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UMTRI-87-10

MICHIGAN'S COMPULSORY RESTRAINT USE POLICIES: EFFECTS ON INJURIES AND DEATHS

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MARCH 1987

UMTRI The University of Michigan Transportation Research Institute

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-87-10	-	

4. Title and Subtitle	5. Report Date
Michigan's Compulsory Restraint Use Policies: Effects on Injuries and Deaths	March 1987
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Wagenaar, A.C., Maybee, R.G., Sullivan, K.P.	UMTRI-87-10
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
The University of Michigan Transportation Research Institute 2901 Baxter Rd. Ann Arbor, Michigan 48109-2150	11. Contract or Grant No. MDE-87-006A
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Michigan Office of Highway Safety Planning 111 South Capitol Avenue Lansing, Michigan 48913	Final October 1, 1986 - September 30, 1987
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

On April 1, 1982, Michigan began requiring that children under age 4 be restrained when traveling in automobiles. On July 1, 1985, compulsory seat belt use was expanded to front-seat motorists of all ages. We measured the long-term effect of the child restraint law on injuries to children, and the short-term effects of the 1985 seat belt law on injuries and fatalities among adults. Monthly frequencies of crash-induced injuries (from Jan. 1978 through Dec. 1985) and fatalities (from Jan. 1978 through June 1986) were analyzed using Box-Jenkins time-series methods. Exposure to risk of injury was controlled through examination of injury rates based on population, number of crashed vehicles, and vehicle miles traveled.

We found the following statistically significant effects associated with the child restraint law:

- 28.2% reduction in the frequency of injured children,
- 26.0% reduction in the rate of injured children per million population,
- 31.5% reduction in the rate of injured children per crashed vehicle,
- 27.7% reduction in the rate of injured children per vehicle mile traveled.

We found the following statistically significant effects associated with the adult belt law:

- 12.1% reduction in the frequency of injured occupants age 16 and over,
- 11.6% reduction in the rate per population of injured occupants age 16 and over,
- 16.1% reduction in the rate per crashed vehicle of injured occupants age 16 and over,
- 29.9% reduction in the rate per crashed vehicle of front-seat fatalities among occupants age 10 and over.

Estimated reductions in the frequency of front-seat fatalities (10.0%), rate of fatalities per population (14.0%), rate of fatalities per vehicle mile traveled (9.3%), and rate of injured occupants per vehicle mile traveled (8.7%) at the time of the adult belt law were not statistically significant.

Based on these results, the child restraint law has prevented injuries to 552 children per year. The adult seat belt law has prevented injuries to 7,278 adults in the first six months it was in effect, and prevented 98 deaths in the first year it was in effect.

17. Key Words	18. Distribution Statement
Motor-vehicle crashes, injuries, occupant restraint, mandatory restraint laws, seat belts, time-series analysis	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	77	

This report was prepared in cooperation with the Michigan Office of Highway Safety Planning and the U.S. Department of Transportation, National Highway Traffic Safety Administration. Support of these organizations is gratefully acknowledged.

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Acknowledgments

Assistance of Charles P. Compton with data file management, and helpful comments of Fredrick M. Streff are gratefully acknowledged.

1 INTRODUCTION

Michigan has two major statutes requiring motor vehicle occupants to use restraint devices. First, on April 1, 1982, a child restraint law was implemented, requiring children under the age of 4 to be restrained by a child safety seat when traveling in a motor vehicle (Public Act 117 of 1981). If the child is age 1 to 4 and riding in the rear seat, a seat belt is a permissible substitute for a child safety seat. Second, on July 1, 1985, legislation took effect requiring motor vehicle occupants of any age to use seat belts when traveling in the front seat of a motor vehicle (Public Act 1 of 1985).[1] We examined the effectiveness of these policies on frequency and rate of injuries and fatalities resulting from motor vehicle crashes.

This report is one of a series of reports tracking trends in crash-related injuries in Michigan (Wagenaar, 1984a; Wagenaar and Webster, 1985; Wagenaar and Maybee, 1986). The literature cited below includes only recent studies not discussed in previous reports. Plots of rates of injuries by age in Section 3 use the same age-breakdowns as previous reports.

1.1 Review of Recent Literature

Previous reviews of the literature on effects of compulsory restraint laws indicated that there is evidence that such laws increase restraint use and reduce crash-related injuries, although results are not consistent across jurisdictions studied. It was also noted that there are significant design, measurement, and reporting problems with a number of the studies. Recent studies of the effects of seat belt laws on injuries or fatalities are briefly reviewed here.

McCarthy and others (1984) examined the effect of mandatory seat belt laws in 14 countries for which both pre- and post-law crash data, vehicle mileage information, and seat belt use rates were available (Australia, Austria, Belgium, Ontario Canada, Denmark, France, Ireland, Israel, Netherlands, Norway, South Africa, Sweden, Switzerland, and West Germany). For 12 of these countries, belt use rates were obtained from Fisher (1980), who provided little detail concerning the specific measurement methods used. A linear regression model was used to estimate the percent reduction in rate of injuries per miles driven. Results indicated no significant reduction in fatalities in jurisdictions where seat belt use was less than 60%, and that fatality reductions of 26 to 48% would not be realized until compliance levels reached 80% to 100%. The authors argue that this is due to the fact that belt users tend to be more safety-conscious, careful drivers than nonusers. The results should be interpreted cautiously, not only because of the unknown origin of some of the seat belt use figures, but also because other investigators have been able to show that mandatory seat belt laws are associated with significant declines in injury and fatality rates in jurisdictions where seat belt use is less than 60%.

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1. There are a few exceptions to the requirement to use seat belts, including: motorcycles, mopeds, buses, commercial or post office vehicles which make frequent stops for pick-up and delivery, rural mail carriers while serving their postal route, passengers on a school bus, and persons who are unable to wear seat belts due to a medical or physical condition and have written verification from a physician.

Recently, Campbell and others (1986) examined the preliminary effects of seat belt legislation in the United States. During 1985 mandatory seat belt laws went into effect in eight states. Fatal Accident Reporting System data for the years 1975-1985 were obtained for these states. Methods included time-series analyses, simple month-by-month pre- to post-law comparisons, and comparisons between front-seat occupants, rear-seat occupants, and non-occupants. Results of the time-series and month-to-month comparisons clearly indicate a drop in fatalities in the eight law states. The time-series analyses indicated an estimated decrease of 9.9% in target-group occupant deaths in the eight states at the time the belt laws took effect. However, the estimated fatality reductions associated with the belt laws were statistically significant in only four of the eight states. Since there was no discernible change in fatalities among rear-seat occupants and non-occupants, the authors concluded that the belt laws were responsible for observed fatality declines.

Lund and others (1986a) examined the effect of the New York seat belt law for the first nine months it was in effect. New York was the first state to enact an adult seat belt law, which was implemented January 1, 1985. It is considered to be one of the strongest mandatory use laws passed to date, since it carries a fine of up to fifty dollars and permits primary enforcement by police. Regression analyses were performed using fatality data from New York as the dependent variable and fatalities in Pennsylvania and Ohio as predictor variables. Monthly totals of vehicle occupant deaths for January 1980 to September 1985 were used to control for historical trends, and only vehicles covered by the New York law were included. Results showed a significant ($p<.05$) reduction in fatalities of "approximately nine percent."

Expanding their study, Lund and others (1986b) examined the effects of mandatory seat belt laws in the four states which had belt laws in effect for at least six months of 1985 (New York, New Jersey, Michigan, Illinois). Eight states without seat belt laws were used for comparisons. Time-series analyses identified reductions in fatalities of 5% in New York, 4% in New Jersey, 4% in Michigan, and 17% in Illinois. However, only the New York result was statistically significant ($p<.01$). The authors concluded that much higher use rates will have to be attained in order to realize "substantial reductions in motor vehicle occupant deaths."

Mackay (1985) examined the effect of Britain's mandatory seat belt law on traffic casualties. In a simple comparison between the first eleven months after the law and the same eleven calendar months of the preceding year, a 23% decrease in front-seat occupant deaths and a 26% decrease in serious injuries to front-seat occupants were observed. The seat belt use rate in England during this period was 90%. Mackay cites a related study of crash-involved motorists at 15 hospitals, and points out that an effect of the law "is transferring belt users to less severe injury levels." Both of these studies used raw monthly counts for the year before and the first year after the belt law, and did not include time-series or regression controls for long-term trends.

Hedlund (1986) analyzed fatalities in New York for the first nine months following implementation of that state's seat belt law, as part of a study on the effectiveness of mandatory seat belt legislation in twelve jurisdictions. The author computes "belt law performance" which is the casualty reduction resulting from a mandatory belt law. These calculations were based on pre- and post-law belt usage rates, injury and fatality counts, and a trend factor. The jurisdictions included in this study were: State of Victoria in Australia, Canada, Denmark, Germany, Great

Britain, Ireland, Israel, New Zealand, New York State, Norway, Sweden, and Switzerland. The casualty reduction performance of the belt laws was computed separately for injuries and fatalities. As might be expected, the injury results indicated a trend of increasing belt law performance with increasing post-law usage; results for all locales but one fall between 25-45%. The fatality results were more variable. The belt law performance for seven of the jurisdictions fell between 31-51%; of the remaining five, all based on fairly small fatality counts, three fell between 13-23%, one was zero and one was negative. In the case of New York, only fatality reductions were computed. Preliminary fatality data for the first nine months after implementation of the seat belt law were compared to the same period of the previous year and the 1980-1984 average for these months in New York, as well as to the fatality data for the same months for the rest of the United States. The calculations were based on a 57% average belt use rate in New York during these months. The author reports a casualty reduction of 15% as the "conservative preliminary estimate" of the New York belt law's performance.

Latimer and Lave (1987) examined the effects of New York's mandatory seat belt law for the first six months of 1985. Crash-related injuries (as reported by the Department of Motor Vehicles) were classified as light, moderate, severe, or fatal. Poisson and least squares regression modeling methods were used. Results using the least squares regression indicate the following reductions in the first six months with the law: fatalities down 24%, severe injuries down 17%, moderate injuries down 18%, and light injuries down 5%. Results using the Poisson model were: fatalities down 20%, serious injuries down 11%, moderate injuries down 13%, and light injuries down 3%.

These recent studies confirm conclusions of our previous reviews of the literature on effects of compulsory restraint use. Such laws can significantly increase the proportion of motorists restrained, with reductions in rates of crash-related injuries and deaths a likely consequence. However, it is worth noting that the short-term injury and fatality reductions observed thus far in several states are not statistically significant. The purpose of this study is to examine the short-term effects of Michigan's adult seat belt law and follow-up the long-term effects of Michigan's child restraint law.

2 METHODS

This study evaluated the effects of Michigan's restraint policies using data from January 1978 through December 1985 and Fatal Accident Reporting System data from January 1978 through June 1986. Details on the research design, data collection, and statistical analyses are provided in Appendix A.

3 RESULTS

This study follows up the long-term effects of the child restraint law documented in previous reports and papers (Wagenaar, 1984b; Wagenaar, 1985; Wagenaar and Webster, 1986; Wagenaar and Maybee 1986), and examines the initial short-term effects of the adult seat belt law.

Time-series statistical models were developed to measure the effects of four interventions:

1. A public information and education (PI&E) program occurring January 1 through March 31, 1982, before the child restraint law was implemented;

2. Implementation of a child restraint law from April 1, 1982 through December 31, 1985;

3. Public information campaigns and mass media coverage of the passage and signing of the adult seat belt law from April 1 through June 30, 1985; and

4. Implementation of an adult seat belt law from July 1 through June 30, 1986.[2]

A chart of each outcome measure is provided and results of time-series modeling are summarized in a condensed table. When examining the plots, note that the solid line represents a moving average trend line, which is useful for discerning overall trends. Also note carefully differences in the vertical axis scale across plots. Understanding the scale used is important for discerning the magnitude of discontinuities associated with the restraint laws. All legal impact estimates are based on carefully developed Box-Jenkins time-series models for each dependent variable. All final models met the multiple criteria for model adequacy, such as significant noise model parameters, insignificant residual autocorrelations, and lack of high correlations among the parameters. Estimated intervention effects are summarized here as the percent change of the post-intervention period from the levels expected, given baseline patterns. In addition, t-ratios for each impact estimate are provided; a t-ratio smaller than 1.67 indicates that the estimated pre-law to post-law change is not statistically significant at the 0.05 level. Major findings are summarized first, followed by detailed results from each of the analyses.

3.1 Summary of Results

Alternative estimates of the effect of the child restraint law in reducing child injuries associated with automobile travel were remarkably similar. Over the entire 45-month post-law period, analyses revealed the following injury reductions (all statistically significant):

- 28.2% reduction in the frequency of injured children,

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2. Nonfatal injury data were only available through December 1985.

- 26.0% reduction in the rate of injured children per million population,
- 31.5% reduction in the rate of injured children per crashed vehicle, and
- 27.7% reduction in the rate of injured children per vehicle mile traveled.

Clearly Michigan's child restraint law has resulted in a substantial long-term reduction in injuries to young children.[3]

The short-term effects of Michigan's adult seat belt law are not as dramatic as the effects of the earlier child restraint law. Analyses revealed the following reductions in nonfatal injuries of which all but the last are statistically significant:

- 12.1% reduction in the frequency of injured occupants age 16 and over,
- 11.6% reduction in the rate per population of injured occupants age 16 and over, and
- 16.1% reduction in the rate per crashed vehicle of injured occupants age 16 and over,
- 8.7% reduction in the rate per vehicle miles traveled of injured occupants age 16 and over.

Analyses also revealed the following reductions in fatal injuries with only the rate per crashed vehicle being statistically significant:

- 10.0% reduction in the frequency of front-seat fatalities among occupants age 10 and over,
- 14.0% reduction in rate per population of front-seat fatalities among occupants age 10 and over,
- 29.9% reduction in rate per crashed vehicle of front-seat fatalities among occupants age 10 and over,
- 9.3% reduction in rate per vehicle mile traveled of front-seat fatalities among occupants age 10 and over.

There are two reasons why three of the four fatality estimates above were not significant. First, the effects of the law were assessed only for a short time after it was implemented and the short post-law period increased the variance of the time-series model parameter estimates. Second, fatality frequencies and rates within a single state are based on a substantially smaller number of events than injury frequencies and rates. One result of smaller counts is that a higher proportion of the total variance in the frequency or rate over time is random, that is, cannot be explained by baseline patterns. The higher random variation over time increases the variance of time-series model parameter estimates.

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3. The frequency or rate of fatalities among 0-3-year-olds was not examined because of the very small numbers of cases available for analyses.

3.2 Effects on Use of Seat Belts and Child Safety Seats

The rate of restraint use among injured children under 4 years old is depicted in Figure 3.1. Restraint use within this age group increased gradually from 1979 through 1981. Restraint use before the PI&E program and mandatory child restraint law were implemented averaged about 12%. During the January-March 1982 PI&E program, restraint use increased slightly. The dramatic increase occurred immediately after the child restraint law took effect, with restraint use during the April 1982 to December 1984 period 307% higher than it was during the 1978-81 baseline period (Wagenaar and Maybee, 1986). The proportion of crash-involved children reported as restrained increased further during the last six months of 1985, when the adult seat belt law was in effect, indicating a spill-over effect of the adult law on restraint use of children. Direct observation of restraint use at a probability sample of intersections throughout the state confirmed an increase in child restraint use at the time the adult seat belt law took effect (Wagenaar and others, 1987).

From 1978 through 1981, restraint use among occupants age 4 to 15 averaged about 5% to 6%, with little variation from month to month (Figure 3.2). An identifiable increase in restraint use can be seen in early 1982 with introduction of the child restraint law. A gradual upward trend in restraint use then continued through June 1985. The upward trend accelerated in early 1985, when attention to the forthcoming adult belt law intensified. Beginning in July 1985 reported restraint use jumped up sharply, from 20.3% in the first half of 1985 to 59.1% in the second half. Comparison of these results, based on restraint use among crash-involved children, with the results of observations of children traveling on the road indicates interesting differences. The direct-observation results confirm a significant increase in restraint use at the time the adult belt law took effect among 4-15-year-olds, from 31.4% before to 48.9% after. The direct-observation results show higher rates of restraint use than the police-report results before the law, but lower rates than the police-report results after the law. The lower rates among crash-involved than noncrash-involved passengers before the law are consistent with the well-established finding that those involved in crashes are less likely to be restraint users than those not involved in crashes. The higher reported use rates after the law among crash-involved than noncrash-involved passengers indicates that the law appears to have encouraged some drivers to report to police officers that children in the car were restrained at the time of the crash, when in fact they were not.

Restraint use among 16-17-year-old occupants remained constant at about 6% between 1978 and 1982, and increased slightly to about 13% from 1982 to 1984 (Figure 3.3). In the first half of 1985, however, belt use among 16-17-year-olds increased more noticeably. When the mandatory seat belt law took effect, reported restraint use jumped to 58.4%.

The pattern of restraint use among occupants age 18-24 (Figure 3.4) was similar to that of 16- and 17-year-olds. Use rates averaged about 8% from 1978 through 1981, with little variation. A slight upward trend occurred in 1983 and 1984 with an average of 11%, and that trend accelerated to 16% in the first half of 1985. In contrast, reported belt use among 18-24-year-olds averaged 64.4% during the last six months of 1985.

