Contractual Research
GDOT Research Project No. 8904
Final Report

SAFETY EFFECTS OF THE 65 MPH SPEED LIMIT AND THE MANDATORY SEAT BELT LAW

by

Paul H. Wright
Project Director

Wayne Sarasua
Graduate Research Assistant

in cooperation with
U.S. Department of Transportation
Federal Highway Administration
and
Governor's Office of Highway Safety
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16. Abstract
This study consisted of several tasks to measure the safety effects of the 65 mph speed limit, effective in Georgia in February 1988, and the mandatory seat belt law, effective September 1988. Before and after periods were used in the analysis of fatalities, fatal accidents, and injuries for different highway classifications. The researchers found no significant effect of the 65 mph speed limit on the occurrence of fatal accidents and fatalities on the Rural Interstate system in the six month period after the law. Time series analyses revealed significant increases in fatalities beginning about nine months after the effective date of the speed limit increase. There was also a significant increase in reported injuries on the Rural Interstates after the speed limit increase.

Statistical analyses using odds ratios compared accident experience in a six month period before the seat belt law to the experience in a six month period after the law. The results failed to show any significant decrease in the number of fatalities or fatal accidents. However, time series analyses of reported injuries showed that the seat belt law had a beneficial effect.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

Executive Summary

SAFETY EFFECTS OF THE 65 MPH SPEED LIMIT AND THE MANDATORY SEAT BELT LAW

In 1988, the General Assembly of Georgia enacted two laws relating to the use of motor vehicles: (1) a law which increased the speed limit to 65 mph on any federal interstate highway which is outside of an urbanized area of 50,000 population or more, and (2) a mandatory seat belt law applicable to front seat occupants of passenger vehicles. The speed limit law became effective February 19, 1988, and the seat belt law became effective September 1, 1988.

On June 5, 1989, researchers at Georgia Institute of Technology began an 18-month project to measure the safety effects of the 65 mph speed limit and the mandatory seat belt law. Accident and travel data for the project were provided by the Georgia Department of Transportation. This research was sponsored by the Governor's Office of Highway Safety and the Georgia Department of Transportation in cooperation with the Federal Highway Administration.

Literature Review

The first task for the project involved an extensive review of other studies relating to the safety effects of the 65 mph speed limit and mandatory seat belt laws.

These studies showed that the 65 mph speed limit has resulted in relatively small increases in observed speeds. For example, Upchurch (25) reported that speeds observed on Arizona's Rural Interstate system increased about 3 miles per hour. However, researchers agree that the speed limit increase has had a detrimental effect on safety. The National Highway Traffic Safety Administration reported (24) that 38 states had instituted the 65 mph speed limit by the end of 1987. Twenty-seven of the 38 states had experienced an increase in fatalities in 1987 compared to the same period in 1986. Collectively, the 38 states that raised their speed limit had a 19 percent average increase in Rural Interstate fatalities. Researchers from the Insurance Institute for Highway Safety used data from 1988 and compared it to data for 1982-1986 and reported a 29 percent increase in Rural Interstate crash deaths for the 38 states that had adopted the higher speed limit (26). Others (27) have reported that property damage only (PDO) and injury accidents have significantly increased in the areas that were rezoned for 65 mph.

Mandatory seat belt laws have resulted in greater seat belt use, the highest compliance rates being in those states with the toughest laws (17). Surveys taken in states with seat belt laws have indicated that belt use remains under 50 percent, but in North Carolina, a state with a vigorous enforcement of a strong law,

usage increased to nearly 64 percent (8). Increased seat belt use has been shown to significantly reduce fatalities (10), as well as the number and severity of injuries (6,14) in traffic accidents.

Analysis Methodology

The analyses performed for this project comprised 12 tasks.

Four of the tasks (Nos. 3,5,7,13) were designed to measure the safety effects of the 65 mph speed limit. These tasks compared the numbers of fatal accidents, fatalities, and injuries during a six month period after the establishment of the 65 mph speed limit to the numbers reported for a six month period before the speed limit change. See Figure 2-1, page 17. For these tasks the study periods were

Before Period: March 1, 1987 - August 31, 1987
After Period: March 1, 1988 - August 31, 1988

Three tasks (Nos. 2, 8, and 9) were designed to measure the effects of the mandatory seat belt law. These tasks compared accident experience in a six month period before the effective date of the seat belt law to the experience in a six month period after the law. The study periods for these tasks were

Before Period: March 1, 1988 - August 31, 1988
After Period: March 1, 1989 - August 31, 1989

Two tasks (Nos. 4 and 6) were designed to measure the combined effects of the 65 mph speed limit and the mandatory seat belt laws. Those studies compared the accident experience during a twelve month period before the effective date of either the speed limit or seat belt law to a similar period after the effective dates of both laws. The study periods for these tasks were

Before Period: Calendar Year 1987
After Period: Calendar Year 1989

The final group of tasks (Tasks 10,11,12) consisted of time series analyses designed to more clearly define patterns of change in accident data and speed data and identify the effects of time-related causes of change (termed interventions).

Safety Effects of the 65 mph Speed Limit

In an earlier project (20), Georgia Tech researchers found that mean speeds on Georgia's Rural Interstate highways increased approximately 4 mph following the establishment of the 65 mph speed limit. Similar increases were reported for the 85th percentile speeds. Mean speeds on Urban Interstate highways (which did not have a speed limit change) increased approximately 0.5 mph following the establishment of the 65 mph for non-Interstate highways.

Time series analyses performed as Task 12 generally confirmed the earlier speed change findings. However, the time series analyses revealed, for the Rural Interstate system, a sustained increase in the average and 85th percentile speeds of about 2.5 mph. For the Urban Interstate highways, little change in average speeds was noted, but there was an increase of about 1.5 mph for the 85th percentile speeds.

It was expected that the increase in speeds on Rural Interstate highways would result in greater losses from highway crashes. The results of Tasks 3,5, and 7 generally confirmed this expectation.

By means of a classical statistical methodology using odds ratios, the researchers found no significant effect of the 65 mph speed limit on the occurrence of fatal accidents and fatalities on the Rural Interstate in the six month period after the law. However, there was a 10 percent increase in fatalities from 1987 to 1988 on this system, while most of the other functional classes experienced a decrease in fatalities.

Time series analyses revealed significant increases in fatalities on the mainline Rural Interstate system following the institution of the 65 mph speed limit. The analyses for this system showed significant changes in the trend of fatalities beginning in December, 1988, approximately nine months after the effective date of the speed limit increase. See Figure 5-1, page 73.

To examine further whether the speed limit change increased the severity of Rural Interstate crashes, the researchers compared the number of injuries reported for this system during the before and after periods. Reported injuries included the number of fatalities, visible injuries, and complaint of injuries as recorded by the investigating officers. The researchers discovered that there was an extremely significant increase in injuries on the Rural Interstate system following the institution of the 65 mph limit.

The researchers also compared the accident rates, in accidents per vehicle mile, before and after the 65 mph speed limit, and all but one experienced significant change. These changes were both positive and negative. The greatest changes were noted for the Interstates and other high speed highways.

The researchers performed a special study to determine if differences in weather conditions could explain observed differences in fatal accidents before and after the 65 mph speed limit change. No evidence was found to indicate that weather differences could explain the increases in fatal accidents.

Safety Effects of the Mandatory Seat Belt Law

Although Georgia has what most traffic safety professionals would regard a weak mandatory seat belt law, studies performed by University of Georgia researchers (35) found that safety belt use in Georgia increased after passage of the law. They reported that safety belt use throughout the state increased from 28 percent in July, 1988 to 40 percent in October and November, 1989. By May, 1990, overall seat belt usage had climbed to 46 percent. Special studies by those researchers indicated that seat belt usage by drivers and front seat passengers on the Rural Interstate system increased from 34 percent in July and August, 1988 to 44 percent October and November, 1989. By the beginning of 1990, seat belt usage on the Rural Interstate highways had leveled off at 50 percent.

Georgia Tech researchers used odds ratios to compare accident experience in a six month period before the seat belt law to the experience in a six month period after the law. The results failed to show a significant decrease in the number of fatalities and fatal accidents between the before and after periods ($\alpha = 0.05$) as expected. In fact, Rural Interstate and Urban Interstate tests showed significant increases in the number of fatalities and fatal accidents ($\alpha = 0.10$). In addition, the fatality and fatal accident occurrences increased in 11 of 14 functional classes tested. Similar results were obtained in comparisons of fatality and fatal accident rates.

In the comparison of reported injuries before and after the seat belt law, significant decreases in injuries were reported for the Rural Interstate, the Rural Minor Arterial and the Urban Collector systems. Though not statistically significant, a decrease was also noted for the Urban Other Freeway system. On the other hand, significant increases in the number of injuries were noted for the Urban Interstate system. This increase in injuries may be explained by a noticeable increase in the 85th percentile speeds on Urban Interstate highways.

Comparisons were made of accident experiences in calendar year 1987 with the experience in 1989, giving a measure of the combined effects of the 65 mph speed limit and seat belt laws. The mainline Rural Interstate system showed an increase of 44 percent in fatal accidents between 1987 and 1989, while all other roadways showed a decrease of about 4 percent. Over the same period, fatalities on the mainline Rural Interstate highways increased approximately 60 percent, while fatalities on all other highways decreased about 1 percent. These findings were statistically significant ($P < 0.05$). This same pattern was apparent for fatal accident and fatality rates. In addition, the number of reported injuries for Rural Interstate System increased 28.9 percent between 1987 and 1989, while the reported injuries on all other highways increased only 7.5 percent.

To further examine the effects of the mandatory seat belt law, the researchers performed time series analyses for fatal accidents, fatalities, and injuries on all non-Interstate highways. Since none of those systems experienced a speed limit increase, these tests provided an uncluttered examination of the effects of the seat belt law. For fatalities and fatal accidents, the time series analyses failed to reveal any decrease after the implementation of the seat belt law. However, the time series analysis of reported injuries showed that the seat belt law did have a beneficial effect. This is illustrated by Figure 6-2, page 94, which shows that the actual or modeled values after the seat belt law are lower than those forecast by the pre-seat belt experience.

Summary of Findings

It is helpful to interpret the findings of this project in terms of three groups of highways:

1. The Rural Interstate system (plus any other Interstate highway outside an urbanized area of 50,000 population or more), the only system rezoned for 65 mph.

2. The Urban Interstate highways which were not rezoned for 65 mph but which experienced a slight spillover effect from the speed limit change.

3. The non-Interstate highways, which should have been affected only by the mandatory seat belt law.

The Rural Interstate system did not experience a significant increase in fatalities or fatal accidents during the 6-month period immediately following institution of the 65 mph speed limit. There was, however, a significant increase in reported injuries on the Rural Interstate highways during that period. Fatal accidents and fatalities increased on those highways during 1989, the effects of the increased speeds evidently outweighing any beneficial effects of increased usage of seat belts. During 1989, some benefit from the mandatory seat belt law was evidenced by significant decreases in reported injuries for the Rural Interstate system.

The Urban Interstate system experienced a significant increase in reported injuries in the 6-month period following implementation of the 65 mph speed limit. This increase is best explained by an observed increase of about 1.5 mph in the 85th percentile speed, an apparent spillover effect of the speed limit change on the Rural Interstate system. A trend analysis revealed that fatalities on the mainline Urban Interstate system increased following the implementation of the seat belt law. This finding suggests that whatever benefits gained from increased seat belt usage on Urban Interstate highways were outweighed by the harmful effects of higher speeds.

Nevertheless, evidence was found that the seat belt law has had a beneficial effect. Time series analysis of injuries on non-Interstate highways revealed that the actual values after the seat belt law were lower than those forecast by the pre-seat belt law experience.

Chapter 1

BACKGROUND

This report describes the results of the research work carried out on Project No. 8904, Task Orders 19, 20, and 21, for the period June 5, 1989, through December 31, 1990. In addition to the reporting requirements, this work involved thirteen tasks which are described in Chapter 2.

This report contains an executive summary, seven chapters, a list of references, and an appendix.

Chapter 1 gives the background of the research and contains an extensive literature review of other studies relating to the safety effects of mandatory seat belt laws and the 65 mph speed limit.

Chapter 2 lists the objectives of the research and outlines the general methodology employed. It describes the 13 tasks which form the framework for this research effort.

Chapter 3 gives the results of the analyses of the safety effects of the 65 mph speed limit in Georgia.

Chapter 4 describes the results of the analyses relating to the effects of the mandatory seat belt law.

Chapter 5 describes the results of time series analyses that were conducted using accident and injury data for the years 1983 through 1989.

Chapter 6 summarizes the findings for the entire project.

Chapter 7 lists the conclusions or inferences drawn from the factual evidence contained in the report.

The Georgia Legislation

In 1988, the General Assembly of Georgia enacted two laws relating to the use of motor vehicles. The first Act, "Motor Vehicles and Traffic -- Speed Limits on Interstate Highways," simply increased the speed limit to 65 mph on any federal interstate highway which is outside of an urbanized area of 50,000 population or more. That law was passed in response to The Surface Transportation and Uniform Relocation Assistance Act enacted by Congress on April 2, 1987, which permitted that change. It became effective February 19, 1988.

The second Act was entitled "Motor Vehicles and Traffic -- Seat Safety Belts." Compared with mandatory seat belt legislation enacted in other states, the Georgia law is weak. The law can be enforced only on those persons who are charged with violation of certain other sections of the Motor Vehicle Code. Persons convicted of violating the law may be fined not more than $15.00. Furthermore, the law prohibits the court from forwarding a record of the disposition of the case to the Department of Public Safety. The seat belt law became effective on September 1, 1988.

Previous Research by Georgia Tech Researchers

Researchers from Georgia Institute of Technology undertook a study in September, 1987, for the Georgia Department of Transportation to evaluate the effects of the 65 mph speed limit on speeds and safety. That study had very limited resources and modest objectives. It revealed:

1. During the six-month period following the establishment of the 65 mph speed limit, the number of fatalities on the Rural Interstate system increased 44 percent over the number reported for the six-month "before" period. This increase was statistically significant ($\alpha = 0.05$).

2. The number of fatal accidents that occurred on Rural Interstate highways during the 6-month period following establishment of the 65 mph speed limit was 21 percent higher than the number that occurred during the 6-month period prior to the speed limit change. This effect was not statistically significant.

The study, however, left unanswered some questions regarding possible confounding effects of seasonal variations and changes in traffic volumes. It also was constrained because of the mandatory seat belt law which became effective approximately six months after the 65 mph speed limit law. The need for further study of the effects of these laws was therefore indicated.

A follow-on research project, the subject of this report, was undertaken on June 5, 1989, to more precisely define the safety effects of the 65 mph speed limit and measure the safety effects of the mandatory seat belt law.

Literature Survey

Using the computerized literature search programs available through the Georgia Tech Library, the researchers conducted a search of the literature to document the findings of other researchers on the safety effects of mandatory seat belt laws. In addition, the researchers updated the literature survey of the effects of the 65 mph speed limit reported in the December 1988 report (Task Order 12 under BOA DTD 84). The results of this work are described in the following paragraphs.

Safety Effects of Mandatory Seat Belt Laws

According to the National Highway Traffic Safety Administration (NHTSA), restraints have saved over 7,500 lives since 1983 (1). Of these, the agency estimates 6,700 were saved by safety belts and 800 by child restraints. NHTSA estimates that belt use laws have achieved an additional 7 percent savings in traffic deaths in those states with the law, in comparison to those without it.

Surveys done by the Insurance Institute for Highway Safety (IIHS) and other researchers in states with belt laws indicate that belt use remains under 50 percent. In a recent study performed by North Carolina Highway Safety Research Center, the belt usage rate were found to be 48 percent in states with belt laws.

IIHS researchers also examined the relationship between enforcement and belt use, using state police records of tickets written. They found the highest rates of compliance in states with "primary" enforcement law, meaning that the police officer could stop and ticket the driver whenever a motorist is seen without a belt, as contrasted to states where the motorist could only receive citation if stopped for some other violation. It was noted that the key to improvement is improved enforcement and vigorous public information campaign coupled with official support (1).

Prior to the mandatory belt use laws, use rates of under 10 percent were commonly observed. Also, some researchers have found that media campaigns had no effect on the use rates.

Unfortunately the drivers at high crash risk - the very ones who need belts the most - are least likely to buckle up. A series of IIHS studies have identified several such groups: teenagers, high speed drivers, bar patrons, and drivers with prior crash records.

High belt use rates were observed immediately after the laws took effect in New York and New Jersey, the first two states to enact such laws. However, a year later, the use rate began to drop substantially. This pattern of use was also observed in Illinois and California. Typically, the pattern was high belt use rates followed by a leveling off at or below 50 percent.

It was found that use rates are higher in states where police are allowed to stop and ticket a motorist solely for failure to use belts, compared to states where the police must observe other types of violations before they can enforce the safety belt laws.

In states that enacted belt laws, front-seat occupant deaths were reduced by 5-16 percent. These increases in belt use were directly attributed to the laws (2).

According to Hoxie and Skinner (3), mandatory seatbelt laws have the promise of preventing the deaths of many car passengers in highway accidents. Using data from NHTSA's Fatal Accident Reporting System (FARS), analysis was done on a pooled cross-section of highway fatalities in the seventeen states and the District of Columbia that had implemented the seat belt law as of June 1986. The results indicate that the use of front seat restraints reduced front seat occupant fatalities by an average of

5.8 percent. The results also indicate that the effect of the belt laws are greater in the first quarter than in subsequent quarters.

Further analysis indicates that there are differences between states in the size of effects. State-to-state differences in compliance, enforcement, and driver characteristics are probably largely responsible for these variations. Also, the national models indicate that the effect of enactment is about 9 percent the first quarter and half of that the subsequent quarters. The heightened awareness of the law in both the public and the police officers who enforce the law is probably responsible for the strong initial effect.

Canada used three types of approaches to promote seat belt use. According to Jonah, et al. (4), these approaches were as follows: (1) a cooperative public education program, (2) Selective Traffic Enforcement Program (STEP), and (3) feedback to the public. The specifics of each approach and their evaluation are as follows.

The cooperative education program was conducted by the federal government and ten provinces in the spring of 1981. This program used a number of public service announcement techniques such as the mass media, lectures, pamphlets, posters, etc. It was found that the attitude and behavior of those who reported being exposed to the campaign were no different than those not exposed.

The second approach is the Selective Traffic Enforcement Program (STEP). In this program the police forces in jurisdictions with seat belt laws step up their enforcement efforts and publicize this increased effort through the media. The STEP was shown to be an effective tool in increasing seat belt usage. Although the initial belt use rates achieved through STEP did not remain at their high level, 10 to 20 percent above baseline, the usage rates do level off and remain at a level 5 to 10 percent above the baseline. The implication of these findings is that with each successive STEP, the belt usage rate can permanently be raised by 5 to 10 percent. STEP is considered to be a very cost-effective method of increasing belt usage rates in jurisdictions where the law exists.

The final approach is the use of feedback to the public through use of changeable signs posted at the roadside, informing the public of the previous day's belt use rate. In a study of this approach, binoculars were used to determine the new daily rates at a "T" intersection. This approach showed a small but significant increase in the belt usage rate of 4 percent. The cost of making, posting and changing of the sign plus daily observation of the belt usage rates at specific locations is relatively small. This approach may prove to be a cost-effective method of increasing seat belts, especially in jurisdictions which have seat belt laws (4).

A study performed by Partyka (5) of eight states during a 48 month period showed that the mandatory safety belt use laws produced a 7 percent drop in fatalities among the front seat passenger vehicle occupants. There were a number of different techniques and variables that were used in this evaluation such as trend analysis, and variable baseline. In each evaluation, the decline in fatalities was on the order of 7 percent. This similarity suggests that this decline is probably the direct result of the mandatory seat belt laws themselves rather than some other variable.

Florida's mandatory safety belt and child restraint use laws went into effect on July 1, 1986, with a six month education phase before fines were levied against violators. In order to evaluate the effects of the law, a study was conducted by the Florida Department of Highway Safety and Motor Vehicles (Management and Planning Services).

The study examined a six-year history of data on traffic deaths and serious injuries to persons now covered by the law, namely, front seat occupants of passenger cars and light trucks. The study's objective was to evaluate the effects of the law on the number of fatalities and injuries during the first 18 months after the law became effective.

Florida's safety belt law was shown to have a clear and statistically significant effect on reducing serious injuries in traffic accidents. The effect was most evident in daytime traffic accidents, where the law alone produced a 12.1 percent reduction and subsequent enforcement produced an additional 20.5 percent reduction in the number of incapacitating injuries of front seat occupants.

In the Florida study, statistically significant fatality reductions were detected among drivers in daytime traffic accidents. Estimated reductions in this category ranged from 88 to 133 driver fatalities prevented during the post-law study period. Additional evidence was presented for positive, though not statistically significant, effects on daytime fatalities among all covered vehicle occupants. Despite these substantial numbers of lives saved, it was reported that continued increasing trends in nighttime traffic deaths offset much of the decrease that would otherwise have been apparent in the total.

The disparity between daytime and nighttime effects of the law was an important finding of the Florida study. This difference suggests that a high-risk segment of nighttime drivers is not complying with the law to the same degree as Florida's general motoring population. The report recommended that further compliance efforts should focus on motorists who do relatively more of their driving at night.

In regard to belt use rate, Florida seems to follow the same trend as the rest of the nation. Prior to the law, belt use rates were around 28 percent; once the law went into effect the rate increased to approximately 40 percent. As the state began enforcement of the law, the usage rates went up to 60 percent for a short period of time and began to drop off and eventually leveled off at the upper 40th percentile (6).

A more detailed study of Florida's experience with the mandatory seat belt law was performed by Levy (7) using an intervention time-series analysis. Various fatality and injury related data were obtained and compared to increases in gasoline consumed, the number of licensed drivers and the presence of other traffic safety factors such as alcohol legislation and Interstate speed limit increases. Two classes of injuries were studied; fatal and non-fatal. Only front seat occupants were considered in the study. Impacts were divided between nighttime and daytime. The following are Levy's findings:

1. Throughout the total time period of the study, monthly gasoline consumed and the number of Florida licensed drivers continued in a steady upward trend with no detectable interventions.

2. Daytime front seat occupants sustaining incapacitating injuries declined 12.2 percent as a result of the implementation or presence of the law and 20.5 percent resulting from the enforcement of the law.

3. Nighttime front seat occupants sustaining incapacitating injuries declined 9.4 percent coincident with enforcement of the law but not beginning with implementation of the law.

4. Increases in the belt usage rates observed throughout the study period showed a strong inverse correlation with occupants injured as usage rates increased.

5. When the enforcement aspect of the law became effective a 50 percent increase in usage rates was observed.

6. The number of monthly daytime and nighttime fatal crashes did not appear to have been affected during the presence of the usage law.

7. Daytime and nighttime fatalities of restrained front seat occupants actually increased during the presence of the law, while unrestrained daytime and nighttime front seat occupant fatalities declined.

8. Total traffic fatalities remained relatively steady during the presence of the usage law and was not found to be correlated with either gasoline consumed nor number of Florida licensed drivers.

Levy concluded that the evidence presented above showed significant reductions of front seat occupant injuries.

In the spring of 1985, the North Carolina General Assembly enacted a mandatory occupant restraint law which became effective

October 1, 1985. Warning tickets were issued to violators of the law during the fifteen month period between October 1, 1985 and December 31, 1986. As of January 1, 1987, violators have been subject to fine of $25. Violation of the law does not result in driver license points, insurance points or court costs.

The results of surveys done in North Carolina indicate that driver belt usage in the urban area is higher than in the rural areas. Urban areas also proved to have higher belt usage during commuting hours than non-commuting hours. For the most part belt usage is higher for the following:

- In the piedmont and coastal regions
- For female drivers and occupants
- For white drivers and occupants
- For drivers rather than front seat occupants
- Cars and vans rather than pick-ups

Belt usage during the pre-law period was 25 percent. During a 15-month warning ticket phase (October 1, 1985 - December 31, 1986), driver belt usage ranged from 41 to 49 percent. During a $25 citation phase, driver belt usage immediately hit a high of 78 percent which is the highest use rate ever recorded in the U.S. The rate leveled off at around 60 percent nearly one and one half years later. In 1988, usage was at nearly 64 percent.

During the warning phase, there was no improvement in fatalities relative to the forecast made from long-term, pre-law trends. Serious and fatal injuries to occupants covered by the law during the same phase indicated a significant reduction of 5.4 percent, which is an estimated annual reduction of 857 such injuries during the 15-month period. During the citation phase, the first 18-month period indicated a 11.6 percent decrease in fatalities among occupants covered by the law. During the same period, serious and fatal injuries to occupants covered by the law showed a 14.6 percent reduction from the forecasted level.

The level of enforcement by the Highway Patrol was 9,666 warnings per month during the warning ticket phase and 4,130 $25 citations per month during the first 21 months of the citation phase (January 1, 1987 to September 30, 1988). The level of enforcement by local police and county sheriffs varied across the state.

Using motor vehicle accident costs recommended by the Federal Highway Administration, the injury and fatality reductions would represent a savings of over $500 million from October 1985 through June 1988.

It was also discovered that many people falsely tell police officers that they were using their belt at the time of the crash in accident situations. Reported belt use in crashes considerably exceeded the level observed in roadside surveys (8).

The Transportation Research Board (TRB) has reported that public support for mandatory safety belt use laws have shifted dramatically over the past 15 years (18). For example, in 1972, only 23 percent of those polled supported belt use laws. By 1988, more than 50 percent supported belt use laws.

In motor vehicle crashes, regardless of restraint use, the head is the most frequently injured part of the body. Head injuries are also the most likely injuries to cause death or permanent disability. Experience in the United Kingdom indicates that the increase in lap-shoulder belt usage from roughly 40 to 90 percent has been accompanied by a 37 percent reduction in head injuries to drivers (9).

New York State's mandatory occupant restraint law was implemented on December 1, 1984. Full enforcement of the law began on January 1, 1985. The occupants covered by law consisted of all front seat occupants and children under the age of ten, regardless of seating position.

A study performed by Institute for Traffic Safety Management and Research to determine whether the pattern of injuries and fatalities sustained by these occupants in 1985 differed from a two year baseline period prior to the law.

