed limit, decreased exposure, changes in vehicle sizes and occupancy, and shifts in the times at which trips were made and the roads on which they were made. Further research is planned on exposure changes, analysis of the accident and injury data, the use of the T.A.D. severity ratings for severity analysis, the effect of Daylight Savings Time, especially on bicycle and pedestrian accidents, and other areas.

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I. INTRODUCTION

This interim report presents a preliminary analysis of the effects of the 55 mph maximum speed limit and fuel shortage on highway safety in North Carolina. 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 were to 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 this 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 (1) 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 stations were closed.

During this time, gasoline prices 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 December 22 (Saturday) to December 26. Holiday travelers chose trains and airlines over automobiles as their means of transportation. The National Opinion Research Center study (1) reported a large increase just prior to Christmas (from 21 to 37 percent) in the percentage of people reporting difficulty in getting gas. 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.

By the first of January, service station hours of operations 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 resulted between approximately 5:30 and 6:30 p.m. During January, gasoline prices continued a steady spiral ranging now 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 $3 limit or a 10 gallon limit. Most stations were closed on nights and weekends, as well as restricting daytime hours of operation. On February 17, Governor Holshouser outlined an odd-even rationing plan for North Carolina, under which vehicles with odd-numbered tags would get gasoline on Monday, Wednesday, and Friday, while vehicles with even numbered tags would get 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 a half-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 one to two hours. 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 around the 55 cents to 60 cents mark. 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 and 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, and this would remain until June, 1975; 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.

A national trend toward decreased traffic fatalities has been observed. Early in 1974 the National Safety Council reported that fatalities for December, 1973 were 19 percent below those of December a year earlier, 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. The remainder of this report involves a preliminary analysis of accident and vehicle data in North Carolina, relative to the effects of the fuel shortage.

II. OBSERVED EFFECTS ON HIGHWAY SAFETY

Accidents and Injuries

Figure 1 gives total accidents by month for January, 1962 through September, 1974. The relevant data is in Appendix A. There is an evident yearly trend as well as seasonal pattern, and just as evident is the interruption of this pattern after October, 1973. Table 1 shows that there has been a 9.5 percent decrease in total accidents in the first four months of this year (1974) over the same period last year (1973). All comparisons in this report involve these periods of time, unless otherwise stated.

Figure 2 shows total fatalities for 1962 through present, and the same trend and seasonality can be observed. Table 2 shows a 20.4

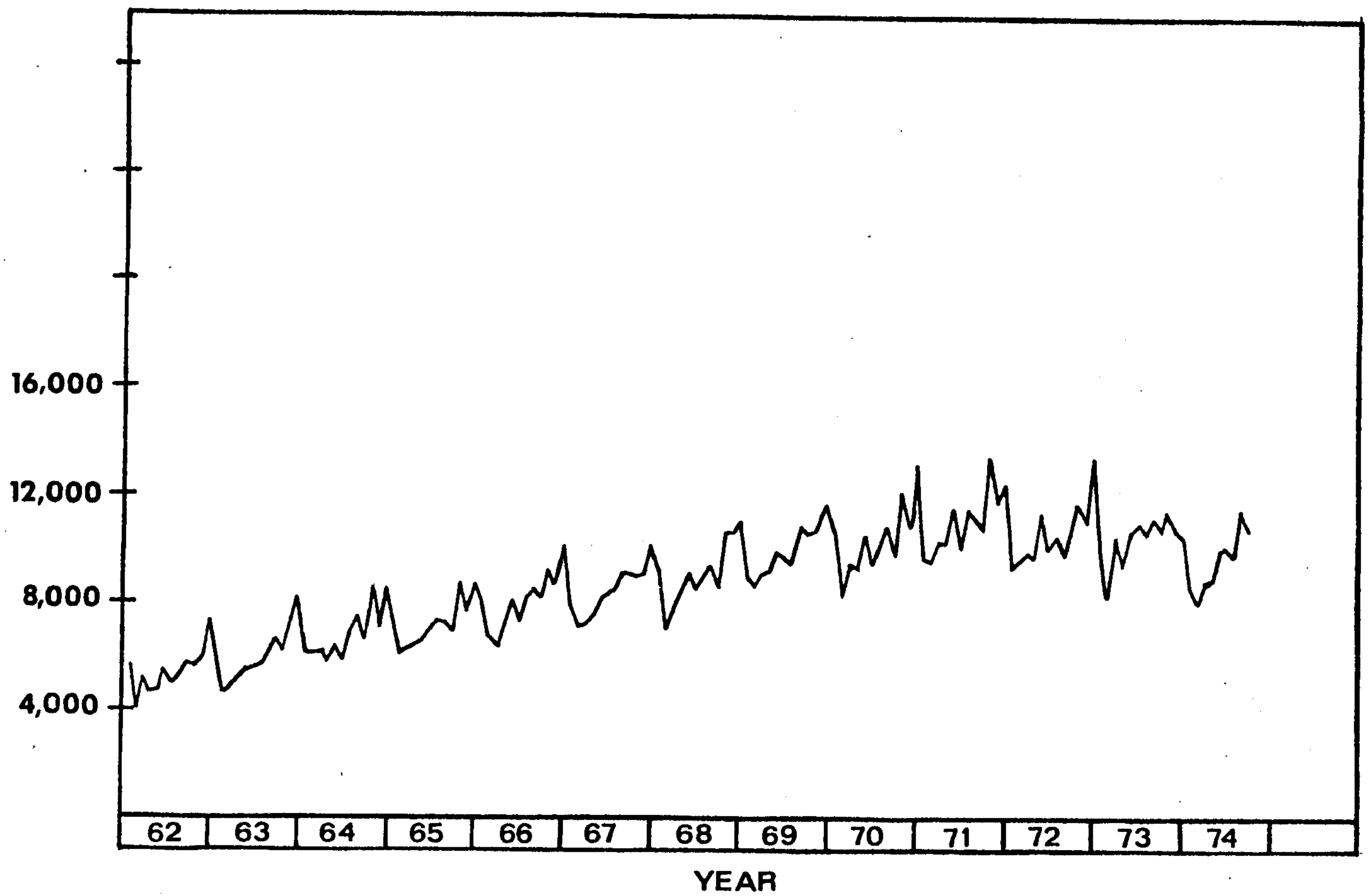


Figure 1. Total accidents per month in North Carolina.

Table 1. Accidents for first four months of 1973 and 1974*

	Total Accidents		Fatal Accidents		Injury Accidents	
	1973	1974	1973	1974	1973	1974
January	9911	8872	117	109	3280	3082
February	8379	8083	98	72	2982	2751
March	10560	8878	136	102	4083	3289
April	9581	8952	130	97	3869	3393
Total	38431	34785	481	380	14214	12515
Change	-9.5%		-21.0%		-12.0%	

*Source: N.C. Department of Motor Vehicles
Monthly Traffic Accident Summary

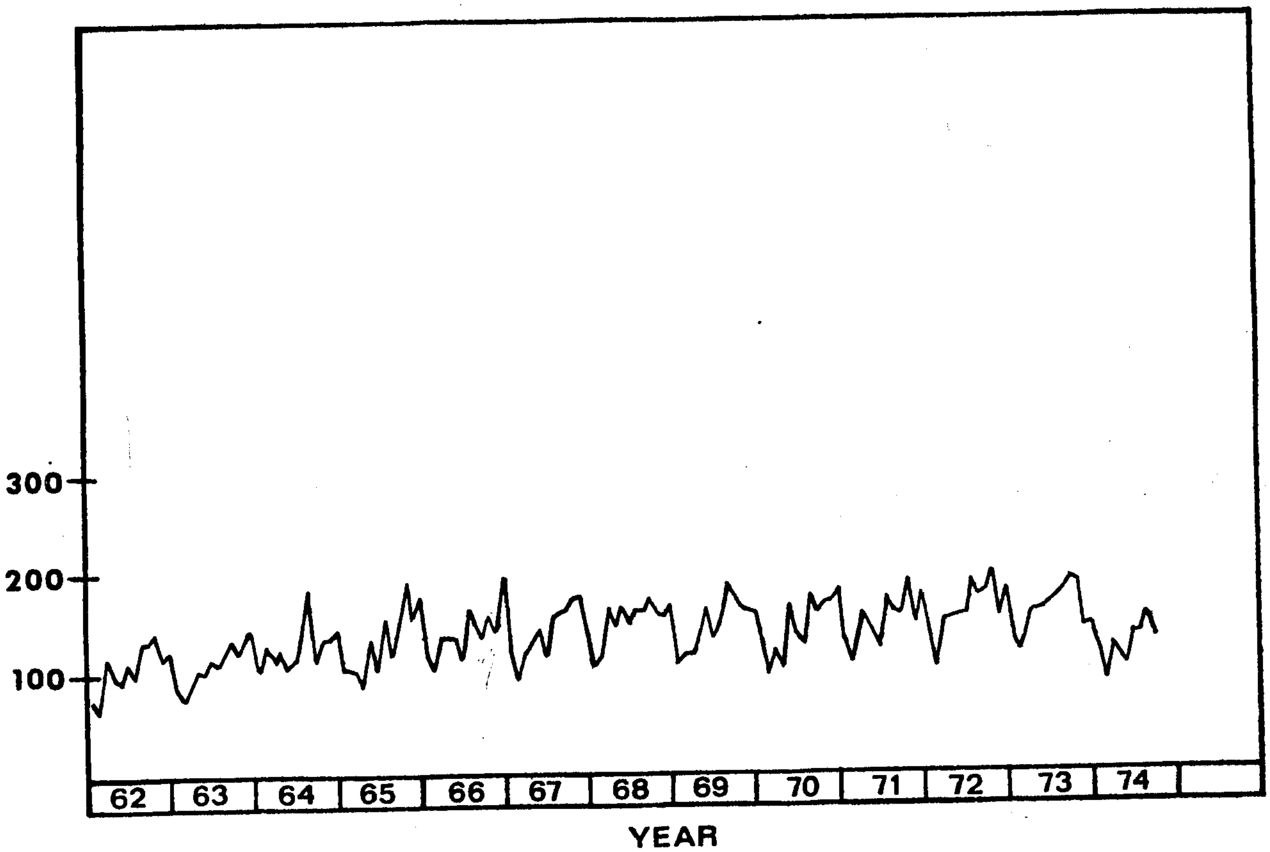


Figure 2. Fatalities per month in North Carolina.

Table 2. Persons injured by severity*

	K		A		B		C	
	1973	1974	1973	1974	1973	1974	1973	1974
January	133	125	948	791	1858	1839	2161	1958
February	119	86	838	636	1740	1527	2051	1944
March	150	122	1114	824	2302	1979	2844	2131
April	158	113	1156	924	2416	2141	2570	2179
Total	560	446	4056	3175	8316	7486	9626	8212
Change	-20.4%		-21.7%		-10.0%		-14.7%	

*Source: N.C. Department of Motor Vehicles,
<u>Monthly Traffic Accident Summary</u>

percent decrease in fatalities. Similarly, from Table 2, there was a 21.7 percent reduction in A-injuries, a 10.0 percent reduction in B-injuries, and a 14.7 percent reduction in C-injuries. Although a prediction has not been made for these quantities, they are substantially lower than the trend indicates that they should have been.