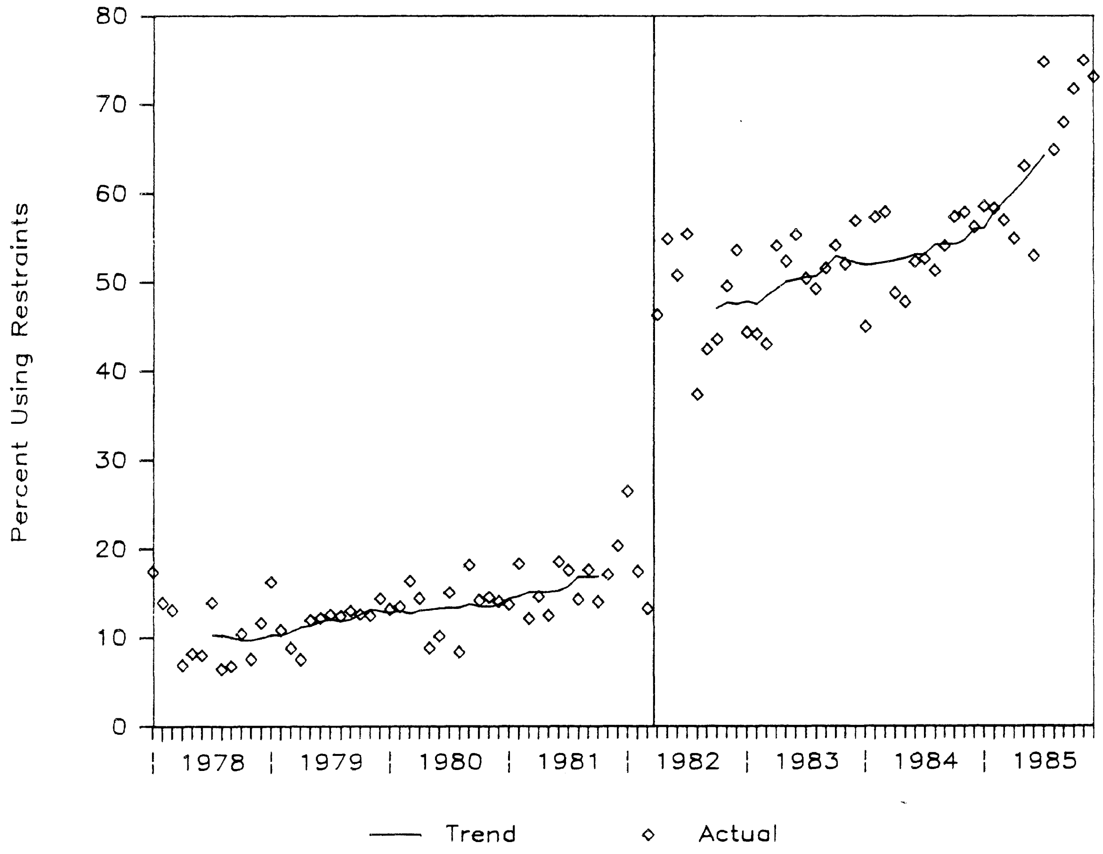

Figure 3.1 Restraint Use Among Injured Occupants Age 0-3

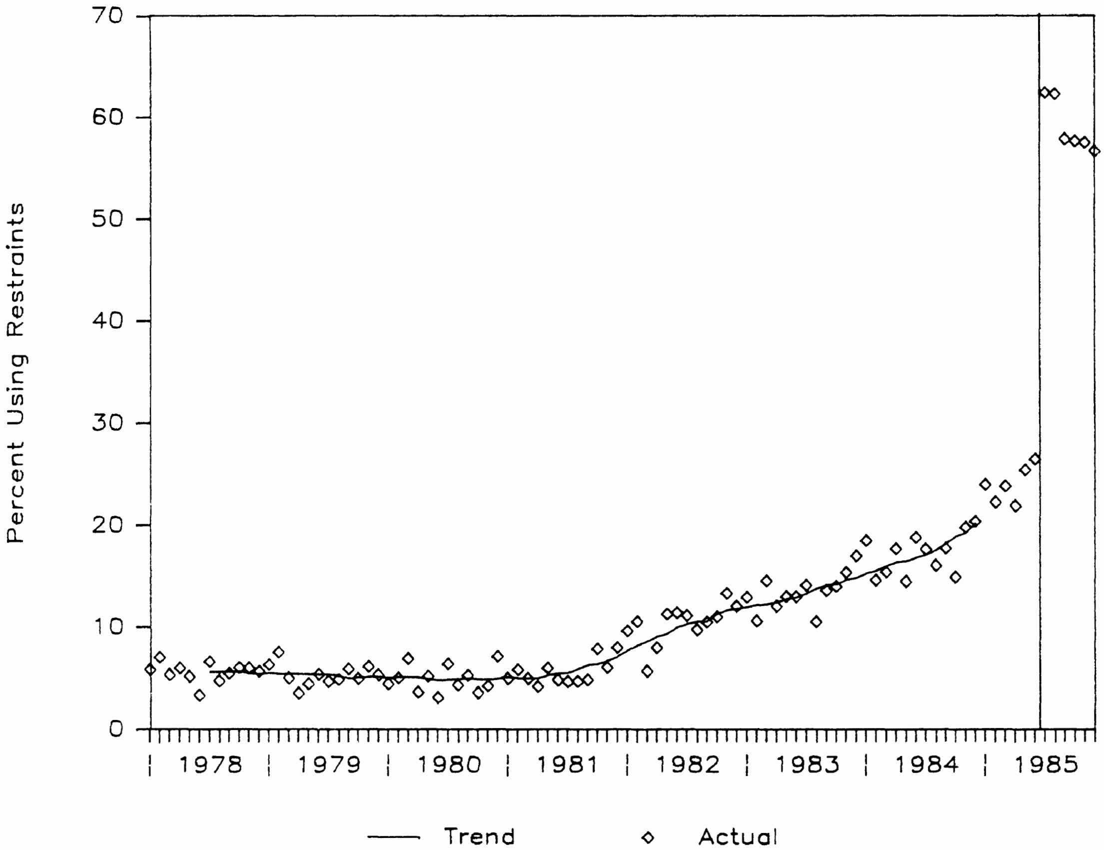

Figure 3.2 Restraint Use Among Injured Occupants Age 4-15

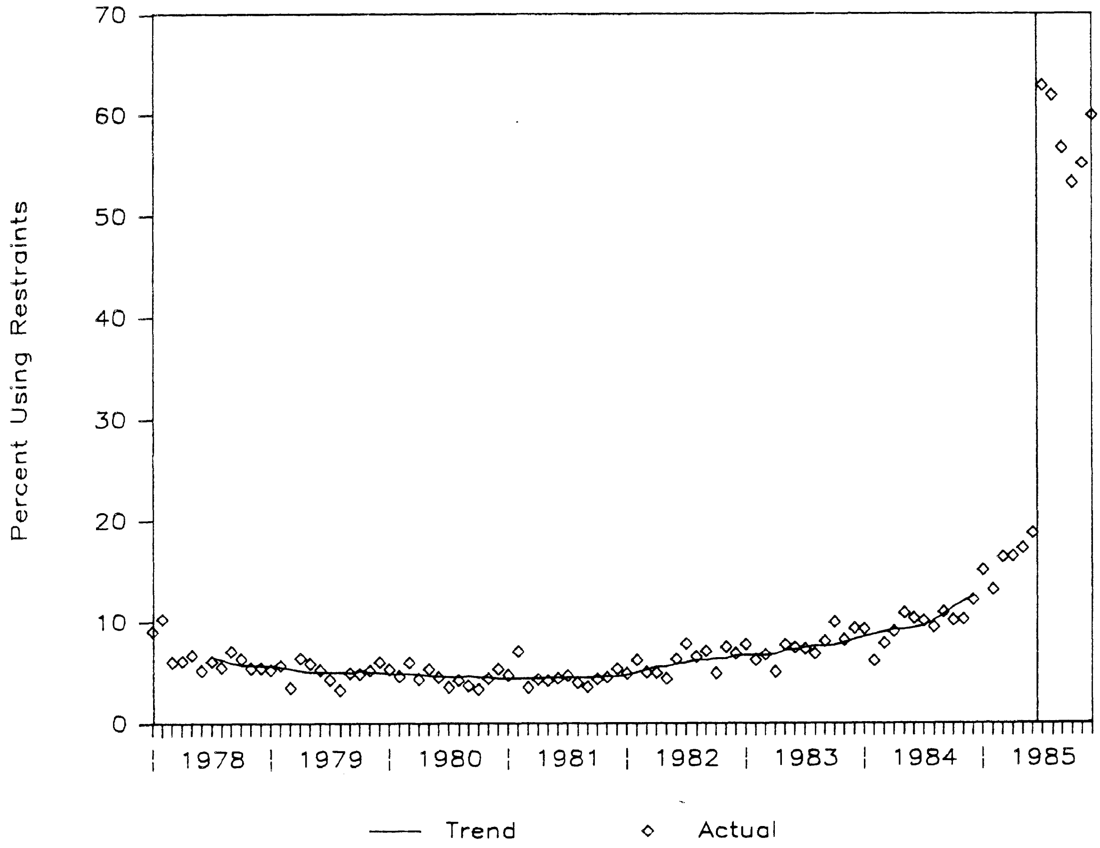

Figure 3.3 Restraint Use Among Injured Occupants Age 16-17

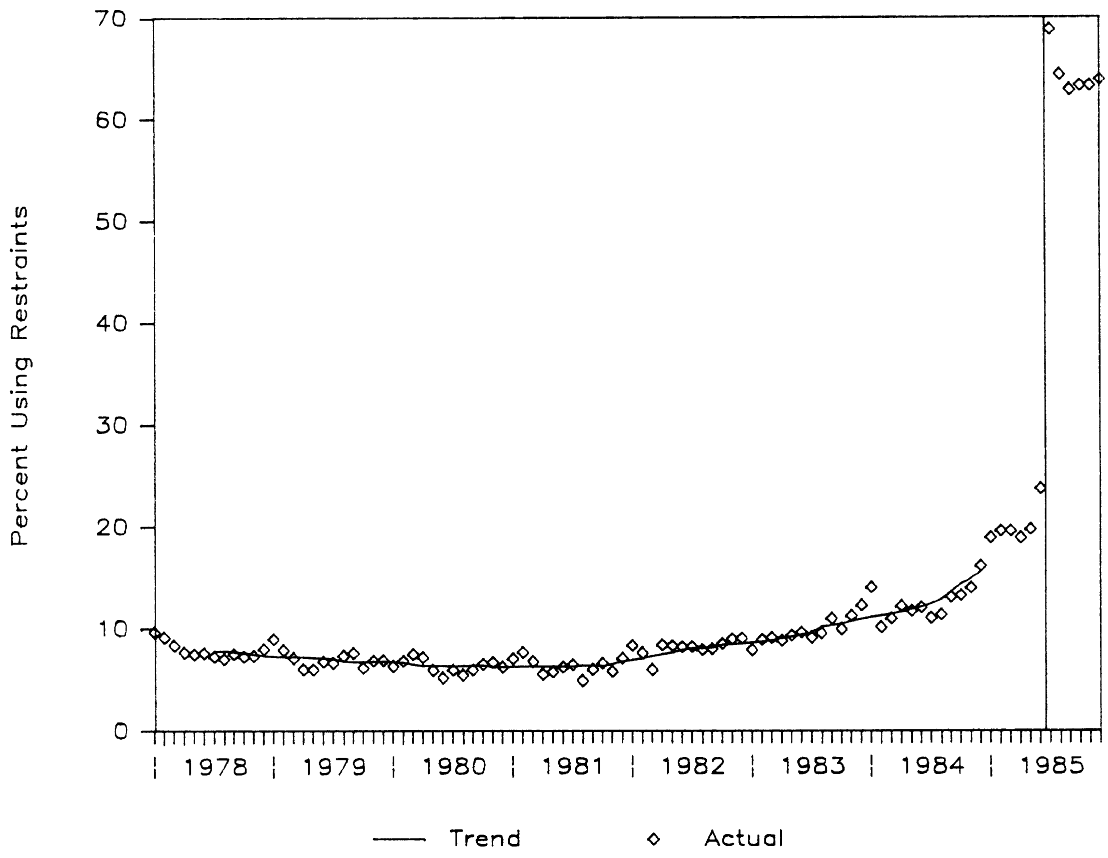

Figure 3.4 Restraint Use Among Injured Occupants Age 18-24

Belt use among 25-34-year-old occupants decreased very slightly between 1978 and 1981, and gradually increased to 20% during the 1982 through 1984 period (Figure 3.5). The upward trend increased in early 1985, and reported restraint use averaged 24% the first half of the year. During the second half of the year, with the compulsory use law in effect, reported belt use averaged 74%.

The pattern of restraint use for occupants age 35-54 (Figure 3.6) was similar to that for the 25-34 age group. Reported belt use averaged 27.1% the first half of 1985, jumping to 80.6% during the second half of the year.

Seat belt use among crash-involved motorists age 55 and over increased slightly in the early 1980s to about 18% in 1983 (Figure 3.7). By late 1984 use averaged 25%. Use increased further to 26.8% from January through June 1985, before jumping to 84% from July through December of that year. The post-law use rates for motorists age 55 and above clearly indicate that these data overestimate actual use rates. Our direct-observation studies confirm the finding shown here that older motorists have the highest rates of belt use under compulsory use. However, observed use rates of 54% in December 1985 are substantially lower than the 84% shown in Figure 3.7 for that month. It seems clear that a substantial proportion of crash-involved motorists are reporting to police officers at the scene of crashes that they were belted when in fact they were not.

Results presented thus far indicate that both of Michigan's compulsory restraint use statutes have had a substantial effect in increasing police-reported restraint use. In April 1982 when the child restraint law took effect, there were dramatic increases in reported restraint use among children under age 4, and only small increases in reported belt use among adult motor vehicle occupants. In July 1985 when the adult restraint law took effect, there were dramatic increases in belt use among motor vehicle occupants age 4 and over, and a slight further increase in restraint use among children under age 4. While the basic effect patterns are clear from these data, one should not place too much emphasis on the exact rate of restraint use indicated because of questions about the measurement of restraint use. If the use of a restraint is not obvious to a police officer investigating a crash, the officer may rely on the self-report of the drivers involved. One effect of compulsory use laws may have been to increase the number of crashed drivers who report that they or their passengers were restrained when in fact they had not been, since reporting lack of restraint use is admitting a violation of law. Such an effect would bias upward these estimates of restraint use after the compulsory use statutes were in effect. To avoid inferences based only on a potentially inaccurate measure of restraint use, the major focus of this study is on the effects of the policies on the ultimate outcome of interest, namely numbers and rates of people injured and killed in crashes.

3.3 Effects on Numbers and Rates of Injuries

The number of injured crash-involved occupants under age 4 is depicted in Figure 3.8.[4]

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4. All estimates of injury reductions reported here are based on the **number** of motor vehicle occupants injured. As indicated in Appendix A, 2.2, all analyses are based on counts of injured occupants; while many occupants in crashes sustain multiple injuries, each injury was not counted separately.