Comparison between the baseline and post-law periods were made for five categories of accident outcomes. The categories are: fatalities, serious injuries, moderate injuries, minor injuries and persons injured.

The results of these comparisons at the statewide level indicated that the mandatory occupant restraint law produced substantial savings in 1985. If the fatality/injury pattern in 1985 had followed the baseline pattern, approximately 220 more occupants would have been killed, 3,500 more occupants would have received a serious injury, 11,400 occupants would have sustained a moderate injury, and 470 more occupants would have sustained a minor injury. A total of 15,600 fewer occupants were injured than would have been expected. These savings represent reductions of 18 percent in fatalities, 19 percent in serious injuries, 21 percent in moderate injuries, and less than one percent in minor injuries.

Based on the statewide usage rates measured in roadside surveys (16% baseline, 55% post law) and the predicted effectiveness of safety belts in preventing deaths (45%), a 19 percent reduction in fatalities would have been anticipated. Based on the analysis here, there was an estimated 18 percent reduction in fatalities among front seat occupants (10).

Surveys completed in November of 1986 of cars crossing the Golden Gate Bridge and the San Francisco-Oakland Bay Bridge during the morning rush hours showed that 72 percent of the drivers and 62.8 percent of the front seat passengers were belted.

The prelaw surveys completed back in 1984 indicated a belt use of between 39.7 and 47.1 percent for drivers and 34.4 and 44.2 percent for front seat passengers (11).

The evaluation of restraints in preventing fatalities and reducing injury severity is affected by differences in the crash conditions experienced by unrestrained, lap-belted, and lap-and-shoulder-belted car occupants. Partyka (12) has observed that restraints are less useful in the more serious accidents where massive intrusions occur. Nevertheless, the overall benefits of using seat belts are large. Based on the available data the belts are 40-50 percent effective in reducing moderate, serious, and fatal accidents (12,13).

In a study done by Partyka (5), the restraint effectiveness was found to be as high as 58 percent for the driver and 50 percent for the right front seat passenger, based on the 1985 Fatal Accident Reporting System.

While a reduction in fatalities is an important outcome, Wolf and Levy have suggested that seat belt legislation may be more effective in reducing the severity of traffic injuries (14). These researchers believe that the new law may have a greater impact in reducing injuries in the "less serious" non-fatal crashes that occur with greater frequency than fatal crashes. State-level data obtained from police accident reports (PARs) were made available to the DOT for this study.

Wolf and Levy used a time-series technique that can measure the effect of different legislative actions on changes in injury levels. Their approach was to use monthly injury data, controlling for four levels of injury severity (fatal, incapacitating, non-incapacitating, and "possible injury"), two seating positions (front and rear), and two time periods (day and night). This yields 16 time series.

In Texas, a decrease in injury was found for four of the front seat series with the intervention of seat belt legislation: daytime front seat incapacitating injuries decreased 15 percent, daytime front seat fatalities decreased 13 percent, daytime front seat fatalities and non-incapacitating injuries decreased 17 percent, nighttime front seat fatalities decreased 21 percent. A decrease in the remaining front seat series was not found to be associated with the seat belt legislative activity.

In the state of Virginia (15), both drivers and right-front seat passengers with non-fatal injuries were less likely to require medical treatment after the belt use law was in place. Before the law, 49 percent of the drivers needed medical treatment following their crashes. After the law went into effect, this figure was reduced to 37 percent. For the right front seat passengers, 59 percent needed medical attention before the law and 47 percent after. Another important fact is that drivers and right front-seat passengers were less likely to sustain face and head injuries after the belt use law. Windshield and instrument panel contacts decreased as sources of injuries for both passengers and drivers after the law. The percentage of drivers injured from steering wheel contacts was reduced from 13 to 10 percent.

The length of time a seat belt law must be in effect before it can be adequately measured depends on a number of factors including the size of the population, the proportion of people who conform to the new law, the characteristics of these people and of those who do not wear belts, the presence of other traffic safety programs, the general state of the economy, and other factors (16).

According to the Insurance Institute for Highway Safety, the toughest belt use law may be the most effective (17). A survey in cities of the 3 most populated states -- New York, California, and Illinois -- gave evidence that the state with the toughest belt laws had the highest compliance rate.

Elmira, New York, had the highest belt use rate, where 62 percent of all front seat passengers and drivers were found to be belted. Before the law only 14 percent wore seat belts. The highest rate in California and Illinois was 42 percent. New York is regarded as having the toughest seat belt laws of the three states.

The danger of being non-belted can readily be seen in the fact that fatalities involving non-belted occupants have been recorded as low as 12 mph. Eighty percent of serious and fatal injuries occur at speeds less than 40 mph. It was found that at a speed of 30 mph a collision would throw occupants forward with a force equal to thirty times their body weight. For a non-belted passenger, this means contact with the steering wheel or windshield (18).

The potential life savings of universal seat belt usage is estimated at about 40 percent of the 26,138 front seat occupant fatalities that occurred in 1985 (19). In 1985, the decrease in front seat occupant fatalities was only 6.7 percent. Notice that 6.7 percent is a long way from the potential 40 percent.

Effects of the 65 mph Speed Limit

As a part of an earlier research project, the researchers conducted an extensive literature search on the effects of speed zoning on observed speeds and safety. The results of that search, which were reported in December 1988 (20), documented the positive and significant effects due to the national maximum speed limit of 55 mph that was imposed in 1973. At the time of that report, little research had been completed and published on the effects of raising the speed limit on rural portions of the Interstate System to 65 miles per hour. The following paragraphs provide an update of the earlier study of the literature, giving some insight into the experiences of other jurisdictions with the 65 mph limit.

The Surface Transportation and Uniform Relocation Assistance Act enacted by Congress on April 2, 1987, permitted states to raise the speed limit up to 65 mph on their rural interstate highways. By December 1987, 38 states had raised their speed limits to 65 mph on some or all their eligible rural interstates. There was understandable concern among traffic safety professionals that the increased speed limit would have a detrimental effect on traffic safety.

In 1986, Hoskin indicated that raising the speed limit uniformly on the rural interstate highway system would likely increase the number of accidental deaths of motor vehicle occupants on that system by at least 200 per year if raised to 60 mph, at least 450 per year if raised to 65 mph, and at least 600 per year if raised to 70 mph (21).

Miller (22) expressed the belief that the increase in the speed limit had resulted in four principal effects, all time-related: (a) travellers saved travel time, (b) increased fatalities cost future years of life, (c) increased non-fatal injuries caused impairment that cost years of functioning, and (d) increased crashes caused traffic jams that delayed travel. Miller describes a time series model performed by the National Highway Transportation Safety Administration that estimated changes in fatalities and fatal crashes on rural interstates after the speed limit was raised. The model indicated that raising the speed limit increased fatalities 16 percent. Increasing traffic volume caused an additional two percent increase. A second study by Baum, Lund and Wells (23), compared the number of deaths on rural interstates and other rural roads. They estimated the higher speed limit caused a 15 percent increase in fatalities. This was in close agreement with the NHTSA estimate. Both studies used data from the Fatal Accident Reporting System (FARS).

In January 1989, the National Highway Traffic Safety Administration (NHTSA) made a preliminary report to Congress on the results of the 65 mph speed limit during 1987 (24). Substantial variations in accident data among the 38 states were reported. Twenty-seven of the 38 states reported an increase in fatalities during the time the 65 mph speed limit was in effect in 1987 compared to the same time period in 1986, while 11 states reported no increase or a decrease in rural interstate fatalities. Likewise of the 10 states that retained 55 mph speed limit, six remained unchanged or had a fatality increase, while four had decreases. Collectively, the 38 states that raised their speed limit had a 19 percent average increase in rural interstate fatalities. A large portion (64 percent) of this increase is from only six states. The ten states that retained 55 mph speed limit also showed an increase in rural interstate fatalities of seven percent (24).

A paper presented by Upchurch (25) presented at the 1989 Annual Meeting of the Transportation Research Board described Arizona's experience with the 65 mph speed limit. He describes the results of a before and after comparison of speeds and accident experience relative to April 15, 1987, the date the speed limit on Arizona rural interstates was raised to 65 mph.

Upchurch found that while speeds driven by motorists on Arizona's rural interstate system was almost constant during the three-year before period, speeds observed during the one year after period increased about three mph. He reported that the number of accidents, the total accident rate, and the injury accident rate increased on rural interstate highways after the speed limit was changed. He further indicated that the fatal accident rate on the Rural Interstate System was higher in the one year after period than in any of the years 1983 through 1986.

The Insurance Institute of Highway Safety (IIHS) (26) has recently published literature stating that a 29 percent increase in rural interstate crash deaths has occurred in the 38 states that have adopted the higher speed laws. They used data from 1988 and compared it to data from the years 1982-1986.

A study performed by Auburn University researchers (27) investigated the effects of the change of the speed limit on rural Alabama Interstate highways from 55 to 65 mph which took effect on August 1, 1987. One aspect of this work involved a comparison of accident experience along the 65 mph test area to that for the interstates remaining at 55 mph as well as to that for the entire state excluding the test areas. The researchers reported that property damage only and injury type accidents were significantly higher in the 65 mph test area then for the rest of the state. In a similar comparison, they found an 18.5 percent increase in fatal accidents; however, because of the small sample size, this effect was not significant.

In March of 1990, Chang and Paniati (28) reported the safety impacts of the new speed limit using nationwide fatality data which stretches from January 1975 to September 1988. Box-Jenkins modeling techniques were used to forecast the number of fatalities that would have occurred if the speed limit had remained at 55 mph. They conclude that in the short-term, the effect of the higher speed limit on rural interstate highway fatalities appears to be statistically insignificant by various measures. They suggest that there may be other factors which offset the increased speeds, such as reduced risk taking and decreased speed variance. The increasing enforcement of the seat-belt laws may also significantly reduce potential fatalities. Failure to accurately assess such effects will seriously underestimate the impacts of the increased speed limit on traffic safety.

In a study performed by the Insurance Institute for Highway Safety (IIHS), it was found that in late 1988 six times the proportion of motorists of New Mexico, the first state to raise their speed limit, were going faster than 70 mph, compared to the proportion right after the law was changed (29). Some concern has been expressed over the possible effects that the 65 mph speed limit may be having in that state on the frequency of overturning accidents. It was reported in 1988 that overturns had increased threefold over the previous three years, and occupant ejections had increased fourfold (30).

In a study by McKnight and Klein (31), it was suggested that the apparent increase in fatalities is associated with the increased number of speeding drivers. Their study showed a 48.3 percent increase in the proportion of drivers exceeding 65 mph. In states retaining the 55 mph speed limit on rural interstates, the increase in speeders was 18 percent. In states retaining the 55 mph speed limit, fatal accidents on the rural interstates and other 55 mph highways rose an estimated 10 percent and 13 percent, respectively. While the increased numbers of fatal accidents in 55 mph states cannot be directly attributed to the change in speed limit, it appears to be the result of significant increases in the number of speeders coinciding with the change in speed limit.

Chapter 2

OBJECTIVES AND GENERAL METHODOLOGY

This chapter sets forth the principal objectives of the research and describes research tasks undertaken to accomplish those objectives.

Objectives

The principal objectives of this project were:

1. To review and summarize the experience of other jurisdictions with mandatory seat belt laws.

2. To measure the effects of the 65 mph speed limit law on fatal accidents, fatalities, fatal accident rates, and fatality rates.

3. To measure the effects of the 65 mph speed limit law on accident severity as measured by police report injury codes.

4. To measure the effects of the mandatory seat belt law on fatal accidents, fatalities, fatal accident rates and fatality rates.

5. To measure the effects of the mandatory seat belt law on accident severity as measured by police report injury codes.

6. To measure the effects of the 65 mph speed limit law on the numbers and rates of occurrence of accidents.

General Methodology

Using accident and travel data for the state route system from the files of the Georgia Department of Transportation, the researchers conducted a series of 13 studies, identified as Tasks 1-13. These tasks are described below. The statistical procedures used in these analyses are described along with the test results in Chapters 3, 4, and 5.

Task 1. Literature Survey. Using the computerized literature search programs available through the Georgia Tech Library (including the TRIS system), the researchers conducted a search of the literature to document the experience of other jurisdictions with mandatory seat belt laws. The researchers examined NHTSA Research Reports, Insurance Institute for Highway Safety Reports, as well as articles in medical and automotive engineering journals. This task included an update of the literature survey of the effects of the 65 mph speed limit reported in the December, 1988, report (20).

Task 2. Study Fatal Accidents and Fatalities to Measure the Effects of the Mandatory Seat Belt Law. This study was a 6-month before, 6-month after study of accident experience referenced to September 1, 1988, the effective date of the mandatory seat belt law. Before and after comparisons of the number of fatal accidents and fatalities were made for each of the major functional classes of highways. To avoid seasonal effects, the same months were chosen for the before and after periods. See Figure 2-1. Classical statistical procedures (odds-ratios) were used to compare the number of fatal accidents and fatalities during the two study periods. The researchers also compared fatal accident rates and fatality rates for the study periods to account for possible effects of changing traffic volumes.

Task 3. A Study of Fatal Accidents and Fatalities to Measure the Effects of the 65 mph Speed Limit. This study was a before and after comparison of accident experience to measure the effects of the 65 mph speed limit. The study periods were carefully chosen to avoid seasonal effects and possible confounding effects of the mandatory seat belt law. Classical statistical procedures (odds-ratios) were used to compare the number of fatal accidents and fatalities on each of the state functional class of roadways. The researchers also compared fatal accident rates and fatality rates for the study periods to account for possible effects of changes in traffic volumes.

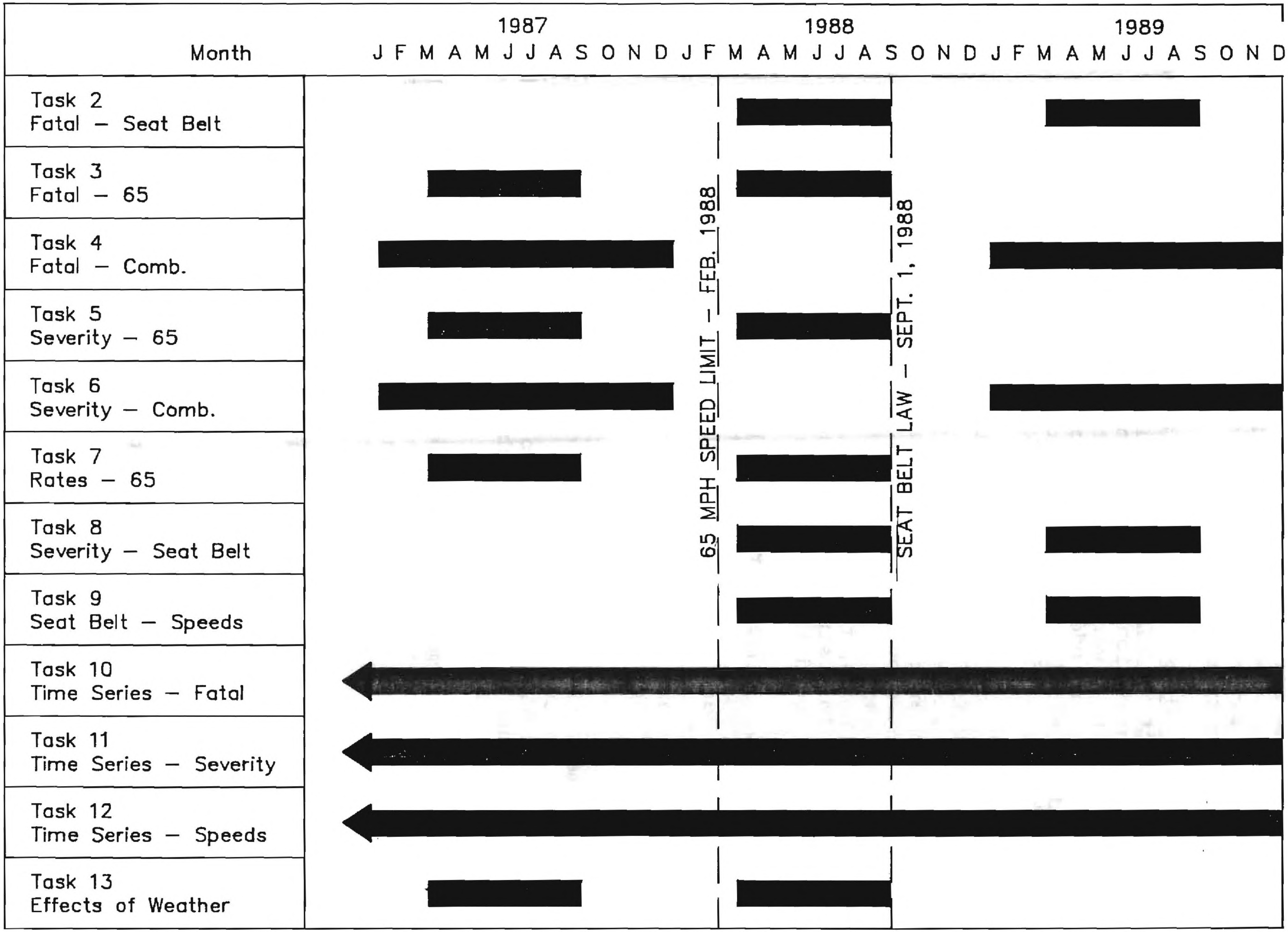
Task 4. A Study of Fatal Accidents and Fatalities to Measure the Combined Effects of the Speed Limit and Seat Belt Laws. This study compared the fatal accidents and fatalities during a twelve month period before the effective date of either the speed limit or seat belt law to a similar period after the effective dates of both laws. The researchers also compared fatal accident rates and fatality rates to account for possible effects of changes in traffic volumes.

Task 5. A Study of Accident Severity to Measure the Effects of the 65 mph Limit. The purpose of this task was to evaluate the effects of the 65 mph limit in terms of accident severity. The researchers used odds-ratios to compare the number of injuries reported (fatalities, visible injuries, and complaint of injuries) in a period before the 65 mph speed limit to those reported in a period after the limit.

Task 6. Study Accident Severity to Measure the Combined Effects of the 65 mph Limit and the Seat Belt Law. As this task, the researchers used odds-ratios to compare the number of injuries reported on the accident reports during a before period (when neither law was in effect) to similar data for an after period (when both laws were in effect).

Task 7. A Study of Accident Occurrence Rates to Measure the Effects of the 65 mph Limit. This study examined the rates of accidents that occurred in a 6-month period before the imposition of the 65 mph limit to similar data for a 6-month after period.

Figure 2-1
FOCUS PERIODS FOR VARIOUS TASKS



Using the same before and after periods that were used for Task 3, the researchers looked for changes in accident occurrence rates for each of the major functional classes of highways by calculating incident density ratios.

Task 8. Study Accident Severity to Measure the Effects of the Mandatory Seat Belt Law Using the Police Report Injury Codes. This task was a companion to Task 2, and the before and after periods used for Task 2 were used for this task. For this task, the researchers used odds-ratios to compare the number of injuries reported (fatalities, visible injuries, and complaint of injuries) in the before period to those reported in the after period.

Task 9. Study Fatal Accidents, Fatalities and Injuries to Measure the Effects of the Mandatory Seat Belt Law by Speed Limit Categories. It was hypothesized that the mandatory seat belt law will be more effective on roads zoned for higher speeds. This study was designed to test this hypothesis. This task was a companion to Task 2. It consisted of before and after comparisons of fatal accidents, fatalities and injuries for various speed limit categories. This study included comparisons of injuries/accident ratios among speed limit categories.

Task 10. Time-Series Analyses of Fatal Accidents and Fatalities Including the 1989 Data. Time-series analyses were performed for accident data for the years 1983 through 1989 using the Box-Jenkins procedure (with the aid of the ARIMA computer model) to test possible effects on these trends by the intervention of the 65 mph speed limit and the mandatory seat belt law.

Task 11. Time-Series Analyses of Injuries Including 1989 Data. Time-series analyses were performed for injury data for the years 1983 through 1989 using the Box-Jenkins procedure (with the aid of the ARIMA computer model) to test possible effects on injury trends by the intervention of the 65 mph speed limit and the mandatory seat belt law.

Task 12. Time-Series Analyses of Observed Speeds Including 1989 Data. Time-series analyses were performed for observed speeds for the years 1986 through 1989 using the Box-Jenkins procedure (with the aid of the ARIMA computer model) to test possible effects on observed speeds by the intervention of the 65 mph speed limit.

Task 13. Special Study of Possible Effects of Weather. A special study was conducted to determine if differences in precipitation could explain the observed differences in fatal accidents and fatalities before and after the 65 mph speed limit. The following entries from the accident reports were examined to evaluate such effects:

1. Weather (clear, overcast, raining, etc.)
2. Surface (dry, wet, muddy, etc.)

Chapter 3

SAFETY EFFECTS OF THE 65 MPH SPEED LIMIT IN GEORGIA

This chapter describes the results of studies conducted by Georgia Tech researchers to measure the safety effects of the speed limit change. It encompasses five tasks: 3, 5, 7, 12, and 13.

Traffic safety specialists have long understood that losses from highway are directly related to vehicle speeds. In 1966, Arthur D. Little, Inc. published a comprehensive report entitled The State of the Art of Traffic Safety (32). The report stated: "...speed limits are effective in reducing the proportion of vehicles operating at extreme speeds, that is, more than 10 miles per hour over the speed limit introduced. Studies suggest that this limiting of speeds has been responsible for reductions in accident and injury rates which have accompanied imposition of speed limits...".

The report went on to say: "The severity of an accident that occurs has been clearly shown to increase with vehicle speed, other factors being equal."

In 1974, in the wake of the Arab oil embargo, Public Law 93-643 was enacted establishing a uniform national maximum speed limit of 55 miles per hour. Safety experts have estimated that the imposition of this speed limit resulted in the saving of thousands of lives per year on the nation's highways. They believe that the lower speed limit also lessened the losses from highway accident injuries, property damages, lost productivity, and legal court costs.

There was understandable concern, therefore, when the Surface Transportation and Uniform Relocation Assistance Act of 1987 was enacted, allowing states to raise the 55 mph speed limit on rural portions of the interstate system to 65 mph. The resulting increase in the speed limit in the various states created a need to carefully study and monitor accident rates.

Effects of the 65 mph Limit on Speeds

In 1988, Georgia Tech researchers made a study of effects of the 65 mph speed limit on speeds on Rural Interstate highways and on other functional classes of highways. They evaluated speed data that had been collected by Georgia Department of Transportation personnel at 47 randomly selected speed monitoring sites. The researchers compared speed data collected before the institution of the 65 mph speed limit (Fall, 1987) with similar data collected after the speed change (Spring, 1988). They reported (20):

1. Mean speeds on Georgia's Rural Interstate highways increased approximately 4 mph following the establishment of the 65

mph speed limit. Similar increases were noted in the 85th percentile speeds.

2. Mean speeds on Urban Interstate highways (which did not have a speed limit change) increased very little following the establishment of the 65 mph limit. These increases varied but amounted to about 0.5 mph.

3. For other classes of highways (non-Interstate), no consistent patterns of speed changes could be identified, and the impact of any spillover effect that might have been caused by the 65 mph speed limit was not apparent.

Task 12

As a part of this research, there was further analysis of the effects of the 65 mph limit on speeds. Time-series analyses, explained in Chapter 5, were performed of observed speeds for the years 1986 through 1989.

The available speed data were not well suited for time series analysis. Only 14 quarterly data points were used in the analysis, and these points represented averages of speed parameters measured throughout the quarter. The measurements were made by GDOT personnel at 47 randomly chosen sites as a part of an ongoing speed monitoring program.

Nevertheless, time series analysis confirmed that the average and 85th percentile speeds for the Rural Interstate system increased following the implementation of the 65 mph law. The magnitude and pattern of these speed changes can be seen in Figures 3-1 and 3-2. The step interventions found in these analyses were statistically significant ($P < 0.2$). Figures 3-3 and 3-4 show speed patterns for the Urban Interstate system, which experienced little change in the average speeds but a noticeable increase in the 85th percentile speeds.

Effects of the 65 mph Limit on Safety

Tasks 3, 5, and 7 were designed to evaluate the effects of the 65 mph speed limit on safety.