Accident Severity

Not only were there fewer accidents, but the evidence is that the accidents were less severe than was to be expected. Table 1 shows that fatal accidents were reduced considerably more than total accidents (21.0 percent vs. 9.5 percent) which indicates that accidents were less likely to involve fatalities. Injury accidents were also reduced, but not as much as fatal accidents (12.0 percent vs. 21.0 percent). The implication appears to be that some potentially fatal accidents became injury accidents due to the less severe nature of the accidents that were occurring. Table 3, which includes only a portion of accidents from the HSRC accident files, namely those for which a posted speed limit was available, indicates that driver injuries were down, with serious driver injuries (K and A) being down relatively more than less severe injuries (B and C). Figure 3 is a histogram of most severe TAD reported and Table 4 gives the relevant data. It should be noted that this data is heavily biased toward rural accidents because the N.C. Highway Patrol, which investigates all reported accidents outside municipal boundaries, reports TAD ratings on all accidents; whereas, presently between 70 and 90 percent of accidents occurring within municipal boundaries had no TAD reported. As can be seen from Figure 3, there has been a small but consistent decrease in TAD severity. The mean TAD severity for 1974 is

Table 3. Driver injury by severity*

	K		A		B		C	
	1973	1974	1973	1974	1973	1974	1973	1974
January	63	57	590	467	960	1044	1147	1120
February	66	45	472	357	1008	929	1107	1117
March	72	67	617	494	1343	1147	1546	1160
April	77	51	614	504	1303	1214	1365	1158
Total	278	220	2293	1822	4614	4334	5165	4555
Change	-20.8%		-20.5%		-6.1%		-11.8%	

*Source: HSRC Accident Files

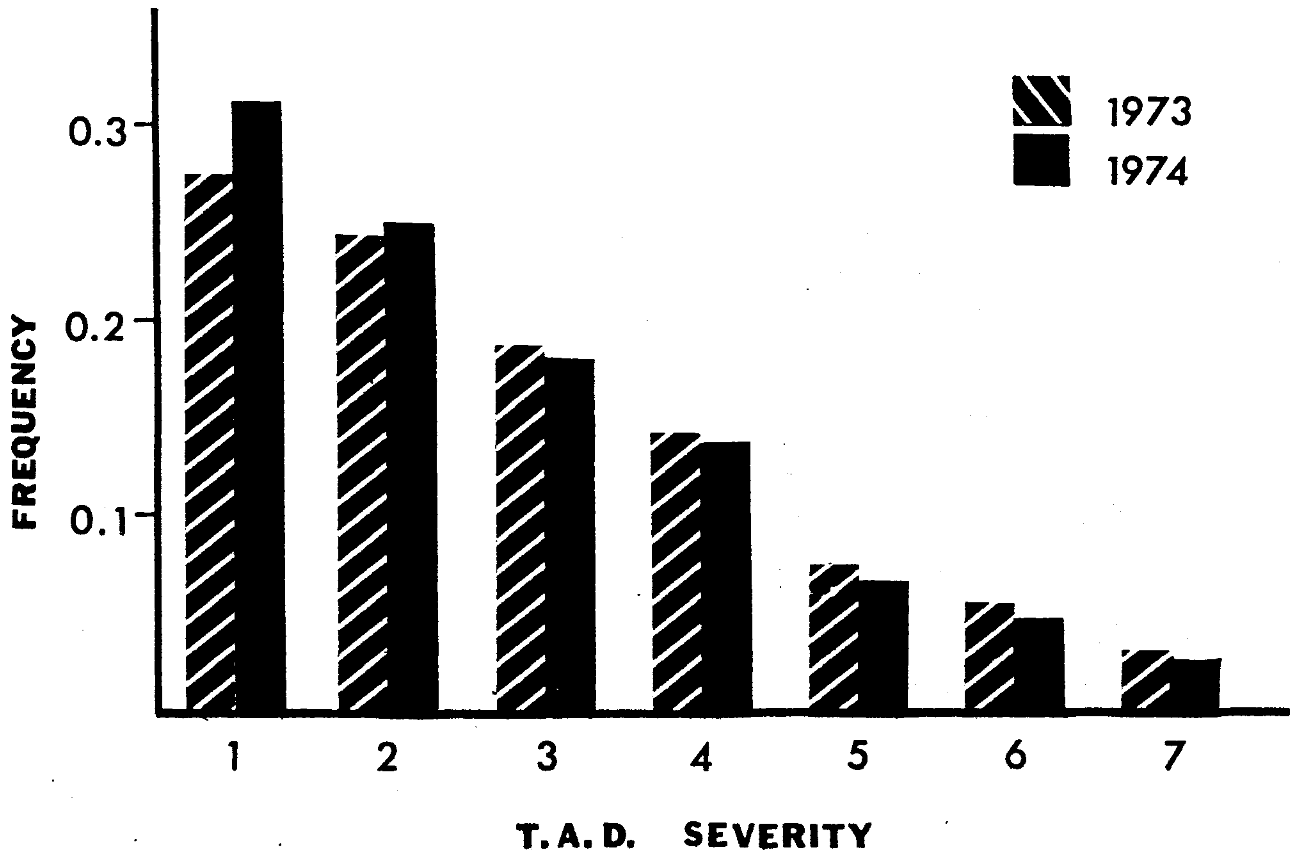


Figure 3. T.A.D. severity distribution.

Table 4. T.A.D. severity distribution.

T.A.D. Severity	1973 Number	1973 Percent	1974 Number	1974 Percent
1	8537	27.4	7339	29.9
2	7595	24.3	6137	25.0
3	5802	18.6	4423	18.0
4	4391	14.1	3317	13.5
5	2203	7.1	1579	6.4
6	1660	5.3	1117	4.6
7	1004	3.2	626	2.6
Total Reported T.A.D.'s	31192		24538	
Total Vehicles	79021		62305	
Percent Unreported T.A.D.'s	60.5%		60.6%	
Mean T.A.D.	2.779		2.657	

*Source: HSRC Accident Files

2.657; whereas, for 1973 it is 2.779. The Chi-square test statistic for the equality of the two TAD distributions is not significant at any reasonable confidence level; however, due to the fact that higher TAD severity ratings are associated with larger probabilities of injury (2), the small relative decrease in higher TAD severities (4,5,6,7) could explain the observed decrease in injuries.

Gasoline Consumption and Estimated Vehicle Mileage

Figure 4 is a plot of estimated vehicle mileage in North Carolina from January, 1962 through September, 1974. This estimate is obtained by multiplying total taxable wholesale gasoline sales by approximately 12.6 miles per gallon. Since the motorist may not purchase and use a quantity of gasoline in the same month that its wholesale sale is recorded some adjustment of the data is necessary. Nevertheless, over a four month period, these errors should diminish. Table 5 shows that, during the shortage, motor vehicle mileage dropped approximately 3.2 percent below that for the same period in 1973. This is a relatively modest decrease, and Figure 4 shows that the drop occurred mainly in January and February. At present, detailed data sufficient to allocate the drop in vehicle mileage to various road, driver, and vehicle types is not available; however, some data is expected to be available soon. Data on traffic volume is available, but it has not been processed as yet.

Accident and Injury Rates

The monthly fatality rate for January, 1971 through September, 1974, shown in Figure 5, gives an indication of the trend in the fatality rate

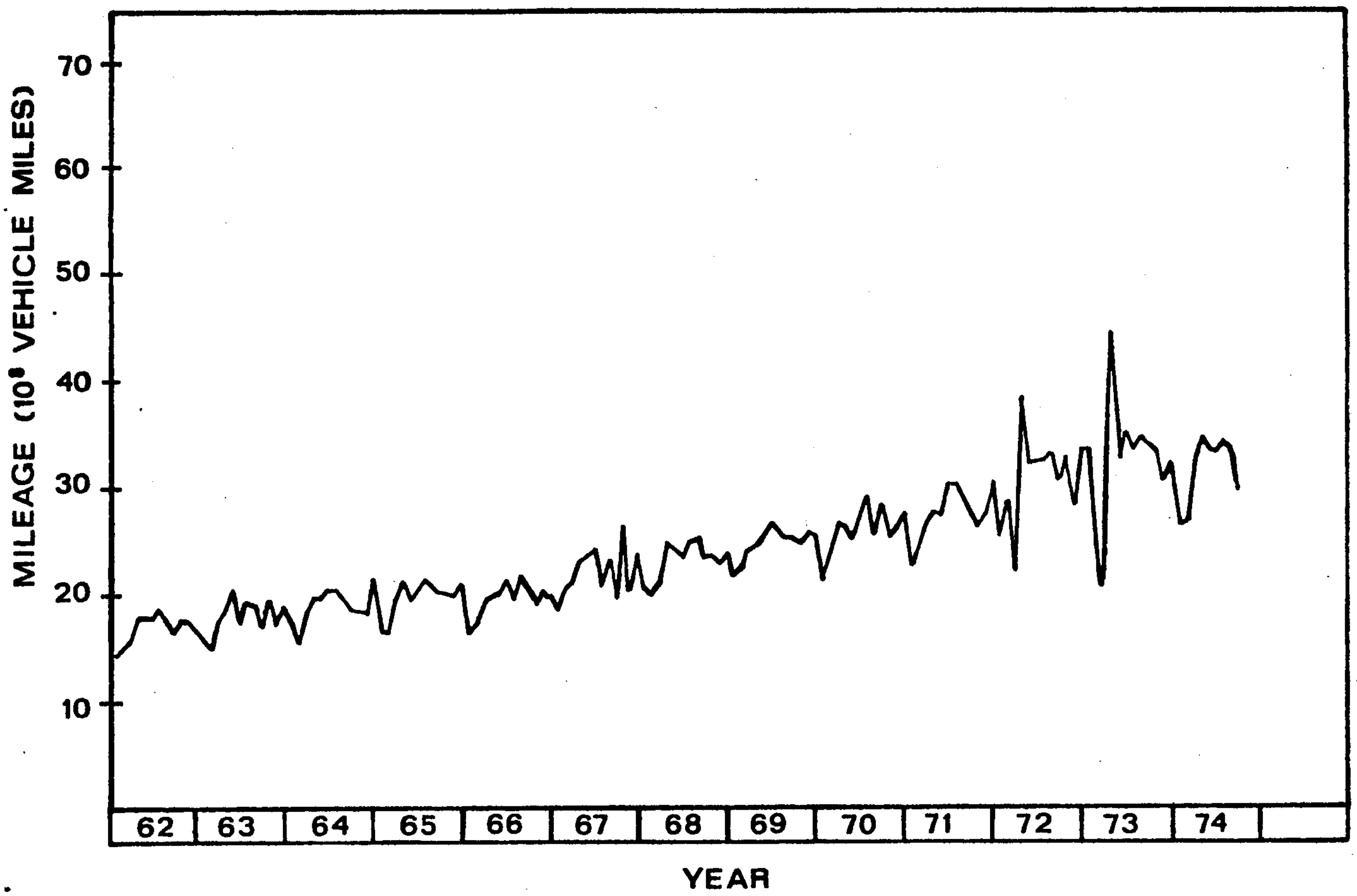


Figure 4. Estimated vehicle miles per month in North Carolina.