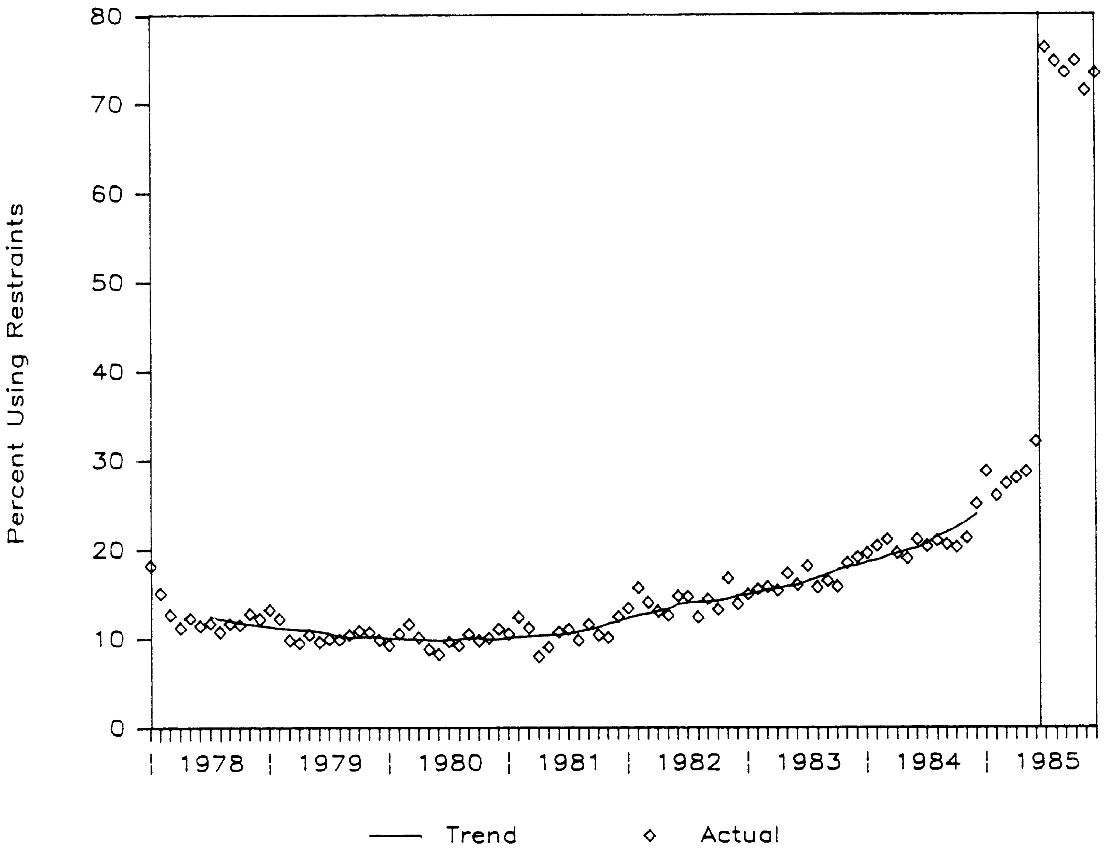

Figure 3.5 Restraint Use Among Injured Occupants Age 25-34

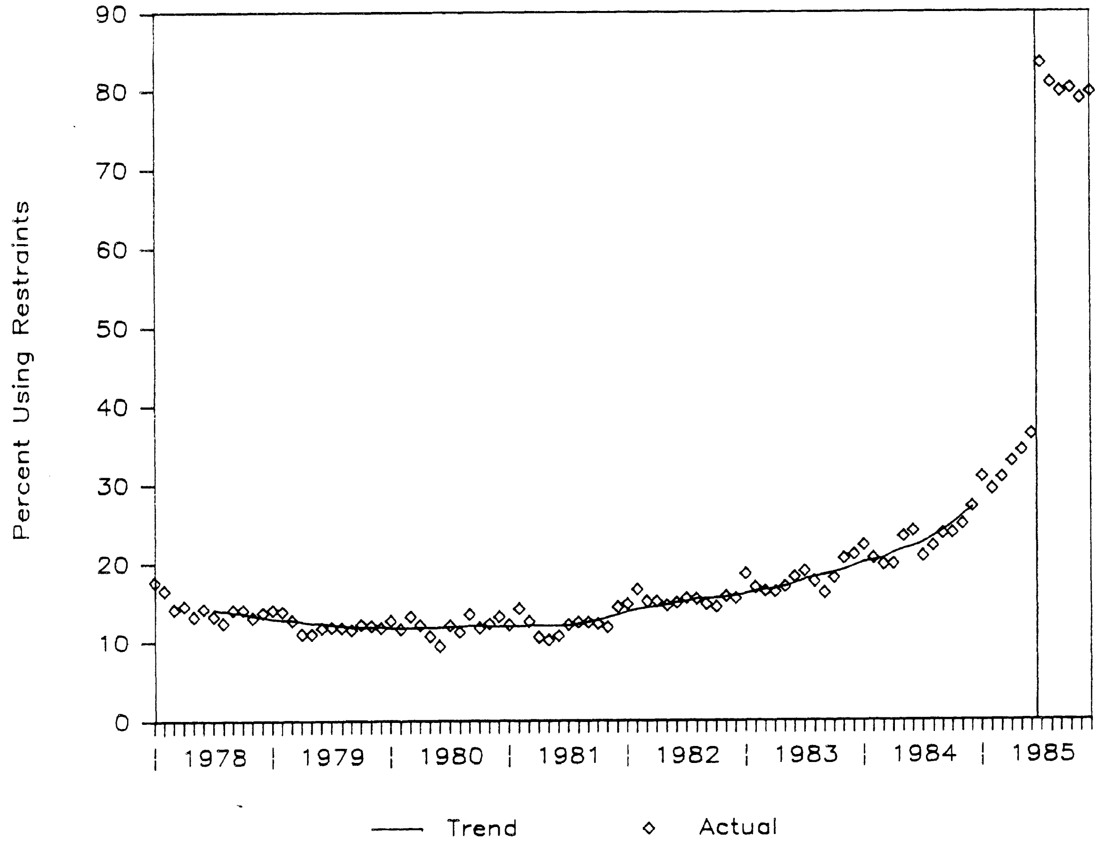

Figure 3.6 Restraint Use Among Injured Occupants Age 35-54

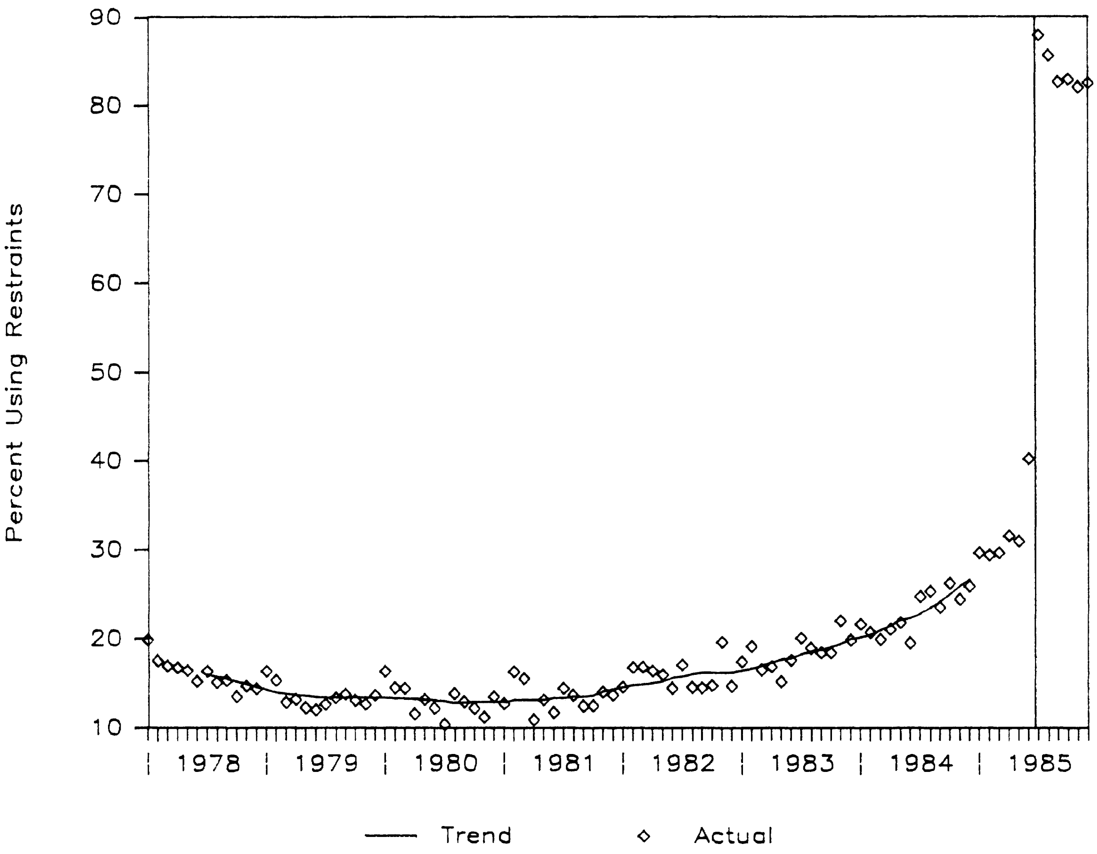

Figure 3.7 Restraint Use Among Injured Occupants Age 55 and Over

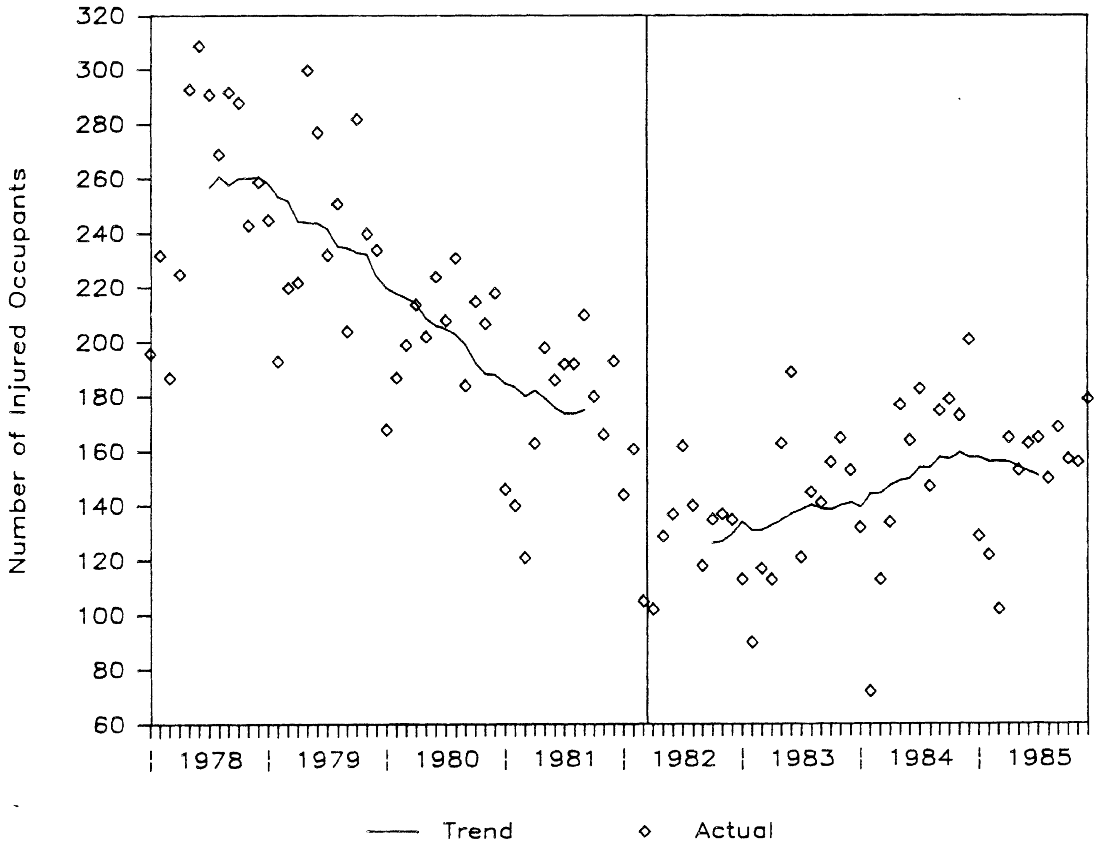

Figure 3.8 Number of Injured Occupants Age 0-3

	Percent Change	*t*-Ratio
Effects of CRD PI&E, January-March 1982	-25.4	1.92
Effects of CRD Law, April 1982-December 1985*	-28.2	2.42

Baseline time-series model: ARIMA (0,1,3) $(0,0,0)_{12}$

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* Effective date of mandatory child restraint law was April 1, 1982.

The number of children injured in this age group declined from 1978 through the beginning of 1983, drifted upward in late 1983 and 1984, before decreasing again in 1985. Results of the time-series analyses shown in Figure 3.8 reveal a significant decline in the number of children under age 4 injured in crashes after the child restraint law was implemented. The estimated effect of the law over the entire 45-month post-law period was a 28.2% decline in child injuries (from 180 to 133 per month).

One way to assess whether the child restraint law was indeed responsible for the reduction in children injured after April 1982 is to compare patterns across age groups. Since only children under age 4 were covered by the 1982 law, observed changes in injuries should be more dramatic in this age group than among older occupants. Figure 3.9 displays how the number of injured occupants age 4-15 has varied in recent years. Although the overall pattern is similar to that of younger children, the decline beginning in April 1982 is much smaller, and the increased number of injuries during 1983 and 1984 is more pronounced than for 0-3-year-olds. By 1984, injuries among 4-15-year-olds returned to the level observed in 1981, while injuries among 0-3-year-olds remained substantially below 1981 levels.

Our analyses of the effects of the adult belt law concentrated on adult motorists because of the apparent spill-over effect of the child restraint law on older children. Teenagers and adults were first exposed to compulsory use in 1985. The number of injuries among those age 16 and over showed a consistent downward trend from 1978 through mid-1982, and increased in 1983 and 1984 (Figure 3.10). After controlling for these long-term trends via time-series models, we found a statistically significant 12.1% decline in the number of injured occupants age 16 and over during the second half of 1985, when the compulsory use law was in effect. The April-June 1985 period, characterized by increased publicity about the soon-to-take-effect belt law, showed an estimated 3.7% decline in number of occupants injured (not statistically significant). Subgroups within the 16-and-over age category are shown in Figures 3.11 through 3.15.

Similarly, the number of fatalities among occupants age 10 and over in front-seat positions was examined.[5] The plot reveals a consistent decline from 1978 through mid-1983, and an increase in late 1983 and 1984 (Figure 3.16). During the first 12 months with compulsory belt use, the number of fatalities was down an estimated 10%, based on Box-Jenkins time-series model results. However, this decrease was not statistically significant, given the substantial month-to-month and year-to-year variation in number of fatalities in Michigan during the baseline period.

The number of people in Michigan of a given age changes slightly from year to year as birth rates change and the population ages. For example, Figure 3.17 shows the estimated Michigan resident population from 1978 through 1985. Examination of this expanded scale not only shows the upward trend in population during the past decade, but also reveals a temporary decline in the number of Michigan residents age 10 and over in 1982 and 1983. This population

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5. The "children" versus "adult" age split was at age 16 for the injury time series, for consistency with previous reports in this series tracking crash involvement and injury trends in Michigan (Wagenaar, 1984a; Wagenaar and Webster, 1985; Wagenaar and Maybee, 1986). Given that the fatality series were added for the first time during the current study, we concluded that age 10 was an optimal cut-point because there is no evidence that the child restraint law influenced restraint use among those age 10 and over.

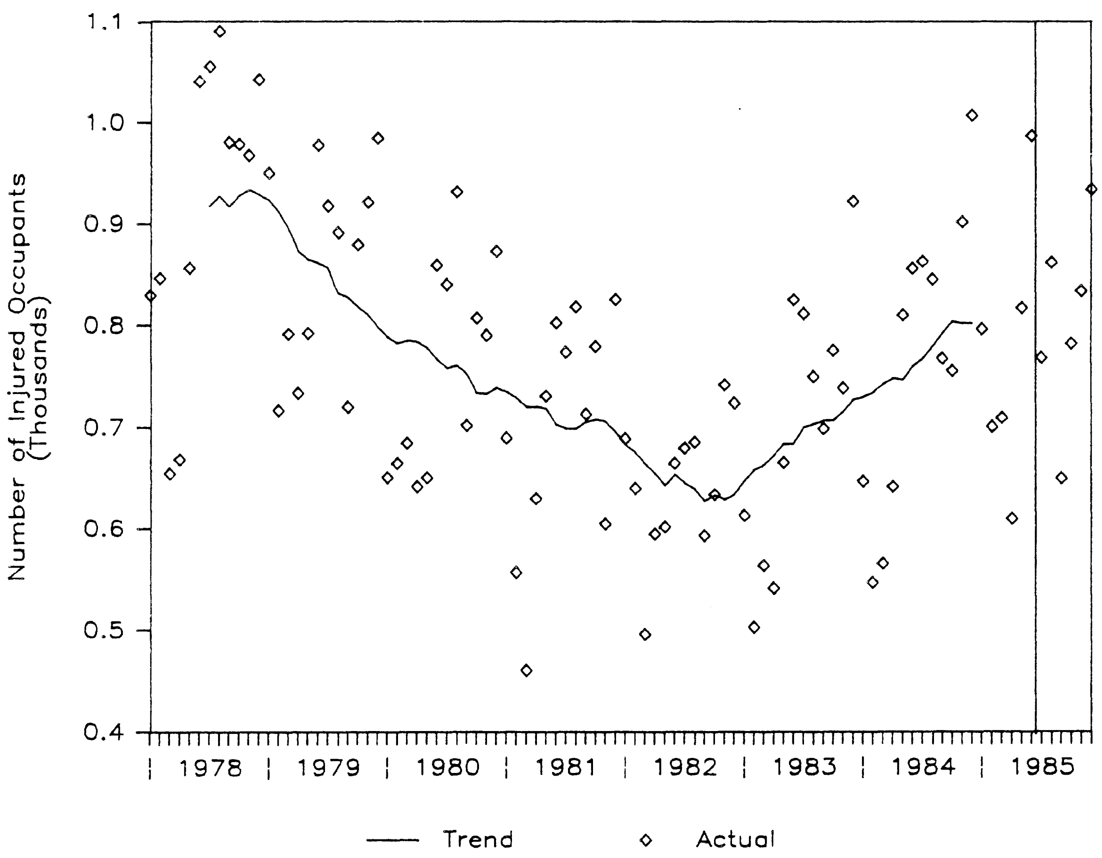

Figure 3.9 Number of Injured Occupants Age 4-15

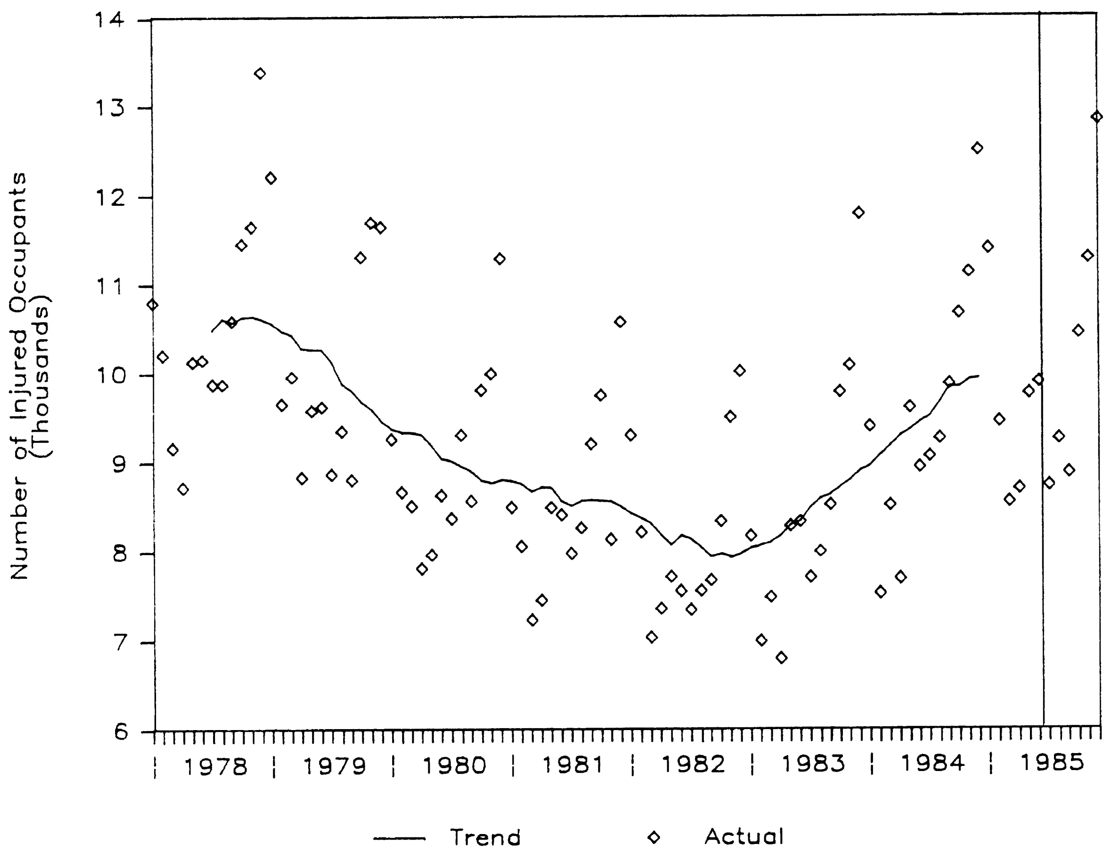

Figure 3.10 Number of Injured Occupants Age 16 and Over

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	-3.7†	1.04
Effects of Adult Law, July 1985-December 1985*	-12.1	2.33

Baseline time-series model: ARIMA (1,1,4) $(0,1,1)_{12}$

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* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