Task 3

This task was designed to measure the effects of the 65 mph speed limit on the occurrence of fatal accidents and fatalities on each of the state functional classes of roadway. This analysis is an extension of the work "Study of Effects of 65 MPH Limit on Speeds and Safety" (20) submitted by the researchers in December, 1988. The study periods used in the analysis were:

Before Period: March 1, 1987 - August 31, 1987
After Period: March 1, 1988 - August 31, 1988

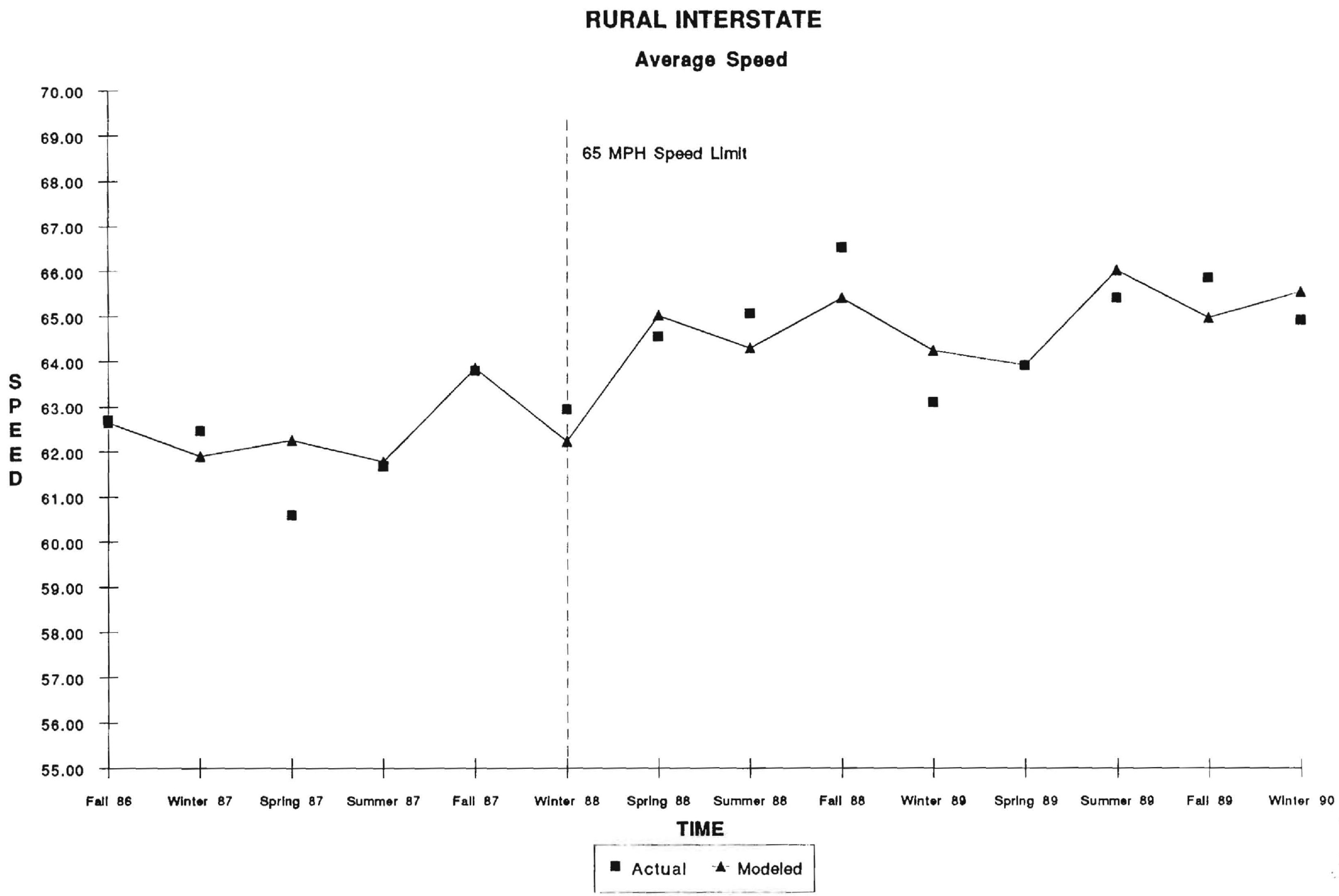


Figure 3-1. Time series analysis of average speeds, Rural Interstate highways.

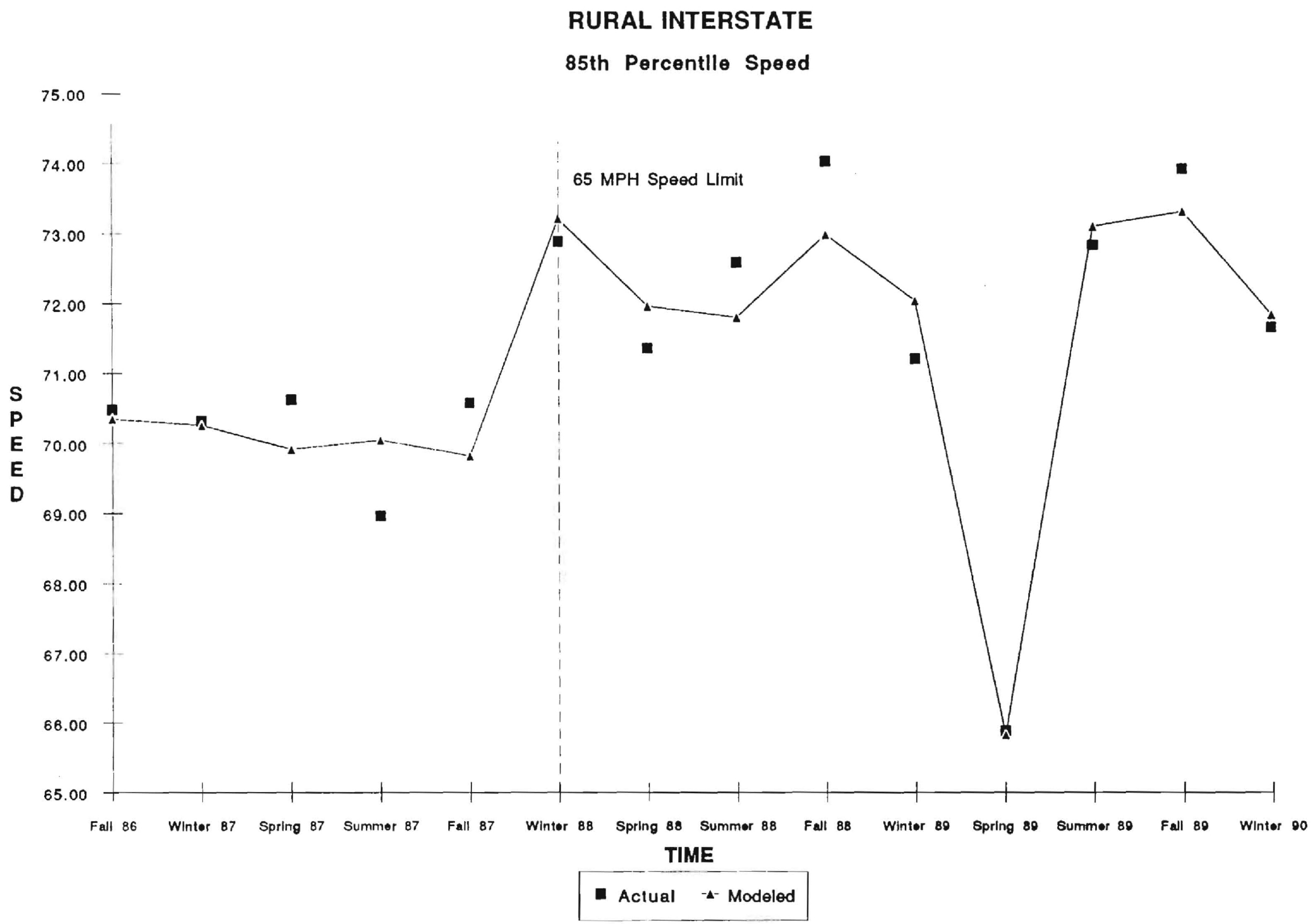


Figure 3-2. Time series analysis of 85th percentile speeds, Rural Interstate highways.

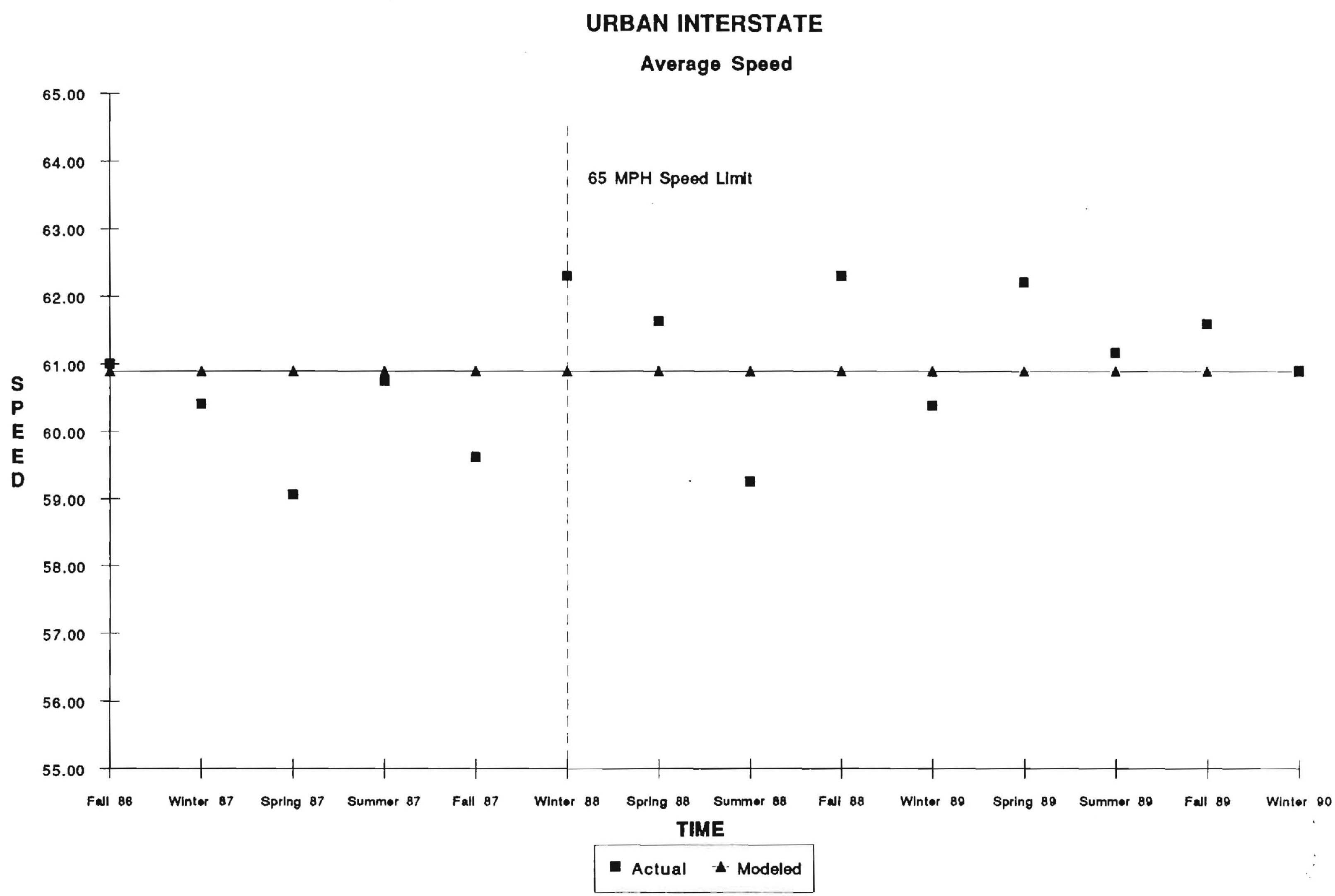


Figure 3-3. Time series analysis of average speeds, Urban Interstate highways.

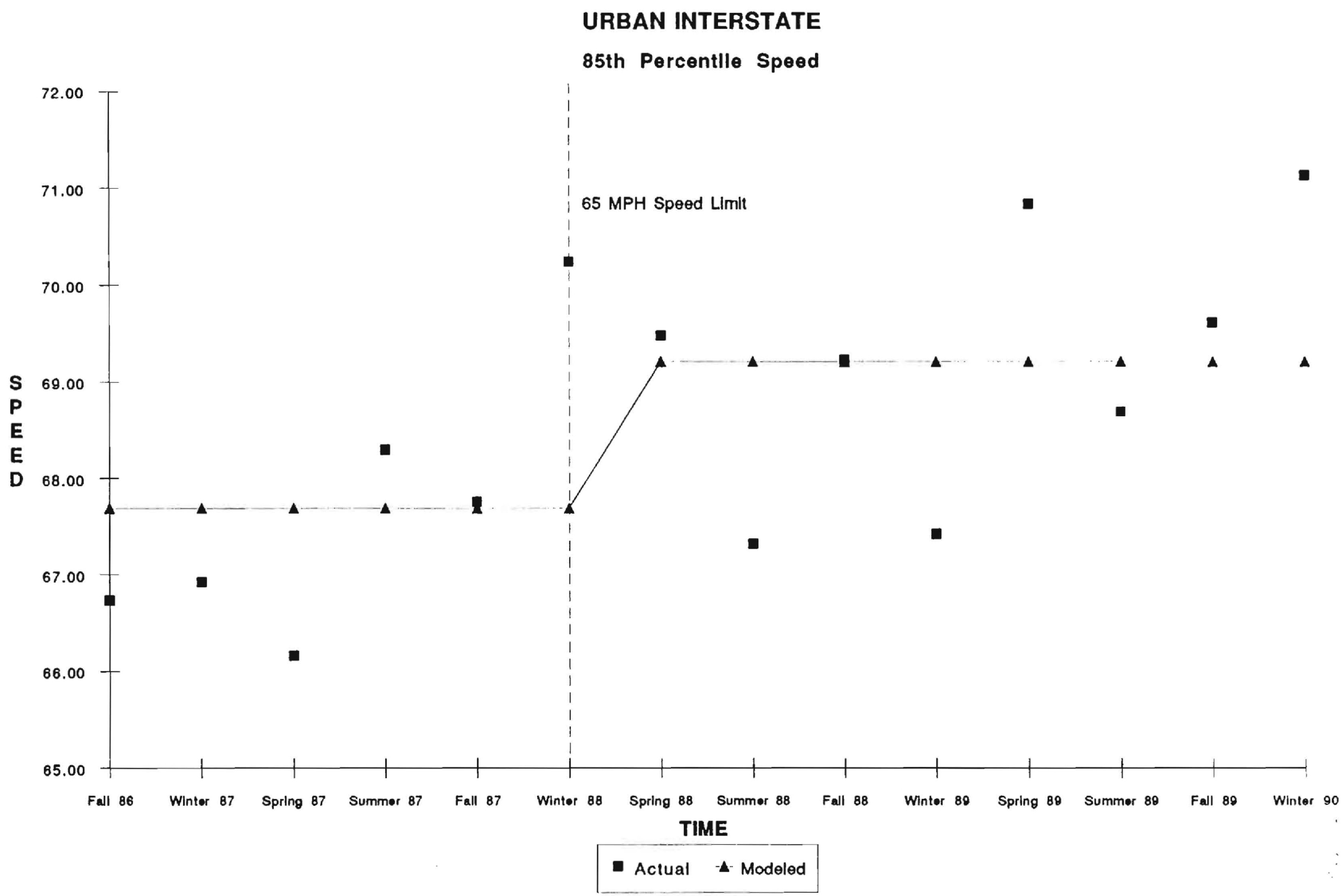


Figure 3-4. Time series analysis of 85th percentile speeds, Urban Interstate highways.

The same six months of the year were used for the before and after periods to avoid seasonal effects. The after period extended only to August 31, 1988, to avoid possible confounding effects of the mandatory seat belt law, which became effective on September 1, 1988. The fatality and fatal accident data used for this task are included in the Appendix.

Method of Analysis. Classical statistics were used to determine the statistical significance of differences between fatalities during the two study periods. Likewise, the differences between fatal accidents during the two study periods were analyzed in the same manner. The statistical method involving probabilities (proposed by Duncan) used in the previous study (33) was not used in this study. The Duncan method, while still applicable, is cumbersome to use and does not readily provide a P-value (measure of significance). A methodology using odds ratios which was recommended to the researchers by NHTSA for this type of before and after study, was chosen for this analysis. A major benefit of using odds ratios is that a level of significance or P-value can be quickly determined. Furthermore, it is much more practical than the Duncan method because it uses smaller numbers and therefore can be easily programmed.[1]

The odds ratio is a measure of the degree of inequality between two events. It is equal to the odds of an event happening in a group divided by the odds of an event happening in a second group.

The analysis using odds ratios is based on the following hypothesis:

Odds Ratio = 1	No change
Odds Ratio > 1	Improved Condition
Odds Ratio < 1	Deteriorated Condition

The significance of the odds ratio is given by the Mantel Haenszel Chi-Square statistic and its P-value (34). A P-value less than 0.05 indicates that the odds ratio is statistically significant at a level of confidence greater than 95%. The 0.05 degree of significance was used in this analysis for the minimum level of acceptance of the hypothesis. If the P-value is greater than 0.05, the odds ratio is said not to be statistically significant and the hypothesis is rejected. It is important to note that while an odds ratio may not be statistically significant at the 95% confidence level, the odds ratio may indicate an important yet imprecisely measurable effect.

The computation of the odds ratio is a straightforward process. If no time trend existed, the odds ratio would simply be equal to the number of fatalities (or fatal accidents) being analyzed in the before period divided by the number of fatalities

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[1]The large numbers that are dealt with in the method proposed by Duncan are a result of factorials of accident data which in many cases are extremely large causing overflows in calculations made by a computer.

(or fatal accidents) being analyzed in the after period. Stated another way, the odds ratio would be the odds of a fatality (or fatal accident) occurring in the before period vs a fatality (or fatal accident) occurring in the after period divided by the trend, which in this case is equal to 1 (no trend). Again, if this odds ratio is greater than one, the condition is said to improve. Likewise, if the odds ratio is less than one, the condition is deteriorating and the number of fatalities (or fatal accidents) have increased.

A control group is used in the analysis to reflect trends in overall accident experience during the two periods. The control group was established based on the recommendations of statisticians at NHTSA. There is no restriction that the control group must come from functional classes that are related to the analysis group (e.g., freeways). This is because the primary purpose of the control group is to represent the trend in time from the before and after period, independent of the 65 mph speed limit. To provide the best results, the control group should be chosen in such away as to avoid including those functional classes that are most likely to be affected by the change in the 65 mph speed limit. Thus, choosing Urban Interstate roads as control group when analyzing Rural Interstate may give erroneous results because of the increased likelihood of spillover effects of the 65 mph speed limit on the Urban Interstate.

To try to reduce the spillover effect, the researchers decided to use a control group that included all other state functional class roadways other than the analysis group. The thinking here is that the size of the control group would offset any spillover effect while providing the best overall representation of the trend of accident experience in Georgia. The odds ratio reflecting trends for an analysis of fatalities is given by the following formula:

$$\text{Odds Ratio} = \frac{N_{fb}/N_{fa}}{N_{cb}/N_{ca}}$$

where

N_{fb} = Number of fatalities <u>before</u> 65 mph speed limit in the <u>analysis</u> group.

N_{fa} = Number of fatalities <u>after</u> 65 mph speed limit in the <u>analysis</u> group.

N_{cb} = Number of fatalities <u>before</u> 65 mph speed limit in the <u>control</u> group.

N_{ca} = Number of fatalities <u>after</u> 65 mph speed limit in the <u>control</u> group.

Notice that if $N_{cb} = N_{ca}$, the denominator would be equal to 1, indicating no trend.

The statistical significance of the odds ratio as reflected by the Mantel Haenszel Chi-Square statistic and its P-value depends on the sizes of the analysis and control groups. The larger the sample size, the more confident one can be that a given odds ratio reflects the "truth" as opposed to random variation in data. Thus, an odds ratio approaching one does not necessarily indicate that there is little or no change between the before and after periods with regards to fatalities or fatal accidents. Theoretically, an odds ratio close to one may be found to be statistically significantly different from one if the sizes of the analysis and control groups are sufficiently large enough. In many cases, sample sizes are not large enough to detect very small differences in effects.

Reference groups which ensure that analysis groups reflect the total population are irrelevant in this study because the fatality data and fatal accident information used in the analysis represents accident experience of the whole state of Georgia and not a subsample.

<u>Results</u>. Results for Task 3 are summarized for fatalities in Table 3-1 and for fatal accidents in Table 3-2. Multiple scenarios were analyzed for the freeway functional classes. These included analyzing just the mainline segments and the mainline segments in conjunction with ramp areas (gore area, bottom of ramp, etc.). Ramp codes used in this and other tasks are defined in footnotes to the various tables.

The results given in Tables 3-1 and 3-2 show no significant effect of the 65 mph speed limit on the occurrence of fatalities and fatal accidents. The urban principal arterial functional class experienced a significant (P-value = .05) increase in the number of fatalities, but no basis could be established to relate this increase to the 65 mph speed limit. The researchers feel that it is unlikely that this significant increase can be attributed to the 65 mph speed limit because it was the only Urban roadway to experience this type of increase.

The precision of this analysis may be influenced by random fluctuations of accident occurrence. The small number of fatalities and fatal accidents during the two study periods makes the analysis more susceptible to chance. While no significance was found in the analysis in Task 3, a number of observations can be made.

First, there was a 10 percent increase in fatalities from 1987 to 1988 on the Rural Interstate system. This result supports a principle widely accepted by highway safety researchers: higher speeds lead to greater accident severity. This principle is further illustrated in Table 3-3 which shows fatality-to-fatal

Table 3-1
TASK 3 RESULTS
Fatalities

Funtional Class	Ramp Code	Fatalities Before	Fatalities After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-value	Significant at alpha = .05
RURAL								
Interstate	0	39	42	7.7	0.87	0.26	0.607	no
Interstate	0,1	43	47	9.3	0.85	0.40	0.528	no
Interstate	0,1,2	43	48	11.6	0.83	0.55	0.458	no
Interstate	0,1,2,3	45	52	15.6	0.80	0.91	0.340	no
Principal Arterial		94	74	-21.3	1.22	1.37	0.242	no
Minor Arterial		137	125	-8.8	1.02	0.03	0.872	no
Collector		74	76	2.7	0.89	0.46	0.498	no
Local Roads		0	2			Values too small		no
Urban								
Interstate > 50K pop	0	37	27	-27.0	1.29	0.72	0.398	no
Interstate > 50K pop	0,1	48	30	-37.5	1.53	2.15	0.143	no
Interstate > 50K pop	0,1,2	49	31	-36.7	1.51	2.16	0.142	no
Interstate > 50K pop	0,1,2,3	51	35	-31.4	1.38	0.87	0.352	no
Other Freeway		11	10	-9.1	1.02	0.00	0.962	no
Principal Arterial		84	101	20.2	0.72	3.85	0.050	yes
Minor Arterial		30	17	-43.3	1.68	2.83	0.092	no
Collector		3	3	0.0		Values too small		no
Local Roads		0	0					no

Ramp Codes
- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1987 - August 31, 1987
   After period is: March 1, 1988 - August 31, 1988

Table 3-2
TASK 3 RESULTS
Fatal Accidents

Functional Class	Ramp Code	Fatal Accidents Before	Fatal Accidents After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-value	Significant at alpha = .05
RURAL								
Interstate	0	34	34	0.0	0.93	0.03	0.862	no
Interstate	0,1	37	35	-5.4	0.99	0.00	0.951	no
Interstate	0,1,2	37	36	-2.7	0.96	0.15	0.694	no
Interstate	0,1,2,3	39	40	2.6	1.01	0.02	0.877	no
Principal Arterial		79	65	-17.7	1.16	0.65	0.419	no
Minor Arterial		121	109	-9.9	1.05	0.08	0.773	no
Collector		66	69	4.5	0.87	0.55	0.460	no
Local Roads		0	1			Values too small		no
Urban								
Interstate > 50K pop	0	34	26	-23.5	1.23	0.41	0.523	no
Interstate > 50K pop	0,1	45	29	-35.6	1.49	1.84	0.175	no
Interstate > 50K pop	0,1,2	46	30	-34.8	1.47	1.77	0.183	no
Interstate > 50K pop	0,1,2,3	48	34	-29.2	1.34	0.62	0.432	no
Other Freeway		11	10	-9.1	1.02	0.00	0.957	no
Principal Arterial		74	90	21.6	0.72	3.64	0.056	close
Minor Arterial		30	17	-43.3	1.68	3.22	0.073	no
Collector		3	3	0.0	2.80	Values too small		no
Local Roads		0	0					no

Ramp Codes
0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1987 - August 31, 1987
   After period is: March 1, 1988 - August 31, 1988

Table 3-3
FATALITY TO FATAL ACCIDENT RATIOS
by Functional Class

Functional Class	Before 65 MPH Limit (3/1/87 - 8/31/87)	After 65 MPH Limit (3/1/87 - 8/31/87)	Change in Percent After 65 MPH
Rural Roadways			
Interstate - Ramp Code 0,1,2	1.16	1.34	16
Other Principal Arterial	1.19	1.14	-4
Minor Arterial	1.13	1.15	1
Collector	1.12	1.10	-2
Local	N/A	2.00	N/A
Urban Roadways			
Interstate - Ramp 0,1,2	1.07	1.03	-3
Other Freeway	1.00	1.00	0
Other Principal Arterial	1.14	1.12	-1
Minor Arterial	1.07	1.13	6
Collector	1.00	3.00	200
Local	N/A	N/A	0

Ramp Codes
0 Mainline only
1 Gore area
2 Middle of ramp

accident ratios during the before and after periods for the various highway functional classes. The greatest overall increase in the fatality-fatal accident ratio (16%) was for the Rural Interstate system and the Urban Interstate highways in areas less than 50,000 population, which were the only highway classes to experience the speed limit increase.

Second, while the Rural Interstate functional class experienced an increase of approximately 10 percent in fatalities and little change in fatal accidents from 1987 to 1988 most of the other functional classes experienced a substantial decrease (though not statistically significant) in the number of fatalities and fatal accidents in the period after the 65 mph speed limit.

Task 5

Task 5 was a study of accident severity to measure the effects of the 65 mph limit using police report injury codes. This was a companion task to Task 3 with the same before and after periods. This analysis was designed to compare some measure of accident severity in the before period to that measure in the after period. A distribution of the severity data as reported by the police officers' injury codes is given in Table 3-4.

Method of Analysis. The researchers initially intended to analyze the accident severity by comparing the distribution of accidents by injury codes in the before period with the similar distribution of accidents in the after period. This analysis, known as category or ridit analysis, was abandoned for this task because of deficiencies in the initial results. These deficiencies are due to the small number of categories used (only 4 categories were available) and the omission of uninjured persons that were not driving (only uninjured drivers are listed on the police reports). A detailed discussion of ridit analysis is included in Chapter 4 in analysis of speed distributions (Task 9).

Instead of using ridit analysis, statistical odds ratios were used to analyze changes in accident severity data. Severity data used in this analysis was the sum of the number of fatalities, visible injuries and complaint of injuries as reported by the investigating officers. These data were summed in the before and after periods, and the resultant totals were compared using the same odds ratio procedure discussed in Task 3.