Table 5. Summary of accidents and injuries*--
first four months, 1973, 1974

	1973	1974	Percent Change
Accidents			
Fatal	481	380	-21.0
Injury	14214	12515	-12.0
Total	38431	34785	-9.5
Persons Injured			
K	560	446	-20.4
K + A	4616	3621	-21.6
K + A + B	12932	11107	-14.11
Estimated Vehicle Mileage (Hundred Million Vehicle Miles)	123.47	119.54	-3.2
Rate Per Hundred Million Vehicle Miles			
Accidents	311.26	290.99	-6.5
Fatalities	4.54	3.73	-17.74
Injuries K + A	37.39	30.29	-19.0
Injuries K + A + B	104.74	92.91	-11.3
Injury Rate Per Hundred Accidents			
K	1.457	1.282	-12.0
K + A	12.01	10.41	-13.3
K + A + B	33.65	31.93	-5.1

*Source: N.C. Department of Motor Vehicles, Monthly Traffic Accident Summary

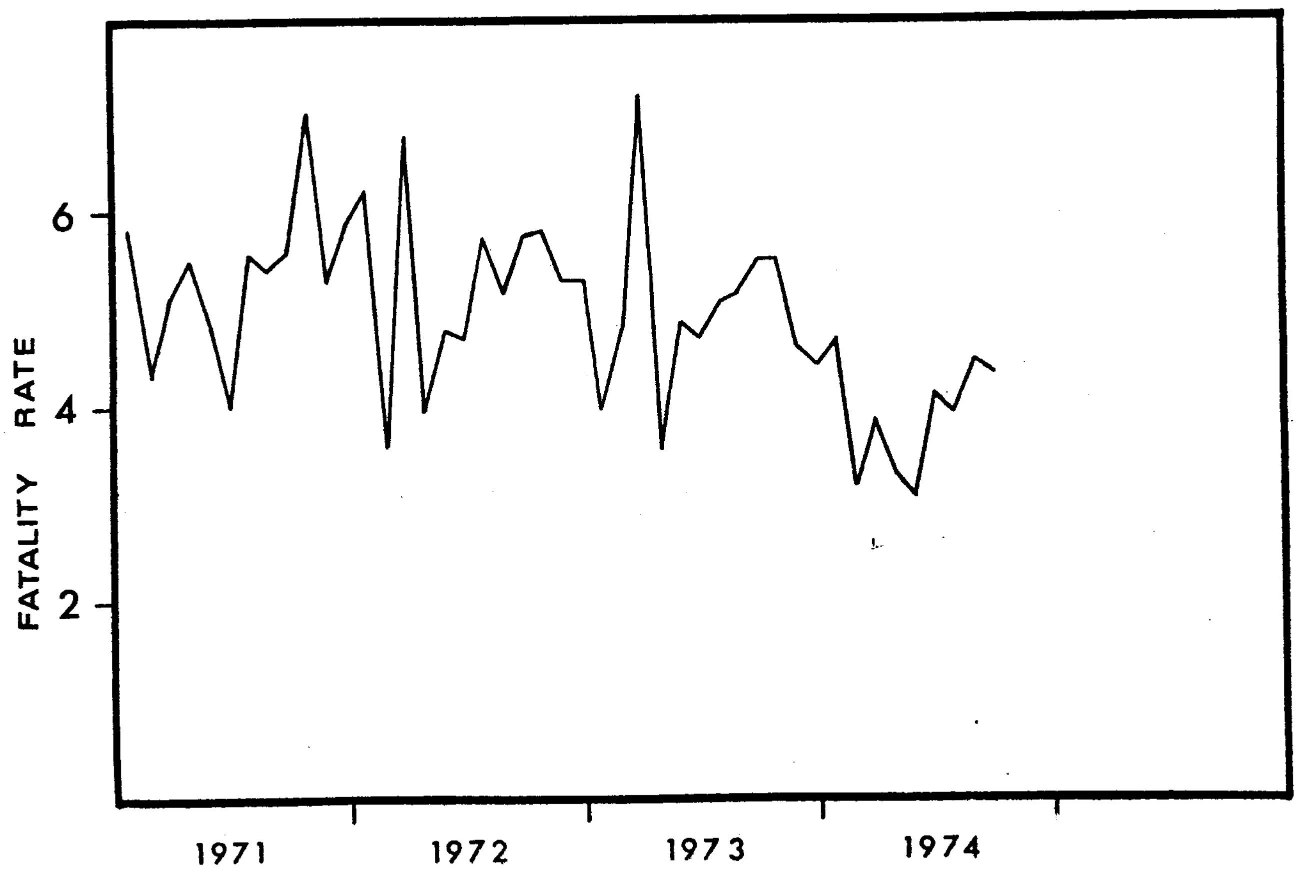


Figure 5. Monthly fatality rate.
(fatalities per hundred million vehicle miles)

over the recent past. Although there is considerable variation, due to the variation in estimated vehicle mileage and natural variation in fatalities, there is a clear drop in the fatality rate after October, 1973. Table 5 gives various accident and injury rate statistics. The fatality and serious injury rates show the most noticeable drops of 17.7 and 19.0 percent, respectively. This is consistent with the observations that fatalities, serious injuries, and fatal accidents have fallen off more than less serious accidents.

A measure of the average severity of accidents is the injury rate per hundred accidents for various severities of injury (see Table 5). Again, it can be noted that accidents became less severe with the serious injury rates (K and K+A) per hundred accidents falling off relatively more than the overall injury rate (K+A+B).

III. PRELIMINARY ANALYSIS OF OBSERVATIONS

It has been observed that not only have the actual numbers of accidents, injuries, and fatalities fallen, but also their overall rates per vehicle mile or per accident have dropped. Thus, fewer crashes occurred, and those crashes which did occur were less severe. The energy crisis precipitated a number of changes in the driving environment, some aspects of which are:

a. The 55 mph speed limit

b. Vehicle miles driven

c. Vehicle size distribution

d. Vehicle occupancy

e. Time of day and day of week in which driving is done

f. Type of road used

A complete analysis of these changes would involve an estimate of their individual effects, as well as their interactions. The following is a preliminary analysis of some of their individual effects.

The 55 mph Speed Limit

Speed is known to be associated not only with accident severity, but also with the frequency of occurrence of accidents. It is thus reasonable to expect that the 55 mph speed limit was instrumental both in the reduction of the number of accidents and in the decrease in severity of those accidents which did occur. Therefore, the number of fatalities resulting is a function both of accident frequency and severity.

Table 6 is a cross-tabulation of crash-involved vehicles by posted speed limit at the crash site and by estimated speed prior to impact. The entries are also separated by fatal and non fatal vehicles, where a fatal vehicle is defined to be one in which one or more fatalities occurred. The estimated speed prior to impact is the estimate provided by the investigating officer, and it is recognized that considerable variance could be involved. The change in the number of fatal vehicles produced by the 55 mph speed limit can be estimated by making some assumptions about how the change in posted speed limit affects the speed at which motorists drive. Table 7 and Figure 6 illustrate the relationship between speed and likelihood of a fatality. Three assumptions will be considered:

a) Straight 70 percent compliance with 55 mph limit: If all vehicles involved in crashes at estimated speeds greater than 55 mph were involved in crashes from 51 to 55 mph, then the fatalities would have been 133, rather than the 412

Table 6. Nonfatal and fatal crash-involved vehicles by posted speed limit and estimated speed prior to impact.*

Estimated Speed Prior to Impact	Posted Speed Limit < 55	55	60	65	70	Total	Fatal Frequency
< 50	126298** 183***	50281 365	11422 96	1422 3	351 4	189774 651	.00342
51-55	865 10	6577 101	2166 26	338 1	93 1	10178 139	.0137
56-60	865 19	2486 45	2564 49	628 8	284 6	6827 127	.0183
61-65	262 8	1404 32	274 1	545 15	190 2	2675 58	.0212
66-70	257 16	1155 47	202 9	90 2	207 7	1911 81	.0407
71-75	126 10	588 45	132 8	40 1	21 3	907 67	.0688
76-80	106 3	457 47	105 16	18 4	15 2	701 72	.0931
81-85	20 3	114 12	21 4	4 2	5 0	164 21	.1135
86-90	41 4	166 35	36 5	10 2	7 1	260 47	.1531
90+	55 7	132 44	30 11	7 4	3 0	227 66	.2253

*Source: HSRC Accident Files
**Top entry is non-fatal vehicles.
***Bottom entry is fatal vehicles.

Table 7. Fatal vehicles at various crash speeds* 1973

Crash Speed	Total Vehicles	Fatal Vehicles	Fraction Fatal x10^3	S.D. x10^3
1-5	26863	24	.89	.18
6-10	22866	44	1.92	.29
11-15	15461	31	2.00	.36
16-20	18766	20	1.06	.24
21-25	15394	17	1.10	.27
26-30	17629	16	.91	.23
31-35	21258	53	2.49	.34
36-40	13323	65	4.88	.60
41-45	14984	99	6.61	.66
46-50	13723	143	10.42	.87
51-55	10178	139	13.66	1.15
56-60	6954	127	18.26	1.61
61-65	2733	58	21.22	2.76
66-70	1992	81	40.66	4.43
71-75	974	67	68.79	8.11
76-80	773	72	93.14	10.45
81-85	185	21	113.51	23.32
86-90	307	47	153.09	20.55
90+	292	66	226.03	24.48
Total		1190		