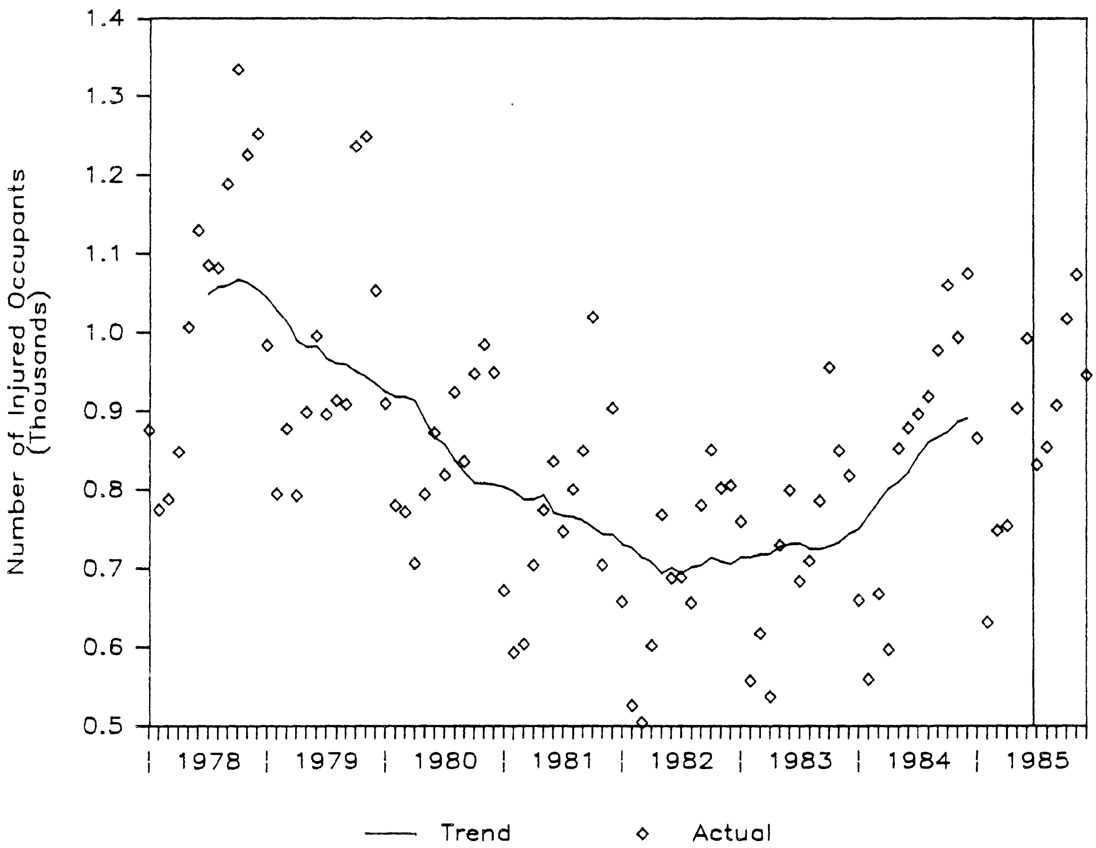

Figure 3.11 Number of Injured Occupants Age 16-17

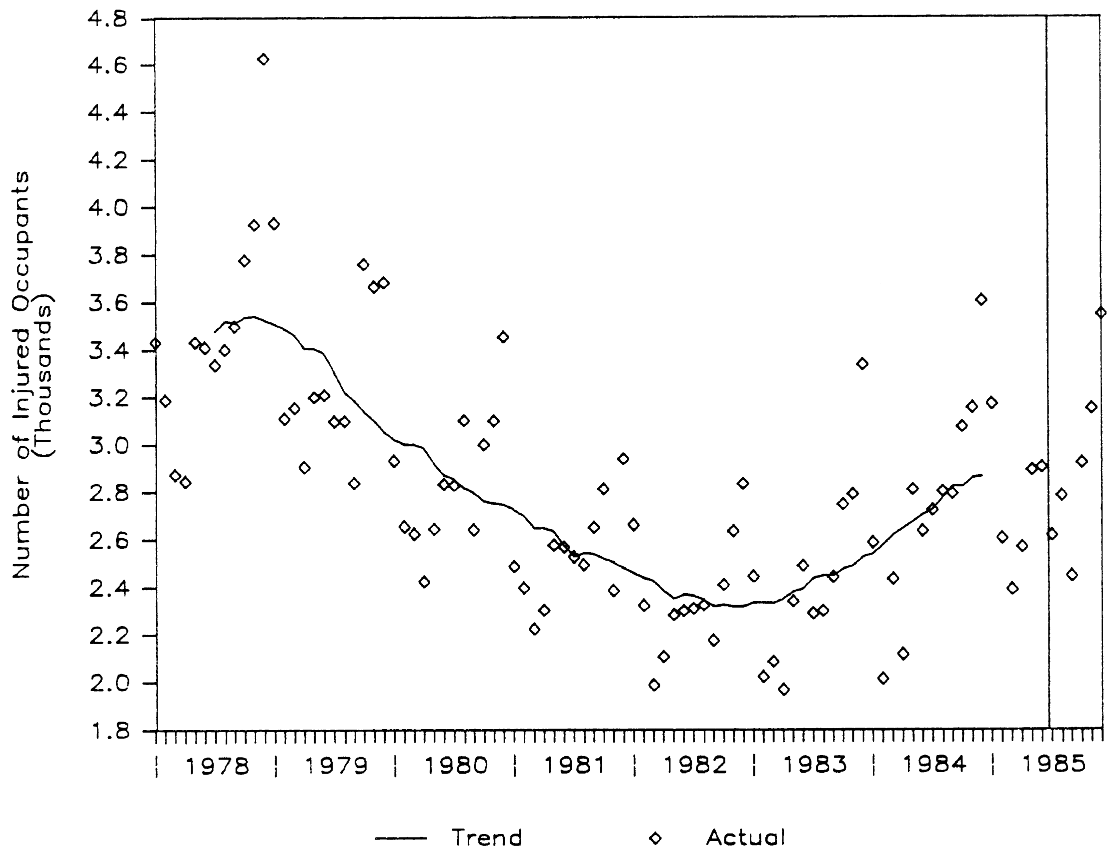

Figure 3.12 Number of Injured Occupants Age 18-24

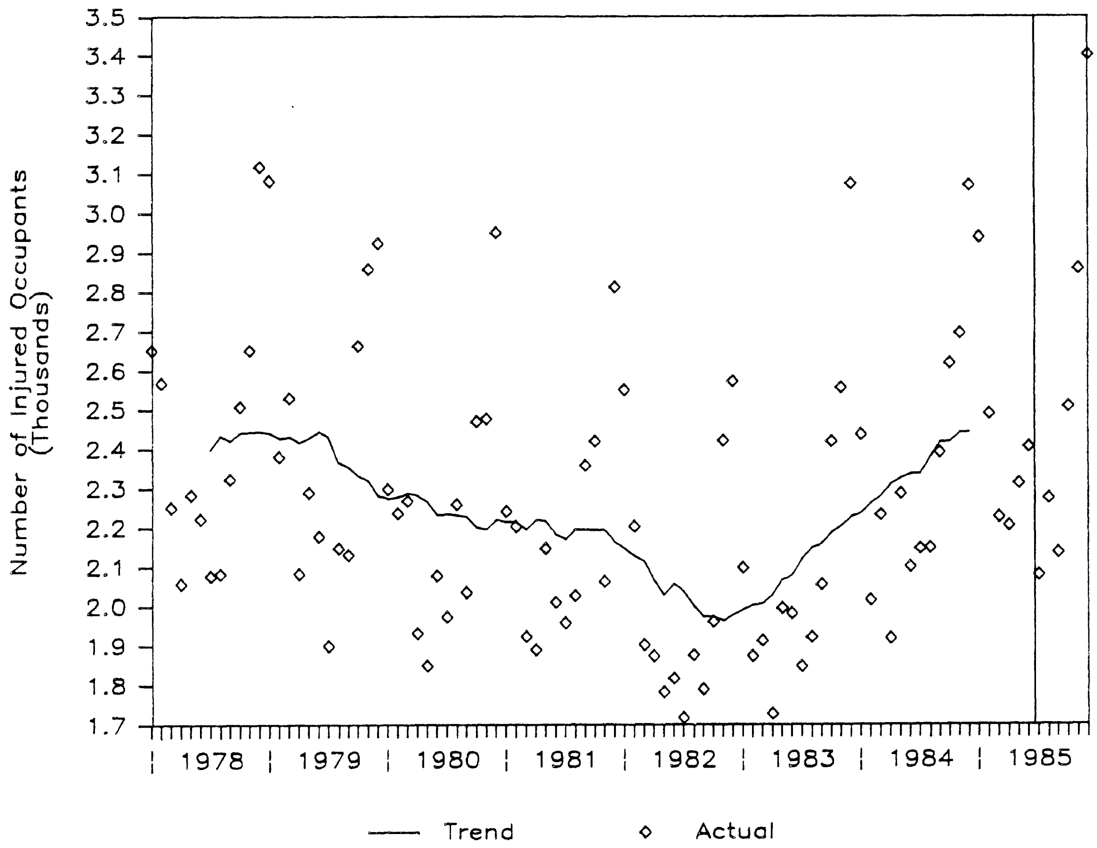

Figure 3.13 Number of Injured Occupants Age 25-34

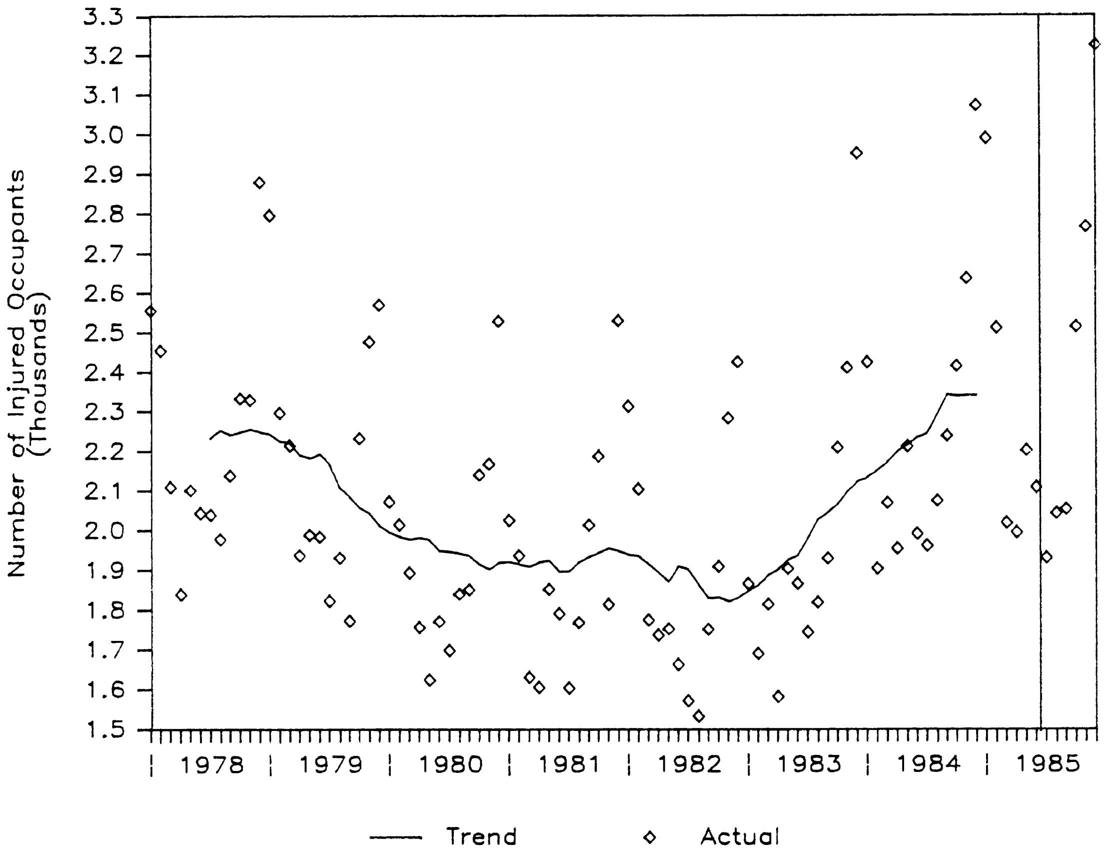

Figure 3.14 Number of Injured Occupants Age 35-54

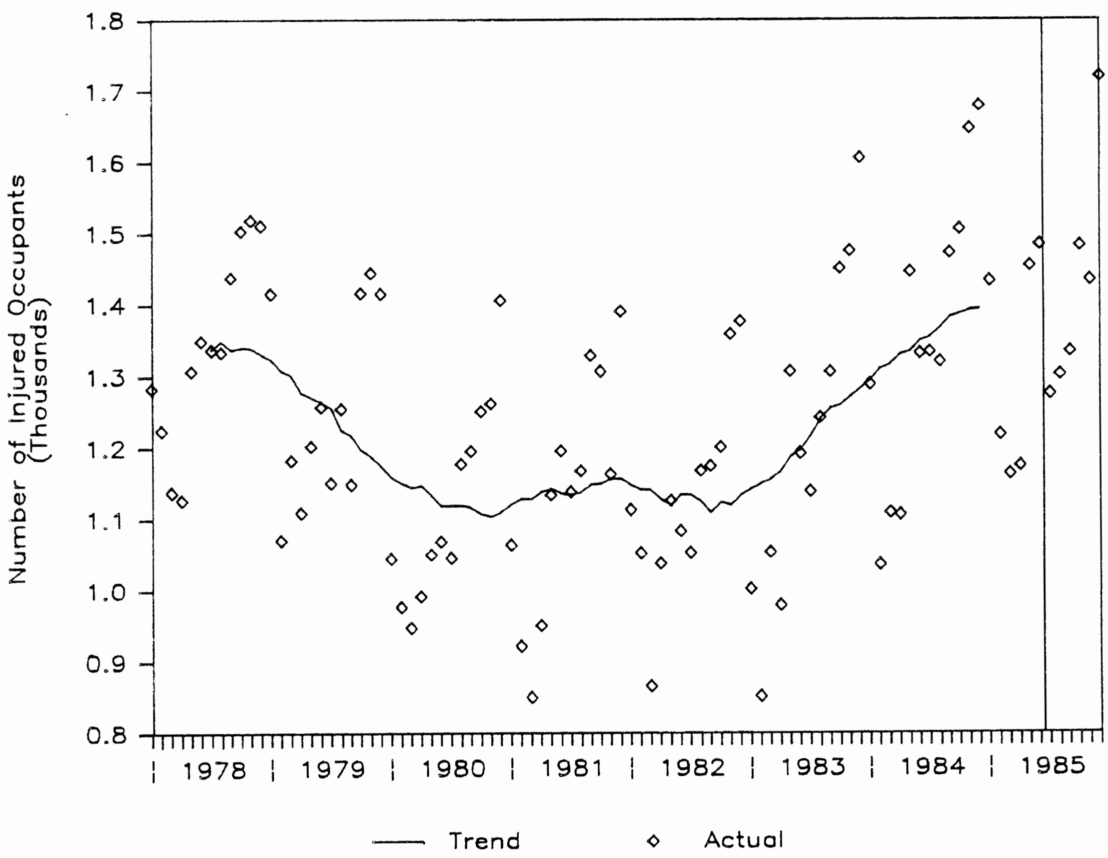

Figure 3.15 Number of Injured Occupants Age 55 and Over

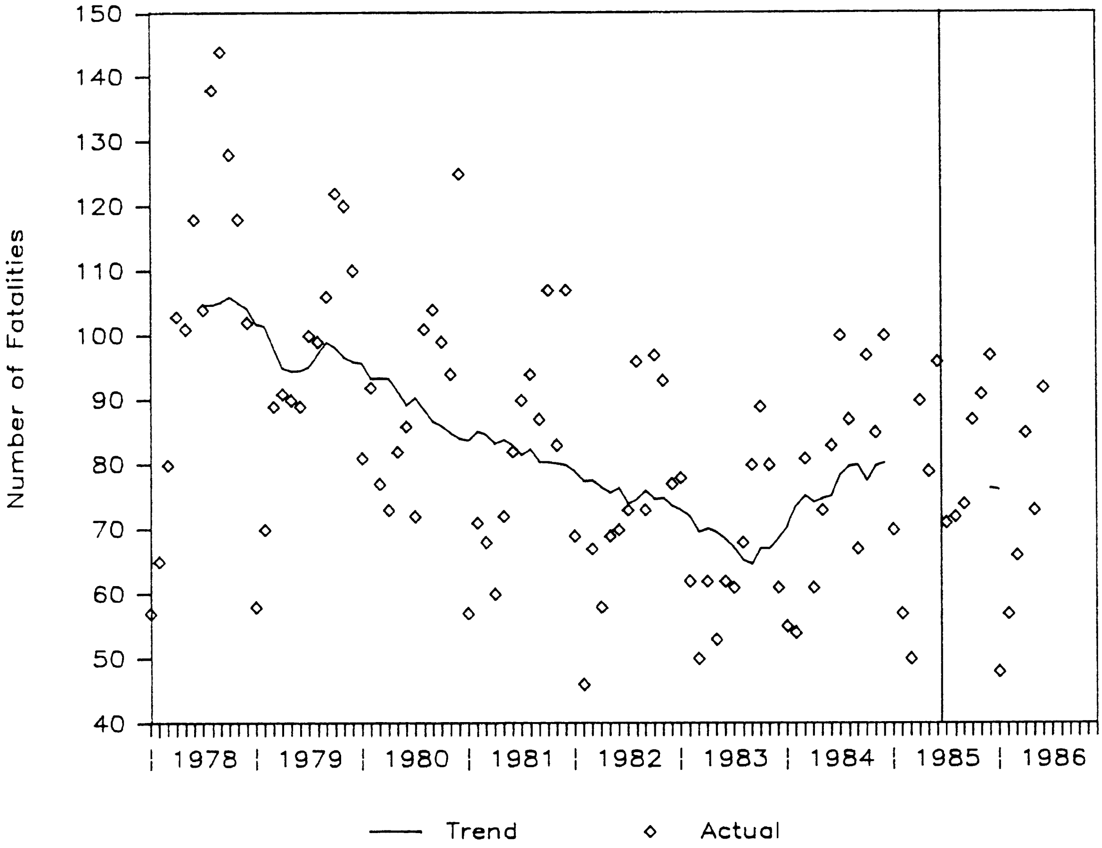

Figure 3.16 Number of Front Seat Fatalities Age 10 and Over

	Percent Change	t-Ratio
Effects of Adult PI&E, April 1985-June 1985	-0.4†	0.03
Effects of Adult Law, July 1985-June 1986*	-10.0†	1.24

Baseline time-series model: ARIMA (0,0,3) $(0,1,1)_{12}$

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* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

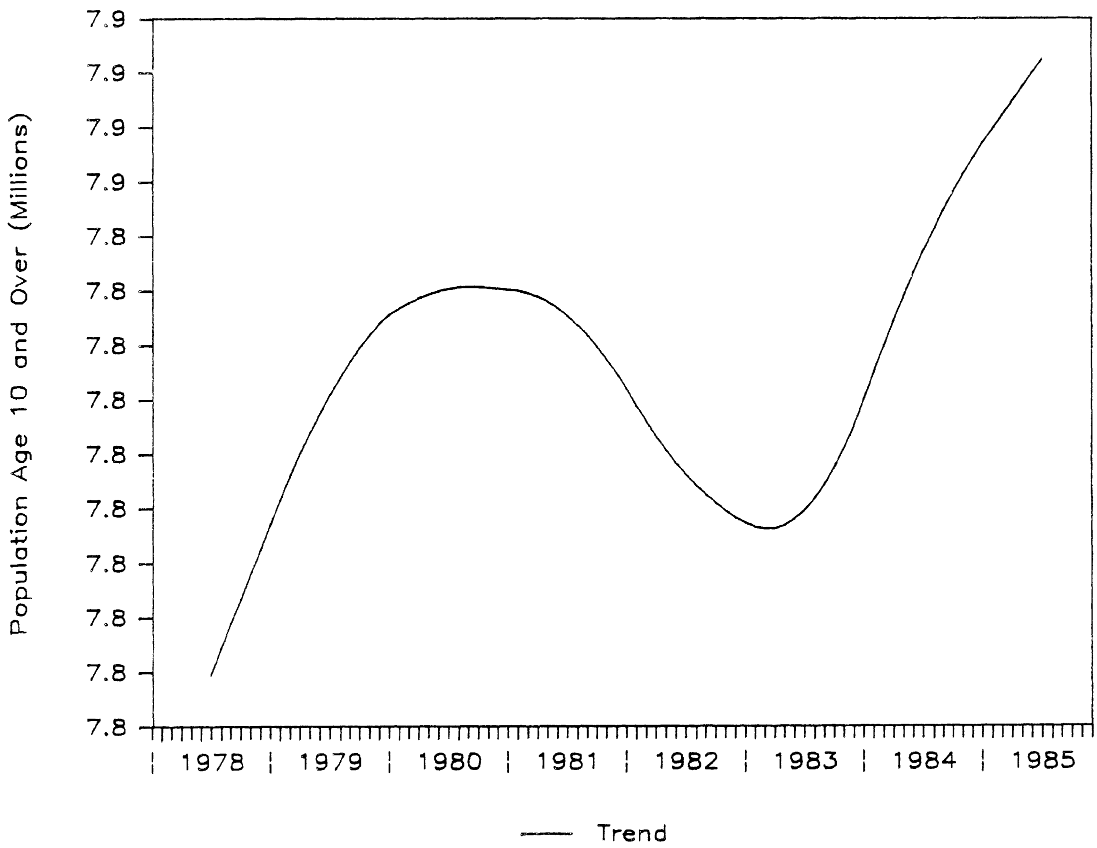

Figure 3.17 Michigan Resident Population Age 10 and Over

decline may partially explain the decreased number of injuries in those years. To ensure that observed reductions in the number of occupants injured at the time Michigan restraint laws took effect were not due to a reduction in the number of Michigan residents of a given age, rates of crash injuries for Michigan population were also examined.