Results. The results of this analysis is given in Table 3-5. This table shows that there were extremely significant increases (P-value < 0.000001) in the number of injuries and fatalities on the Rural Interstate system in the period after the 65 mph speed limit was instituted. The odds ratios for the other functional classes were not significant except for Rural Minor Arterial (significant increase), the Urban Interstate category that includes all ramp codes (significant decrease), and Urban Collector (significant increase). The researchers have concluded from this analysis that the extremely significant increases (over 30%) in the

Table 3-4
SUMMARY OF ACCIDENT SEVERITY DATA
Uninjured drivers, complaint of injury, visible injury and fatalities

			Before 65 MPH (3/1/87 - 8/31/87)				After 65 MPH (3/1/88 - 8/31/88)			
Code	Name	Ramp code	Uninj. Drivers	Comp. inj.	Vis. inj.	Fatal-ities	Uninj. Drivers	Comp. inj.	Vis. inj.	Fatal-ities
Rural										
	Interstate	0	2056	388	571	39	2813	607	728	42
	Interstate	0-9	3053	526	720	45	3802	770	879	52
	Principal Art.		4557	939	1186	93	4881	1140	1197	74
	Minor Art.		8799	1868	2059	137	9827	2111	2283	125
	Collector		3696	851	1238	74	4174	882	1217	76
Urban										
	Interstate >50K	0	7637	1196	728	37	7963	1212	731	27
	Interstate >50K	0-9	14867	2075	1247	51	14461	2040	1200	38
	Other freeway		2151	309	208	11	2676	314	256	10
	Principal Art.		48554	6604	3962	84	50315	7120	4013	101
	Minor Art.		12688	1921	1219	30	13752	2051	1139	17
	Collector		909	118	78	3	690	81	64	3

Note: Urban areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 3-5
TASK 5 RESULTS
Accident Severity

Functional Class Code Name	Ramp Code	Total of Injuries & Fatalities Before 65	After 65	Mantel-Haenszel Chi-Square	P-Value	Significant at Alpha = .05
Rural						
Interstate	0	998	1377	42.98	0.000000	yes (extremely)
Interstate	0,1-9	1291	1701	37.62	0.000000	yes (extremely)
Principal Art.		2218	2411	1.99	0.159	no
Minor Art.		4064	4519	9.89	0.002	yes
Collector		2163	2175	1.72	0.189	no
Urban						
Interstate >50K	0	1961	1970	1.63	0.202	no
Interstate >50K	0,1-9	3373	3278	9.93	0.002	yes
Other freeway		528	580	0.71	0.399	no
Principal Art.		10650	11234	0.85	0.357	no
Minor Art.		3170	3207	1.87	0.171	no
Collector		199	148	9.96	0.002	yes

Notes:
1. Urban areas with population less than 50,000 have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1987 - August 31, 1987
After period is: March 1, 1988 - August 31, 1988

number of injuries and fatalities on the rural interstate are likely due to the increase in the 65 MPH speed limit. An explanation for the significant increase in accident severity on the Rural Minor Arterial and Urban Collector classes has not been determined. The significant decrease of injuries and fatalities on the Urban Interstate system coincides with a decrease in the total vehicle miles of travel (VMT) for Urban Interstate roads (ramp codes 0-9) during the before and after analysis periods. VMT is discussed in the next section.

Task 7

This task is concerned with accident occurrence rates to measure the effects of the 65 mph limit. It examines the rates of accidents that occurred in the before and after periods as outlined in Task 3. The main purpose of this task is to account for possible effects of changes in traffic volumes in the two analysis periods.

Method of Analysis. The method of analysis used in this task is similar to the method used for Task 3, but instead of analyzing odds ratios, incidence density ratios (IDR) are used. An incidence density ratio is simply a ratio comparison of two rates. In our study, the incidence density ratio would be the number of accidents per vehicle miles traveled (VMT) in the after period divided by the number of accidents per VMT in the before period. We hypothesize in this analysis that if:

IDR = 1	No change
IDR < 1	Improved Condition
IDR > 1	Deteriorated Condition

If, for example the incident density ratio of a functional class was equal 1.10, this would represent a ten percent increase in the accident rate between the before and after periods.
The significance of the value of the incidence density ratio varies depending on the number of accidents, but is not affected by the magnitude of VMT.

VMT data were available in the form of average daily VMT for a year. Monthly factors that were provided by the GDOT were applied to the annual data to produce average daily VMT's on a monthly basis. To calculate the total VMT for a six month study period, the average daily VMT for a month was multiplied by the number of days for that month and the resultant monthly VMT's were added. Thus, the total VMT for the six month study period for a particular functional class would be equal to:

(VMT for March X 31 Days in March)
\+ (VMT for April X 30 Days in April)
\+ (VMT for May X 31 of Days in May)
\+ (VMT for June X 30 of Days in June)
\+ (VMT for July X 31 of Days in July)
\+ (VMT for August X 31 of Days in August)

Results. A summary of the results from the incidence density analysis in Task 7 is given in Table 3-6. Note the VMT for Urban Interstate in small urban areas was added to the Rural Interstate VMT in the table. This was done to be consistent with the accident data for Rural Interstate which also includes accident data for Urban Interstate in areas with less than 50,000 population. The table shows that all but one of the mainline functional classes experienced a significant increase in accident experience between the before and after periods. The number of significant changes arises mainly from the magnitude of accident data. Because of the large values in the accident data, changes in the accident rates of less than five percent can show significance.

Study of Effects of Weather

As Task 13, the researchers performed a special study to determine if differences in precipitation could explain observed differences in fatal accidents before and after the 65 mph speed limit.

Task 13

The researchers compared the weather related entries on the accident reports for the 6 month periods before and after the establishment of the 65 mph speed limit. The study periods were:

Before: March 1, 1987 through August 31, 1987
After: March 1, 1988 through August 31, 1988

The distribution of weather related entries for the fatal accidents that occurred during the before and after periods are shown in Tables 3-7 and 3-8. These tables give only a slight indication that rainy weather and wet pavements were more prominent during the after period. However, because of the small numbers of fatal accidents during inclement weather, Chi-square tests could not be used to test for any significant effect.

The researchers then studied the distribution of weather-related entries for all accidents that occurred during the before and after periods, i.e., including all levels of accident severity. The distributions of the following entries from the accident reports were examined to evaluate weather related effects:

1. Weather (Clear/Cloudy, Rain/Snow/Sleet, Fog/Others)
2. Surface (Dry, Wet, Others)

This study focused mainly on those accidents that occurred on the rural interstate system, mainline only (ramp code 0).

Chi-square goodness of fit tests were used to compare the distributions for the before and after periods. The results of these tests are shown in Tables 3-9 and 3-10. No significant differences were found either for the weather or surface conditions reported by the investigating officers. In other words, the

Table 3-6
TASK 7 RESULTS
Incidence Density Analysis on Accident Rates

Functional Class	Ramp Code	Before 65 MPH (3/1/87 - 8/31/87) Acc.	Before 65 MPH (3/1/87 - 8/31/87) VMT (millions)	After 65 MPH (3/1/88 - 8/31/88) Acc.	After 65 MPH (3/1/88 - 8/31/88) VMT (millions)	IDR	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-value	Significant at Alpha = .05
Rural									
Interstate	0	1571	3589	1950	4041	1.10	8.28	0.004	yes *
Interstate	0-9	2185	3589	2557	4041	1.04	1.76	0.187	no
Principal Art.		3283	2283	3480	2281	1.06	5.91	0.015	yes *
Minor Art.		6355	3203	7010	3184	1.11	36.83	0.000	yes *
Collector		3042	1433	3340	1494	1.05	4.27	0.039	yes *
Urban									
Interstate >50K	0	4420	4256	4557	4058	1.08	13.72	0.000	yes *
Interstate >50K	0-9	8501	4256	8221	4058	1.01	0.84	0.363	no
Other freeway		1303	615	1539	647	1.12	9.46	0.002	yes *
Principal Art.		27188	3696	28094	3686	1.04	17.40	0.000	yes *
Minor Art.		7265	995	7710	995	1.06	13.22	0.000	yes *
Collector		519	55	389	37	1.11	2.60	0.107	no

* Accident rate increased significantly.

Note: Urban areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 3-7
Weather Conditions Reported for Fatal Accidents

	Clear/Cloudy/Fog	Rain/Snow/Sleet	Total
Before Period	30	2	32
After Period	27	5	32
Total	57	7	64

Note: Before period is: March 1, 1987 - August 31, 1987
After period is: March 1, 1988 - August 31, 1988

Table 3-8
Surface Conditions Reported for Fatal Accidents

	Dry	Wet/Snowy/Icy	Total
Before Period	28	3	31
After Period	27	5	32
Total	55	8	63

Note: Before period is: March 1, 1987 - August 31, 1987
After period is: March 1, 1988 - August 31, 1988

Table 3-9
Weather Conditions Reported for All Accidents
For Mainline Rural Interstate Highways (Ramp Code 0)

	Clear	Cloudy	Rain/Snow/Sleet	Others	Total
Before Period	855	294	232	16	1,397
After Period	1,110	316	312	19	1,757
Total	1,965	610	544	35	3,154

Degrees of Freedom = 3   Chi-Square = 4.92   Not Significant ($\alpha=0.05$)

Note: Before period is: March 1, 1987 - August 31, 1987
After period is: March 1, 1988 - August 31, 1988

Table 3-10
Surface Conditions Reported for All Accidents
For Mainline Rural Interstate Highways (Ramp Code 0)

	Dry	Wet	Others	Total
Before Period	1,095	293	9	1,397
After Period	1,380	373	4	1,757
Total	2,475	666	13	3,154

Degrees of Freedom = 2   Chi-Square = 3.30   Not Significant ($\alpha=0.05$)

Note: Before period is: March 1, 1987 - August 31, 1987
After period is: March 1, 1988 - August 31, 1988

researchers found no evidence to indicate that precipitation could explain observed differences in accidents before and after the 65 mph speed limit.

Chapter 4
SAFETY EFFECTS OF THE MANDATORY SEAT BELT LAW IN GEORGIA

It will be recalled from Chapter 1 that the General Assembly of Georgia enacted a mandatory seat belt law that became effective on September 1, 1988. This chapter describes the results of five tasks that were performed to evaluate the safety effects of Georgia's seat belt law. These studies are identified in the research plan as:

Task 2. A Study of Fatal Accidents and Fatalities to Measure the Effects of the Mandatory Seat Belt Law

Task 4. A Study of Fatal Accidents and Fatalities to Measure the Combined Effects of the 65 mph Limit and Seat Belt Law

Task 6. A Study of Accident Severity to Measure the Combined Effects of the 65 mph Limit and Seat Belt Law

Task 8. A Study of Accident Severity to Measure the Effects of the Mandatory Seat Belt Law

Task 9. A Study of the Effect of the Seat Belt Law by Speed Limit Categories

A description of the results of these tasks follows a discussion of safety belt use in Georgia.

Safety Belt Use in Georgia

The Cooperative Extension Service of the University of Georgia has performed a comprehensive set of surveys on the use of automobile occupant protection devices in the State of Georgia (35). These surveys, which began in October, 1987, included a series of safety belt observation studies designed to estimate the the rate of safety belt use in private passenger vehicles. The observation sites were roadway intersections selected by probability sampling within three designated sampling strata:

Stratum 1 - the Atlanta Metropolitan Statistical Area (SMSA)

Stratum 2 - MSA's other than Atlanta (Athens, Augusta, Macon, Columbus, Albany, Savannah, and the Georgia portion of Chattanooga's MSA)

Stratum 3 - rural Georgia counties

These surveys showed an increase in safety belt use throughout the state following the passage of the mandatory seat belt law. Specifically, the following percentages of drivers were reported to be using safety belts:

July, 1987	20%
July, 1988	28%
September 1, 1988	Passage of seat belt law
October/November, 1989	40%
January/February, 1990	41%
April/May, 1990	46%

These observations are consistent with the results of opinion surveys conducted by the University in which 55% of Georgia drivers reported increasing their seat belt usage as a result of Georgia's seat belt law (36).

The University of Georgia researchers also reported (35):

1. More women drivers wear safety belts (32.8%) than do men drivers (24.3%).

2. Drivers who are white tend to wear belts more than nonwhite drivers (29.6% vs. 20.4%).

3. More drivers use safety belts (27.8%) than do front seat passengers (26.3%).

4. Safety belt usage overall is higher on the weekends than during the week.

5. Safety belt use is highest in the Atlanta SMSA (34.3%) and lowest in rural areas (20.5%).

In addition, special surveys have been conducted by the Cooperative Extension Service of safety belt use on segments of the Rural Interstate highways. These surveys were first conducted from July 20 through August 7, 1988, along exit ramps at 14 sites throughout the state. These studies have been replicated at quarterly intervals since that time. The July/August, 1988, surveys indicated that for travellers on the Rural Interstate system:

1. 37% of drivers observed were using safety belts.

2. 44% of all front seat passengers observed were using safety belts.

3. Female drivers used safety belts more than male drivers (44% vs. 33%).

4. White drivers wear safety belts more often than nonwhite drivers (38% vs. 26%).

5. Drivers of vans and cars wear safety belts more often than drivers of trucks.

6. Use of safety belts by drivers and passengers did not vary significantly by day of week.

These and subsequent surveys along the rural interstate system indicated a gradual increase in seat belt usage, possibly spurred by the passage of the mandatory seat belt law:

July/August, 1988	34%
September 1, 1988	Passage of seat belt law
October/November, 1989	44%
January/February, 1990	51%
April/May, 1990	50%

Safety Effects of Georgia's Seat Belt Law

Task 2

Task 2 of the research was designed to measure the effects of the mandatory seat belt law on the occurrence of fatal accidents and fatalities on each of the state functional classes of roadway. The study made a comparison of fatal accidents and fatalities for a six month before and a 6 month after period the seat belt law. The study periods used in the analysis were:

Before Period:	March 1, 1988 - August 31, 1988
After Period:	March 1, 1989 - August 31, 1989

The same six months of the year were used for the before and after periods to avoid seasonal effects. The accident data used for this task are included in the Appendix.

An additional study in this task examined changes in fatal accident rates and fatality rates between the study periods to account for possible effects of changing traffic volumes.

Method of Analysis. Statistical odds ratios were used to determined the statistical significance of differences between fatalities during the two study periods. Likewise, the differences between fatal accidents during the two study periods were analyzed in the same manner. Odds ratios were discussed in detail in Chapter 3. A brief discussion of their use in this task are included here.

The odds ratio is a measure of the degree of inequality between two events. It is equal to the odds of an event happening in a group divided by the odds of an event happening in a second group.

The analysis in Task 2 using odds ratios is based on the following hypothesis:

Odds Ratio = 1	No change
Odds Ratio > 1	Improved Condition
Odds Ratio < 1	Deteriorated Condition

The significance of the odds ratio is given by the Mantel Haenszel Chi-Square statistic and its P-value (34). A P-value less than 0.05 indicates that the odds ratio is statistically significant at a level of confidence greater than 95%. The 0.05 degree of significance was used in this analysis for the minimum level of acceptance of the hypothesis. If the P-value is greater than 0.05, the odds ratio is said not to be statistically significant, and the hypothesis is rejected. As mentioned previously in this report, while an odds ratio may not be statistically significant at the 95% confidence level, the odds ratio may indicate an important yet imprecisely measurable effect.

The control groups used to reflect trend in this study included all other state functional class roadways other than the analysis group during the same before and after time periods. The odds ratio reflecting trends for an analysis of fatalities is given by the following formula:

$$\text{Odds Ratio} = \frac{N_{fb}/N_{fa}}{N_{cb}/N_{ca}}$$

where

N_{fb} = Number of fatalities <u>before</u> the seat belt law in the <u>analysis</u> group.

N_{fa} = Number of fatalities <u>after</u> the seat belt law in the <u>analysis</u> group.

N_{cb} = Number of fatalities <u>before</u> the seat belt law in the <u>control</u> group.

N_{ca} = Number of fatalities <u>after</u> the seat belt law in the <u>control</u> group.

Incidence density ratios (IDRs) were used to compare fatal accident rates and fatality rates during the before and after periods. IDRs are further discussed in Chapter 3. For Task 2, the incidence density ratio for fatal accidents is the number of fatal accidents per vehicle miles traveled (VMT) in the before period divided by the number of accidents per VMT in the after period. We hypothesize in this analysis that if:

IDR = 1 No change
IDR < 1 Improved Condition
IDR > 1 Deteriorated Condition

An incident density ratio equal to 1.10, would thus represent a ten percent increase in the fatal accident rate between the before and after periods. The significance of the value of the incidence density ratio varies depending on the number of accidents but is not affected by the magnitude of VMT.

VMT data were available in the form of average daily VMT for a year. Using the same process discussed in Task 7, monthly factors were applied to the annual data to produce average daily VMT's on a monthly basis. To calculate the total VMT for a six month study period, the average daily VMT for a month was multiplied by the number of days for that month, and the resultant monthly VMT's were added. Thus, the total VMT for the six month study period for a particular functional class would be equal to:

(VMT for March X 31 Days in March)
+ (VMT for April X 30 Days in April)
+ (VMT for May X 31 of Days in May)
+ (VMT for June X 30 of Days in June)
+ (VMT for July X 31 of Days in July)
+ (VMT for August X 31 of Days in August)

<u>Results</u>. Results for the odds ratio analysis done for Task 2 are summarized for fatalities in Table 4-1 and for fatal accidents in Table 4-2. Multiple scenarios were analyzed for the freeway functional classes. These included analyzing just the mainline segments and the mainline segments in conjunction with ramp areas (gore area, bottom of ramp, etc.). In analyzing the effects of the seat belt law, the researchers were looking for decreases in fatalities or fatal accidents that may have occurred which could possibly be attributed to increased seat belt usage.

The results given in Tables 4-1 and 4-2 fail to show significant changes in the number of fatalities and fatal accidents between the before and after periods at a confidence level greater than 95th percentile. It is of interest, however, that some of the rural interstate and urban interstate tests showed significant <u>increases</u> in the number of fatalities and fatal accidents at a 90 percent confidence level. It is also noteworthy that in 11 of 14 tests, the fatality and fatal accident occurrences increased. The Rural Interstate functional classes showed increases in fatalities as great as 60% between the before and after periods. Because the increases were most apparent in the higher speed functional classes, the researchers looked for possible changes in the distribution of speeds during these periods for the Rural Interstate and Urban Interstate functional classes to try to account for the fatality and fatal accident increases. No differences in either the average or 85th percentile speeds between the before and after periods were apparent.

While no positive effects of the seat belt law could be observed on the rural interstate and urban interstate functional classes, some interesting observations can be made on some of the arterial roads. For example, the Urban Principal Arterial roads showed a near significant (alpha = 0.067) decrease in fatalities. Increased seat belt usage could be a contributing factor to this. However, other arterial roads showed increases in fatal accidents

Table 4-1
TASK 2 RESULTS
Fatalities

Functional Class	Ramp Code	Fatalities Before	Fatalities After	Percent Change	Odds Ratio	Mantel-Haenstel Chi-Square	P-Value	Significance alpha = 0.05
RURAL								
Interstate	0	42	67	59.5	0.67	3.73	0.053	close
Interstate	0,1	47	70	48.9	0.72	2.75	0.097	no
Interstate	0,1,2	48	71	47.9	0.72	2.68	0.101	no
Interstate	0,1,2,3	52	72	38.5	0.77	1.78	0.182	no
Principal Art.		74	95	28.4	0.80	1.7	0.193	no
Minor Arterial		125	120	-4.0	1.16	0.98	0.322	no
Collector		76	94	23.7	0.84	1.08	0.298	no
Local Roads		2	0		undefined	Values too small		no
URBAN								
Interstate	0	27	40	48.1	0.70	1.92	0.166	no
Interstate	0,1	30	46	53.3	0.68	2.58	0.108	no
Interstate	0,1,2	31	48	54.8	0.67	2.8	0.094	no
Interstate	0,1,2,3	35	51	45.7	0.71	2.2	0.138	no
Other Freeway		10	5	-50.0	2.17	2.06	0.152	no
Principal Art.		101	85	-15.8	1.35	3.35	0.067	close
Minor Arterial		17	24	41.2	0.75	0.8	0.370	no
Collector		3	0		undefined	Values too small		no
Local Roads		0	0		undefined	Values too small		no

<u>Ramp Codes</u>
0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1988 - August 31, 1988
After period is: March 1, 1989 - August 31, 1989

Table 4-2
TASK 2 RESULTS
Fatal Accidents

Functional Class	Ramp Code	Fatal Accidents Before	Fatal Accidents After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-Value	Significance alpha = 0.05
RURAL								
Interstate	0	34	51	50.0	0.68	2.77	0.096	no
Interstate	0,1	35	54	54.3	0.66	3.31	0.069	close
Interstate	0,1,2	36	55	52.8	0.67	3.27	0.070	close
Interstate	0,1,2,3	40	56	40.0	0.73	2.1	0.147	no
Principal Art.		65	76	16.9	0.85	0.79	0.374	no
Minor Arterial		109	95	-12.8	1.24	0.17	0.193	no
Collector		69	80	15.9	0.85	0.74	0.388	no
Local Roads		0	0		undefined	Values too small		no
URBAN								
Interstate	0	26	35	34.6	0.74	1.29	0.256	no
Interstate	0,1	29	40	37.9	0.72	1.68	0.195	no
Interstate	0,1,2	30	42	40.0	0.71	1.91	0.167	no
Interstate	0,1,2,3	34	45	32.4	0.75	1.46	0.227	no
Other Freeway		10	5	-50.0	2.07	1.8	0.180	no
Principal Art.		90	79	-12.2	1.21	1.21	0.271	no
Minor Arterial		16	22	37.5	0.73	0.87	0.351	no
Collector		1	0		undefined	Values too small		no
Local Roads		0	0		undefined	Values too small		no

Ramp Codes
- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1988 - August 31, 1988
   After period is: March 1, 1989 - August 31, 1989

and fatalities (e.g. Rural Principal Arterial, Urban Minor Arterial).

The researchers compared the fatality-to-fatal accident ratios experienced during the before period to those experienced in the after period. It was hypothesized that the life-saving effects of greater seat belt use would be manifest in a decrease in the fatality-to-fatal accident ratios. As Table 4-3 shows, no decreasing pattern in the ratios was noted.

The results of the analysis of fatality and fatal accident rates for Task 2 are shown, respectively, in Tables 4-4 and 4-5. Only one incidence density ratio, that for the Rural Interstate system (ramp code 0), showed a significant change, and that change resulted from an increase in the fatality rate. It is also interesting to note that in 11 of 14 functional classes, the fatality and fatal accident rates increased between the before and after periods. (The IDR values were greater than 1.0.) From this and the odds-ratio analyses, it is concluded that whatever positive effect there was due to increased seat belt use was obscured by greater, but unknown, negative impacts that caused the fatal and fatal accident rates to increase.

<u>Task 4</u>

Task 4 of the research was designed to measure the combined effects of the 65 MPH speed limit and the mandatory seat belt law on the occurrence of fatal accidents and fatalities on each of the functional classes of roadway. The study made a comparison of fatal accidents and fatalities in 1987 (before either law had been passed) to similar data for 1989 (after both laws had been passed). The accident data used for this task are included in the Appendix.

An additional study in this task examined changes in fatal accident rates and fatality rates between the study periods to account for possible effects of changing traffic volumes.

<u>Method of Analysis</u>. Statistical odds ratios were again used to determine the statistical significance of differences between fatalities and fatal accidents during the two study periods.

The analysis in Task 4 using odds ratios is based on the same hypothesis of Task 2, that is:

Odds Ratio = 1	No change
Odds Ratio > 1	Improved Condition
Odds Ratio < 1	Deteriorated Condition

The control groups used to reflect trend in this study included fatality or fatal accident data for all other state functional class roadways other than the analysis group during 1987 and 1989 time periods.

Table 4-3
FATALITY TO FATAL ACCIDENT RATIOS
by Functional Class

Functional Class	Before Seat Belt Law (3/1/88 - 8/31/88)	After Seat Belt Law (3/1/89 - 8/31/89)	Change in Percent After Seat Belt Law
Rural Roadways			
Interstate - Ramp Code 0,1,2,3	1.30	1.29	-1
Other Principal Arterial	1.14	1.25	10
Minor Arterial	1.15	1.26	10
Collector	1.10	1.18	7
Local	2.00	N/A	N/A
Urban Roadways			
Interstate - Ramp 0,1,2,3	1.03	1.13	10
Other Freeway	1.00	1.00	0
Other Principal Arterial	1.12	1.08	-4
Minor Arterial	1.06	1.09	3
Collector	3.00	N/A	N/A
Local	N/A	N/A	N/A

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Table 4-4
TASK 2 RESULTS
Incidence Density Analysis on Fatality Rates

Functional Class	Ramp code	Before Seat Belt (3/1/88 - 8/31/88) Fat.	Before Seat Belt (3/1/88 - 8/31/88) VMT (millions)	After Seat Belt (3/1/89 - 8/31/89) Fat.	After Seat Belt (3/1/89 - 8/31/89) VMT (millions)	IDR	Mantel-Haenszel Chi-Square	P-value	Significant at Alpha = .05
Rural									
Interstate	0	42	4041	67	4330	1.49	4.14	0.042	yes *
Interstate	0,1	47	4041	70	4330	1.39	3.08	0.080	no
Interstate	0,1,2	48	4041	71	4330	1.38	3.00	0.084	no
Interstate	0,1,2,3	52	4041	72	4330	1.29	2.00	0.159	no
Principal Art.		74	2281	95	2404	1.22	1.62	0.204	no
Minor Art.		125	3184	120	3263	0.94	0.26	0.610	no
Collector		76	1494	94	1552	1.19	1.28	0.258	no
Urban									
Interstate >50K	0	27	4058	40	4415	1.36	1.55	0.215	no
Interstate >50K	0,1	30	4058	46	4415	1.41	2.16	0.144	no
Interstate >50K	0,1,2	31	4058	48	4415	1.42	2.37	0.126	no
Interstate >50K	0,1,2,3	35	4058	51	4415	1.34	1.78	0.184	no
Other freeway		10	647	5	705	0.46	2.13	0.147	no
Principal Art.		101	3686	85	3766	0.82	1.74	0.190	no
Minor Art.		17	995	24	994	1.41	1.20	0.276	no
Collector		3	37	0	20		Values too small		

* Accident rate increased significantly.
** Accident rate decreased significantly.