*Source: HSRC Accident Files

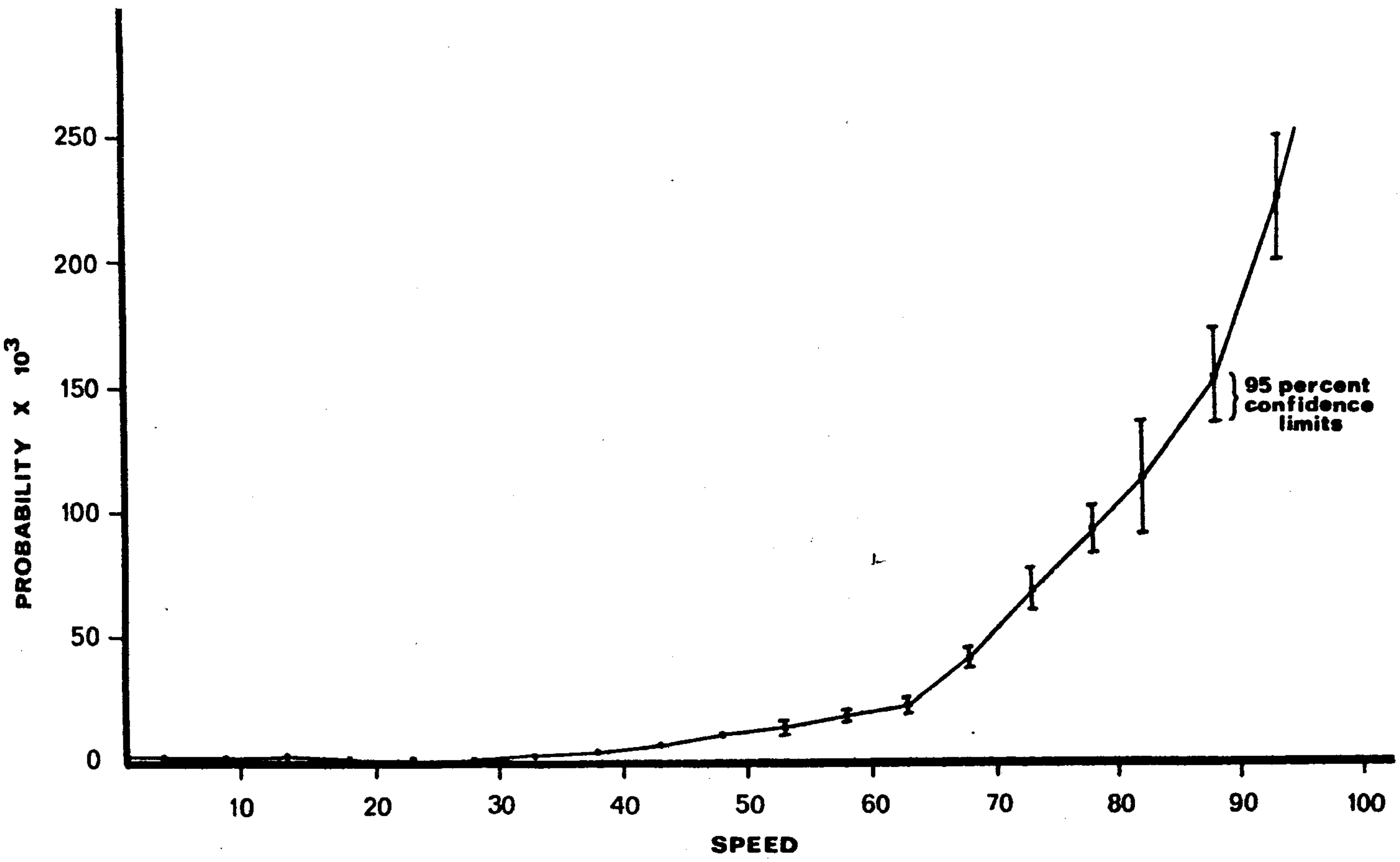


Figure 6. Estimated probability of fatality as a function of speed.

experienced for crashes at speeds over 55 mph. This would have resulted in a net savings, therefore, of 279 fatal vehicles, and assuming a 70 percent compliance figure, the saving would have been 195, which is a 16.4 percent reduction from the 1190 total fatal vehicles.

b) All crash speeds above 60 mph reduced by 10 mph: Table 8 gives the expected number of crash-involved vehicles and the expected number of fatal vehicles under the assumption that all vehicles involved in crashes above 60 mph would have their crash speeds reduced by 10 mph. This assumption leads to an estimate of 200 fatal vehicles, which is a reduction of 212 over the 412 observed in 1973 for crashes at speeds over 55 mph. This reduction amounts to 17.8 percent.

c) Motorists travelling over the old speed limit maintain their same speed relative to the 55 mph limit: The assumption is that those vehicles travelling under the old speed limit when the old speed limit was over 55 mph would travel at 51 to 55 mph and those vehicles which were going over the old speed limit would maintain their same speed relative to the new speed limit, with the speed category 90+ being considered 91-95. Table 9 gives the new crash speeds as a function of old crash speeds and posted speed limit, and the computation of expected fatalities under this assumption is given in Table 10. The expected number of fatal vehicles is 106, out of an observed 162. This is a reduction of 56, or 4.7 percent.

From Highway Patrol reports of a noticeable decrease in traffic speeds during early 1974 and the large observed reduction in crash

Table 8. Computation of fatal vehicles under assumption b.

Speed Range	Number of Vehicles	Probability of Fatal Vehicle*	Expected Fatal Vehicles
61-65	2733	.01366	38
66-70	1992	.01826	37
71-75	974	.02122	21
76-80	773	.04066	32
81-85	185	.06879	13
86-90	307	.09314	29
90+	292	.11351	34
Total	7256		200

*This is the probability that the vehicle has a fatality, assuming the crash speed is reduced by 10 mph.

Table 9. Crash speeds under assumption C as a function of previous crash speed and posted speed limit.

Estimated Speed Prior to Impact 1973 Data	1973 Speed Limit 55	60	65	70
56-60	56-60	51-55	51-55	51-55
61-65	61-65	56-60	51-55	51-55
66-70	66-70	61-65	56-60	51-55
71-75	71-75	66-70	61-65	56-60
76-80	76-80	71-75	66-70	61-65
81-85	81-85	76-80	71-75	66-70
86-90	86-90	81-85	76-80	71-75
90+	90+	86-90	81-85	76-80

Table 10. Computation of expected number of fatal vehicles under assumption C.

New Speed	Vehicles Involved	Fatal Frequency	Expected Fatals	Actual Fatals
51-55	4505	.01366	61.54	87
56-60	391	.01826	7.14	6
61-65	269	.02122	5.71	12
66-70	167	.04066	6.79	12
71-75	135	.06879	9.29	19
76-80	40	.09314	3.73	6
81-85	52	.11351	5.90	9
86-90	41	.15309	6.28	11
Total			106.37	162

speeds, assumption (c) seems to be too conservative; whereas, assumptions (a) and (b) may be overly optimistic. It thus seems, on the basis of this preliminary analysis, that the savings due to the speed effect of the 55 mph limit would be at least 5 percent, and it is likely that it is on the order of 10 percent.

Vehicle Mileage

It was noted earlier that estimated motor vehicle mileage was reduced by 3.2 percent. This is a very rough estimate, but although it seems low, it appears to be fairly realistic, since motor vehicle mileage has experienced a steady increase in the past. In fact, based on a linear extrapolation of 1970 through 1973 data, the decrease amounts to 10 percent from the predicted mileage. The estimated decrease in vehicle miles is 393 million, and at the fatality rate of 4.5355 per hundred million vehicle miles, this represents 18 fewer fatalities, or 3.2 percent of the observed 560 for January through April, 1973, as it must be. The decreased exposure could account for a larger percentage of the reduction of fatalities. The above analysis assumes that the decrease in exposure is across the board - in all categories of drivers, vehicles, roads, and trip purposes; whereas, it will be shown later that there is reason to believe that more dangerous social trips were curtailed more than other, less dangerous driving. The 3.2 percent decrease in fatalities due to exposure should be considered a lower bound to the effect of exposure reduction.

Vehicle Sizes and Types

During the fuel shortage, the demand for smaller cars increased substantially, due to their relatively low fuel consumption. The major dealers reported increased sales. Because of this, one would expect involvement in crashes to increase for compacts and subcompacts. Table 11 gives the number and distribution of crash-involved vehicles by the HSRC classifications of vehicle size. It can be noted that there was a very slight decrease in the involvement of medium and large-sized cars (classes 1, 2, and 3), and an increase in the involvement of smaller cars (classes 4, 5, and 6). These observations are consistent with increased small car sales, since normally only 10 percent of vehicles driven are new cars (i.e. less than one year old), and the number of new cars sold in three or four months is but a fraction of this ten percent. There may be a bias in that persons conscientious enough to purchase a car to save gas may also be unusually careful drivers, and they may reduce their driving a disproportionate amount. There may also be an unobserved effect from the practice of using the smaller car by families which own two cars - a large one and a small one.

Table 12 gives the vehicle type distribution for crashes for the first four months of 1973 and 1974. It can be observed that there is a relative decrease in passenger car involvement, and an increase in truck involvement. This is perhaps a reflection of the reduction in passenger car mileage.

Both Table 11 and Table 12 have excluded from them vehicles for which the vehicle identification number (VIN) was not given or could not be decoded by HSRC programs to classify the vehicle. These vehicles are largely imported cars and domestic trucks, and hence caution should be exercised in interpreting Tables 11 and 12.

Table 11. Vehicle size distribution.*

Vehicle	Class	1973 Number	1973 Percent	1974 Number	1974 Percent
Luxury	1	2711	4.9	1805	4.6
Medium	2	4867	8.8	3219	8.2
Standard	3	12987	23.5	8261	21.0
Intermediate	4	11760	21.3	8451	21.5
Compact	5	7531	13.6	5334	13.6
Subcompact	6	1857	3.4	1652	4.2
Specialty	8	79	.1	48	.1
Imported	9	4376	7.9	3342	8.5
Multi-Purpose	10	1408	2.5	1420	3.6
Truck or Semi	11	705	1.3	690	1.8
Truck - Size Unknown	12	7008	12.7	5041	12.9
Total		55289	100.0	39263	100.0

*Source: HSRC Accident Files

Table 12. Vehicle type distribution*

Vehicle Type	1973		1974	
	Number	Percent	Number	Percent
Passenger Car	4168	83.5	32112	81.8
Van	439	0.8	373	1.0
Utility Vehicle	126	0.2	144	0.4
Mobile Home	3	0.0	3	0.0
Pickup Truck	951	1.7	995	2.5
Straight Truck	167	0.3	194	0.5
Tractor - Trailer	427	0.8	401	1.0
Truck - Unclassified	7008	12.7	5041	12.8
Total	55289	100.0	39263	100.0

*Source: HSRC Accident Files

Vehicle Occupancy

It has been hypothesized that since driving on evenings and weekends decreased, and this type of driving has a higher occupancy, that the mean number of occupants per crash-involved vehicle should decrease. The distribution of the number of occupants per crash-involved vehicle is given in Figure 7 and Table 13. Vehicles with no occupants have been eliminated from the totals. These represent parked cars, pedestrians and bicyclists. It can be seen that the mean occupancy has been reduced slightly from 1.587 to 1.573. This data includes only vehicles involved in accidents, and hence is biased by the occupancy characteristics of those vehicles which are more likely to be involved in accidents. An analysis of driver fatalities compared to occupant fatalities has not been done but it is contemplated for further research.

Time of Day and Day of Week Distribution

Since it is probable that social driving was decreased more than business driving, and social and pleasure driving is done mostly at night and during weekends, one would expect a larger decrease in the number of accidents at night and during the weekends.