A careful comparison of the injury **rate** per million population (Figure 3.18) with the **frequency** of injuries among those under age 4 (Figure 3.8) reveals that the post-child-restraint-law trend line for the rate is slightly but consistently higher than the post-law trend line for the frequency. This observation is confirmed by the time-series results, which show a 28.2% decline in the **frequency** of child injuries during the post-law period, and a 26.0% decline in the **rate** of child injuries (Figure 3.18). The main point is that the estimated effect of the child restraint law changes little when population levels are taken into account.

The effect of the adult seat belt law on the rate of injured occupants age 16 and over per thousand population was also analyzed using time-series methods (Figure 3.19). Results showed a statistically significant 11.6% decline in the rate of injured occupants the first six months belt use was compulsory for adults. The estimated effect of the adult belt law changed little after taking into account changes in the resident population (i.e., an estimated 12.1% reduction in number of injuries versus an 11.6% estimated reduction in rate per population). Occupant injury rates for other age subgroups are shown in Figures 3.20 through 3.25.

Results for the rate per population of front-seat fatalities among occupants age 10 and over were also similar to the results for the frequency of fatalities (Figure 3.26). Time-series models estimated a 14% reduction in the rate of fatalities associated with the adult belt law, but this effect was not statistically significant, given the short post-law period covered and the random month-to-month variability over the baseline period.

Note that all of the injury and fatality plots show an increase in number and rate of injured or killed occupants in 1983 and 1984. These increases are consistent with the heightened exposure to risk of injury or death as reflected in an increase in the total number of crash-involved vehicles in the state during those years. Because the number of motor vehicle crashes in the state is one obvious influence on the frequency of injury or death, we examined rates of injuries or fatalities per 10,000 crashed vehicles.[6] Analyses of injuries or fatalities per 10,000 crashed vehicles is particularly appropriate, since compulsory restraint policies are expected to increase the protection of automobile occupants once they are involved in a crash, but not affect the number of crashes.[7] Figure 3.27 depicts the trend in the total number of motor vehicle crashes in Michigan from 1978 through 1984.

Time-series modeling of the rate of children injured per 10,000 crashed vehicles revealed an estimated 31.5% reduction following implementation of the child restraint law (Figure 3.28). The PI&E program and associated publicity three months before the law took effect was associated with an 18.5% reduction. The 31.5% estimated reduction in rate of child

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6. These rates are the number of injured occupants in a specific age group per 10,000 total crashed vehicles in the state. The denominator of the rate is not age specific because the age of uninjured crash-involved occupants is not recorded.

7. One might argue that increased restraint use may also reduce the number of crashes because restrained passengers, especially children, may be less of a distraction to drivers. However, this effect is assumed to be small.

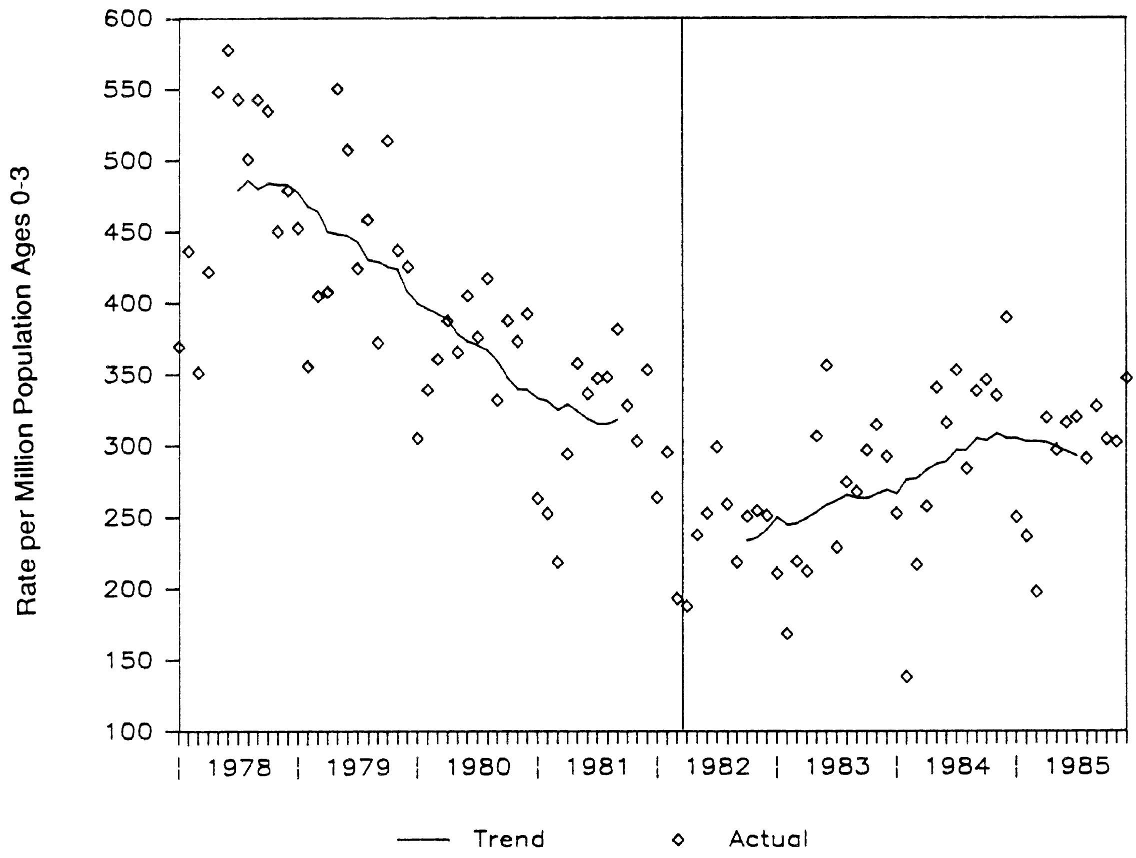

Figure 3.18 Rate of Injured Occupants Age 0-3 per Million Population

	Percent Change	*t*-Ratio
Effects of CRD PI&E, January-March 1982	-24.2	1.80
Effects of CRD Law, April 1982-December 1985*	-26.0	2.15

Baseline time-series model: ARIMA (0,1,3) $(0,0,0)_{12}$

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* Effective date of mandatory child restraint law was April 1, 1982.

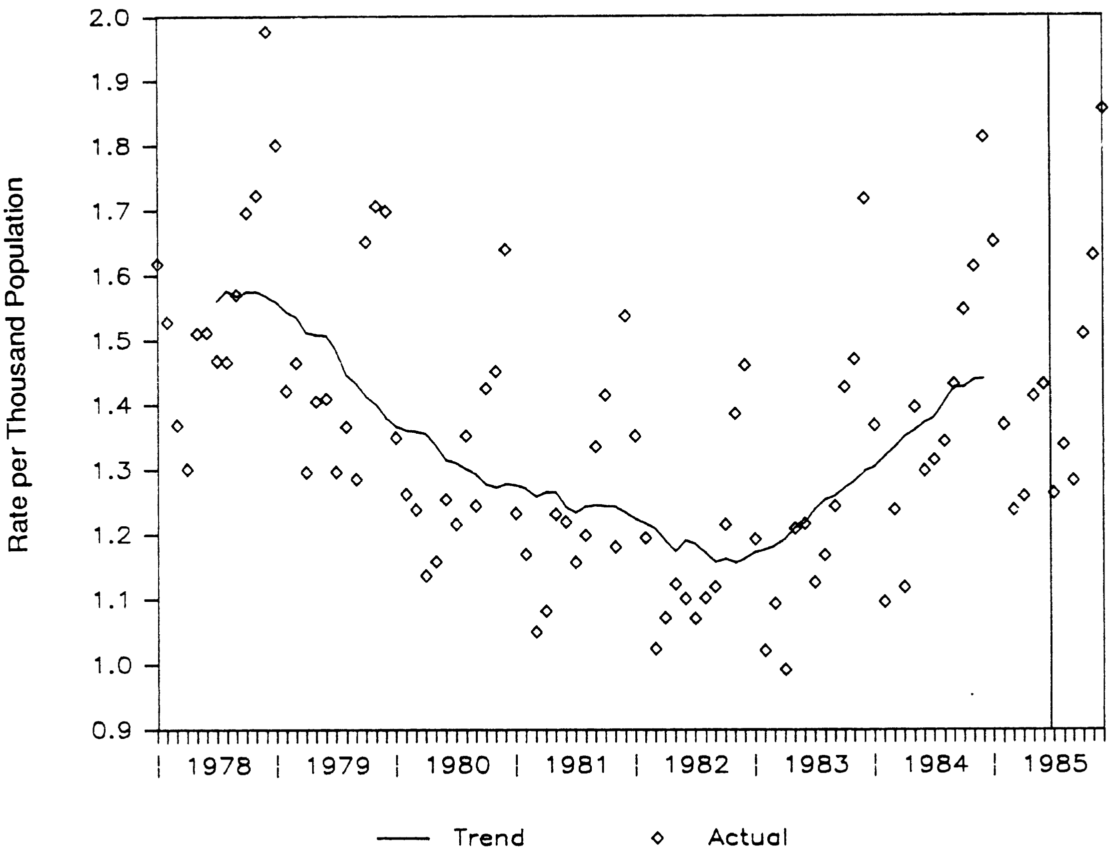

Figure 3.19 Rate of Injured Occupants Age 16 and Over per Thousand Population

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	-3.3†	0.86
Effects of Adult Law, July 1985-December 1985*	-11.6	2.10

Baseline time-series model: ARIMA (0,1,4) $(0,1,1)_{12}$

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* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