Note: Urban Interstate roadways in areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 4-5
TASK 2 RESULTS
Incidence Density Analysis on Fatal Accident Rates

Functional Class Code Name	Ramp code	Before Seat Belt (3/1/88 - 8/31/88) Fatal Acc.	Before Seat Belt (3/1/88 - 8/31/88) VMT (millions)	After Seat Belt (3/1/89 - 8/31/89) Fatal Acc.	After Seat Belt (3/1/89 - 8/31/89) VMT (millions)	IDR	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-value	Significant at Alpha = .05
Rural									
Interstate	0	34	4041	51	4330	1.40	2.33	0.129	no
Interstate	0,1	35	4041	54	4330	1.44	2.85	0.093	no
Interstate	0,1,2	36	4041	55	4330	1.43	2.77	0.097	no
Interstate	0,1,2,3	40	4041	56	4330	1.31	1.68	0.197	no
Principal Art.		65	2281	76	2404	1.11	0.38	0.542	no
Minor Art.		109	3184	95	3263	0.85	1.33	0.250	no
Collector		69	1494	80	1552	1.12	0.45	0.509	no
Urban									
Interstate >50K	0	26	4058	35	4415	1.24	0.68	0.412	no
Interstate >50K	0,1	29	4058	40	4415	1.27	0.95	0.332	no
Interstate >50K	0,1,2	30	4058	42	4415	1.29	1.12	0.294	no
Interstate >50K	0,1,2,3	34	4058	45	4415	1.22	0.75	0.390	no
Other freeway		10	647	5	705	0.46	2.13	0.147	no
Principal Art.		90	3686	79	3766	0.86	0.97	0.327	no
Minor Art.		16	995	22	994	1.38	0.95	0.332	no
Collector		1	37	0	20		Values too small		

* Accident rate increased significantly.
** Accident rate decreased significantly.

Note: Urban Interstate roadways in areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Incidence density ratios (IDRs) were used to compare fatal accident rates and fatality rates during the before and after periods. In this analysis, it was hypothesized that if:

IDR = 1	No change
IDR < 1	Improved Condition
IDR > 1	Deteriorated Condition

VMT data were available in the form of average daily VMT for a year. Using the same process discussed in Task 7, monthly factors were applied to the annual data to produce average daily VMTs on a monthly basis for the entire year.

Results. Results for the odds ratio analysis done for Task 4 are summarized for fatalities in Table 4-6 and for fatal accidents in Table 4-7. Multiple scenarios were analyzed for the freeway functional classes. These included analyzing just the mainline segments and the mainline segments in conjunction with ramp areas (gore area, bottom of ramp, etc.).

The mainline Rural Interstate system showed an increase in fatal accidents of 44 percent between the before and after periods, while all other roadways showed an overall decrease of about 4 percent. This increase was statistically significant.

The results for the analysis of fatalities were more striking. Those studies revealed that mainline Rural Interstate highways showed a significant increase in fatalities of approximately 60 percent between the before and after periods. In contrast, for all other highways, there was an overall decrease in fatalities of about 1 percent.

The results of the analysis of fatality and fatal accident rates for Task 4 are shown in Tables 4-8 and 4-9. None of the tests shown in these tables was statistically significant (P-value < 0.05). Nevertheless, the tables give an interesting insight into the combined effects of the 65 mph speed limit and the mandatory seat belt law. For example, the IDR values for the mainline Rural Interstate System were 1.19 and 1.32 for fatal accident and fatality rates, respectively. For the remaining systems, the IDR values were less than or only slightly greater than 1.0.

These results paralleled those for the odds ratio analyses. For the Rural Interstate system, the only system which experienced the higher speed limit, the results revealed a large increase in fatal accident and fatality rates. For all other highway classes, the results showed a decrease or only a small increase in fatal accident and fatality rates. These tests appear to reveal both the hazard of higher speeds as well as the benefits of increased seat belt use.

Task 6

Task 6 is a study of accident severity to measure the combined effects of the 65 mph limit and the seat belt law using police

Table 4-6
TASK 4 RESULTS
Fatalities

Functional Class	Ramp Code	Fatalities Before	Fatalities After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-Value	Significance alpha =0.05
RURAL								
Interstate	0	67	107	59.7	0.62	8.93	0.0028	yes
Interstate	0,1	73	110	50.7	0.65	7.29	0.007	yes
Interstate	0,1,2	73	111	52.1	0.65	7.64	0.006	yes
Interstate	0,1,2,3	79	114	44.3	0.68	6.2	0.013	yes
Principal Art.		187	178	-4.8	1.05	0.14	0.704	no
Minor Arterial		270	262	-3.0	1.02	0.05	0.823	no
Collector		140	167	19.3	0.80	3.28	0.070	close
Local Roads		3	3		0.99	Values too small		no
URBAN								
Interstate	0	64	70	9.4	0.90	0.36	0.547	no
Interstate	0,1	82	79	-3.7	1.02	0.01	0.909	no
Interstate	0,1,2	83	87	4.8	0.99	0.00	0.965	no
Interstate	0,1,2,3	90	92	2.2	0.96	0.07	0.795	no
Other Freeway		22	12	-45.5	1.83	2.86	0.091	no
Principal Art.		187	182	-2.7	1.02	0.02	0.885	no
Minor Arterial		60	53	-11.7	1.12	0.37	0.5457	no
Collector		5	0		undefined	Values too small		no
Local Roads		0	1		0.00	Values too small		no

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: January 1, 1987 - December 31, 1987
   After period is: January 1, 1989 - December 31, 1989

Table 4-7
TASK 4 RESULTS
Fatal Accidents

Functional Class	Ramp Code	Fatal Accidents Before	Fatal Accidents After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-Value	Significance alpha = 0.05
RURAL								
Interstate	0	59	85	44.1	0.67	5.38	0.020	yes
Interstate	0,1	64	88	37.5	0.70	4.46	0.035	yes
Interstate	0,1,2	64	89	39.1	0.69	4.76	0.029	yes
Interstate	0,1,2,3	68	92	35.3	0.71	4.27	0.039	yes
Principal Art.		154	147	-4.5	0.93	0.32	0.571	no
Minor Arterial		233	207	-11.2	1.11	0.87	0.352	no
Collector		122	142	16.4	0.79	2.94	0.086	no
Local Roads		2	3		0.64	Values too small		no
URBAN								
Interstate	0	61	61	0.0	0.96	0.05	0.836	no
Interstate	0,1	79	69	-12.7	1.10	0.3	0.587	no
Interstate	0,1,2	80	77	-3.8	1.00	0.00	0.985	no
Interstate	0,1,2,3	86	82	-4.7	1.01	0.00	0.970	no
Other Freeway		21	12	-42.9	1.70	2.13	0.144	no
Principal Art.		170	171	0.6	0.94	0.25	0.620	no
Minor Arterial		56	49	-12.5	1.10	0.23	0.6290	no
Collector		5	0		undefined	Values too small		no
Local Roads		0	1		0.00	Values too small		no

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: January 1, 1987 - December 31, 1987
After period is: January 1, 1989 - December 31, 1989

Table 4-8
TASK 4 RESULTS
Incidence Density Analysis on Fatality Rates

Functional Class Code Name	Ramp code	Before 65 MPH/Belt (1/1/87 - 12/31/87) Acc.	VMT (millions)	After 65 MPH/Belt (1/1/89 - 12/31/89) Acc.	VMT (millions)	IDR	Mantel-Haenszel Chi-Square	P-value	Significant at Alpha = .05
Rural									
Interstate	0	67	7609	107	9181	1.32	3.26	0.072	no
Interstate	0,1	73	7609	110	9181	1.25	2.18	0.142	no
Interstate	0,1,2	73	7609	111	9181	1.26	2.37	0.126	no
Interstate	0,1,2,3	79	7609	114	9181	1.20	1.50	0.222	no
Principal Art.		187	4702	178	4950	0.90	0.93	0.337	no
Minor Art.		270	6597	262	6720	0.95	0.31	0.582	no
Collector		140	2951	167	3195	1.10	0.72	0.400	no
Urban									
Interstate >50K	0	64	8970	70	9306	1.05	0.09	0.764	no
Interstate >50K	0,1	82	8970	79	9306	0.93	0.22	0.646	no
Interstate >50K	0,1,2	83	8970	74	9306	0.86	0.90	0.347	no
Interstate >50K	0,1,2,3	90	8970	92	9306	0.99	0.01	0.928	no
Other freeway		22	1234	12	1413	0.48	4.47	0.035	yes *
Principal Art.		187	7412	182	7552	0.96	0.19	0.660	no
Minor Art.		60	1996	53	1993	0.88	0.42	0.516	no
Collector		5	110	0	39		Values too small		

* Accident rate decreased significantly.

Note: Urban Interstate roadways in areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 4-9
TASK 4 RESULTS
Incidence Density Analysis on Fatal Accident Rates

Functional Class Code Name	Ramp code	Before 65 MPH/Belt (1/1/87 - 12/31/87) Acc.	Before 65 MPH/Belt (1/1/87 - 12/31/87) VMT (millions)	After 65 MPH/Belt (1/1/89 - 12/31/89) Acc.	After 65 MPH/Belt (1/1/89 - 12/31/89) VMT (millions)	IDR	Mantel-Haenszel Chi-Square	P-value	Significant at Alpha = .05
Rural									
Interstate	0	59	7609	85	9181	1.19	1.10	0.300	no
Interstate	0,1	64	7609	88	9181	1.14	0.63	0.430	no
Interstate	0,1,2	64	7609	89	9181	1.15	0.75	0.390	no
Interstate	0,1,2,3	68	7609	92	9181	1.12	0.51	0.478	no
Principal Art.		154	4702	147	4950	0.91	0.72	0.400	no
Minor Art.		233	6597	207	6720	0.87	2.05	0.153	no
Collector		122	2951	142	3195	1.08	0.34	0.562	no
Urban									
Interstate >50K	0	61	8970	61	9306	0.96	0.04	0.841	no
Interstate >50K	0,1	79	8970	69	9306	0.84	1.09	0.298	no
Interstate >50K	0,1,2	80	8970	68	9306	0.82	1.46	0.226	no
Interstate >50K	0,1,2,3	86	8970	82	9306	0.92	0.30	0.589	no
Other freeway		21	1234	12	1413	0.50	3.84	0.051	close
Principal Art.		170	7412	171	7552	0.99	0.01	0.912	no
Minor Art.		56	1996	49	1993	0.88	0.46	0.500	no
Collector		5	110	0	39		Values too small		

Note: Urban Interstate roadways in areas with population less than 50,000 have been included in the Rural Interstate scenarios.

report injury codes. This is a companion task to Task 4 with the same before and after periods. This analysis compares the magnitude of severity data for the entire year in 1987 to the same data for 1989. A summary of the severity data is given in Table 4-10.

Method of Analysis. Statistical odds ratios were used to analyze changes in accident severity data. Severity data used in this analysis include fatalities, visible injuries and complaint of injuries. These data were summed in the before and after periods and the resultant totals were compared using the same odds ratio procedure discussed in previous tasks.

Results. The results of this analysis are given in Table 4-11. This table shows that there were extremely significant increases (P-value < 0.0001) in the number of injuries and fatalities on both the Rural Interstate and the Urban Interstate systems between the before and after periods. The odds ratios for a number of other functional classes also indicate significant changes during the after period, both positive and negative.

It is interesting to note that the mainline Rural Interstate Highways showed a 28.9 percent increase in reported injuries between the 1987 before period and the 1989 after period, while all other highways experienced only a 7.8 percent increase. This difference is best explained by the increase in the speed limit which applied only to the Rural Interstate System.

The Rural Minor Arterial roads experienced a significant increase in reported injuries, but the percentage increase was lower than that shown for any of the other rural systems.

With the exception of Local Roads, all of the urban non-interstate highways experienced either a decrease or a small increase in reported injuries. The significant increases in reported injuries for rural and urban Local Roads parallel large increases in vehicle miles of travel (VMT) for these systems.

The reason for the sharp decrease in injuries reported for Urban Collector roads is uncertain, but could be explained in part by greater seat belt usage, since it is known that seat belt usage is greater in urban areas (35).

Task 8

Task 8 of the research was designed to measure the effects of the mandatory seat belt law on the severity of accidents on each of the state functional classes of roadway. For this task, the researchers compared the number of injuries reported (fatalities, visible injuries, and complaint of injuries) in the before period to those reported in the after period. The study periods used in the analysis were:

Table 4-10
SUMMARY OF ACCIDENT SEVERITY DATA
Complaint of injury, visible injury and fatalities

Functional Class Code Name	Ramp code	Before 65 MPH & Seat Belt (1/1/87 - 12/31/87) Comp. inj.	Vis. inj.	Fatal-ities	After 65 MPH & Seat Belt (1/1/89 - 12/31/89) Comp. inj.	Vis. inj.	Fatal-ities
Rural							
Interstate	0	740	996	67	1020	1197	107
Interstate	0,1	770	1037	73	1065	1265	110
Interstate	0,1,2	783	1044	73	1088	1288	111
Interstate	0,1,2,3	998	1269	77	1258	1416	114
Principal Art.		1911	2304	187	2361	2328	178
Minor Art.		3747	4095	270	4254	3976	262
Collector		1679	2298	140	1943	2327	167
Local		4	17	3	23	26	3
Urban							
Interstate >50K	0	2147	1350	64	3209	1743	70
Interstate >50K	0,1	2793	1745	82	3719	1986	79
Interstate >50K	0,1,2	2874	1797	83	3971	2137	87
Interstate >50K	0,1,2,3	4012	2306	89	4687	2379	92
Other freeway		650	410	21	660	398	12
Principal Art.		13381	7771	187	15141	7566	182
Minor Art.		3970	2280	60	4620	2102	53
Collector		249	154	5	114	56	0
Local		16	9	0	31	17	1

Note: Urban areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 4-11
TASK 6 RESULTS
Accident Severity

Functional Class	Ramp Code	Totals of Injuries & Fatalities Before	Totals of Injuries & Fatalities After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	Mantel-Haenszel P-Value	Significance alpha = 0.05
RURAL								
Interstate	0	1803	2324	28.9	0.83	34.82	0.0000	yes
Interstate	0,1	1880	2404	27.9	0.83	33.13	0.0000	yes
Interstate	0,1,2	1900	2451	29.0	0.83	36.95	0.0000	yes
Interstate	0,1,2,3	2344	2735	16.7	0.92	9.52	0.0020	yes
Principal Art.		4402	4867	10.6	0.96	3.09	0.0787	no
Minor Arterial		8112	8397	3.5	1.04	4.65	0.0310	yes
Collector		4117	4437	7.8	0.99	0.21	0.6505	no
Local Roads		24	52	116.7	0.49	8.6	0.0034	yes
URBAN								
Interstate	0	3561	4504	26.5	0.84	56.92	0.0000	yes
Interstate	0,1	4620	5784	25.2	0.83	77.82	0.0000	yes
Interstate	0,1,2	4754	6195	30.3	0.81	102.56	0.0000	yes
Interstate	0,1,2,3	6407	7158	11.7	0.95	7.97	0.0049	yes
Other Freeway		1081	1070	-1.0	1.08	3.30	0.0691	no
Principal Art.		21339	22889	7.3	0.99	0.41	0.5229	no
Minor Arterial		6310	6775	7.4	0.99	0.12	0.7301	no
Collector		408	170	-58.3	2.57	114.03	0.0000	yes
Local Roads		25	49	96.0	0.54	6.30	0.0120	yes

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: January 1, 1987 - December 31, 1987
   After period is: January 1, 1989 - December 31, 1989

Before Period: March 1, 1988 - August 31, 1988
After Period: March 1, 1989 - August 31, 1989

The same six months of the year were used for the before and after periods to avoid seasonal effects. A summary of the severity data is given in Table 4-12.

Method of Analysis. Statistical odds ratios were used to analyze changes in accident severity data. Severity data used in this analysis include fatalities, visible injuries and complaint of injuries. These data were summed in the before and after periods and the resultant totals were compared using the same odds ratios.

Results. The results of this analysis are given in Table 4-13. As expected, significant decreases in reported injuries were reported for the Rural Interstate, the Rural Minor Arterial, and Urban Collector systems. Though not statistically significant, a decrease was also noted for the Urban other Freeway system.

Extremely significant increases (P-value < 0.0001) in the number of injuries were noted for the Urban Interstate system. Because the average and 85th percentile speeds during the study periods showed little change, the researchers are uncertain as to the cause of these significant increases.

A significant increase in injuries were also noted for the Urban Local roads, but because of the small numbers, this effect, which likely is explained by increased travel, is of little consequence.

Thus, the results of the analyses performed for this task were inconsistent, showing possible benefits from increased seat belt usage in four systems, but little change in others and puzzling increases in injuries reported for the Urban Interstate system.

Study of Effect of Seat Belt Law by Speed Limit Categories

As Task 9, the researchers performed a special study to test the hypothesis that the mandatory seat belt law would be more effective on roads zoned for higher speeds.

Task 9

This study consisted of before and after comparisons of fatal accidents, fatalities, and injuries for various speed limit categories. The study periods used were:

Before period: March 1, 1988 - August 31, 1988
After period: March 1, 1989 - August 31, 1989

In other words, the before period was the six-month period immediately before the implementation of the mandatory seat belt law, and the after period was the corresponding period in the following year.

Table 4-12
SUMMARY OF ACCIDENT SEVERITY DATA
Complaint of injury, visible injury and fatalities

Functional Class Code Name	Ramp code	Before Seat Belt (3/1/88 - 8/31/88) Comp. inj.	Vis. inj.	Fatal-ities	After Seat Belt (3/1/89 - 8/31/89) Comp. inj.	Vis. inj.	Fatal-ities
Rural							
Interstate	0	598	722	42	578	676	67
Interstate	0,1	623	755	47	596	689	70
Interstate	0,1,2	631	758	48	603	710	71
Interstate	0,1,2,3	756	860	52	659	701	72
Principal Art.		1140	1197	74	1171	1274	95
Minor Art.		2111	2283	125	2100	2132	120
Collector		882	1217	76	945	1249	94
Local		7	7	2	11	12	0
Urban							
Interstate >50K	0	1206	720	27	1650	930	40
Interstate >50K	0,1	1539	924	30	1947	1065	46
Interstate >50K	0,1,2	1575	966	31	2086	1143	48
Interstate >50K	0,1,2,3	2019	1174	35	2451	1279	51
Other freeway		314	256	10	326	219	5
Principal Art.		7120	4013	101	7439	3887	85
Minor Art.		2051	1139	17	2261	1025	24
Collector		81	64	3	67	28	0
Local		3	3	0	10	7	0

Note: Urban areas with population less than 50,000 have been included in the Rural Interstate scenarios.

Table 4-13
TASK 8 RESULTS
Accident Severity

Functional Class	Ramp Code	Totals of Injuries & Fatalities Before	After	Percent Change	Odds Ratio	Mantel-Haenszel Chi-Square	P-Value	Significance alpha = 0.05
RURAL								
Interstate	0	1362	1321	-3.0	1.06	2.36	0.1244	no
Interstate	0,1	1425	1355	-4.9	1.08	4.29	0.0383	yes
Interstate	0,1,2	1437	1384	-3.7	1.07	3.08	0.0792	no
Interstate	0,1,2,3	1668	1501	-10.0	1.15	13.78	0.0002	yes
Principal Art.		2411	2540	5.4	0.98	0.65	0.4186	no
Minor Arterial		4519	4352	-3.7	1.08	12.13	0.0005	yes
Collector		2175	2288	5.2	0.98	0.51	0.4759	no
Local Roads		16	23	43.8	0.72	1.06	0.3043	no
URBAN								
Interstate	0	1953	2620	34.2	0.75	81.9	0.0000	yes
Interstate	0,1	2493	3064	22.9	0.82	45.81	0.0000	yes
Interstate	0,1,2	2572	3277	27.4	0.79	68.63	0.0000	yes
Interstate	0,1,2,3	3228	3781	17.1	0.86	32.64	0.0000	yes
Other Freeway		580	550	-5.2	1.09	2.00	0.1573	no
Principal Art.		11234	11411	1.6	1.02	2.01	0.1587	no
Minor Arterial		3207	3310	3.2	1.00	0.00	0.9506	no
Collector		148	95	-35.8	1.61	13.27	0.0003	yes
Local Roads		6	17	183.3	0.36	4.94	0.0263	yes

Notes:
1. Urban areas < 50,000 population have been included in the Rural Interstate scenarios.
2. Before period is: March 1, 1988 - August 31, 1988
   After period is: March 1, 1989 - August 31, 1989

It will be recalled from Chapter 1 that studies by the Cooperative Extension Service of the University of Georgia indicated that overall seat belt usage throughout the state increased from 28 percent to 40 percent following the passage of the mandatory seat belt law. Variations in usage were found due to type of area (rural vs. urban), class of roadway, gender and race of driver, and day of the week.

It was expected that any positive benefits from increased seat belt usage would be greatest for those roadways zoned for higher speeds. To test this hypothesis the fatal accident data were stratified by speed limit categories, and the distribution of fatal accidents for the "before" period was compared with the corresponding distribution for the "after" period. Similar comparisons were made for the distributions of fatalities and injuries.

Method of Analysis. The statistical method of analysis used in this task was a ridit analysis. The ridit analysis takes advantage of the natural ordering of categories of speed data. Virtually the only assumption made in a ridit analysis is that the categories represent intervals of an underlying but unobservable continuous distribution. No assumption is made about normality or any other form for the distribution.

Ridit analysis is due to Bross (37) and has been applied to the study of automobile accidents (38) as well as in fields of epidemiology (34). The method involves the derivation of ridits for each of the categories. The ridit for a category is nothing more than the proportion of all subjects from the reference group (the before period) falling in the lower ranking categories plus half the proportion falling in the given category.

Given the distribution of any other group over the same categories, the mean ridit for that group may be calculated. The resulting mean value is interpretable as a probability. The mean ridit for the reference group is always 0.50. By comparing the mean ridits for the reference group and the comparison group (after period) conclusions can be made as to the changes in the distribution of injury accidents over the different speed categories. If the mean ridit for the comparison group is greater than 0.50, then more than half of the time a randomly selected subject from it will have a more extreme value than a randomly selected subject from the reference group. In our analysis, we would infer that the after period tends to sustain more injuries at higher speeds than before. If the after period's mean ridit is less than 0.50, we would infer that the distribution of accidents tend to be at lower speeds than those of the before period.

Results. The results of the ridit analyses are shown in Tables 4-14, 4-15, and 4-16. The analyses failed to confirm the hypothesis that the seat belt law was more effective for roadways zoned for higher speeds. In only one instance, the test of the distributions of the number of reported injuries on urban roadways,

Table 4-14
Results for Task 9 - Ridit Analysis
NUMBER OF FATAL ACCIDENTS STRATIFIED BY SPEED LIMIT CATEGORIES

Speed Limit Category	Rural Before	Rural After	Urban Before	Urban After
< 30 MPH	1	2	0	0
30,35,40	22	18	40	30
45,50	13	30	37	44
55,60	208	259	79	81
> 60 MPH	37	68	1	0
Mean Ridit	0.521		0.518	
M-H Chi-Square	1.356		0.370	
P-value	0.246		0.548	
Significant at α=.05	No		No	

Note: Before period is: March 1, 1988 - August 31, 1988
After period is: March 1, 1989 - August 31, 1989

Table 4-15
Results for Task 9 - Ridit Analysis
NUMBER OF FATALITIES STRATIFIED BY SPEED LIMIT CATEGORIES

Speed Limit Category	Rural		Urban	
	Before	After	Before	After
< 30 MPH	1	2	0	0
30,35,40	24	18	44	31
45,50	14	30	42	46
55,60	238	259	85	93
> 60 MPH	49	68	1	0
Mean Ridit	0.510		0.534	
M-H Chi-Square	0.295		1.446	
P-value	0.589		0.230	
Significant at α=.05	No		No	

Note: Before period is: March 1, 1988 - August 31, 1988
After period is: March 1, 1989 - August 31, 1989

Table 4-16
Results for Task 9 - Ridit Analysis
NUMBER OF INJURIES STRATIFIED BY SPEED LIMIT CATEGORIES

Speed Limit Category	Rural Before	Rural After	Urban Before	Urban After
< 30 MPH	97	101	68	67
30,35,40	1,195	987	6,639	6,464
45,50	1,157	1,271	5,804	6,396
55,60	6,669	6,844	6,111	6,487
> 60 MPH	1,511	1,341	10	5
Mean Ridit	0.499		0.510	
M-H Chi-Square	0.146		12.162	
P-value	0.704		0.0006	
Significant at α=.05	No		Yes	

Note: Before period is: March 1, 1988 - August 31, 1988
After period is: March 1, 1989 - August 31, 1989

was there a significant difference in the before and after distributions. In that case, the direction of the change in the distribution was unexpected; that is, a <u>larger</u> proportion of injuries occurred on the high speed roadways <u>after</u> the passage of the seat belt law. This unexpected pattern was apparent in four of the five remaining analyses as evidenced by mean ridit values > 0.50.

There are a number of possible extraneous but unidentified confounding factors that could have affected the results of the ridit analyses for this task including an overall increasing trend in prevailing speeds and differences in the mix of accident types among the speed limit categories.

To summarize the results of Task 9, the researchers found no evidence to conclude that the seat belt law was more effective on roadways zoned for higher speeds.

Chapter 5

TIME SERIES ANALYSES

Thus far, most of the statistical analyses described in the previous chapters concentrated on before and after studies to determine safety effects of the 65 MPH speed limit and the seat belt law. But there are a number of shortcomings that can be associated with before and after statistical comparisons. First, there is uncertainty that a control group can adequately represent accident trends even if the before and after periods are derived from the same seasons. Recall that the odds ratio reflecting trends for an analysis of fatalities is given by the following formula:

$$\text{Odds Ratio} = \frac{N_{fb}/N_{fa}}{N_{cb}/N_{ca}}$$

where:

N_{fb} = Number of fatalities during the before period for the analysis group.

N_{fa} = Number of fatalities during the after period for the analysis group.

N_{cb} = Number of fatalities during the before period for the control group.

N_{ca} = Number of fatalities during the after period for the control group.

In the odds ratio procedure, the denominator of the odds ratio equation represents trend. Thus a denominator equal to one would indicate that there is no trend. But this does not necessarily have to be the case. If, for example during a before period, the control group actually had steadily decreasing monthly values, while in the after period the control group shifted to steadily increasing monthly values, trend would obviously be present. However, in this scenario the denominator could be equal to one which would incorrectly give the impression that no trend was present.

Secondly, when an odds ratio procedure is used to compare accidents before and after a preventive measure, it is assumed that the moment of intervention is known. While the dates of the intervention may be well defined, driver tendencies will dictate when the actual effect of the intervention takes place.