Figures 8 and 9 give the number of accidents and their frequency distribution broken down into the four time periods indicated. These periods correspond mainly to (1) weekday night driving, from 7:00 P.M. to 6:00 A.M. Monday through Thursday, (2) driving to and from work, from 6:00 A.M. to 8:00 A.M. and from 4:30 P.M. to 7:00 P.M. Monday through Friday, (3) daytime weekday driving, from 8:00 A.M. to 4:30 P.M. Monday through Friday, and (4) weekend driving, from 7:00 P.M. Friday to 6:00 A.M. Monday. It can be observed that accidents decreased during all time periods, with weekend accidents decreasing relatively more. This

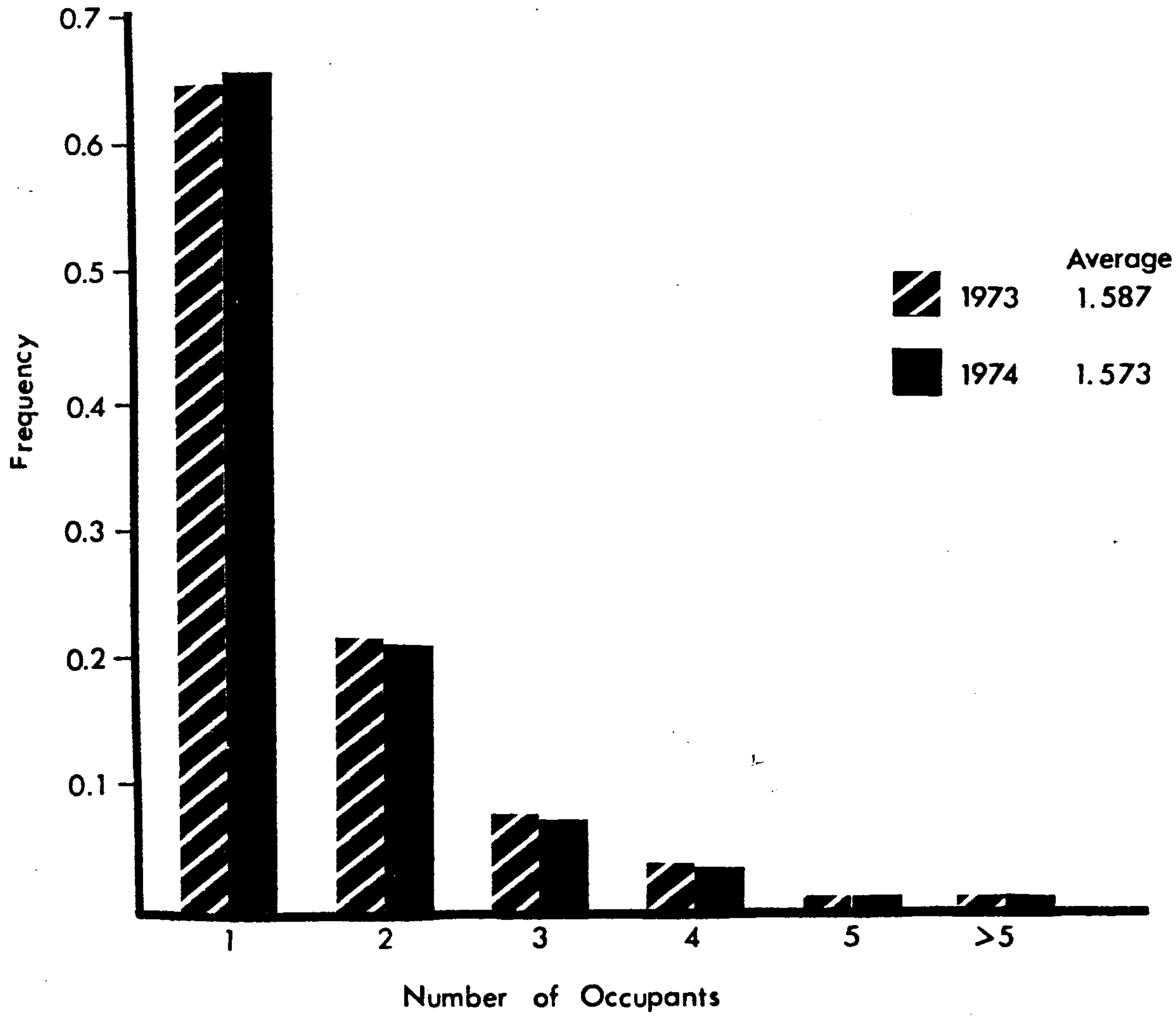


Figure 7. Occupancy distribution for crash-involved vehicles.

Table 13. Occupants per vehicle.*

	1973		1974	
	N	F	N	F
1	44790	.649	37232	.658
2	14852	.215	11997	.212
3	5115	.074	4094	.072
4	2478	.036	1918	.034
5	931	.013	700	.012
6	444	.006	322	.006
7	109	.002	74	.001
8	37	.000	21	.000
8	211	.003	211	.004
Total Vehicles	68967		56569	18.0% decrease
Total Occup.	109451		88983	18.7% decrease
Mean Occup.	1.587		1.573	

*Source: HSRC Accident Files

can perhaps be considered a consequence of service station closings and a decreased willingness for motorists to use scarce gas on unnecessary weekend trips. Figures 10 through 13 are similar to Figures 8 and 9, except that the data represents serious and fatal accidents. In these cases, a reduction in the proportion occurring on nights and weekends was relatively greater than the reduction for weekday accidents. These observations are consistent with expectations.

The day of week distribution for accidents is given in Figures 14 and 15. It can be seen that the number of accidents was reduced for every day of the week with Sunday receiving a disproportionately greater reduction. This is probably due to the "gasless Sundays" and the appeal for a ban on Sunday driving.

Road Type

Due to the difficulty of getting gas, it has been conjectured that, during the fuel shortage, motorists tended to keep trips short, staying in town and as close to home as possible. Table 14 appears to support this conjecture. In 1974, a smaller percentage of vehicles were involved in accidents on Interstate, U.S., N.C., and rural paved roads, with a corresponding increase occurring on city streets, private property, and rural unpaved roads. This shift could account for some of the decrease in fatalities and injuries, since accidents on the Interstate, U.S., N.C., and rural paved roads tend to be more severe than accidents on the other roads.

IV. FURTHER RESEARCH

The previous section of this report presented a preliminary analysis of some of the data that has been gathered. The primary focus was on

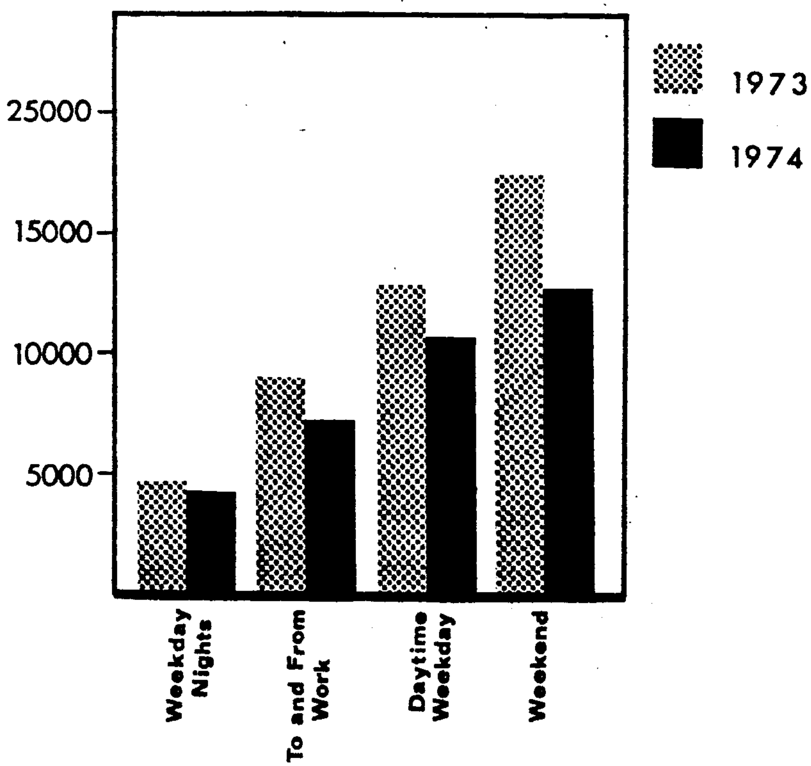


Figure 8. Number of accidents by time of day/week.

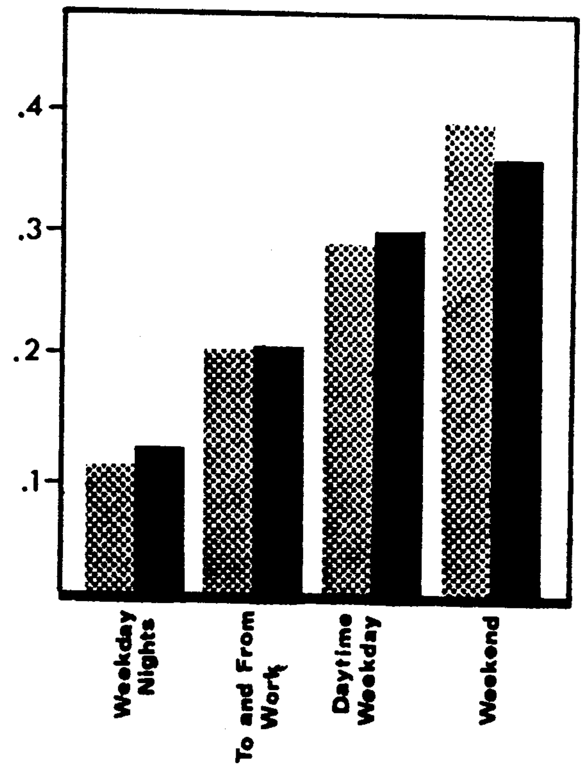


Figure 9. Distribution of accidents by time of day/week.

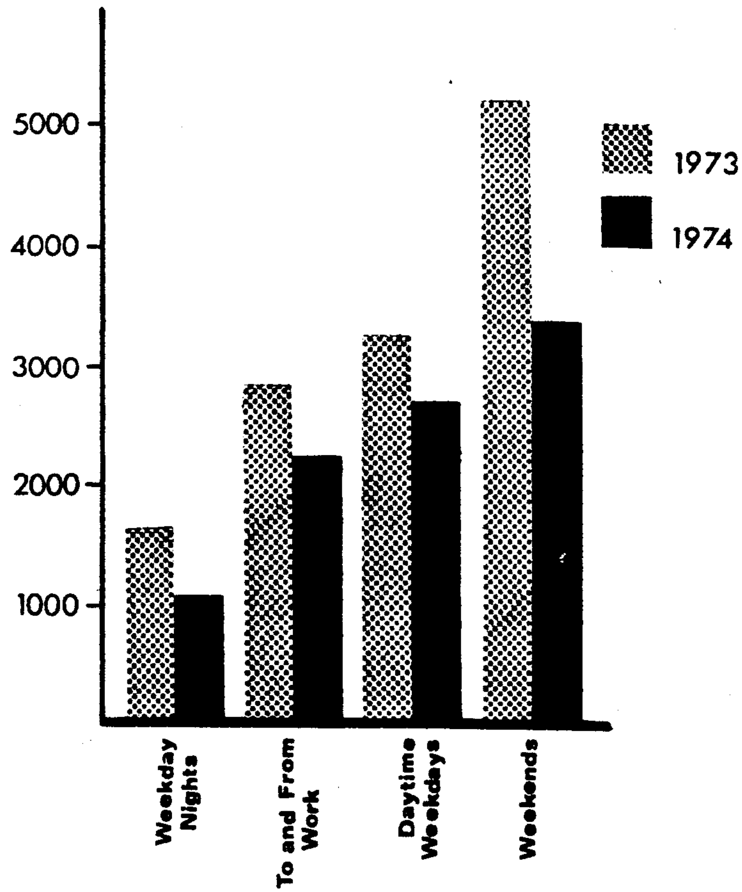


Figure 10. Number of serious accidents by time of day/week.