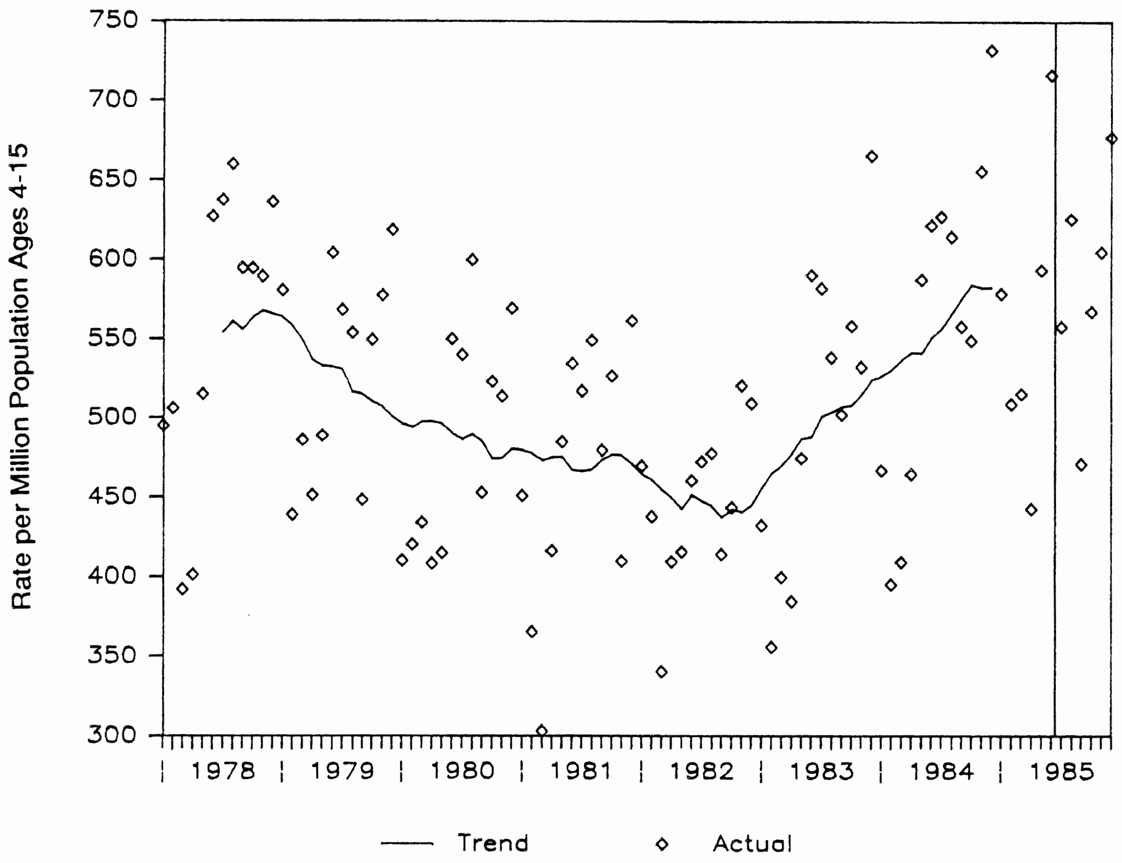

Figure 3.20 Rate of Injured Occupants Age 4-15 per Million Population

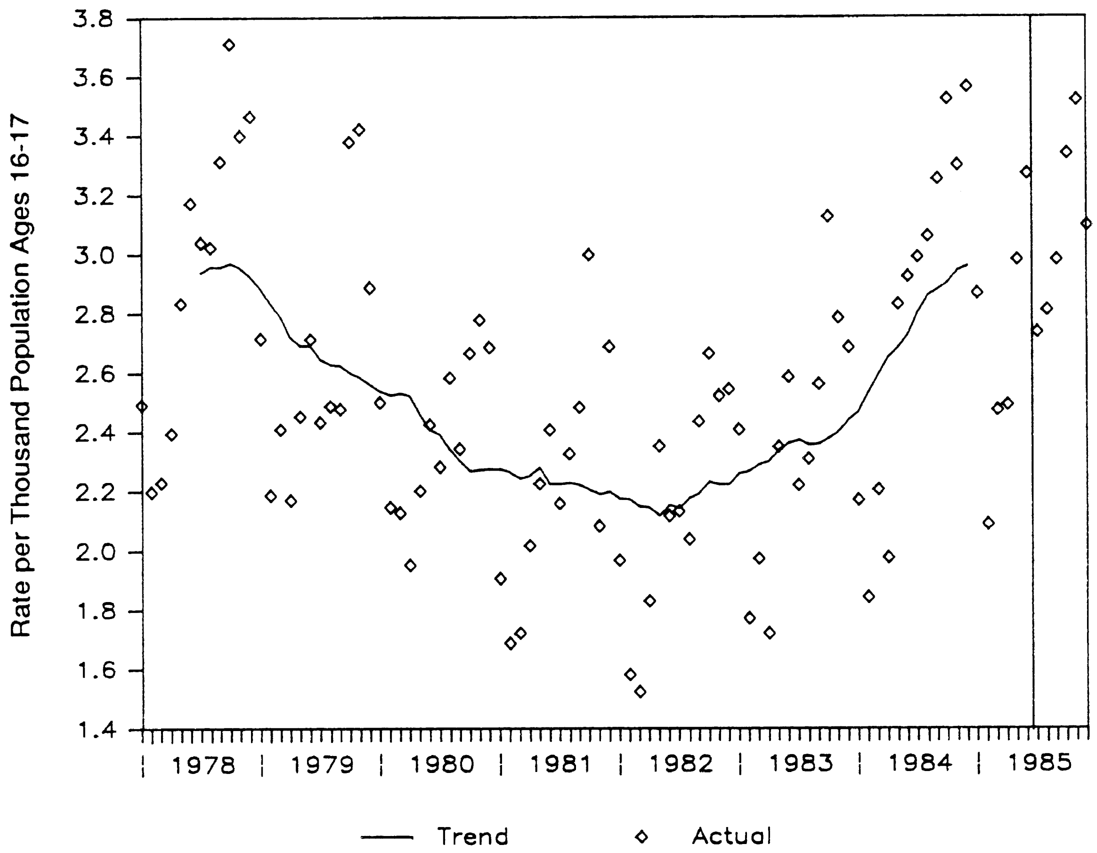

Figure 3.21 Rate of Injured Occupants Age 16-17 per Thousand Population

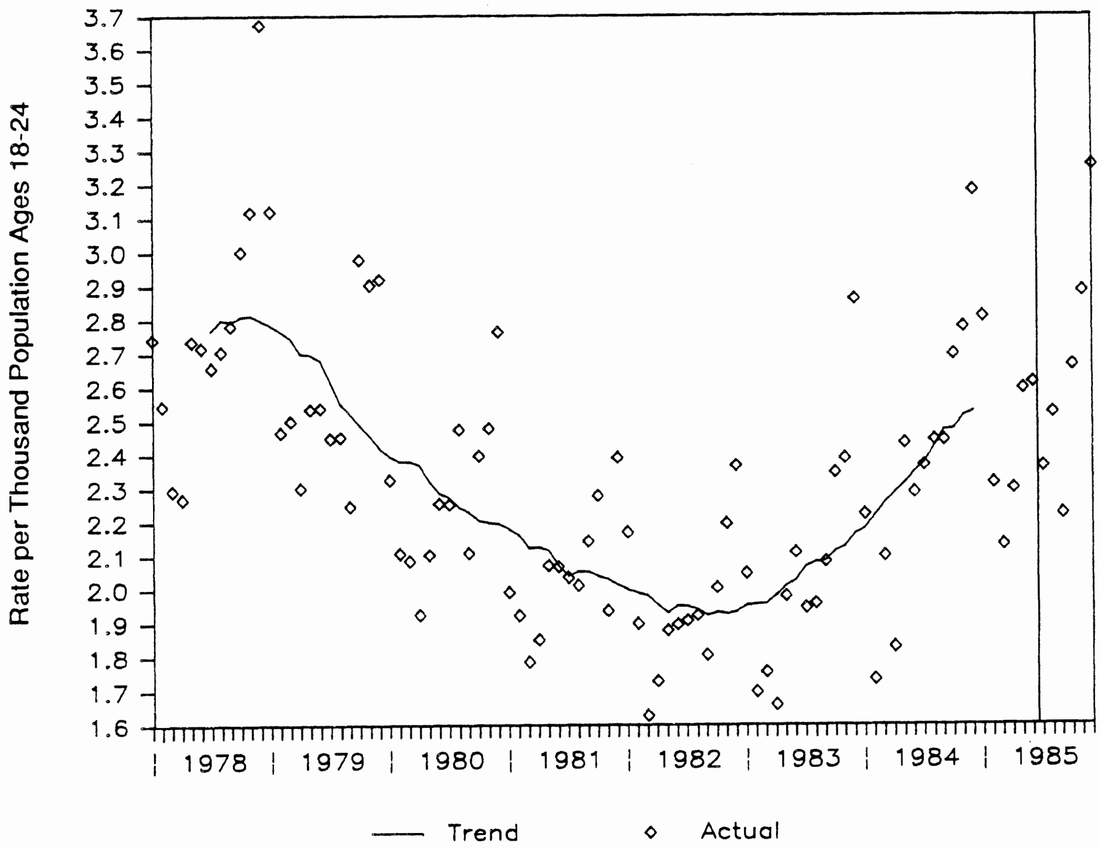

Figure 3.22 Rate of Injured Occupants Age 18-24 per Thousand Population

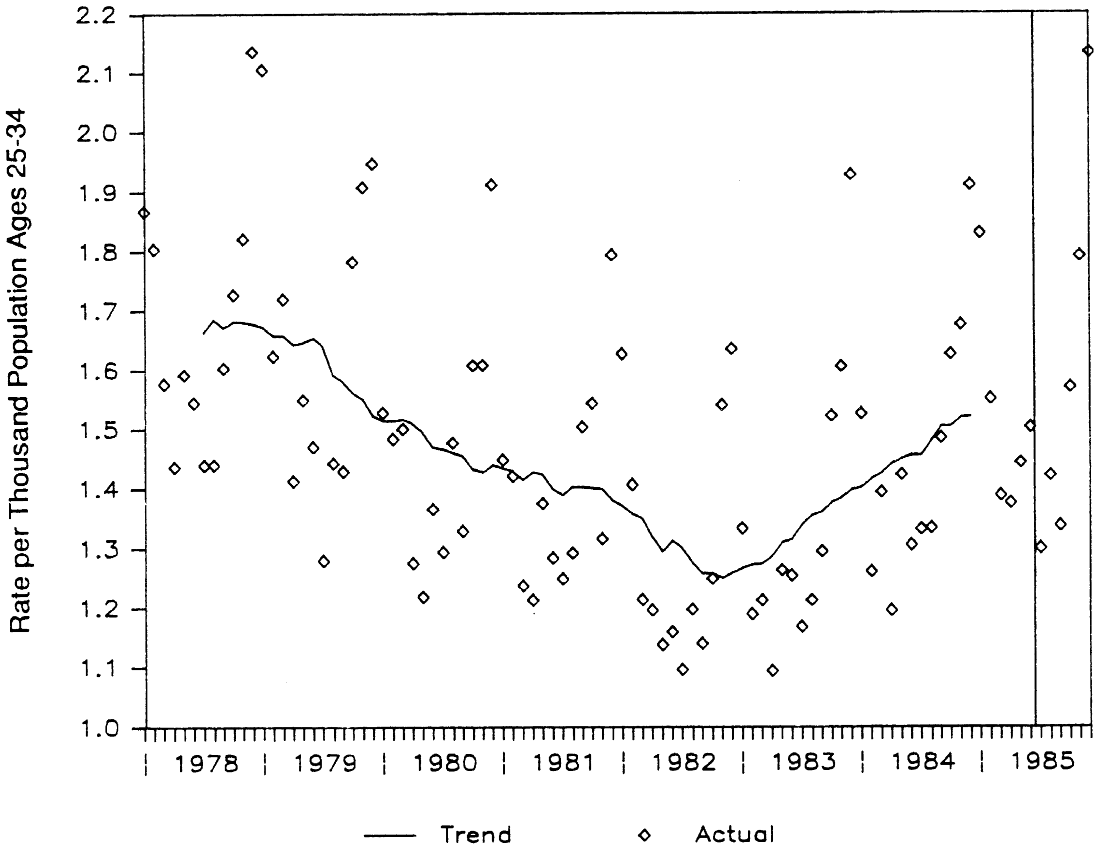

Figure 3.23 Rate of Injured Occupants Age 25-34 per Thousand Population

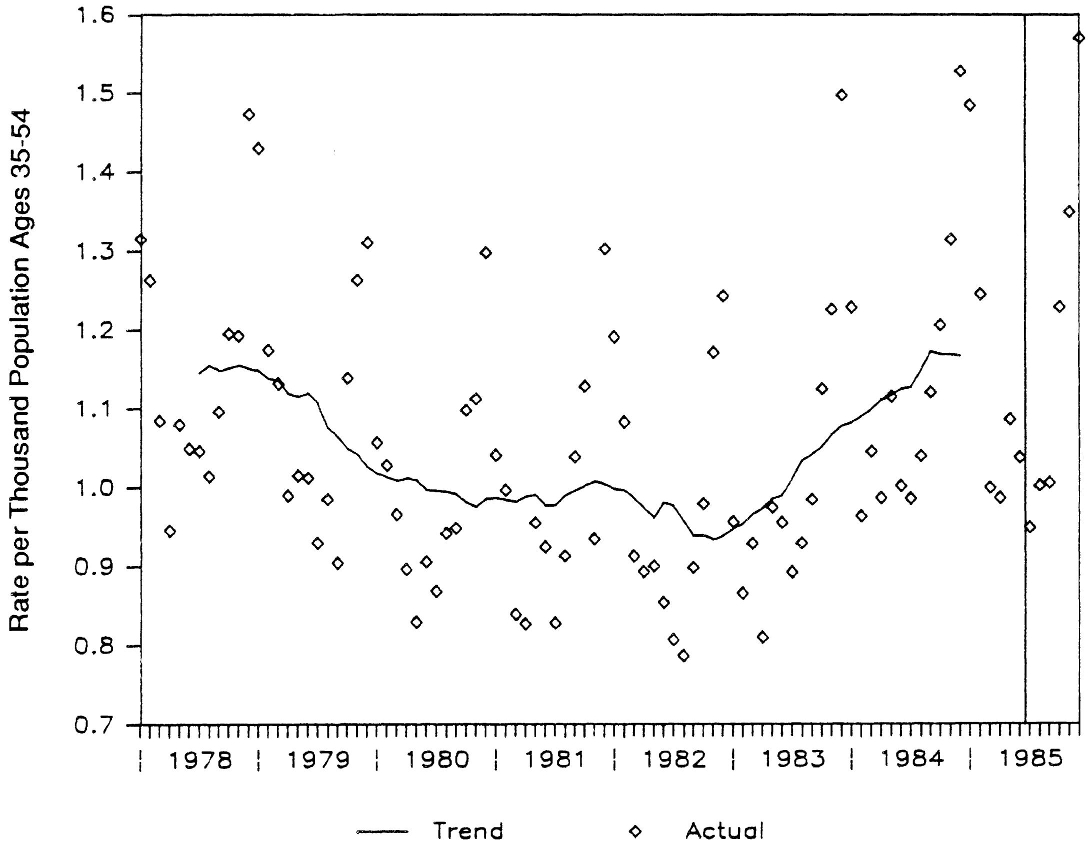

Figure 3.24 Rate of Injured Occupants Age 35-54 per Thousand Population

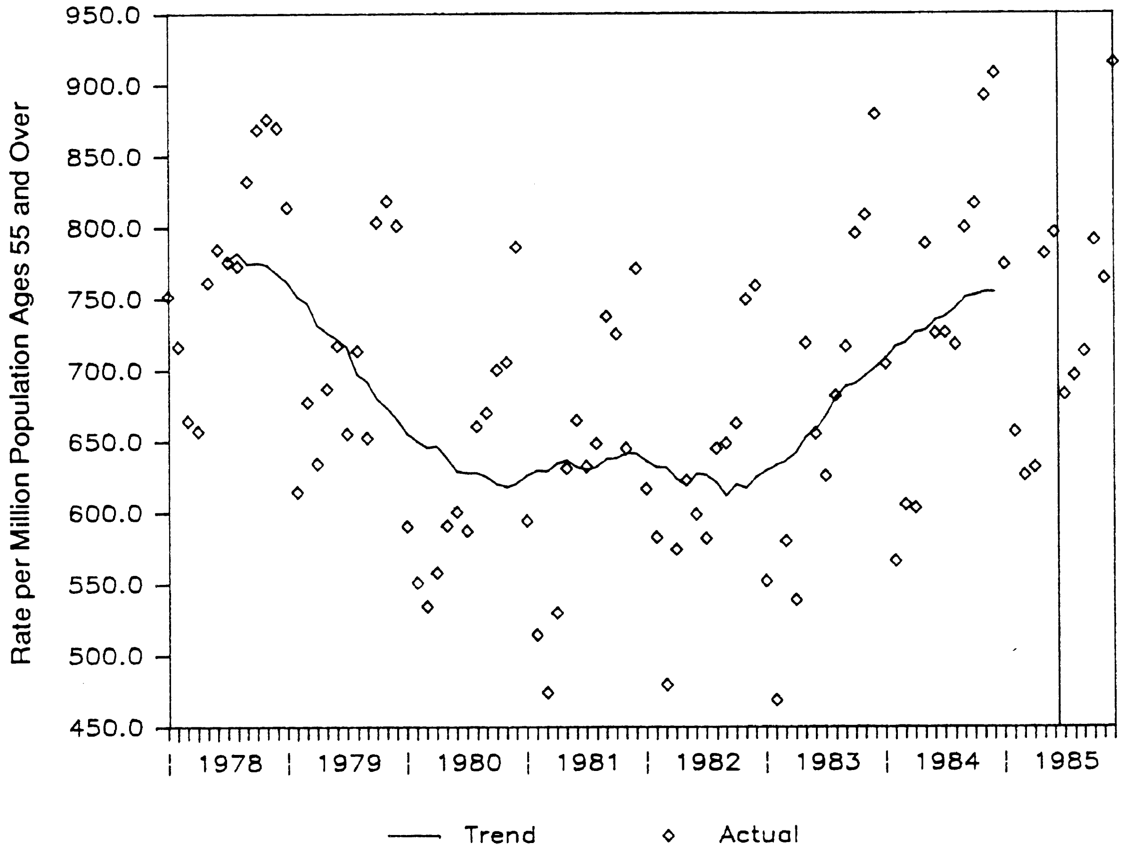

Figure 3.25 Rate of Injured Occupants Age 55 and Over per Million Population

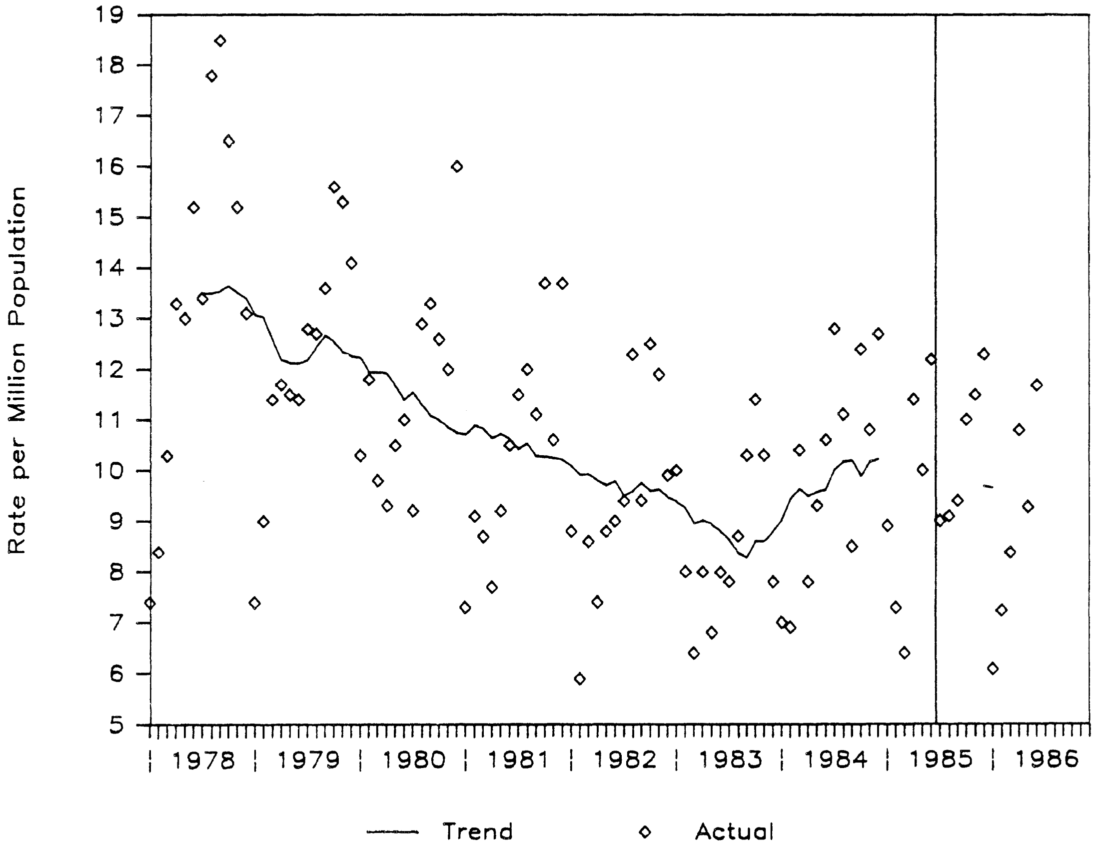

Figure 3.26 Rate of Front Seat Fatalities Age 10 and Over per Million Population

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	2.1†	0.19
Effects of Adult Law, July 1985-June 1986*	-14.0†	1.18