To support any conclusions drawn from the before and after analyses, the researchers performed time series analyses on accident data dating back to 1983. Three different types of data were analyzed. They were fatal accidents, fatalities, and accident severity. For each of these sets of data, separate time series analyses were done for each functional class. Additionally, time series analysis was performed on speed data which was discussed in Chapter 3.

Method of Analysis. The following paragraphs describe the methods of analysis used in Tasks 11 and 12. The time series methodology used in these tasks was the Box-Jenkins intervention analysis. This methodology was recommended to the researchers by NHTSA, and has been used extensively in accident trend analysis both nationally (e.g. 14, 39) and internationally (40). The complexity of Box-Jenkins time series analysis necessitates the use of a computer program to develop the time series models. The researchers used the program Autobox Plus Version 2.0 for this purpose.

The following is a discussion of the process used in the time series analysis. The first step in the time series analysis was to produce a univariate time series model to describe the data to be analyzed (e.g. fatal accident data). A univariate model is one that describes a single series as a function of its own past values. The univariate model was used to identify interventions in the actual data. There are three types of interventions that can be identified:

1. Pulse Interventions or "outliers."
2. Seasonal pulses.
3. Step interventions.

A pulse intervention, often called an outlier, is an observation in the data that differs noticeably from other observations. Significant outliers can have extreme effects on a time series model by inflating the model's standard error which in turn causes a reduction in the precision of other estimated values. For the most part, the researchers rejected deleting outliers from the data unless there was a good reason to believe that it was faulty data.

Seasonal pulses are outliers that reoccur at constant intervals.

A step intervention can be described as a level shift in the mean of the data. In this situation, a univariate model is not sufficient because the data is not homogenous. In a homogenous model, the data would be random about a constant mean. If a series is not homogenous, then the process driving the series has undergone a change in structure. Changes in structure can be represented by a transfer function model which describes a single dependent series as a function of its own past values and the values of one or more independent series. Transfer functions are discussed in the next section.

The next step in the time series analysis is to develop a multiple variable transfer function. Besides the original series, two additional series were used in the transfer function as dummy variables to model possible step interventions caused by the 65 mph speed limit and the seat belt law.

The researchers intended to use vehicle miles of travel (VMT) as a third variable in the time series analyses. This required that travel data be categorized so as to distinguish between the Interstate highways in small urban areas that experienced a speed limit change and those in urbanized areas that did not experience a change. Unfortunately, such data were not available for the years prior to 1987, precluding the incorporation of VMT as a variable in the time series analyses. It was possible, however, to use VMT as a variable in the odds ratio analyses described earlier in this report.

Each of the models developed in the time series analysis were checked for inadequacies. This involves examining model residuals and residual statistics. An ideal model would be one where the residuals are reduced to "white noise." The term white noise describes a distribution of totally random occurrences. There are a number of statistical parameters help to describe a models sufficiency. Only the r^2 statistic will be described here. the value r is known as the correlation coefficient and varies between -1 and +1. It provides a measure of a model's ability of replicating actual values. The square of r is a more useful statistic in time series analysis. The r^2 value lies between 0 and 1. It essentially is the percentage of actual values that can be described by a model. Thus, a model with an r^2 value of 0.75 can describe 75% of the actual values.

<u>Tasks 10 and 11 Results</u>.

This section describes the findings drawn from the time series analyses for each of the functional classes. The results for a particular functional class are divided into three separate sections: 1. Fatalities; 2. Fatal Accidents; and 3. Accident Severity. It is generally the case that the accident severity data produced the best models. This is understandable because the magnitude of the data points for the accident severity data is greater than that of fatalities and fatal accidents. Larger numbers tend to be less prone to random fluctuations. Graphs are included for many of the functional classes.

<u>Rural Interstate - Code 0 (mainline only)</u>

<u>Fatalities</u>. The univariate model identified a significant step intervention beginning in December of 1988. There also were a number of seasonal pulses significant at alpha = 0.05. The r^2

statistic for the univariate model was 0.14. This statistic increased to 0.23 for the transfer function indicating that the speed limit intervention improved the model. The transfer function indicates an increase in fatalities after the seat belt law went into effect. Thus, no beneficial effects of the seat belt law were found. Figure 5-1 illustrates this time series analysis.

Fatal Accidents. The univariate model identified a significant step intervention beginning in July of 1988. The r^2 statistic for the univariate model was 0.12. This statistic increased to 0.21 for the transfer function. Other key statistics also improved. Only the dummy variable representing the seat belt intervention was included in the transfer function. This intervention caused a positive shift (increased fatal accidents) in the model structure indicating no effects of the seat belt law and negative safety effects of the 65 MPH speed limit. See Figure 5-2.

Accident Severity. The univariate model identified a series of significant pulse interventions but no significant step interventions. The r^2 statistic for the univariate model was 0.75. The transfer function included both of the dummy variables. The 65 MPH dummy variable caused a positive shift of the modeled values while the seat belt intervention decreased the total number of injuries and fatalities. This may be seen in Figure 5-3.

Rural Interstate - Codes 0, 1 (including gore areas)

Fatalities. The univariate model identified a significant step intervention beginning in October of 1988. There also were a number of outliers significant at alpha = 0.05. The r^2 statistic for the univariate model was 0.16. This statistic increased to 0.24 for the transfer function indicating that the speed limit intervention improved the model. The transfer function showed that fatalities increased after the seat belt law went into effect. No positive effects of the seat belt law could be identified.

Fatal Accidents. The univariate model identified a significant step intervention beginning in February of 1989. The r^2 statistic for the univariate model was 0.14. This statistic increased to 0.22 for the transfer function. Other key statistics also improved. Only the dummy variable representing the seat belt intervention was included in the transfer function. This intervention caused a positive shift (increased fatal accidents) in the model indicating no benefits of the seat belt law and gradual negative safety effects of the 65 MPH speed limit.

Accident Severity. The univariate model identified a significant step intervention beginning July, 1987. This intervention caused a negative shift in the model structure. The cause of this shift is not clear. The r^2 statistic for the univariate model was 0.79. The transfer function included both of the dummy variables. The 65 MPH dummy variable caused a positive

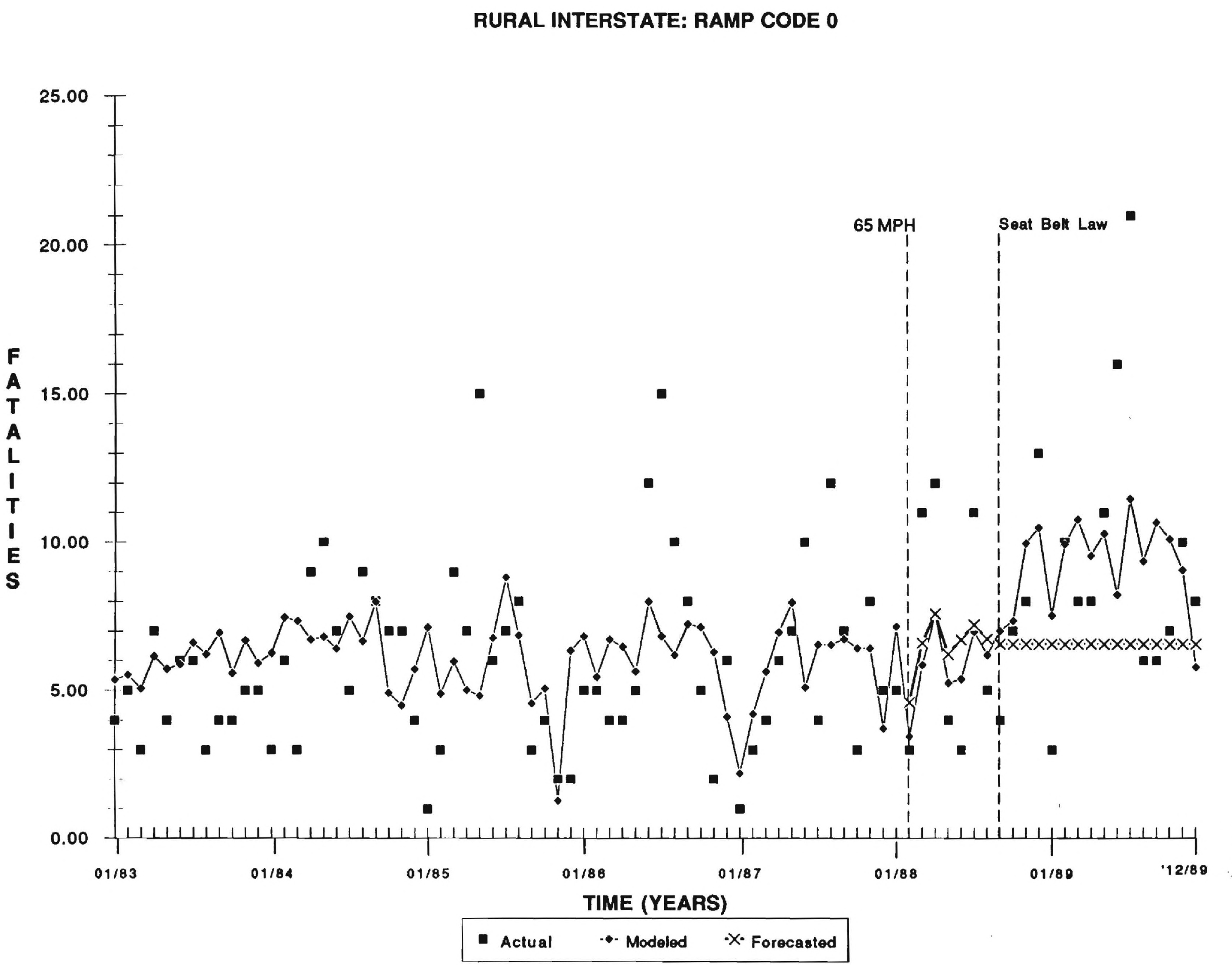


Figure 5-1. Time series analysis of fatalities, Rural Interstate highways, Ramp Code 0.

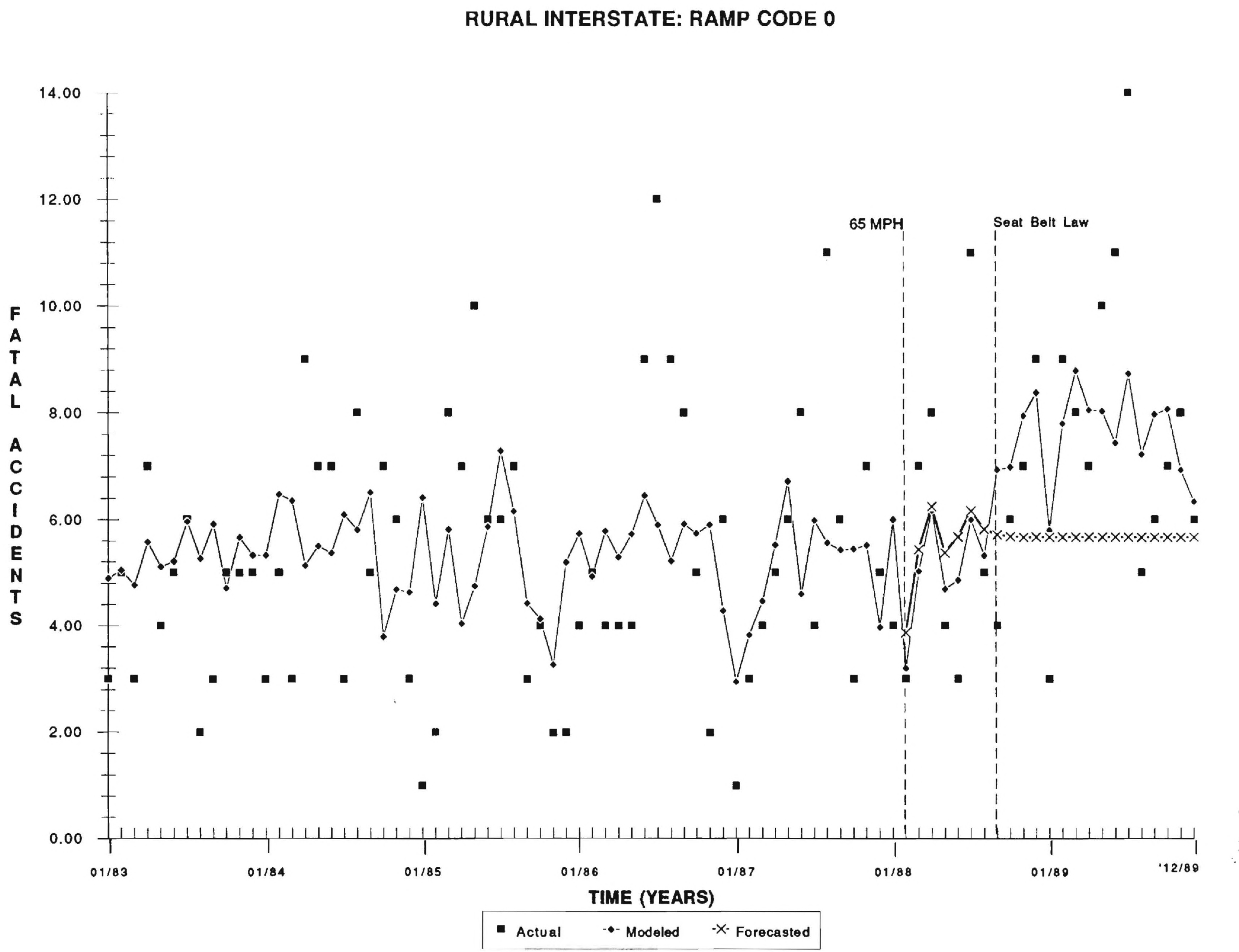


Figure 5-2. Time series analysis of fatal accidents, Rural Interstate highways, Ramp Code 0.

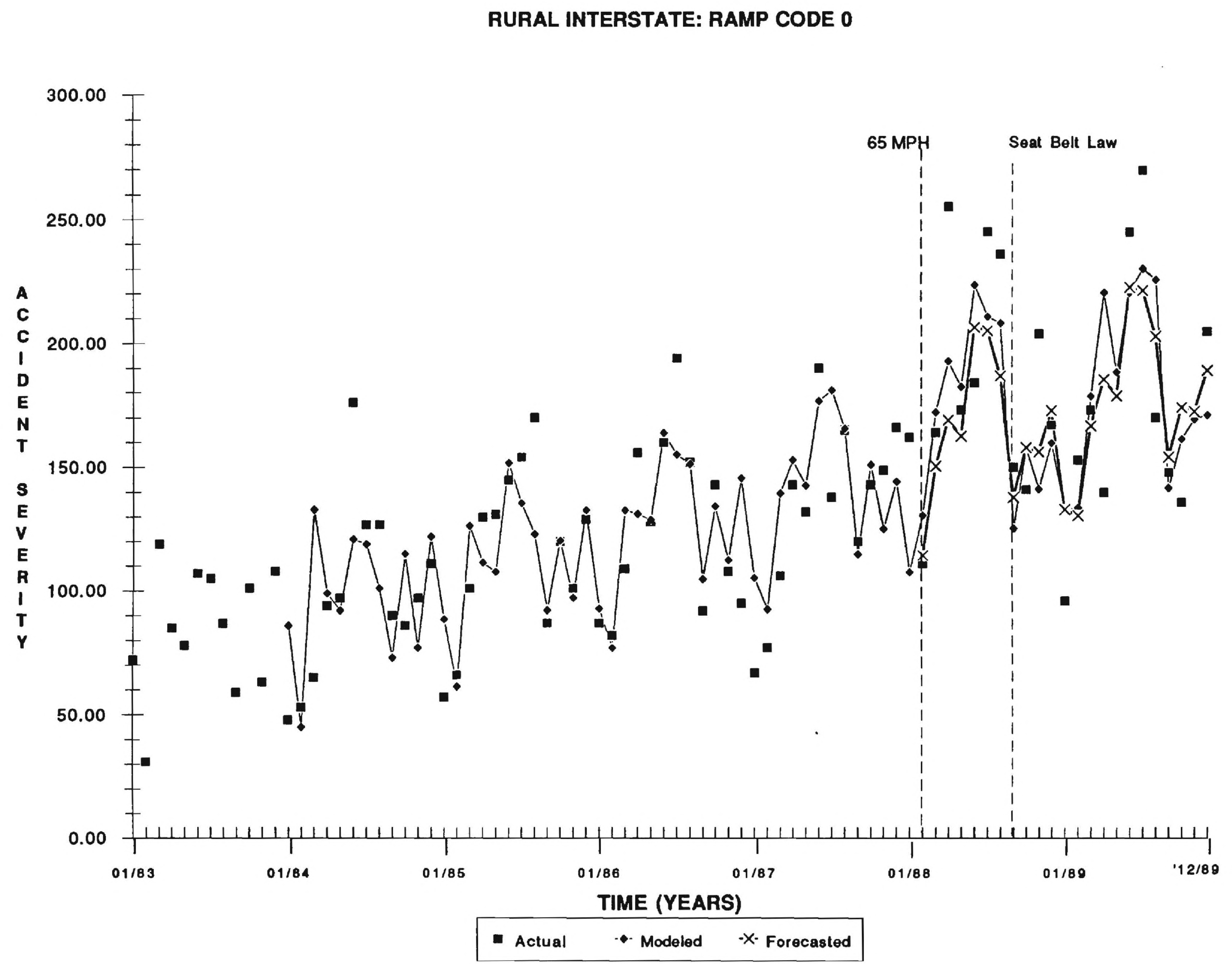


Figure 5-3. Time series analysis of reported injuries, Rural Interstate highways, Ramp Code 0.

shift of the modeled values while the seat belt intervention decreased the total number of injuries and fatalities.

Rural Interstate - Codes 0, 1, 2 (including gore areas, mid-ramps)

Fatalities. The univariate model identified a significant step intervention beginning in October of 1988. There are also a number of outliers significant at alpha = 0.05. The r^2 statistic for the univariate model was 0.18. This statistic increased to 0.25 for the transfer function indicating that the speed limit intervention improved the model. The transfer function indicates an upward shift in fatalities after the seat belt law went into effect.

Fatal Accidents. The univariate model identified a significant step intervention beginning in February of 1989. The r^2 statistic for the univariate model was 0.16. This statistic increased to 0.23 for the transfer function. Other key statistics also improved. Only the dummy variable representing the seat belt intervention was included in the transfer function. This intervention caused a positive shift (increased fatal accidents) in the model indicating no benefits from the seat belt law and gradual negative safety effects of the 65 MPH speed limit.

Accident Severity. The univariate model identified a number of significant outliers but no significant step interventions. The r^2 statistic for the univariate model was 0.79. The transfer function included both of the dummy variables. The 65 MPH dummy variable caused a positive shift of the modeled values while the seat belt intervention decreased the total number of injuries and fatalities.

Rural Interstate - Codes 0, 1, 2, 3 (including all of ramp areas)

Fatalities. The univariate model identified a significant step intervention beginning in October of 1988. There also a number of outliers significant at alpha = 0.05. The r^2 statistic for the univariate model was 0.13. This statistic increased to 0.23 for the transfer function indicating that the speed limit intervention improved the model. The transfer function indicates an upward shift in fatalities after the 65 mph speed limit. Thus the speed limit intervention was detrimental to safety. No effects of the seat belt law could be identified in this analysis.

Fatal Accidents. The univariate model identified a positive significant seasonal intervention beginning in July of 1986 and reoccurring every 12 months after. The r^2 statistic for the univariate model was 0.12. This statistic increased to 0.32 for the transfer function. Other key statistics also improved. The dummy variables representing both the 65 MPH speed limit and the seat belt intervention was included in the transfer function. Both interventions caused a positive shift (increased fatal accidents) in the model indicating no benefits from the seat belt law and a negative safety effect of the 65 MPH speed limit.

Accident Severity. The univariate model identified one significant outlier and no significant step interventions. The r^2 statistic for the univariate model was 0.81. The transfer function included both the seat belt and 65 MPH dummy variables. The 65 MPH dummy variable caused a positive shift of the modeled values while the seat belt intervention provided a better fit of the actual values by decreasing the total number of injuries and fatalities.

Rural Principal Arterial

Fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. No effects of the 65 MPH speed limit or the seat belt law could be identified.

Fatal Accidents. The univariate model identified a number significant outliers. The r^2 statistic for the univariate model was 0.11. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Accident Severity. The univariate model found no significant outliers or significant step interventions. The r^2 statistic for the univariate model was 0.76. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Rural Minor Arterial

Fatalities. The univariate model identified a significant positive step intervention beginning in April of 1986. The r^2 statistic for the univariate model was 0.05. The transfer function reduced to the simple univariate case. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Fatal Accidents. The univariate model identified a positive significant pulse intervention beginning in April of 1986. The r^2 statistic for the univariate model was 0.09. The transfer function was not developed. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Accident Severity. The univariate model identified a significant negative step intervention beginning in October 1988. The r^2 statistic for the univariate model was 0.84. The transfer function included the intervention for the seat belt law. The model indicates that there was a decrease in the severity of accidents after the seat belt law went into effect.

Rural Collector

Fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The r^2 statistic for the univariate model was < 0.01. The transfer function only included the seat belt dummy variable in the model. The model showed an increase in fatalities after the seat belt law. The r^2 statistic for the transfer function was 0.09. No benefits of the seat belt law could be identified by the time series analysis. The effects of the 65 mph speed limit are unclear.

Fatal Accidents. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The transfer function only included the intervention for the 65 mph speed limit. The model showed an increase in fatal accidents after the 65 mph speed limit. The r^2 statistic for the transfer function was 0.06. No effects of the seat belt law could be identified by the time series analysis. The increase in fatal accidents after the 65 mph speed limit may be partially attributable to increases in vehicle miles of travel.

Accident Severity. The univariate model identified one significant outlier. The r^2 statistic for the univariate model was 0.71. The transfer function model was not estimable. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Rural Local Roads

Fatalities. An adequate model could not be developed because of the small number of fatalities.

Fatal Accidents. An adequate model could not be developed because of the small number of fatal accidents.

Accident Severity. The univariate model identified a number of significant outliers and a positive significant step intervention beginning December 1988. The r^2 statistic for the univariate model was 0.21. It improved to 0.39 for the transfer function which included both the seat belt law and the 65 MPH dummy variables. The model showed positive shifts in the number of injuries and fatalities after both of the interventions. The increases in fatalities and injuries seemed to coincide with and may be partially explained by increases in vehicle miles of travel. No benefits of the seat belt law could be identified by the time series analysis. The effects of the 65 mph speed limit are unclear.

Urban Interstate - Code 0 (mainline only)

Fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The r^2 statistic for the univariate model was less than 0.01. The attempt to develop a transfer function reduced to a simple univariate case. No effects of the 65 mph speed limit or the seat belt law could be identified by the time series analysis.

Fatal Accidents. The univariate model identified a negative seasonal pulse beginning January, 1987 and reoccurring every 12 months there after. The r^2 statistic for the univariate model was 0.05. The attempt to develop a transfer function reduced to a simple univariate case. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis. Figure 5-4 illustrates this time series analysis.

Accident Severity. The univariate model identified a series of outliers and a significant positive step intervention beginning in March, 1989. The r^2 statistic for the univariate model was 0.62. A transfer function could not be developed due to certain characteristics of the data. No effects of the seat belt law identified by the time series analysis. See Figure 5-5.

Urban Interstate - Codes 0, 1 (including gore areas)

Fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The model identified a positive step intervention beginning in February, 1987. The r^2 statistic for the univariate model was less than. 0.01. A transfer function could not be developed. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Fatal Accidents. The findings for fatal accidents is basically the same as those found for fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The model identified a positive step intervention beginning June, 1986. The r^2 statistic for the univariate model was less than 0.01. A transfer function could not be developed. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Accident Severity. The univariate model identified no significant outliers or step interventions. The r^2 statistic for the univariate model was 0.56. The transfer function could not be developed. No effects of the seat belt law or the 65 mph law could be established.

Urban Interstate - Code 0, 1, 2 (including gore areas, mid-ramps)

Fatalities. The univariate model developed for the data was very poor and indicated almost completed randomness in the actual series. The r^2 statistic for the univariate model was less than 0.01. The transfer function reduced to the simple univariate case.

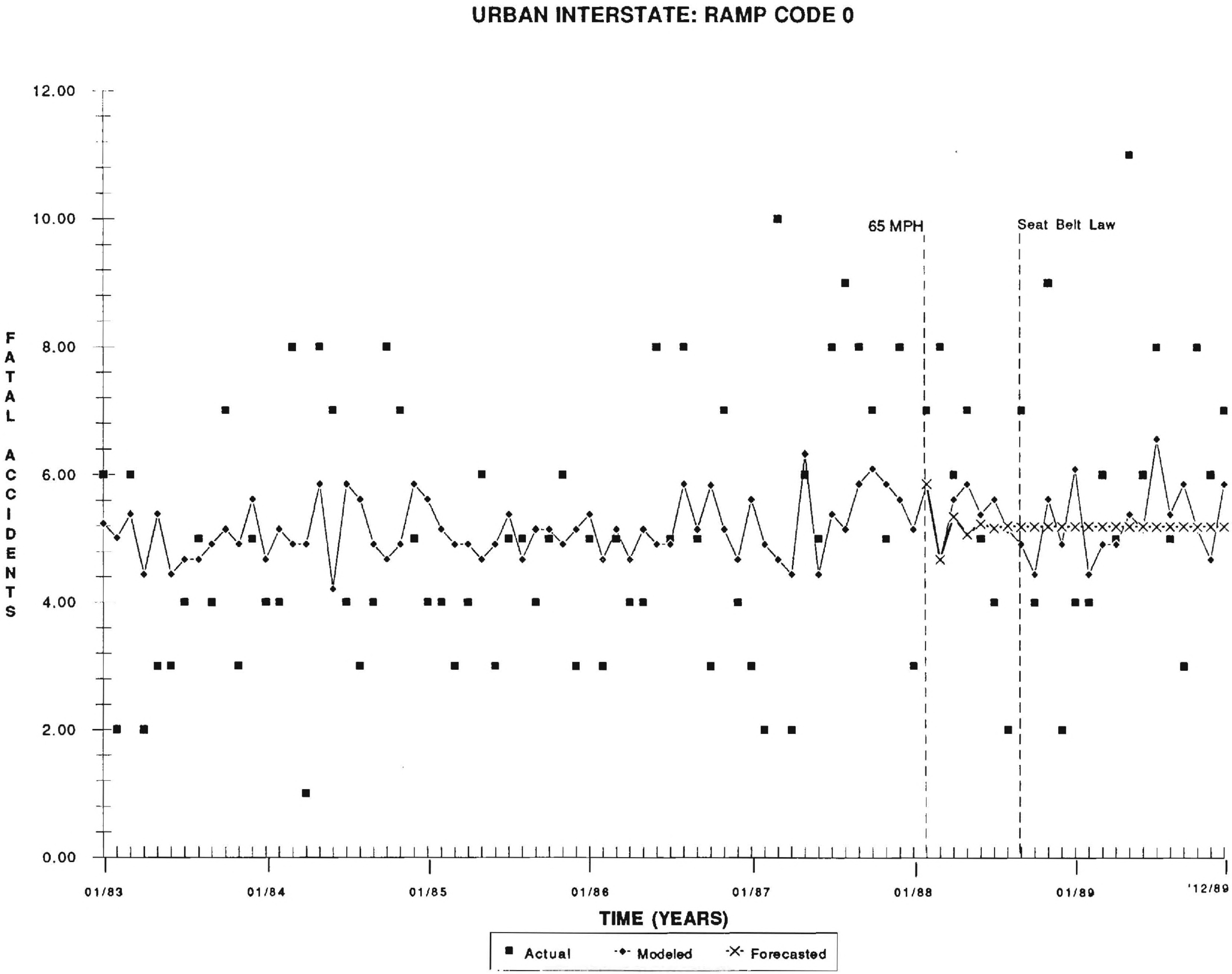


Figure 5-4. Time series analysis of fatal accidents, Urban Interstate highways, Ramp Code 0.