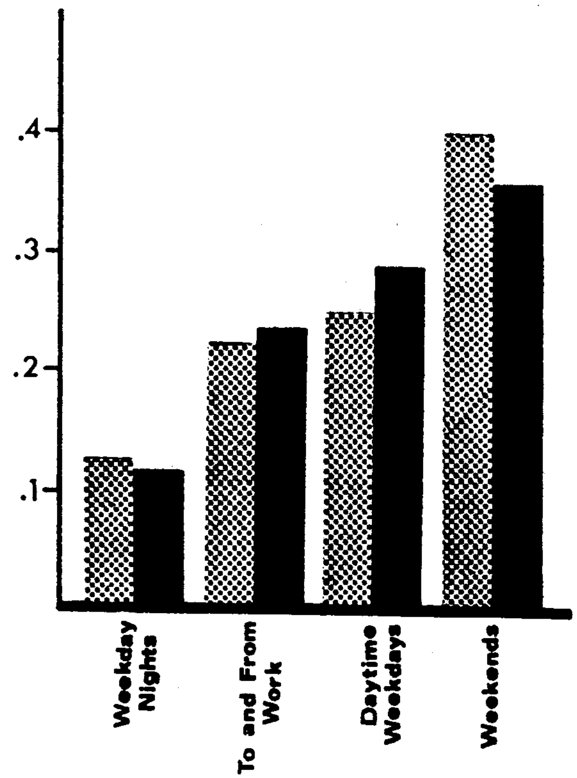


Figure 11. Distribution of serious accidents by time of day/week.

Figure 12. Number of fatal accidents by time of day/week.

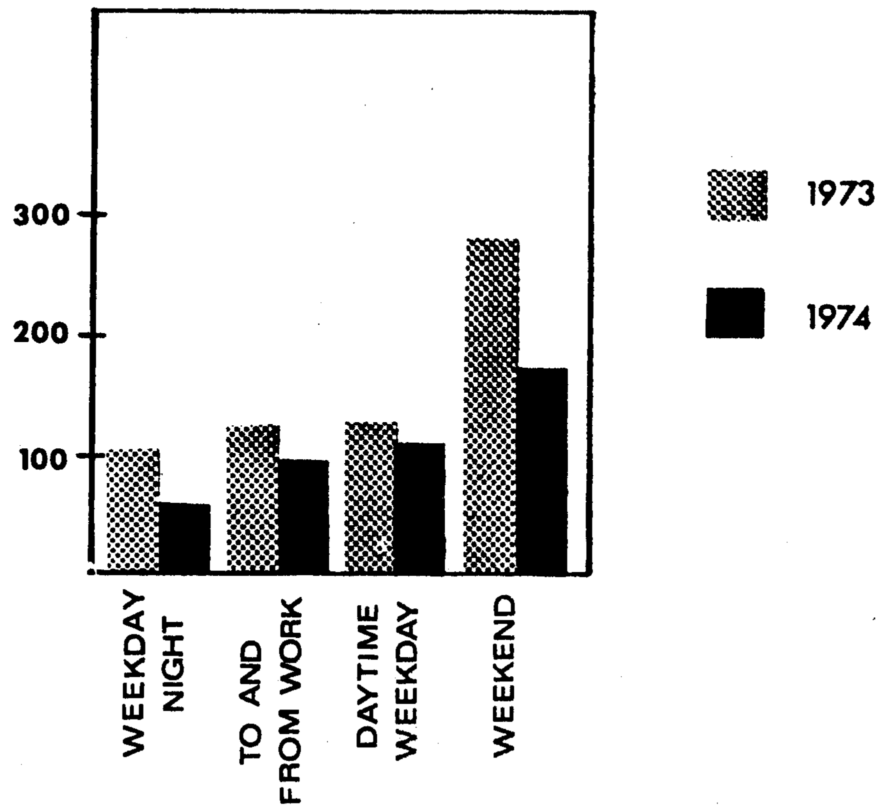
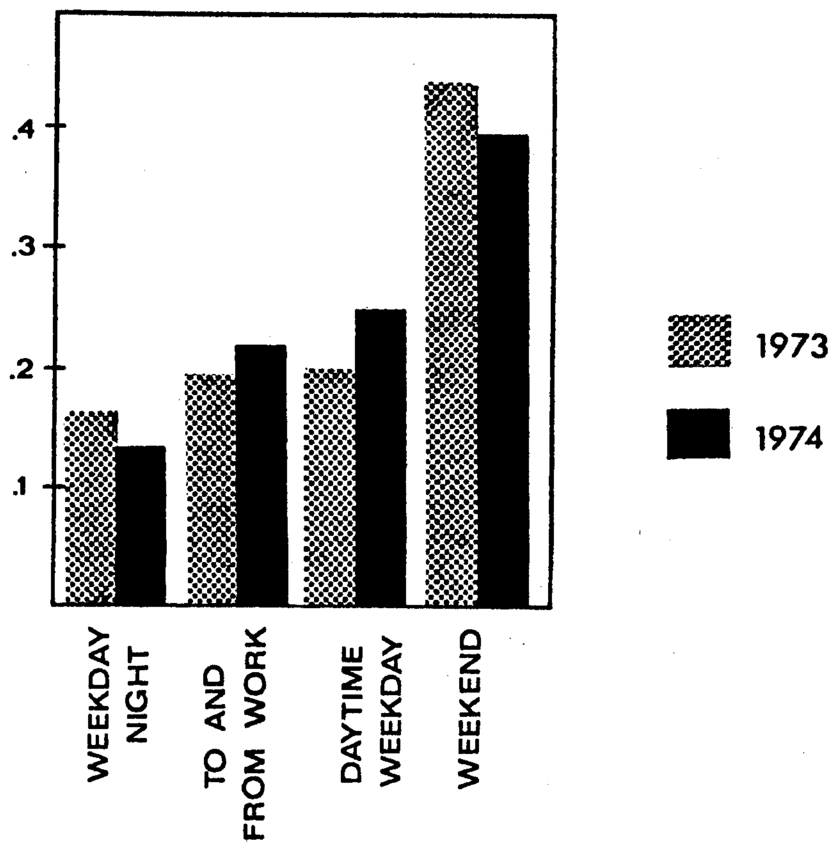


Figure 13. Distribution of fatal accidents by time of day/week.



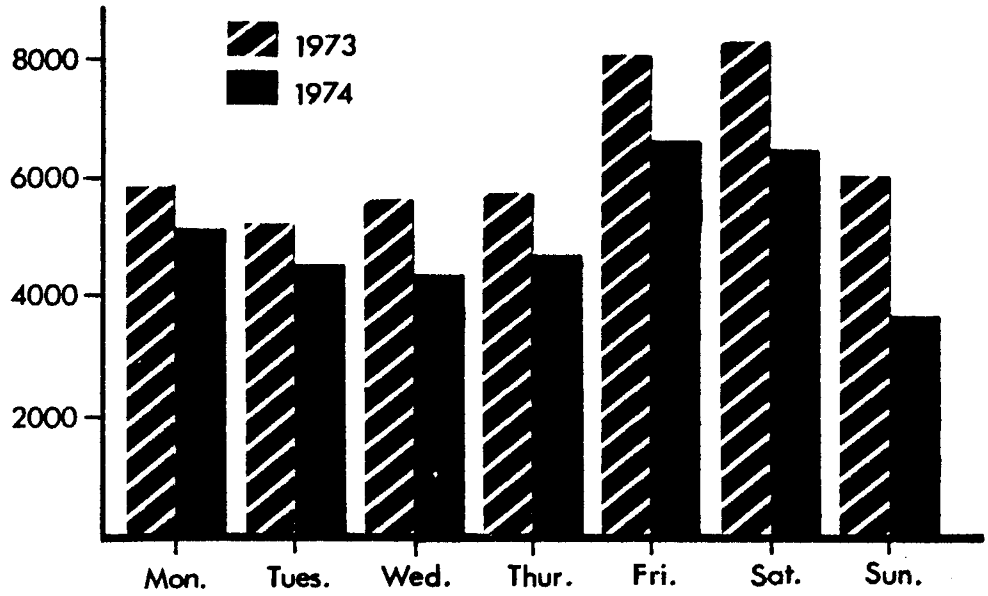


Figure 14. Number of accidents by day of week.

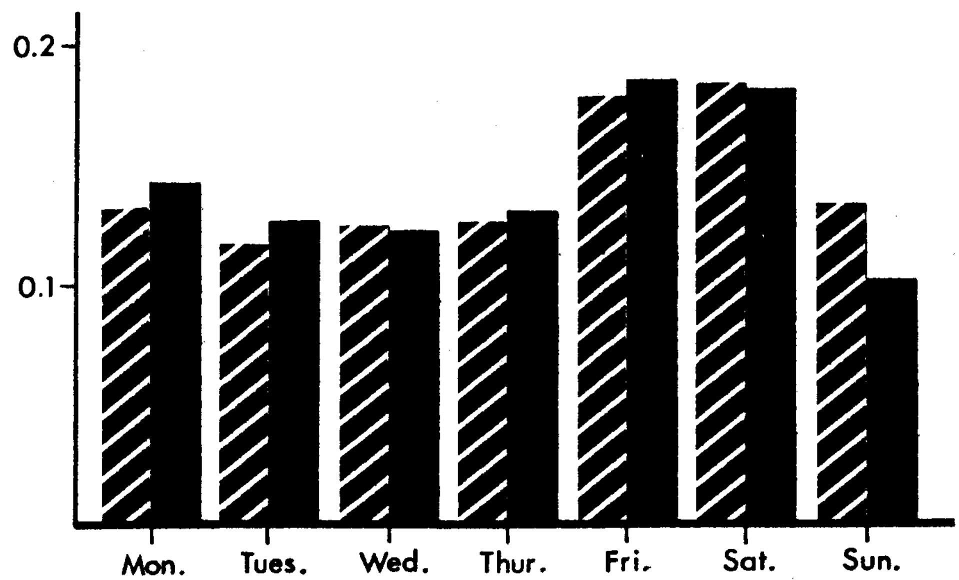


Figure 15. Distribution of accidents by day of week.

Table 14. Road types.*

	1973		1974	
	N	F	N	F
I	1989	.025	996	.016
US	13586	.173	9325	.150
NC	8625	.110	6261	.101
RPR	13659	.174	10481	.169
RUR	902	.011	866	.014
CS	36685	.468	31128	.501
PP	2954	.038	3105	.050
NS	621		143	
Total	79021		62305	
Total, less N.S.	78400		62162	

*Source: HSRC Accident Files

accident and fatality data, with injury data getting relatively little attention. In the analysis, the effects of the 55 mph limit, exposure, vehicle size, etc. were considered individually, but in actuality they worked concurrently. Thus, a more thorough analysis would seek to determine not only marginal effects but also interaction effects. Further research will be directed to this end. The following specific areas of research will be pursued:

Exposure

Presently, the only information that has been used for exposure analysis is gasoline sales data. In its raw form this data is somewhat unsatisfactory because of the uncertain lag between the wholesale sale of gasoline and its use in motor vehicles, and because this data does not furnish a detailed picture of the exposure distribution among a class of drivers, vehicles, road, etc. Thus, some effort will be devoted to adjusting wholesale gasoline sales figures to more closely estimate actual mileage per month. In addition, the North Carolina State Highway Commission has available data from origin and destination surveys conducted in several areas of North Carolina. Appendix B gives the detailed information available from these surveys. Also available is data on traffic volumes by hour for 60 permanent counting sites in North Carolina. This will provide information on traffic volume at various times of the day for various types of roads. Effort will be devoted to investigating the usability of this data to establish changes in exposure for various driver, vehicle, time, and other classes, and the subsequent use of the data in the analysis of accidents, injuries, and fatalities during the fuel shortage. From Appendix B, it can be observed that data is not available from the same city for succeeding years. For this reason, it is not clear whether differences between the 1973 data and the 1974 data are due to differences between the cities surveyed or changes in driving patterns. By examining the consistency of the data between cities, hopefully the usability of the survey data to establish changes in exposure from 1973 to 1974 will be established.