Baseline time-series model: ARIMA (0,1,1) $(0,1,1)_{12}$

* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

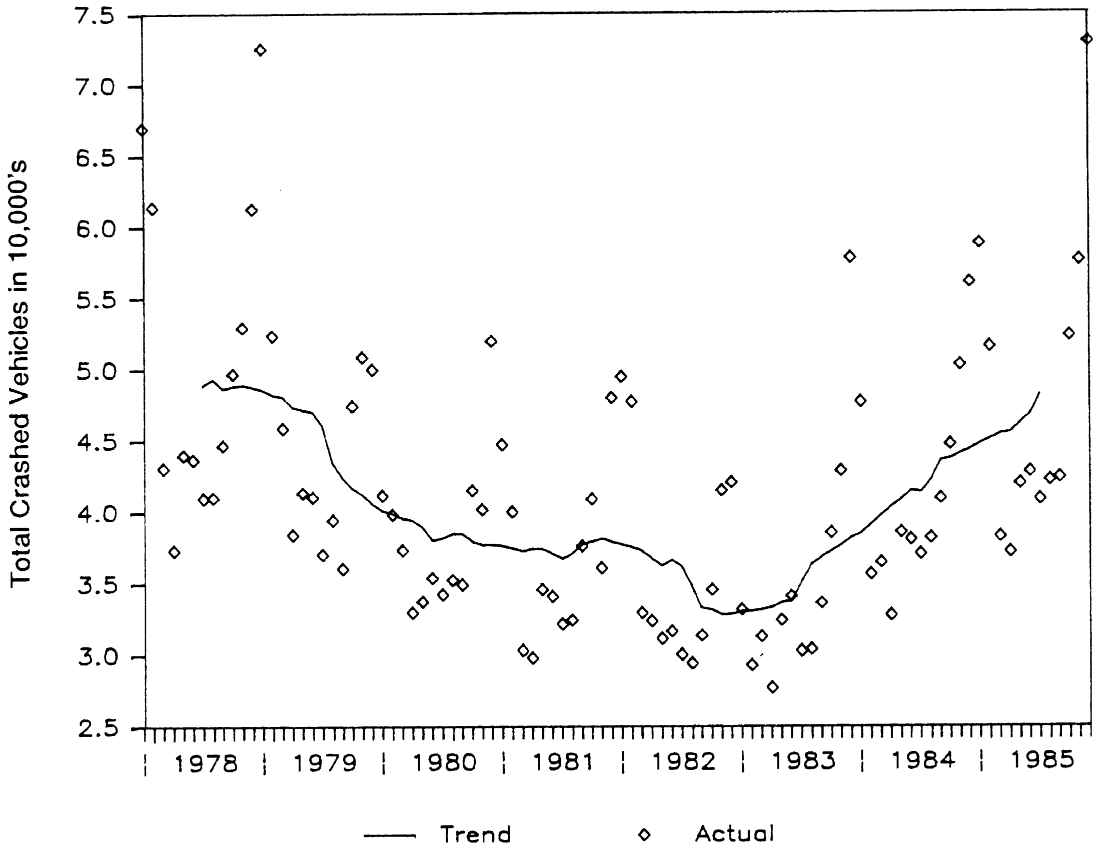

Figure 3.27 Number of Vehicles Involved in Traffic Crashes in Michigan

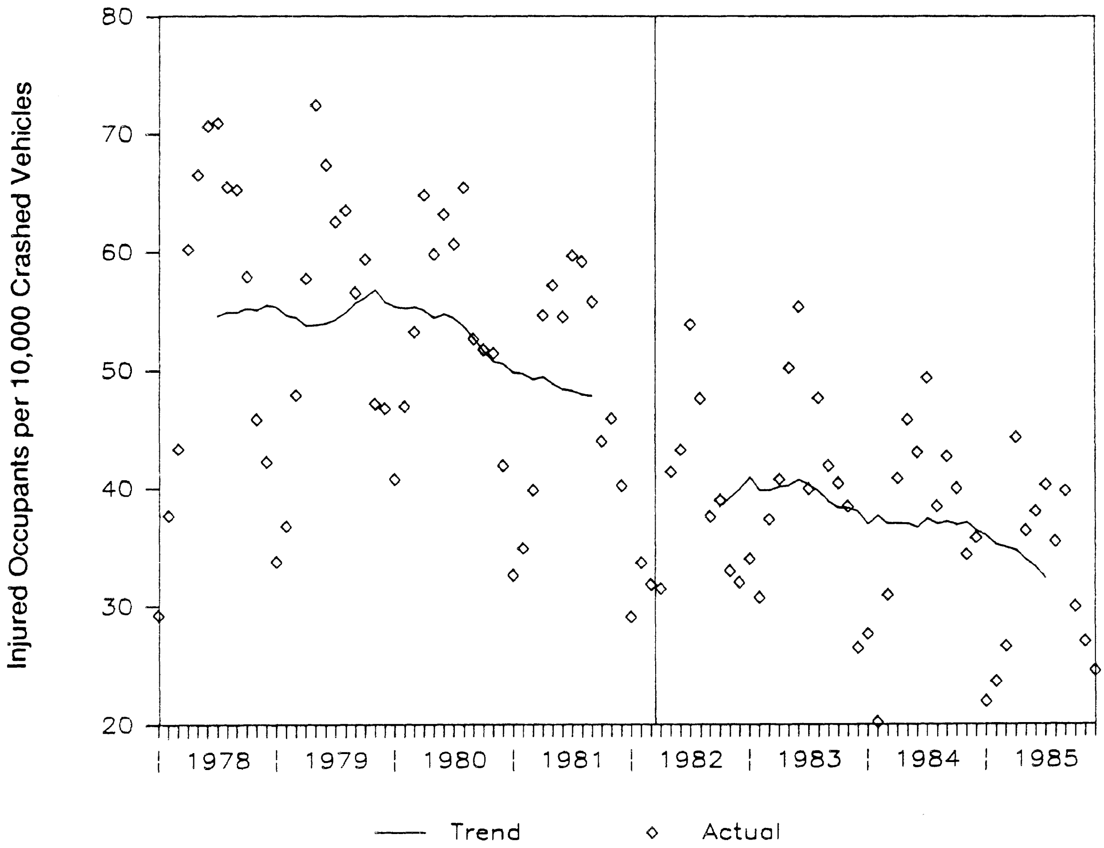

Figure 3.28 Injured Occupants Age 0-3 per 10,000 Crashed Vehicles

	Percent Change	*t*-Ratio
Effects of CRD PI&E, January-March 1982	-18.5	2.40
Effects of CRD Law, April 1982-December 1985*	-31.5	8.78

Baseline time-series model: ARIMA $(0,0,5)(0,1,1)_{12}$

* Effective date of mandatory child restraint law was April 1, 1982.

injuries per 10,000 crashed vehicles is similar to the 28.2% estimated reduction in the raw frequency of children injured (Figure 3.8), and the 26.0% reduction in the rate per population. It is clear that controlling for the effects of broader conditions influencing the number of crashes does not appreciably change the estimated effect of the child restraint law.

The adult seat belt law also had a significant effect on the rate of occupants injured per 10,000 crashes. Time-series modeling results revealed that the injury rate per 10,000 crashed vehicles among those age 16 and over in the last half of 1985 was 16.1% lower than would have been expected had the mandatory seat belt law not been implemented (Figure 3.29). Injury rates per 10,000 crashed vehicles for specific age subgroups are shown in Figures 3.30 through 3.35.

The largest overall estimated effect of the adult seat belt law was a significant 29.9% reduction in the rate per 10,000 crashes of front-seat fatalities among occupants age 10 and over (Figure 3.36). The reason this fatality rate declined in the last half of 1985 so much more than the raw number of fatalities is the substantial increase in total number of crashed vehicles that occurred during this period (Figure 3.27). Despite a clear increase in the number of traffic crashes in late 1985, fatalities apparently did not follow suit because of the substantially higher rates of seat belt use following implementation of the adult seat belt law.

The rate of occupants injured or killed per billion miles traveled in Michigan was also examined as an alternative way to control for exposure to risk of injury. Consistent with the observed increase in total number of crashes in late 1985, VMT also increased substantially during this period (Figure 3.37).

The rate per VMT of injured occupants under age 4 declined 27.7% after Michigan implemented the child restraint law (Figure 3.38). Again, this alternative method of controlling for exposure produces an estimated effect of the child restraint law that is very similar to the estimates based on rate per population, rate per 10,000 crashed vehicles, or raw frequency of injured occupants.

The rate per VMT of injured occupants age 16 and over declined an estimated 8.7% at the time the adult seat belt law took effect (Figure 3.39). This decline is significant at $p<.10$, but not $p<.05$.

The rate per VMT of fatalities among occupants age 10 and over declined an estimated 9.3% when the mandatory belt law went into effect (Figure 3.40). However, this reduction was not statistically significant.

Many of the time-series modeling results indicate very small injury or fatality declines in the three months before the adult seat belt law took effect. However, the pre-law PI&E estimated decreases were not consistent and were not statistically significant in any of the cases. It is clear that the modest 6-percentage-point increase in observed belt use between passage and implementation of the law was not adequate to cause an identifiable decrease in injuries or deaths.

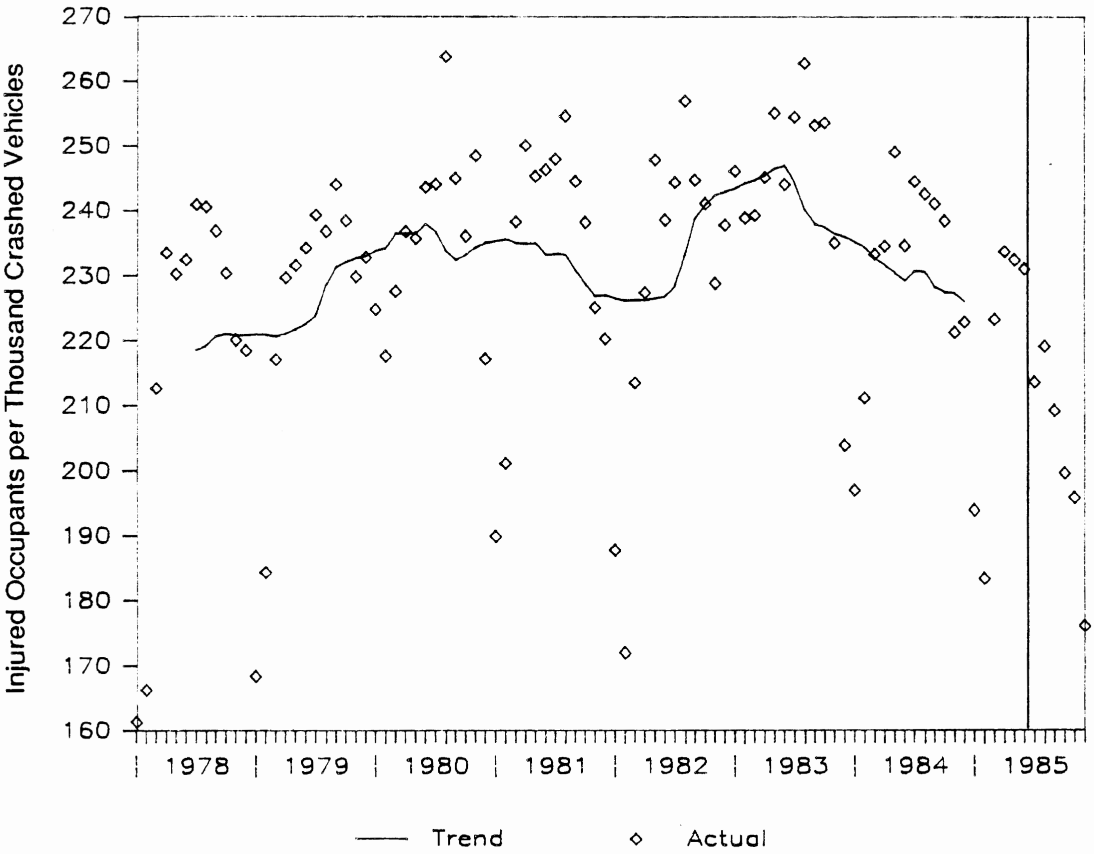

Figure 3.29 Injured Occupants Age 16 and Over per Thousand Crashed Vehicles

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	-1.6†	0.56
Effects of Adult Law, July 1985-December 1985*	-16.1	6.78