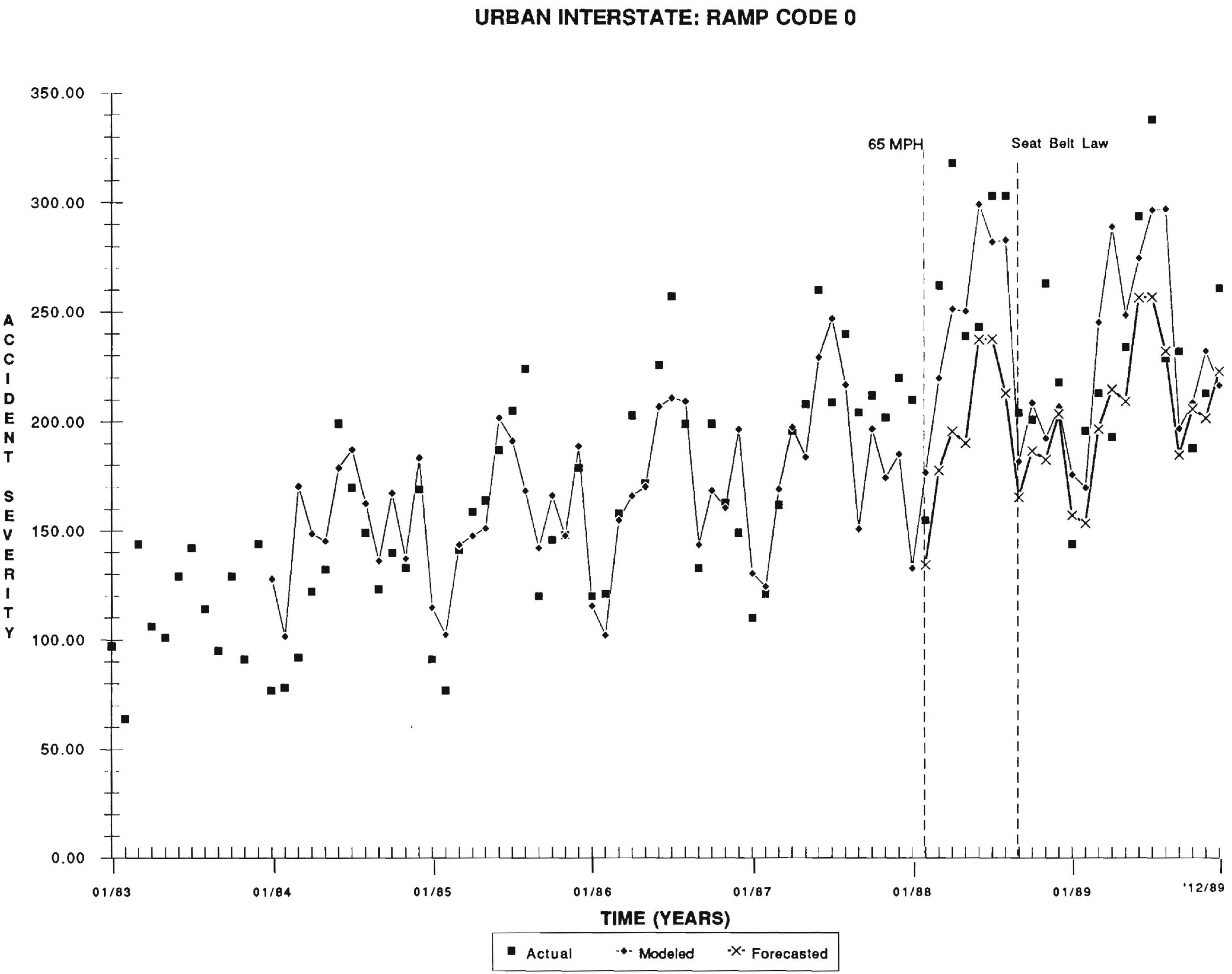


Figure 5-5. Time series analysis of reported injuries, Urban Interstate highways, Ramp Code 0.

No effects of the 65 mph speed limit or the mandatory seat belt law could be established.

Fatal Accidents. The univariate model identified a positive seasonal pulse beginning November, 1984 and reoccurring every 12 months there after. The r^2 statistic for the univariate model was 0.05. A transfer function could not be developed. No effects of the 65 MPH speed limit or the seat belt law could be identified by the time series analysis.

Accident Severity. The univariate model did not identify any significant outliers. The r^2 statistic for the univariate model was 0.58. The transfer function reduced to the simple univariate case. No effects of the 65 mph speed limit or the mandatory seat belt law could be established.

Urban Interstate - Code 0, 1, 2, 3 (including all of ramp areas)

Fatalities. The univariate model developed for the data was very poor and indicated almost complete randomness in the actual series. The r^2 statistic for the univariate model was less than 0.01. A transfer function could not be developed. This analysis did not provide any information regarding the safety effects of the 65 MPH limit or the seat belt law.

Fatal Accidents. The univariate model identified a positive seasonal pulse beginning November, 1984 and reoccurring every 12 months there after. A positive significant step intervention was identified beginning in March, 1987. The r^2 statistic for the univariate model was 0.05. A transfer function could not be developed. The step intervention found by the univariate model could not be related to the 65 MPH speed limit. No effects of the seat belt law could be identified by the time series analysis.

Accident Severity. The univariate model did not identify any significant outliers. The r^2 statistic for the univariate model was 0.58. The transfer function reduced to the simple univariate case. No effects of the 65 mph speed limit or the mandatory seat belt law were found.

Urban Other Freeway

Fatalities. The univariate model identified one significant outlier and no significant step interventions. The r^2 statistic for the univariate model was less than 0.01. The low r^2 statistic can be attributed to the very small number of fatalities that occur in a month on this functional class. The transfer function reduced to the simple univariate case. No effects of the 65 MPH limit or the seat belt law could be identified by the model.

Fatal Accidents. The findings for fatal accidents were virtually the same as those for fatalities. No effects of the 65 MPH limit or the seat belt law could be found.

Accident Severity. The univariate model identified no significant outliers. The r^2 statistic for the univariate model was 0.21. The transfer function was not developed. No effects of the 65 MPH limit or the seat belt law could be found.

Urban Principal Arterial

Fatalities. The univariate model identified one positive significant step intervention beginning August, 1986. A number of significant outliers were also identified by the models. The r^2 statistic for the univariate model was 0.06. A transfer function could not be developed. No effects of the 65 MPH limit or the seat belt law could be identified by the model.

Fatal Accidents. The findings for fatal accidents were virtually the same as those for fatalities. The univariate model identified one positive significant step intervention beginning August, 1986. The r^2 statistic for the univariate model was 0.09. A transfer function could not be developed. No effects of the 65 MPH limit or the seat belt law could be found.

Accident Severity. The univariate model identified a negative significant step intervention beginning September, 1988. The r^2 statistic for the univariate model was 0.85. The transfer function included the dummy variable for the seat belt intervention. This intervention caused a downward shift in the model. The relative decrease in accident severity after September, 1988 seems to coincide with the seat belt law.

Urban Minor Arterial

Fatalities. The univariate model identified a number of significant outliers. The r^2 statistic for the univariate model was less than 0.01. The transfer function reduced to the simple univariate case. No effects of the 65 MPH limit or the seat belt law could be identified by the model.

Fatal Accidents. The univariate model identified a number of seasonal outliers. The r^2 statistic for the univariate model was 0.07. The transfer function reduced to the simple univariate case. No effects of the 65 MPH limit or the seat belt law were identified by the model.

Accident Severity. The univariate model identified a negative significant step intervention beginning September, 1988. The r^2 statistic for the univariate model was 0.85. The transfer function included the dummy variable for the seat belt intervention. This intervention caused a downward shift in the model. The relative decrease in accident severity after September, 1988 seems to coincide with the seat belt law.

Urban Collector

Fatalities. The univariate model identified a number of significant outliers. The r^2 statistic for the univariate model was less than 0.01. The transfer function reduced to the simple univariate case. No effects of the 65 mph speed limit or the seat belt law were identified by the model.

Fatal Accidents. The univariate model identified a number of significant. The r^2 statistic for the univariate model was 0.15. This statistic improved to 0.18 for the transfer function. The 65 MPH speed limit dummy variable was included in the transfer function. The dummy variable caused a negative shift in the model structure indicating that the seat belt law may be a factor here. It is not clear whether the shift could be attributed to the seat belt law. The number of fatal accidents on urban collectors was very small.

Accident Severity. The univariate model did not identify any significant outliers. The r^2 statistic for the univariate model was 0.58. A transfer function could not be developed. No safety effects of the 65 MPH limit or the seat belt law could be identified in the time series analysis.

Urban Local Road

No models could be developed for fatalities or fatal accidents because there was only 1 fatal accident that occurred on urban local roads during the seven year period.

Accident Severity. The univariate identified a number of significant outliers and a significant step intervention beginning in August, 1989. The r^2 statistic for the univariate model was 0.18. This statistic increased to 0.24 for the transfer function which included the seat belt dummy variable. The seat belt law intervention caused an upward shift in the model. No safety effects of the 65 MPH limit or the seat belt law could be identified in the time series analysis.

Summary of Results, Tasks 10 and 11

Tables 5-1 and 5-2 summarize the results of the time series analyses performed as Tasks 10 and 11. The results of these analyses for the mainline Rural and Urban Interstate systems are shown graphically as Figures 5-1 through 5-5.

Briefly stated, these analyses revealed significant increases in fatalities on the mainline Rural Interstate system following the institution of the 65 mph speed limit. The analysis for the mainline Rural Interstate highways showed a significant step intervention beginning in December, 1988, approximately nine months after the effective date of the speed limit increase.

Table 5-1
Summary of Effects of 65 MPH Speed Limit
Based on Time Series Analyses

Functional Class	Effects of 65 mph Speed Limit On: Fatalities	Fatal Accidents	Injuries
Rural Interstate (Code 0)*	Sig. Step Inter-vention, 12/88	Sig. Step Inter-vention, 7/88	Modeled values > forecasted values
Rural Interstate (Codes 0,1)	Sig. Step Inter-vention, 10/88	Modeled values > forecasted values	Modeled values > forecasted values
Rural Interstate (Codes 0,1,2)	Sig. Step Inter-vention, 10/88	Modeled values > forecasted values	Modeled values > forecasted values
Rural Interstate (Codes 0,1,2,3)	Sig. Step Inter-vention, 10/88	Modeled values > forecasted values	Modeled values > forecasted values
Rural Principal Arterial	No effects	No effects	No effects
Rural Minor Arterial	No effects	No effects	No effects
Rural Collector	Unclear	Increased	No effects
Urban Interstate (Code 0)	No effects	No effects	No effects
Urban Interstate (Codes 0,1)	No effects	No effects	No effects
Urban Interstate (Codes 0,1,2)	No effects	No effects	No effects
Urban Interstate (Codes 0,1,2,3)	Effects unclear	Effects unclear	No effects
Urban Other Freeway	No effects	No effects	No effects
Urban Principal Arterial	No effects	No effects	No effects
Urban Minor Arterial	No effects	No effects	No effects
Urban Collector	No effects	No effects	No effects

*Ramp Codes: 0 mainline only; 1 gore area; 2 middle of ramp; 3 top of ramp

Table 5-2
Summary of Effects of the Mandatory Seat Belt Law
Based on Time Series Analyses

Functional Class	Effects of 65 mph Speed Limit On:		
	Fatalities	Fatal Accidents	Injuries
Rural Interstate (Code 0)*	Increased	Increased	Decreased
Rural Interstate (Codes 0,1)	Increased	Increased	Decreased
Rural Interstate (Codes 0,1,2)	Increased	Increased	Decreased
Rural Interstate (Codes 0,1,2,3)	No effects	No effects	Decreased
Rural Principal Arterial	No effects	No effects	No effects
Rural Minor Arterial	No effects	No effects	Decreased
Rural Collector	No effects	No effects	No effects
Urban Interstate (Code 0)	No effects	No effects	No effects
Urban Interstate (Codes 0,1)	No effects	No effects	No effects
Urban Interstate (Codes 0,1,2)	No effects	No effects	No effects
Urban Interstate (Codes 0,1,2,3)	Results unclear	No effects	No effects
Urban Other Freeway	No effects	No effects	No effects
Urban Principal Arterial	No effects	No effects	Decreased
Urban Minor Arterial	No effects	Decreased	Sig. Step Inter-vention, 9/88
Urban Collector	Results unclear	Decreased	No effects

*Ramp Codes: 0 mainline only; 1 gore area; 2 middle of ramp; 3 top of ramp

The increased speed limit also appeared to drive up the numbers of fatal accidents and injuries reported for the Rural Interstate system as the modeled values for these parameters exceeded the forecasted values. (The modeled values are essentially moving averages which take into account seasonal fluctuations, whereas the forecasted values come from a similar model which is based on the values preceding the speed limit intervention.)

Both the numbers of fatalities and fatal accidents on the Rural Interstate system continued to increase after the implementation of the mandatory seat belt law. This effect is attributed to the continued harmful effect of the higher speeds which exceeded any beneficial effects of increased seat belt usage. Interestingly, however, the number of reported injuries decreased for the Rural Interstate system following the implementation of the seat belt law. Such decreases were also noted for the Rural Minor Arterial and Urban Principal Arterial systems.

These findings give evidence that highway losses result from even small increases in speeds and that some benefits can be identified from even modest increases in seat belt usage.

Chapter 6
SUMMARY OF FINDINGS

The purpose of this chapter is to summarize and integrate the findings presented in the previous three chapters. The analyses described in those chapters comprised 12 tasks.

Four of the tasks (Nos. 3,5,7,13) were designed to measure the safety effects of the 65 mph speed limit. These tasks compared the numbers of fatal accidents, fatalities, and injuries during a six month period after the establishment of the 65 mph speed limit to the numbers reported for a six month period before the speed limit change. See Figure 6-1. For these tasks the study periods were:

Before Period:	March 1, 1987 - August 31, 1987
After Period:	March 1, 1988 - August 31, 1988

Three tasks (Nos. 2, 8, and 9) were designed to measure the effects of the mandatory seat belt law. These tasks compared accident experience in a six month period before the effective date of the seat belt law to the experience in a six month period after the law. The study periods for these tasks were:

Before Period:	March 1, 1988 - August 31, 1988
After Period:	March 1, 1989 - August 31, 1989

Two tasks (Nos. 4 and 6) were designed to measure the combined effects of the 65 mph speed limit and the mandatory seat belt laws. Those studies compared the accident experience during a twelve month period before the effective date of either the speed limit or seat belt law to a similar period after the effective dates of both laws. The study periods for these tasks were:

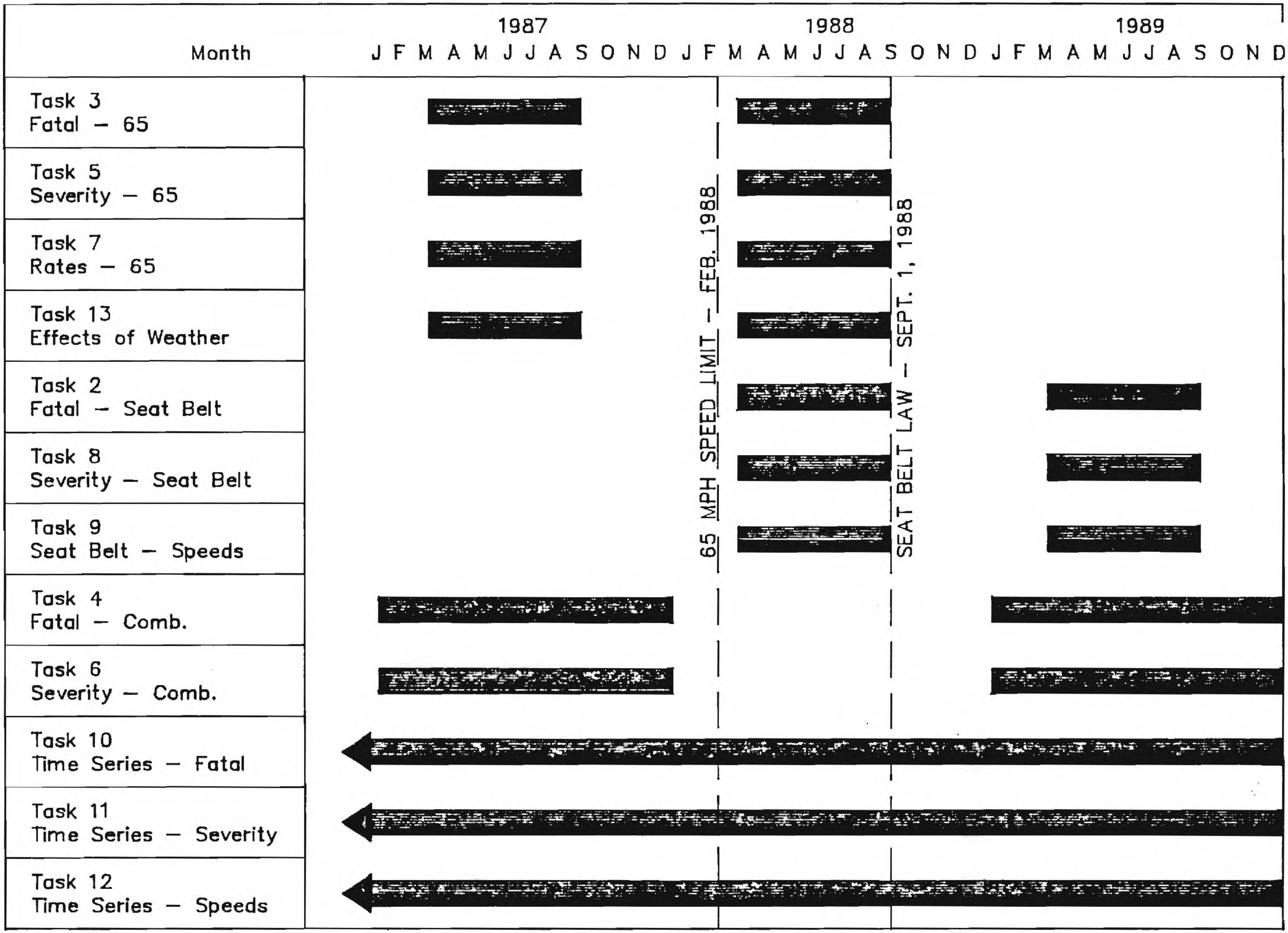
Before Period:	Calendar Year 1987
After Period:	Calendar Year 1989

The final group of tasks (Tasks 10,11,12) consisted of time series analyses designed to more clearly define patterns of change in accident data and speed data and identify the effects of time-related causes of change (termed interventions).

Safety Effects of the 65 mph Speed Limit

In an earlier project (20), Georgia Tech researchers found that mean speeds on Georgia's Rural Interstate highways increased approximately 4 mph following the establishment of the 65 mph speed limit. Similar increases were reported for the 85th percentile speeds. Mean speeds on Urban Interstate highways (which did not have a speed limit change) increased approximately 0.5 mph following the establishment of the 65 mph for non-Interstate highways.

Figure 6–1
FOCUS PERIODS FOR VARIOUS TASKS



Time series analyses performed as Task 12 generally confirmed the earlier findings. However, the time series analyses revealed, for the Rural Interstate system, a sustained increase in the average and 85th percentile speeds of about 2.5 mph, and for the Urban Interstate highways, little change in average speeds but an increase of about 1.5 mph for the 85th percentile speeds. These changes are shown in Figures 3-1 through 3-4.

It was expected that the increase in speeds on Rural Interstate highways would result in greater losses from highway crashes. The results of Tasks 3,5, and 7 generally confirmed this expectation.

By means of a classical statistical methodology using odds ratios, the researchers found no significant effect of the 65 mph speed limit on the occurrence of fatal accidents and fatalities on the Rural Interstate in the six month period after the law. However, there was a 10 percent increase in fatalities from 1987 to 1988 on this system, while most of the other functional classes experienced a decrease in fatalities.

Time series analyses revealed significant increases in fatalities on the mainline Rural Interstate system following the institution of the 65 mph speed limit. The analyses for this system showed significant changes in the trend of fatalities beginning in December, 1988, approximately nine months after the effective date of the speed limit increase.

To examine further whether the speed limit change increased the severity of Rural Interstate crashes, the researchers compared the number of injuries reported for this system during the before and after periods. Reported injuries included the number of fatalities, visible injuries, and complaint of injuries as recorded by the investigating officers. The researchers discovered that there was an extremely significant increase in injuries on the Rural Interstate system following the institution of the 65 mph limit.

The researchers also compared the accident rates, in accidents per vehicle mile, before and after the 65 mph speed limit. The accident rates for the mainline Interstate highways and all other functional classes, except Urban Collectors, increased significantly ($P \leq 0.05$).

The researchers performed a special study to determine if differences in weather conditions could explain observed differences in fatal accidents before and after the 65 mph speed limit change. No evidence was found to indicate that weather differences could explain the increases in fatal accidents.

Safety Effects of the Mandatory Seat Belt Law

Although Georgia has what most traffic safety professionals would regard a weak mandatory seat belt law, studies performed by University of Georgia researchers (35) found that safety belt use in Georgia increased after passage of the law. They reported that safety belt use throughout the state increased from 28 percent in July, 1988 to 40 percent in October and November, 1989. By May, 1990, overall seat belt usage had climbed to 46 percent. Special studies by those researchers indicated that seat belt usage by drivers and front seat passengers on the Rural Interstate system increased from 34 percent in July and August, 1988 to 44 percent October and November, 1989. By the beginning of 1990, seat belt usage on the Rural Interstate highways had leveled off at 50 percent.

Georgia Tech researchers used odds ratios to compare accident experience in a six month period before the seat belt law to the experience in a six month period after the law. The results failed to show significant changes in the number of fatalities and fatal accidents between the before and after periods ($P \leq 0.05$). In fact, Rural Interstate and Urban Interstate tests showed significant <u>increases</u> in the number of fatalities and fatal accidents ($P \leq 0.10$). In addition, the fatality and fatal accident occurrences increased in 11 of 14 functional classes tested. Similar results were obtained in comparisons of fatality and fatal accident rates.

In the comparison of reported injuries before and after the seat belt law, significant decreases in injuries were reported for the Rural Interstate, the Rural Minor Arterial and the Urban Collector systems. Though not statistically significant, a decrease was also noted for the Urban Other Freeway system. On the other hand, significant increases in the number of injuries were noted for the Urban Interstate system. This increase in injuries may be explained by a noticeable increase in the 85th percentile speeds on Urban Interstate highways, shown by Figure 3-2.

Comparisons were made of accident experiences in calendar year 1987 with the experience in 1989, giving a measure of the combined effects of the 65 mph speed limit and seat belt laws. The mainline Rural Interstate system showed an increase of 44 percent in fatal accidents between 1987 and 1989, while all other roadways showed a decrease of about 4 percent. Over the same period, fatalities on the mainline Rural Interstate highways increased approximately 60 percent, while fatalities on all other highways decreased about 1 percent. These findings were statistically significant ($P < 0.05$). This same pattern was apparent for fatal accident and fatality rates. In addition, the number of reported injuries for Rural Interstate System increased 28.9 percent between 1987 and 1989, while the reported injuries on all other highways increased only 7.8 percent.

To further examine the effects of the mandatory seat belt law, the researchers performed time series analyses for fatal accidents, fatalities, and injuries on all non-Interstate highways. Since none of those highways experienced nor were affected by a speed limit increase, these tests provided an uncluttered examination of the effects of the seat belt law. For fatalities and fatal accidents, the time series analyses failed to reveal any decrease after the implementation of the seat belt law. However, the time series analysis of reported injuries showed that the seat belt law did have a beneficial effect. This is illustrated by Figure 6-2 which shows that the actual or modeled values after the seat belt law are lower than those forecast by the pre-seat belt law experience.