Interactions

The effects of the fuel shortage that were discussed in the previous sections are obviously not separate and independent. For example, the 55 mph speed limit not only decreases the probability of accidents and causes accidents to be less severe, but it also acts as a discouragement to driving, resulting in decreased exposure. Moreover, the shortage of fuel perhaps encouraged a higher compliance with the 55 mph limit than would have been expected otherwise. Thus, if, for example, it is desired to predict the effect on accidents and fatalities of keeping the 55 mph limit when the other factors (reduced exposure, shortage of fuel, etc.) are not present, one must analyze the interaction effects between the 55 mph limit and the other factors. This analysis is planned, and at present a regression approach is contemplated.

Analysis of Accident and Injury Data

In the previous section of this report, it was observed that accidents and injuries have appeared to decrease more than would have been expected from earlier data. Further research will be devoted to putting these observations into quantitative form by modelling the accident and injury data. Specifically, a Box-Tiao intervention model (3) will be investigated. Some effort has already been devoted to this study.

Use of TAD for Severity Analysis

Vilardo (2) showed that the TAD severity is highly correlated with injury level. For the present purposes, injury refers to any injury (K, A, B, or C). Table 15 relates TAD severity to the expected probability of driver injury in an accident. By using the relationship

$$Pr(I) = \sum_{t=1}^{7} Pr(I|T=t)\ Pr(T=t),$$

where $Pr(I)$ is the probability of injury;

$Pr(I|T=t)$ is the probability of injury, given the TAD severity is t; and

$Pr(T=t)$ is the probability the TAD severity is t,

the severity of one set of accident conditions (before the fuel shortage) can be related to that of another set of conditions (during the shortage). Table 16 gives the values of $Pr(T=t)$ for $t = 1, 2, \ldots, 7$, and Table 15 gives the values of $Pr(I|T=t)$ for the various TAD values. Thus, computing $Pr(I)$ for the first four months of 1973 and the same period in 1974, we get:

	1973	1974
Pr(I)	0.1479	0.1359

which shows that accidents during the fuel shortage tended to be less severe.

From Table 15, it can be observed that the probability of injury increases quite rapidly for TAD severities greater than 4. Figure 16 gives the percent of reported TAD severity ratings that are greater than or equal to 6 for Interstate, and U.S., N.C., and rural paved roads by month. US., N.C., and rural paved roads were grouped together because when plotted separately, their plots were quite similar. The data for

Table 15. Fraction injured by T.A.D. severity rating*

T.A.D. Severity	Fraction Injured
1	.03 x 30
2	.06 x 40
3	.10 x 90
4	.20 x 90
5	.35 x 80
6	.46 x 20
7	.71 x 60

*Source: Villardo (2)

Table 16. T.A.D. severity distribution for first four months of 1973, 1974*

t	Pr(T=t) 1973	1974
1	0.2734	0.3002
2	0.2430	0.2494
3	0.1848	0.1807
4	0.1418	0.1349
5	0.0709	0.0636
6	0.0532	0.0458
7	0.0329	0.0254
Pr(I)	0.1479	0.1359

*Source: HSRC accident files

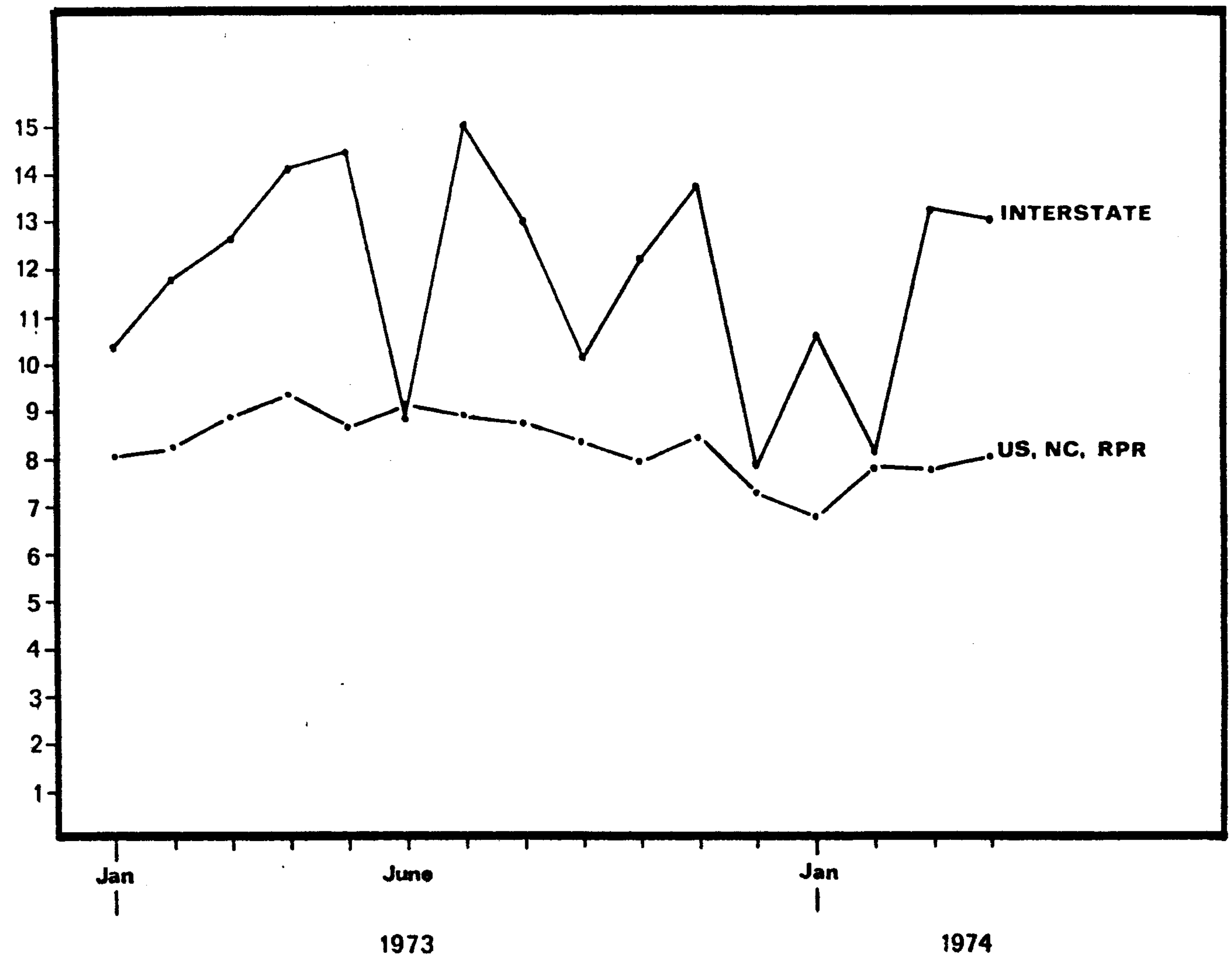


Figure 16. Percent of T.A.D. severity ratings greater than 5 by month by class of road.

Interstate roads shows considerably more variation than the other data because the sample size is much smaller. Although there is a lot of variation, there appears to be a noticeable decrease for December, 1973 through February, 1974 on both categories of roads.

Further work needs to be done to evaluate the analysis already done (with respect to the efficiency of the estimator) and to extend the analysis to other categories of injury, i.e., fatal and serious injury. This work is anticipated in the coming months to determine the usefulness of the TAD severity ratings as an alternative measure of accident severity.

Pedestrian and Bicycle Accidents, and Daylight Savings Time

Other studies (4) have indicated a probable relationship between Daylight Savings Time and pedestrian and bicycle accidents. An analysis of this conjecture is contemplated for North Carolina data. The research will seek to determine if the implementation of Daylight Savings Time has resulted in a change in the rate of pedestrian and/or bicycle accidents. Attention will center on the two times of the day affected by DST.

Other Areas

Further attention will be given to occupant injuries and changes in occupancy, types of accidents occurring, urban vs. rural comparisons, and traffic flow patterns. A study by the National Safety Council (5) has stated that occupant injuries declined more than driver injuries, and the study used this as evidence that the average occupancy decreased during the energy crisis. In the HSRC accident files, occupants are listed by seated position. Thus, a detailed analysis of any change in occupancy and occupant injuries by position can be accomplished.

It is possible that the fuel shortage has caused a shift in the types of accidents in which motorists are involved. An analysis of accident data will be done to determine any shifts that have occurred and assess the effects of such a shift.

It has been observed that urban, as well as rural, accidents have decreased; however, urban roads are less likely to be affected by the lowering of the speed limit or a change in the nature of trips. Some attention will be given to explaining this phenomenon and its implications for future policy decisions.

Solomon (6) has examined the relationship between speed variance and the probability of a crash, and found that the probability of a crash increases quite rapidly when vehicle speeds deviate from the mean speed. It has been suggested in other reports (4, 5) that one result of the 55 mph speed limit is that the variance of vehicle speeds has been reduced, causing a lower likelihood of accidents. By examining traffic speed studies conducted by the N.C. State Highway Commission, the changes in speed variance can be established and their effect on highway safety can be determined. It has been conjectured that the ending of the fuel shortage is causing a division in the vehicles on high-speed highways - some drivers maintain the 55 mph limit while others are returning to old driving habits. If this is true, the variance of speeds would be increased considerably and hence the probability of a crash would be greatly increased. This idea will be investigated as far as possible with the available data.

It is likely that the above efforts will uncover additional unanswered questions that will be addressed as a part of this project.

The primary objective of further research will be to establish viable predictions of the effects on highway safety of the 55 mph speed limit, shifted exposure, and other changes brought about by the fuel shortage.

V. SUMMARY AND CONCLUSIONS

This interim report has presented a preliminary analysis of changes in the highway environment brought about by the fuel shortage which began in November 1973 and lasted through part of March 1974. It has been shown that accidents and injuries decreased substantially (9.5 percent and 14.1 percent, respectively), and that serious accidents decreased relatively more than less serious ones (21.0 percent for fatal accidents vs. 12 percent for injury accidents). Additional evidence of decreasing accident severity during the fuel shortage was obtained from a downward shift in TAD severity ratings. The overall decrease in vehicle miles driven in the first four months of 1974 vs. the same period in 1973 was estimated to be 3.2 percent, a decrease in exposure which could not explain the observed decrease in accidents and injuries. The fatality and serious injury rates (per hundred million vehicle miles) dropped by 17.7 and 19 percent, respectively, which indicates that factors other than gross exposure were responsible for the decrease.

A rough analysis showed that the 55 mph speed limit is probably responsible for 5 percent of the fatality reduction, and it is possible that 10 or 15 percent of the 21 percent fatality reduction can be explained by the 55 mph limit. Gross vehicle mileage could explain a 3.2 percent reduction; however, it is likely that shifts in exposure were away from more dangerous exposure categories and toward less dangerous categories, as shown by the time of day and day of week breakdown. Thus, exposure shifts could explain more than 3.2 percent of the fatality reduction.