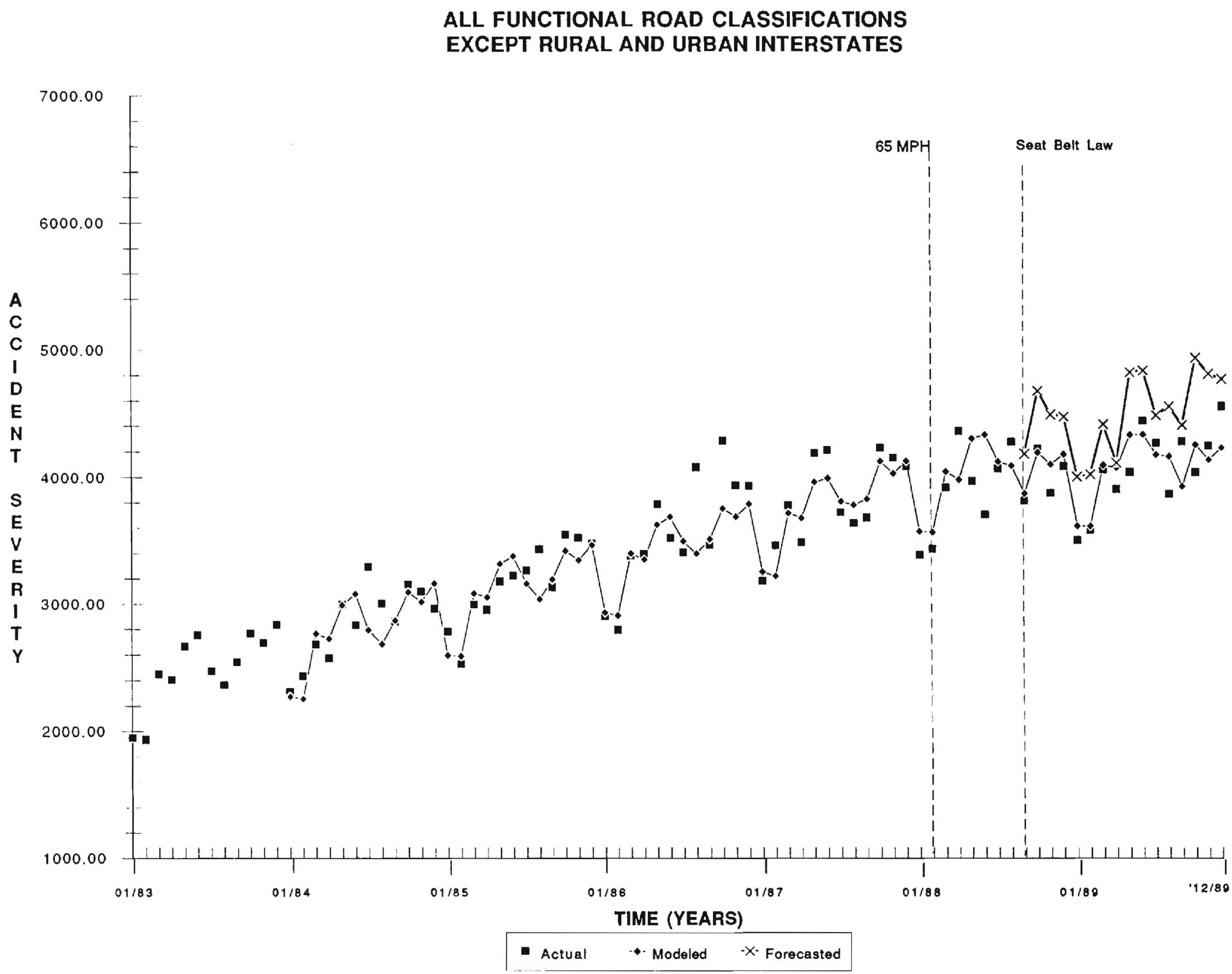


Figure 6-2. Time series analysis of reported injuries, all functional road classifications except Rural and Urban Interstate highways.

Chapter 7

CONCLUSIONS

1. After the implementation of the 65 mph speed limit, mean and 85th percentile speeds on Georgia's Rural Interstate highways increased about 2.5 miles per hour. On the Urban Interstate highways, which did not have a speed limit change, the mean speeds remained virtually unchanged, but the 85th percentile speeds increased about 1.5 miles per hour.

2. On the basis of a 6-month before, 6-month after study of the effects of the 65 mph speed limit using odds-ratios:

a. There was no significant effect of the speed limit on the numbers of fatalities or fatal accidents that occurred on the Rural Interstate system.

b. There was an extremely significant increase ($P < 0.000001$) in reported injuries for the Rural Interstate system following the speed limit change.

3. Time series analyses revealed significant increases ($P < 0.05$) in fatalities and fatal accidents on the mainline Rural Interstate system following the institution of the 65 mph speed limit. The analysis of fatalities showed a significant step intervention ($P < 0.05$) in December, 1988, approximately nine months after the effective date of the speed limit.

4. The increased speed limit also appeared to drive up the numbers of fatal accidents and injuries for the Rural Interstate system as the modeled values for these parameters in the time series analysis exceeded the forecasted values.

5. On the basis of research performed by the University of Georgia (35, 36), safety belt use throughout the state increased from 28 percent in July, 1988, before the mandatory seat belt law, to 44 percent in November, 1989, after the law, and to 46 percent by May, 1990.

6. On the basis of a 6-month before, 6-month after study of the mandatory seat belt law using odds ratios:

a. There was no significant change in the number of fatal accidents ($\alpha = 0.05$) between the before and after periods.

b. Significant decrease in reported injuries were found ($\alpha = 0.05$) for the Rural Interstate, the Rural Minor Arterial, and Urban Collector systems.

c. Extremely significant <u>increases</u> ($P < 0.0001$) in the number of reported injuries were noted for the Urban Interstate system.

7. The researchers used odds-ratios to compare accident experience during calendar year 1987 (when neither the speed limit or seat belt law were in effect) to calendar year 1989 (when both laws were in effect). They found:

a. The mainline Rural Interstate system showed an increase in fatal accidents of 44 percent between the before and after periods, while all other roadways showed an overall decrease of about 4 percent. This increase was significant ($P < 0.05$).
b. The mainline Rural Interstate system showed a significant increase ($P < 0.05$) in fatalities of approximately 60 percent while fatalities on all other roadways decreased about 1 percent.
c. There was an extremely significant ($P < 0.005$) increase in the number of reported injuries on both the Rural Interstate and Urban Interstate systems.
d. Fatal accident rates and fatality rates for the Rural Interstate system increased 19 percent and 32 percent, respectively, between the before and after periods; little change was noted for the other systems.

8. Time series analyses showed significant increases ($P < 0.05$) in the numbers of fatalities and fatal accidents for the Rural Interstate system after the implementation of the mandatory seat belt law. This is attributed to continued harmful effect of higher speeds which exceeded any beneficial effects of increased seat belt usage.

9. The researchers performed time series analyses for fatal accidents, fatalities, and injuries on all functional classes except the Rural Interstate system. Since none of these systems experienced a speed limit change, these analyses provided an uncluttered examination of the effects of the seat belt law. The researchers found:

a. There was no significant decrease in fatal accidents or fatalities after implementation of the seat belt law.
b. The actual or modeled numbers of reported injuries after the seat belt law were lower than those forecast by the pre-seat belt law experience, indicating a beneficial effect of increased seat belt usage.

10. In a comparison of accident rates, in accidents per vehicle mile, before and after the 65 mph speed limit, the rates increased significantly ($P \leq 0.05$) for the mainline Interstate highways and for all other functional classes except Urban Collectors.

11. The researchers compared fatality and fatal accident rates during 6 month periods before and after the seat belt law in terms of incidence density ratios (IDRs), which measure the percent change in rates. They found that only one IDR, that for the mainline Rural Interstate system, showed a significant change (P <

0.05), and that change resulted from an <u>increase</u> in the fatality rate.

12. In a special study to determine if differences in precipitation could explain observed differences before and after the 65 mph speed limit, no significant differences ($\alpha = 0.05$) were found either for the weather or surface conditions reported by investigating officers.

13. No evidence was found to support the hypothesis that the mandatory seat belt law is more effective on roads designed for higher speeds.

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APPENDIX

Task 3 Data
GEORGIA ROADWAY FATALITY SUMMARY
1987 Month by Month Breakdown

NUMBER OF FATALITIES

	Functional Class	1987 March	April	May	June	July	August	1987 Total
Rural Roadways								
1	Interstate Ramp Code 0	3	5	6	9	3	11	37
1	Interstate Ramp Code 1			2		2		4
1	Interstate Ramp Code 2							0
1	Interstate Ramp Code 3	1				1		2
11	Interstate < 50 k pop. Ramp 0			1		1		2
11	Interstate < 50 k pop. Ramp 1							0
11	Interstate < 50 k pop. Ramp 2							0
11	Interstate < 50 k pop. Ramp 3							0
2	Other Principal Arterial	7	19	21	10	20	17	94
6	Minor Arterial	22	16	23	32	27	17	137
7,8	Collector	13	11	19	8	7	16	74
9	Local							0
Urban Roadways								
11	Interstate > 50 k pop. Ramp 0	11	1	5	4	7	9	37
11	Interstate > 50 k pop. Ramp 1	2	2	5	1		1	11
11	Interstate > 50 k pop. Ramp 2					1		1
11	Interstate > 50 k pop. Ramp 3					2		2
12	Other Freeway Ramp 0	3		2	1	2		8
12	Other Freeway Ramp 1	1						1
12	Other Freeway Ramp 2							0
12	Other Freeway Ramp 3			1			1	2
14	Other Principal Arterial	15	17	12	19	8	13	84
16	Minor Arterial	7		2	7	7	7	30
17	Collector		1			1	1	3
19	Local							0
								529

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 3 Data
GEORGIA ROADWAY FATALITY SUMMARY
1988 Month by Month Breakdown

NUMBER OF FATALITIES

		1988						1988
Functional Class		March	April	May	June	July	August	Total
Rural Roadways								
1	Interstate Ramp Code 0	10	10	3	2	11	4	40
1	Interstate Ramp Code 1		5					5
1	Interstate Ramp Code 2			1				1
1	Interstate Ramp Code 3	1	1		1		1	4
11	Interstate < 50 k pop. Ramp 0	1				1		2
11	Interstate < 50 k pop. Ramp 1							0
11	Interstate < 50 k pop. Ramp 2							0
11	Interstate < 50 k pop. Ramp 3							0
2	Other Principal Arterial	10	14	13	18	11	8	74
6	Minor Arterial	16	27	27	21	16	18	125
7,8	Collector	7	11	9	12	17	20	76
9	Local						2	2
Urban Roadways								
11	Interstate > 50 k pop. Ramp 0	7	5	6	5	3	1	27
11	Interstate > 50 k pop. Ramp 1	2	1					3
11	Interstate > 50 k pop. Ramp 2	1						1
11	Interstate > 50 k pop. Ramp 3					1	3	4
12	Other Freeway Ramp 0	1	2	2	1	1	3	10
12	Other Freeway Ramp 1							0
12	Other Freeway Ramp 2							0
12	Other Freeway Ramp 3							0
14	Other Principal Arterial	15	16	18	16	18	18	101
16	Minor Arterial	1	3	2	2	5	4	17
17	Collector					3		3
19	Local							0
								496

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 3 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1987 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class		1987 March	April	May	June	July	August	1987 Total
Rural Roadways								
1	Interstate Ramp Code 0	3	4	5	7	3	10	32
1	Interstate Ramp Code 1			2		1		3
1	Interstate Ramp Code 2							0
1	Interstate Ramp Code 3	1				1		2
11	Interstate < 50 k pop. Ramp 0			1		1		2
11	Interstate < 50 k pop. Ramp 1							0
11	Interstate < 50 k pop. Ramp 2							0
11	Interstate < 50 k pop. Ramp 3							0
2	Other Principal Arterial	5	16	17	8	18	15	79
6	Minor Arterial	19	16	18	28	23	17	121
7,8	Collector	9	11	18	8	7	13	66
9	Local							0
Urban Roadways								
11	Interstate > 50 k pop. Ramp 0	9	1	5	4	7	8	34
11	Interstate > 50 k pop. Ramp 1	2	2	5	1		1	11
11	Interstate > 50 k pop. Ramp 2					1		1
11	Interstate > 50 k pop. Ramp 3					2		2
12	Other Freeway Ramp 0	3		2	1	2		8
12	Other Freeway Ramp 1	1						1
12	Other Freeway Ramp 2							0
12	Other Freeway Ramp 3			1			1	2
14	Other Principal Arterial	14	11	12	18	8	11	74
16	Minor Arterial	6		2	7	7	6	28
17	Collector		1			1	1	3
19	Local							0
								469

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 3 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1988 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class		1988 March	1988 April	1988 May	1988 June	1988 July	1988 August	1988 Total
Rural Roadways								
1	Interstate Ramp Code 0	6	7	3	2	10	4	32
1	Interstate Ramp Code 1		1					1
1	Interstate Ramp Code 2			1				1
1	Interstate Ramp Code 3	1			1		1	3
11	Interstate < 50 k pop. Ramp 0	1				1		2
11	Interstate < 50 k pop. Ramp 1							0
11	Interstate < 50 k pop. Ramp 2							0
11	Interstate < 50 k pop. Ramp 3		1					1
2	Other Principal Arterial	10	12	13	12	10	8	65
6	Minor Arterial	15	23	21	17	15	18	109
7,8	Collector	6	11	8	10	15	19	69
9	Local						1	1
Urban Roadways								
11	Interstate > 50 k pop. Ramp 0	7	5	6	4	3	1	26
11	Interstate > 50 k pop. Ramp 1	2	1					3
11	Interstate > 50 k pop. Ramp 2	1						1
11	Interstate > 50 k pop. Ramp 3					1	3	4
12	Other Freeway Ramp 0	1	2	2	1	1	3	10
12	Other Freeway Ramp 1							0
12	Other Freeway Ramp 2							0
12	Other Freeway Ramp 3							0
14	Other Principal Arterial	15	15	15	12	16	17	90
16	Minor Arterial	1	2	1	2	5	4	15
17	Collector					1		1
19	Local							0
								434

Ramp Codes

- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Task 2 Data
GEORGIA ROADWAY FATALITY SUMMARY
1988 Month by Month Breakdown

NUMBER OF FATALITIES

Functional Class	1988 March	1988 April	1988 May	1988 June	1988 July	1988 August	1988 Total
Rural Roadways							
Interstate Ramp Code 0	10	10	3	2	11	4	40
Interstate Ramp Code 1	0	5	0	0	0	0	5
Interstate Ramp Code 2	0	0	1	0	0	0	1
Interstate Ramp Code 3	1	1	0	1	0	1	4
Interstate < 50 k pop. Ramp 0	1	0	0	0	1	0	2
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0
Principal Arterial	10	14	13	18	11	8	74
Minor Arterial	16	27	27	21	16	18	125
Collector	7	11	9	12	17	20	76
Local	0	0	0	0	0	2	2
Urban Roadways							
Interstate > 50 k pop. Ramp 0	7	5	6	5	3	1	27
Interstate > 50 k pop. Ramp 1	2	1	0	0	0	0	3
Interstate > 50 k pop. Ramp 2	1	0	0	0	0	0	1
Interstate > 50 k pop. Ramp 3	0	0	0	0	1	3	4
Other Freeway	1	2	2	1	1	3	10
Principal Arterial	15	16	18	16	18	18	101
Minor Arterial	1	3	2	2	5	4	17
Collector	0	0	0	0	3	0	3
Local	0	0	0	0	0	0	0

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 2 Data
GEORGIA ROADWAY FATALITY SUMMARY
1989 Month by Month Breakdown

NUMBER OF FATALITIES

Functional Class	1989 March	April	May	June	July	August	1989 Total
Rural Roadways							
Interstate Ramp Code 0	7	7	10	15	20	5	64
Interstate Ramp Code 1	0	0	2	0	1	0	3
Interstate Ramp Code 2	0	0	0	0	0	0	0
Interstate Ramp Code 3	0	0	1	0	0	0	1
Interstate < 50 k pop. Ramp 0	0	3	0	0	0	0	3
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	1	1
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0
Principal Arterial	10	14	13	18	11	8	74
Minor Arterial	31	20	10	22	16	21	120
Collector	17	15	15	17	9	21	94
Local	0	0	0	0	0	0	0
Urban Roadways							
Interstate > 50 k pop. Ramp 0	5	7	11	5	8	4	40
Interstate > 50 k pop. Ramp 1	0	1	0	5	0	0	6
Interstate > 50 k pop. Ramp 2	1	1	0	0	0	0	2
Interstate > 50 k pop. Ramp 3	0	1	1	0	1	0	3
Other Freeway	1	1	0	3	0	0	5
Principal Arterial	19	13	7	18	11	17	85
Minor Arterial	6	3	3	2	5	5	24
Collector	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0
							525

Ramp Codes

- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Task 2 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1988 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class	1988 March	April	May	June	July	August	1988 Total
Rural Roadways							
Interstate Ramp Code 0	6	7	3	2	10	4	32
Interstate Ramp Code 1	0	1	0	0	0	0	1
Interstate Ramp Code 2	0	0	1	0	0	0	1
Interstate Ramp Code 3	1	0	0	1	0	1	3
Interstate < 50 k pop. Ramp 0	1	0	0	0	1	0	2
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 3	0	1	0	0	0	0	1
Principal Arterial	10	12	13	12	10	8	65
Minor Arterial	15	23	21	17	15	18	109
Collector	6	11	8	10	15	19	69
Local	0	0	0	0	0	1	1
Urban Roadways							
Interstate > 50 k pop. Ramp 0	7	5	6	4	3	1	26
Interstate > 50 k pop. Ramp 1	2	1	0	0	0	0	3
Interstate > 50 k pop. Ramp 2	1	0	0	0	0	0	1
Interstate > 50 k pop. Ramp 3	0	0	0	0	1	3	4
Other Freeway	1	2	2	1	1	3	10
Principal Arterial	15	15	15	12	16	17	90
Minor Arterial	1	2	2	2	5	4	16
Collector	0	0	0	0	1	0	1
Local							0
							435

Ramp Codes

- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Task 2 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1989 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class	March (1989)	April (1989)	May (1989)	June (1989)	July (1989)	August (1989)	1989 Total
Rural Roadways							
Interstate Ramp Code 0	7	6	9	10	13	4	49
Interstate Ramp Code 1	0	0	2	0	1	0	3
Interstate Ramp Code 2	0	0	0	0	0	1	1
Interstate Ramp Code 3	0	0	1	0	0	0	1
Interstate < 50 k pop. Ramp 0	0	2	0	0	0	0	2
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0
Principal Arterial	13	6	18	15	15	9	76
Minor Arterial	21	14	9	18	16	17	95
Collector	14	12	12	14	8	20	80
Local	0	0	0	0	0	0	0
Urban Roadways							
Interstate > 50 k pop. Ramp 0	5	4	10	5	7	4	35
Interstate > 50 k pop. Ramp 1	0	1	0	4	0	0	5
Interstate > 50 k pop. Ramp 2	1	1	0	0	0	0	2
Interstate > 50 k pop. Ramp 3	0	1	1	0	1	0	3
Other Freeway	1	1	0	3	0	0	5
Other Principal Arterial	18	12	7	15	10	17	79
Minor Arterial	6	3	3	2	5	3	22
Collector	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0
							458

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 4 Data
GEORGIA ROADWAY FATALITY SUMMARY
1987 Month by Month Breakdown

NUMBER OF FATALITIES

Functional Class	1987 Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	1987 Total
Rural Roadways													
Interstate Ramp Code 0	0	2	3	5	6	9	3	11	6	2	7	4	58
Interstate Ramp Code 1	1	0	0	0	2	0	2	0	0	0	0	0	5
Interstate Ramp Code 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate Ramp Code 3	0	0	1	0	0	0	1	0	0	1	0	0	3
Interstate < 50 k pop. Ramp 0	3	0	0	0	1	0	1	0	2	1	1	0	9
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0	0	0	1	0	0	1
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0	0	0	1	0	0	1
Principal Arterial	15	5	7	19	21	10	20	17	20	7	33	13	187
Minor Arterial	25	15	22	16	23	32	27	17	34	19	22	18	270
Collector	6	7	13	11	19	8	7	16	17	9	8	19	140
Local	2	0	0	0	0	0	0	0	0	1	0	0	3
Urban Roadways													
Interstate > 50 k pop. Ramp 0	2	1	11	1	5	4	7	9	7	6	4	7	64
Interstate > 50 k pop. Ramp 1	0	1	2	2	5	1	0	1	0	2	2	1	17
Interstate > 50 k pop. Ramp 2	0	1	0	0	0	0	1	0	0	0	0	0	2
Interstate > 50 k pop. Ramp 3	0	0	0	0	0	0	2	0	1	0	0	3	6
Other Freeway	2	4	4	0	3	1	2	1	1	0	1	2	21
Principal Arterial	14	14	15	17	12	19	8	13	14	16	25	20	187
Minor Arterial	5	4	7	0	2	7	7	7	1	10	2	8	60
Collector	0	0	0	1	0	0	1	1	0	1	1	0	5
Local	0	0	0	0	0	0	0	0	0	0	0	0	0
													1039

Ramp Codes

- 0 Mainline only
- 1 Gore area
- 2 Middle of ramp
- 3 Top of ramp

Task 4 Data
GEORGIA ROADWAY FATALITY SUMMARY
1989 Month by Month Breakdown

NUMBER OF FATALITIES

Functional Class	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	1989 Total
	1989												
Rural Roadways													
Interstate Ramp Code 0	2	9	7	7	10	15	19	5	3	5	8	7	97
Interstate Ramp Code 1	0	0	0	0	2	0	1	0	0	0	0	0	3
Interstate Ramp Code 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate Ramp Code 3	0	0	0	0	1	0	0	0	1	1	0	0	3
Interstate < 50 k pop. Ramp 0	0	0	0	3	0	0	1	0	2	1	1	2	10
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0	1	0	0	0	0	1
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0	0	0	0	0	0	0
Principal Arterial	12	10	13	8	21	20	22	11	21	16	9	15	178
Minor Arterial	20	18	31	20	10	22	16	21	23	34	23	24	262
Collector	9	14	17	15	15	17	9	21	15	11	16	8	167
Local	0	0	0	0	0	0	0	0	2	0	0	1	3
Urban Roadways													
Interstate > 50 k pop. Ramp 0	3	3	5	7	11	5	8	4	3	9	6	6	70
Interstate > 50 k pop. Ramp 1	1	0	0	1	0	5	0	0	0	1	1	0	9
Interstate > 50 k pop. Ramp 2	0	0	1	1	0	0	0	0	3	0	3	0	8
Interstate > 50 k pop. Ramp 3	1	0	0	1	1	0	1	0	0	1	0	0	5
Other Freeway	0	2	1	1	0	3	0	0	1	1	2	1	12
Principal Arterial	8	12	19	13	7	18	11	17	20	19	18	20	182
Minor Arterial	3	3	6	3	3	2	5	5	8	4	5	6	53
Collector	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0	0	1	1
													1064

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 4 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1987 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class	1987 Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	1987 Total
Rural Roadways													
Interstate Ramp Code 0	0	2	3	3	6	6	4	8	6	2	7	4	51
Interstate Ramp Code 1	1	0	0	0	2	0	1	0	0	0	0	0	4
Interstate Ramp Code 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate Ramp Code 3	0	0	1	0	0	0	1	0	0	1	0	0	3
Interstate < 50 k pop. Ramp 0	2	0	0	1	0	1	0	2	1	1	0	0	8
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0	0	0	1	0	0	1
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0	0	0	1	0	0	1
Principal Arterial	14	5	5	16	17	8	18	15	15	7	23	11	154
Minor Arterial	22	11	19	16	18	28	23	17	27	17	19	16	233
Collector	5	6	9	11	18	8	7	13	13	8	7	17	122
Local	1	0	0	0	0	0	0	0	0	1	0	0	2
Urban Roadways													
Interstate > 50 k pop. Ramp 0	2	1	9	1	5	4	7	8	7	6	4	7	61
Interstate > 50 k pop. Ramp 1	0	2	2	2	5	1	0	1	0	2	2	1	18
Interstate > 50 k pop. Ramp 2	0	0	0	0	0	0	1	0	0	0	0	0	1
Interstate > 50 k pop. Ramp 3	0	0	0	0	0	0	2	0	1	0	0	3	6
Other Freeway	1	4	4	0	3	1	2	1	1	0	1	2	20
Principal Arterial	14	14	14	11	12	18	8	11	13	15	24	16	170
Minor Arterial	4	4	6	0	2	7	7	6	1	9	2	8	56
Collector	0	0	0	1	0	0	1	1	0	1	1	0	5
Local	0	0	0	0	0	0	0	0	0	0	0	0	0
													916

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

Task 4 Data
GEORGIA ROADWAY FATAL ACCIDENT SUMMARY
1989 Month by Month Breakdown

NUMBER OF FATAL ACCIDENTS

Functional Class	Jan	Feb	March	April	May	June (1989)	July	August	Sept	Oct	Nov	Dec	1989 Total
Rural Roadways													
Interstate Ramp Code 0	2	8	7	6	9	10	13	4	5	6	7	5	82
Interstate Ramp Code 1	0	0	0	0	2	0	1	0	0	0	0	0	3
Interstate Ramp Code 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate Ramp Code 3	0	0	0	0	1	0	0	0	1	1	0	0	3
Interstate < 50 k pop. Ramp 0	0	0	0	2	0	0	0	0	0	0	0	1	3
Interstate < 50 k pop. Ramp 1	0	0	0	0	0	0	0	0	0	0	0	0	0
Interstate < 50 k pop. Ramp 2	0	0	0	0	0	0	0	1	0	0	0	0	1
Interstate < 50 k pop. Ramp 3	0	0	0	0	0	0	0	0	0	0	0	0	0
Principal Arterial	10	8	13	6	18	15	15	9	20	13	8	12	147
Minor Arterial	13	16	21	14	9	18	16	17	18	29	20	16	207
Collector	9	9	14	12	12	14	8	20	12	9	16	7	142
Local	0	0	0	0	0	0	0	0	2	0	0	1	3
Urban Roadways													
Interstate > 50 k pop. Ramp 0	3	3	5	4	10	5	7	4	2	7	5	6	61
Interstate > 50 k pop. Ramp 1	1	0	0	1	0	4	0	0	0	1	1	0	8
Interstate > 50 k pop. Ramp 2	0	0	1	1	0	0	0	0	3	0	3	0	8
Interstate > 50 k pop. Ramp 3	1	0	0	1	1	0	1	0	0	1	0	0	5
Other Freeway	0	2	1	1	0	3	0	0	1	1	2	1	12
Other Principal Arterial	8	11	18	12	7	15	10	17	19	18	18	18	171
Minor Arterial	3	3	6	3	3	2	5	3	7	4	4	6	49
Collector	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0	0	1	1
													906

Ramp Codes

0 Mainline only
1 Gore area
2 Middle of ramp
3 Top of ramp

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