Small shifts in vehicle size and type, vehicle occupancy, and time of day/day of week distributions for accidents were shown, and these shifts were all in the directions expected. Similarly, there was a shift in the distribution of the type of roads on which accidents occurred. These shifts undoubtedly affected the number of accidents and injuries that were experienced; however, an estimate of the size of these effects has not been made.

Further research is planned for improved exposure estimates, analysis of the effects of the 55 mph speed limit, modelling the accident, injury, and exposure data, methodology for the use of the TAD severity ratings as a measure of accident severity, and other areas as stated in Section IV. It is expected that this research will not only enhance the understanding of the reduction in accidents and injuries during the fuel shortage, but will also provide methodology to predict the effect of keeping the 55 mph limit and methodology to assess the effect of future events on highway accidents and injuries.

One can conclude from this preliminary analysis that the fuel shortage did indeed have an effect on highway safety. Not only did fewer people drive their cars, but they drove slower and at different times, to different places, and under different circumstances than previously. All of these changes combined to make the highways in North Carolina safer, and this result suggests the possibility that perhaps some of the changes brought about by the fuel shortage had such a profound effect on highway safety that they merit retention on a permanent basis. It should be remembered that the fuel shortage was presented as a crisis, and hence the people complied with conservation measures (e.g. the 55 mph speed limit) to a greater extent than would be expected under more normal circumstances. With a better understanding of these effects, the potential value of these safety measures will be more evident and the appropriate decisions to improve the safety of the highways will be indicated.

APPENDIX A

Monthly Accident and Injury Data

The following is statewide accident, injury, and gross exposure data by month. This data was obtained from the North Carolina Monthly Traffic Accident Summaries, published by the N.C. Department of Motor Vehicles.

STATEWIDE ACCIDENT DATA

		Accidents			Injuries		
Year	Month	Total	Fatal	Injury	K	All	Est. MMVM*
1962	1	5685	66	1737	77	2777	1408
	2	4102	61	1462	65	2387	1490
	3	5207	97	1928	118	3140	1572
	4	4746	78	1764	97	2931	1802
	5	4788	79	1792	93	2957	1798
	6	5498	91	2109	112	3493	1799
	7	5098	88	1877	100	3239	1880
	8	5295	107	1925	131	3261	1764
	9	5810	113	2111	131	3510	1623
	10	5695	114	2089	141	3514	1720
	11	6030	97	2036	117	3384	1755
	12	7382	107	2504	125	4134	1635
1963	1	6017	77	2024	90	3273	1587
	2	4832	70	1560	78	2518	1502
	3	4991	76	1783	86	2893	1733
	4	5314	87	2005	106	3364	1858
	5	5580	89	2055	104	3578	2023
	6	5538	104	2091	119	3630	1701
	7	5766	102	2147	113	3654	1942
	8	6217	108	2388	123	4030	1882
	9	6730	110	2468	135	4245	1705
	10	6223	102	2329	122	3922	1957
	11	7266	117	2571	140	4266	1722
	12	8329	117	2738	143	4659	1859

Year	Month	Accidents: Total	Accidents: Fatal	Accidents: Injury	Injuries: K	Injuries: All	Est. MMVM
1964	1	6125	92	1985	106	3279	1723
	2	6109	100	2170	128	3545	1555
	3	6209	96	2305	115	2860	1816
	4	5980	107	2210	124	3606	1980
	5	6413	101	2414	109	4121	1966
	6	5989	89	2179	112	3719	2034
	7	6885	110	2638	137	4653	2033
	8	7440	154	2806	189	4858	1942
	9	6657	105	2556	116	4254	1870
	10	8585	122	3053	134	5044	1847
	11	7116	119	2753	136	4665	1833
	12	8555	119	3039	144	5086	2158
1965	1	7270	88	2376	107	3950	1632
	2	6100	80	2115	108	3617	1634
	3	6443	88	2384	103	4026	1919
	4	6529	84	2423	92	3911	2106
	5	6598	116	2572	133	4291	1966
	6	6901	87	2535	108	4359	2042
	7	7390	119	2747	153	4611	2148
	8	7314	105	2602	118	4353	2072
	9	7060	121	2539	159	4224	2032
	10	8744	153	3076	191	5033	2024
	11	7734	129	2700	153	4459	1986
	12	8751	157	3026	173	4836	2100
1966	1	8091	101	2399	119	3692	1611
	2	6850	91	2135	105	3383	1743
	3	6443	116	2284	137	3757	1920
	4	7215	118	2644	133	4359	1977
	5	8153	119	2972	135	4812	1997
	6	7305	99	2591	112	4166	2140
	7	8173	140	2904	163	4844	1971
	8	8490	110	2918	141	4762	2185
	9	8245	120	2810	139	4452	2053
	10	9284	132	3194	157	5252	1910
	11	8760	120	2990	135	4794	2022
	12	10283	163	3325	204	5539	1982
1967	1	7953	105	2544	122	4114	1883
	2	7210	78	2322	91	3736	2012
	3	7245	104	2549	118	4052	2090
	4	7559	111	2731	127	4440	2307
	5	8158	118	2870	143	4662	2328
	6	8182	107	2875	128	4672	2422
	7	8551	130	2996	154	4901	2182
	8	9246	133	3190	160	5224	2314
	9	9092	125	3232	160	5188	1977
	10	9010	151	3108	172	5028	2645
	11	9172	153	2999	173	4897	2059
	12	10225	125	3268	147	5243	2397

Year	Month	Accidents: Total	Accidents: Fatal	Accidents: Injury	Injuries: K	Injuries: All	Est. MMVM
1968	1	9048	90	2411	109	3837	2050
	2	6933	98	2215	116	3525	1997
	3	7878	133	2698	163	4404	2121
	4	8299	121	2772	146	4530	2492
	5	9116	134	3153	165	5127	2414
	6	8554	127	2813	147	4562	2340
	7	9014	137	2924	160	4777	2504
	8	9383	136	3103	159	5126	2517
	9	8769	146	2984	171	4838	2359
	10	10603	139	3390	158	5428	2374
	11	10754	139	3388	157	5452	2303
	12	11018	145	3294	169	5363	2375
1969	1	8888	97	2753	110	4301	2184
	2	8635	94	2445	117	3884	2262
	3	9192	96	2850	116	4613	2414
	4	9235	114	2944	129	4782	2473
	5	9888	136	3177	167	5131	2545
	6	9687	112	3073	131	4943	2678
	7	9584	123	3096	146	5023	2604
	8	11051	156	3529	187	5809	2525
	9	10595	141	3325	171	5437	2532
	10	10742	147	3375	161	5395	2490
	11	11260	136	3400	159	5584	2586
	12	11722	138	3430	157	5482	2557
1970	1	10775	106	2931	135	4510	2125
	2	8190	82	2444	97	3878	2378
	3	9421	103	2825	120	4467	2664
	4	9342	95	2911	103	4657	2633
	5	10567	139	3417	163	5613	2554
	6	9517	119	2996	135	4744	2738
	7	10167	112	3226	126	5272	2903
	8	10901	152	3403	172	5576	2526
	9	9792	138	3046	159	4871	2858
	10	12149	137	3987	166	5911	2568
	11	10859	146	3188	168	5098	2622
	12	13100	154	3679	180	5777	2783
1971	1	9689	116	2788	130	4364	2228
	2	9653	97	2547	107	4143	2484
	3	10325	121	2950	137	4626	2669
	4	10353	120	3178	154	5095	2788
	5	11623	108	3631	135	5922	2744
	6	10179	106	3090	123	4851	3015
	7	11542	142	3552	171	5796	3018
	8	11092	138	3431	158	5458	2928
	9	10873	134	3383	156	5464	2788
	10	13381	158	4004	187	6402	2657
	11	11736	138	3387	149	5333	2776
	12	12524	155	3614	180	5723	3067

Year	Month	Accidents Total	Accidents Fatal	Accidents Injury	Injuries K	Injuries All	Est. MMVM
1972	1	9331	144	2919	157	4581	2526
	2	9555	96	2846	104	4412	2883
	3	9976	130	3237	150	5153	2214
	4	9704	128	3309	151	5248	3829
	5	11354	134	3927	154	6255	3219
	6	10155	135	3543	154	5565	3244
	7	10564	161	3666	187	5908	3266
	8	9891	145	3421	172	5469	3328
	9	10982	158	3785	179	6094	3097
	10	11736	165	3895	192	6195	3306
	11	11184	130	3612	152	5622	2858
	12	13429	156	4305	178	6870	3360
1973	1	9911	117	3280	133	5100	3362
	2	8379	98	2982	119	4748	2456
	3	10560	136	4083	150	6410	2082
	4	9581	130	3869	158	6300	4447
	5	10692	131	4104	159	6481	3263
	6	11078	134	4183	165	6671	3505
	7	10586	143	4017	170	6641	3374
	8	11259	149	4246	179	6749	3453
	9	10675	147	4065	188	6458	3394
	10	11536	170	4252	186	6786	3358
	11	10882	119	3837	140	6103	3046
	12	10684	121	3515	143	5512	3232
1974	1	8872	109	3082	125	4713	2651
	2	8073	72	2751	86	4193	2692
	3	8778	102	3289	122	5056	3171
	4	8952	97	3393	113	5357	3440
	5	10067	96	3801	103	6031	3365
	6	10105	116	3901	137	6050	3310
	7	9910	121	3830	134	6109	3402
	8	11504	123	4278	150	6821	3377
	9	10823	112	3936	130	6267	2989

*Million Motor Vehicle Miles

APPENDIX B

Exposure Information

The North Carolina State Highway Commission has collected exposure data in conjunction with their origin and destination surveys. These surveys were all conducted in the month of July in Marion in 1971, Goldsboro in 1972, Hickory, Dunn, Tarboro, Roanoke Rapids, and Elizabeth City in 1973, and Monroe and Mt. Airy in 1974. The following data is available for analysis:

Hour	00	Midnight to 1 AM
	01-23	1 AM - 12 Midnight
Date		Day of month
Vehicle Type	1.	Local - in state passenger cars
	2.	Foreign - out of state passenger cars
	3.	Panel or pickup
	4.	Two axle single tired
	5.	Two axle dual tired
	6.	Three axle single unit
	7.	Tractor-trailer combination
	8.	Taxi
	9.	Bus
Occupancy		Number of occupants (1-9)
Trip Purpose	0.	Home
Origin Purpose	1.	Work
Destination Purpose	2.	Business
	3.	Doctor
	4.	School
	5.	Social-Recreation
	6.	Change mode of travel
	7.	Eat
	8.	Shopping
	9.	Lodging

Driver Race and Sex	1. White Male 2. White Female 3. Non-white Male 3. Non-white Female
Age of Driver	Actual age if estimated to be less than 26; otherwise, estimated age
Right Front Seat Passenger Race and Sex	Same codes as Drive Race and Sex
Age	Same method as Driver Age
Vehicle Information License Plate Number Title Number Year of Car Make of Car VIN HSRC Make-Model Code	

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