Baseline time-series model: ARIMA $(0,0,11)(0,1,1)_{12}$

* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

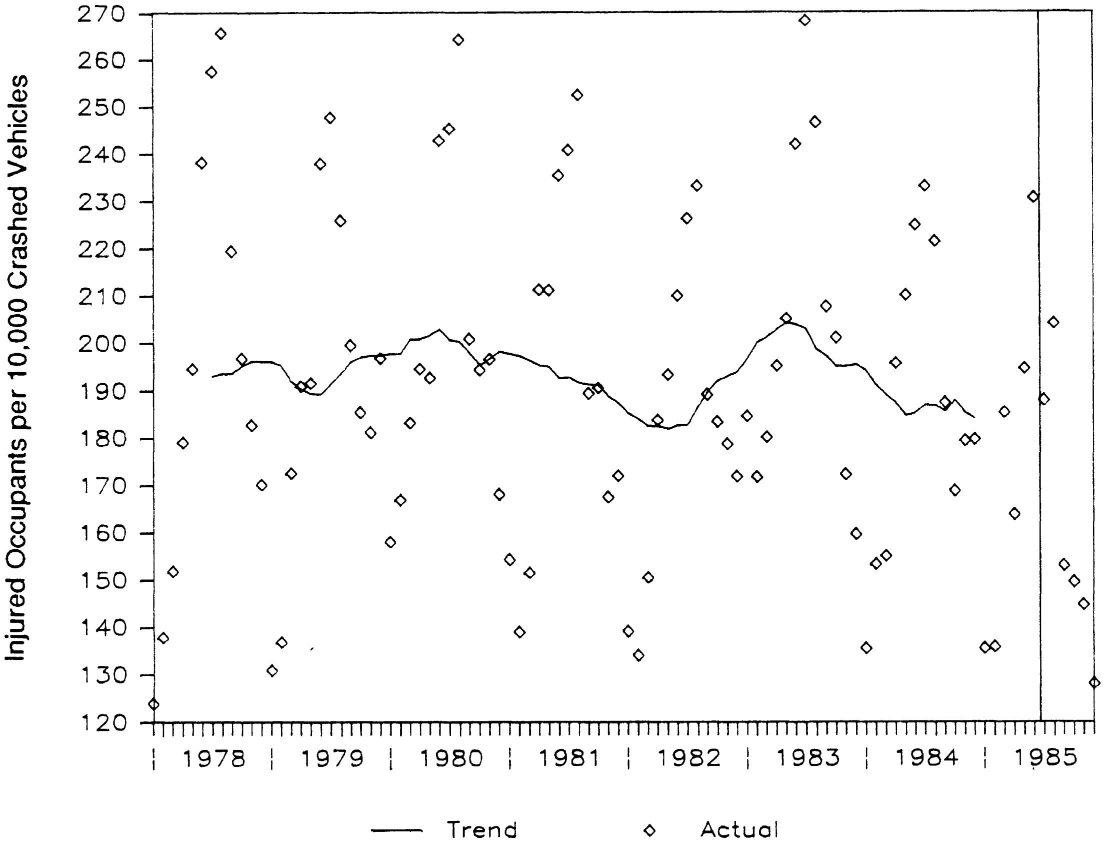

Figure 3.30 Injured Occupants Age 4-15 per 10,000 Crashed Vehicles

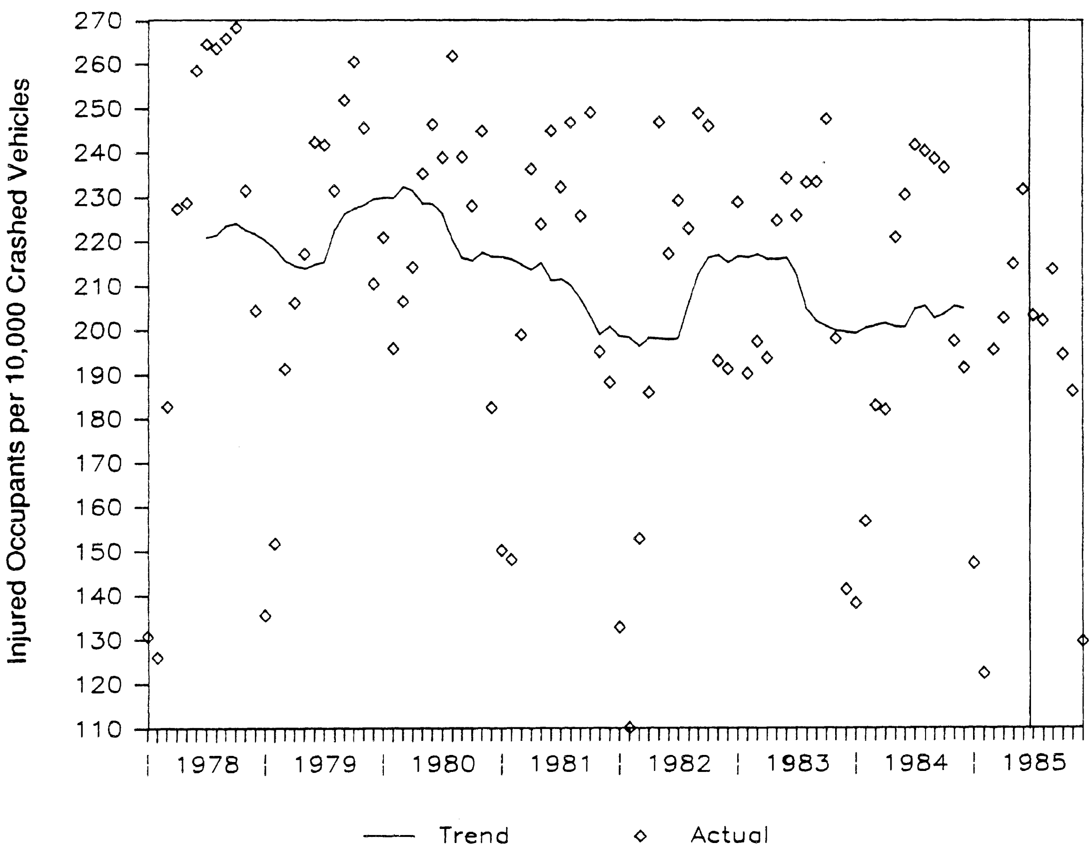

Figure 3.31 Injured Occupants Age 16-17 per 10,000 Crashed Vehicles

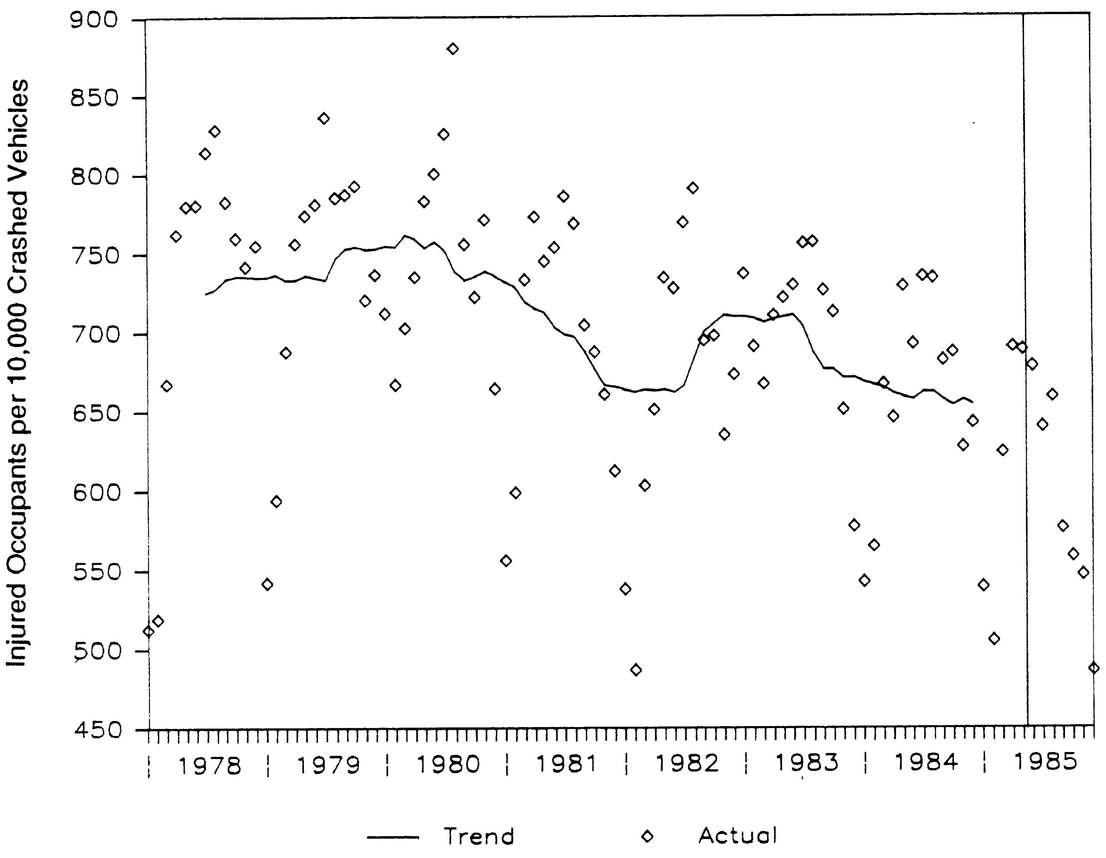

Figure 3.32 Injured Occupants Age 18-24 per 10,000 Crashed Vehicles

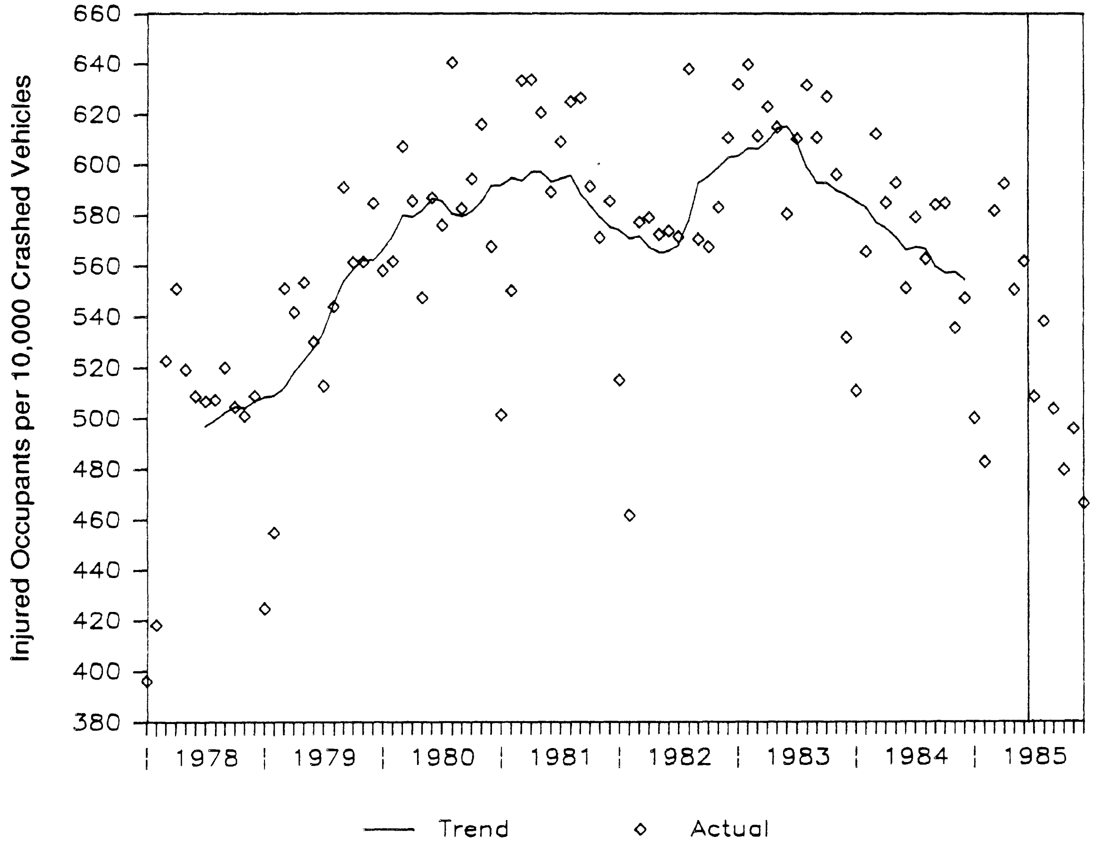

Figure 3.33 Injured Occupants Age 25-34 per 10,000 Crashed Vehicles

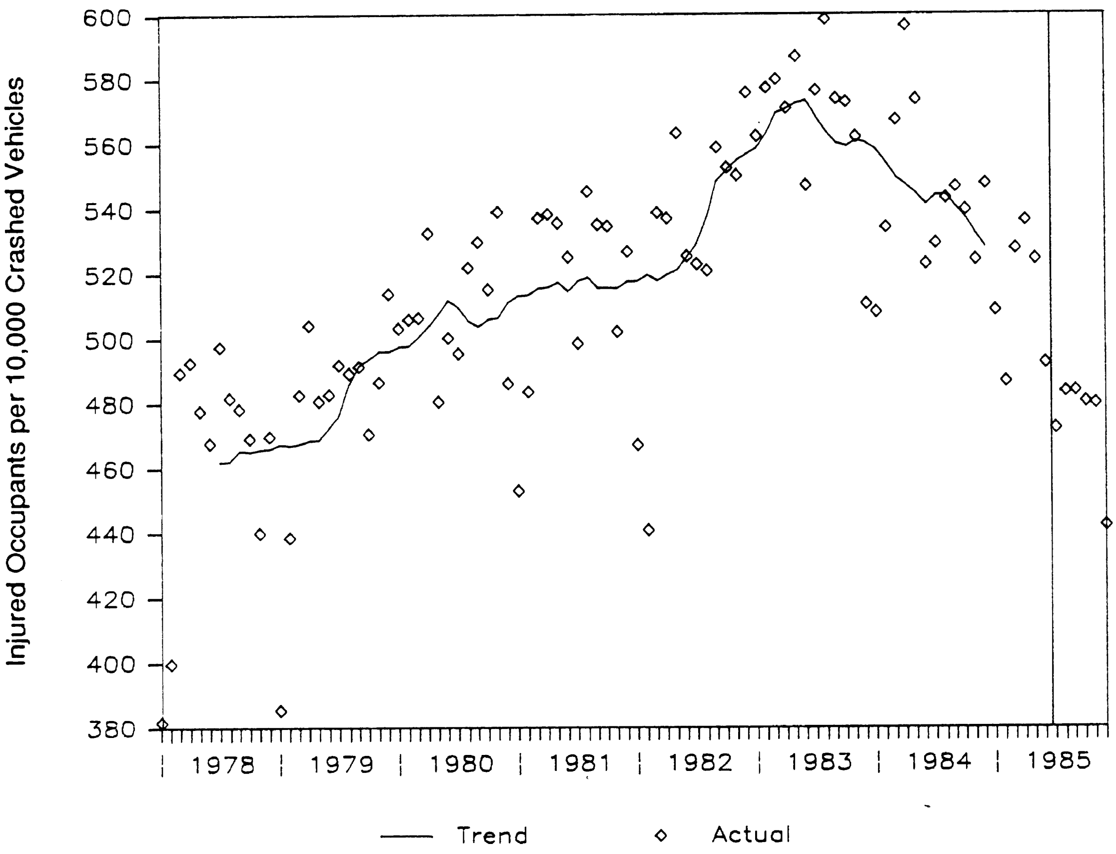

Figure 3.34 Injured Occupants Age 35-54 per 10,000 Crashed Vehicles

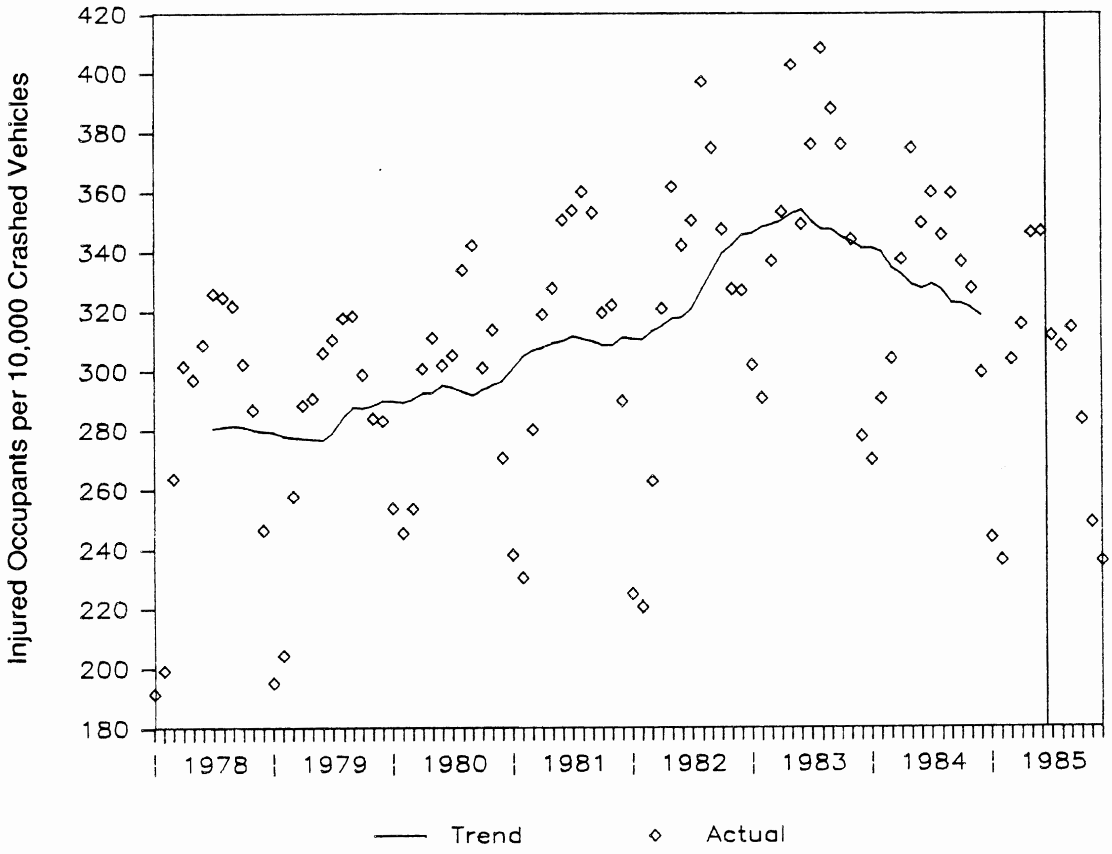

Figure 3.35 Injured Occupants Age 55 and Over per 10,000 Crashed Vehicles

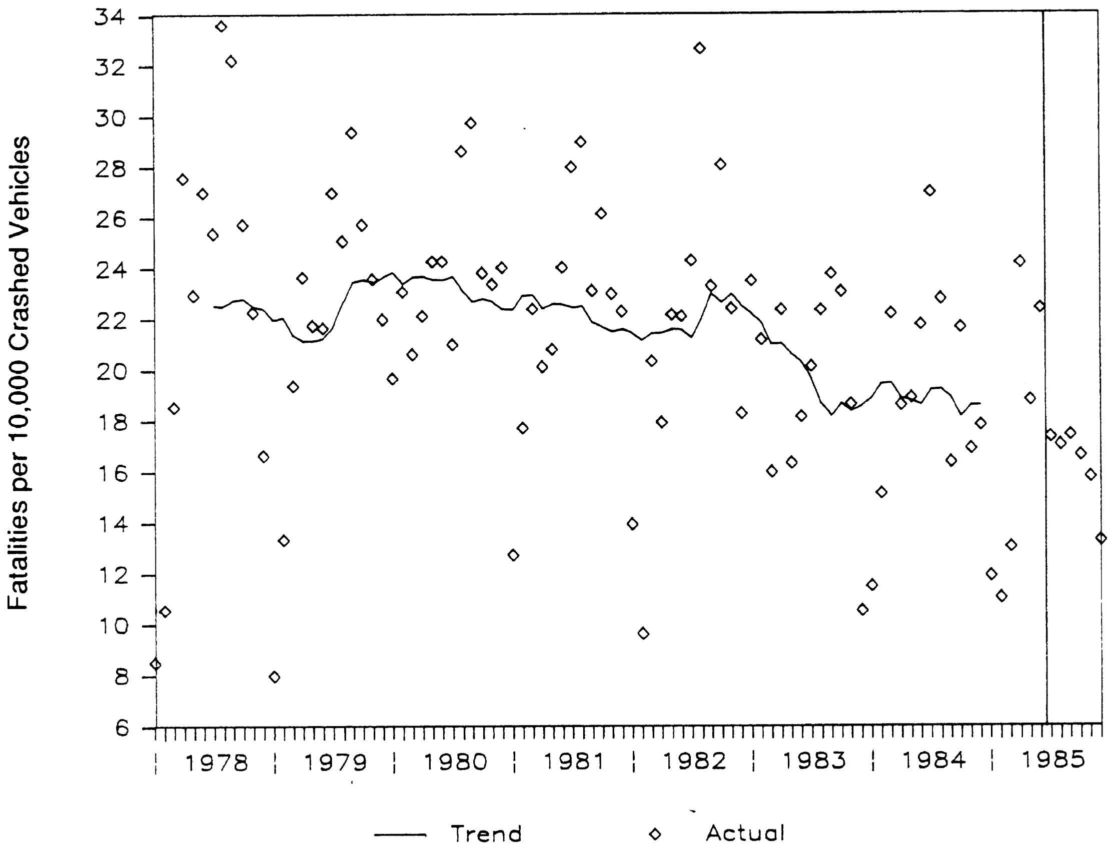

Figure 3.36 Front Seat Fatalities Age 10 and Over per 10,000 Crashed Vehicles

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	-9.8†	0.93
Effects of Adult Law, July 1985-June 1986*	-29.9	3.79

Baseline time-series model: ARIMA $(0,0,1)(0,1,1)_{12}$

* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

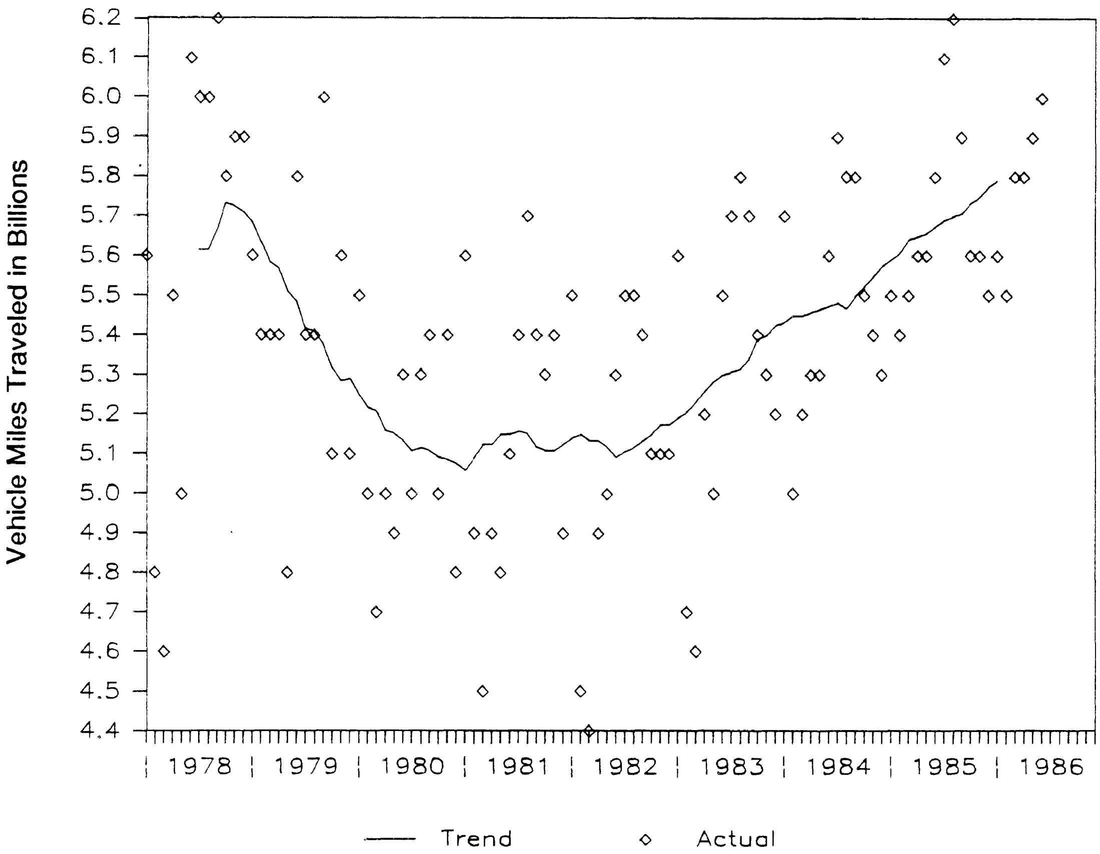

Figure 3.37 Estimated Number of Vehicle Miles Traveled

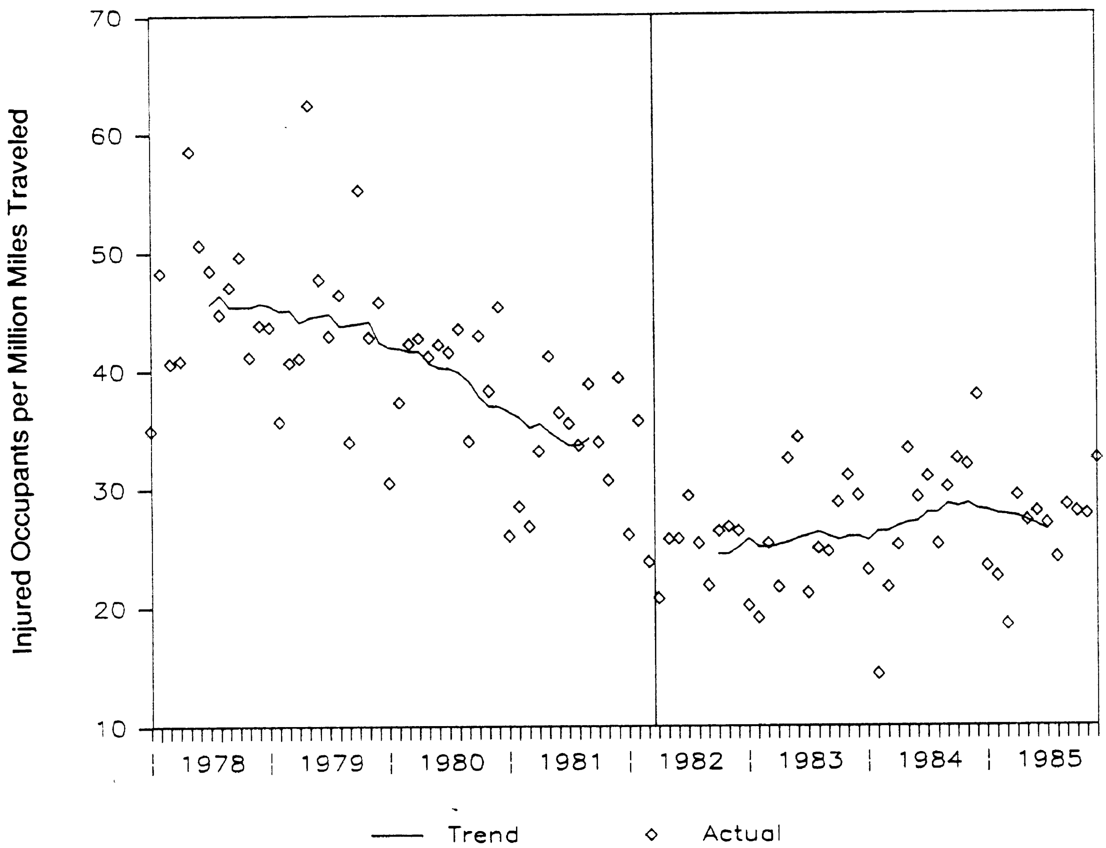

Figure 3.38 Injured Occupants Age 0-3 per Million Miles Traveled

	Percent Change	t-Ratio
Effects of CRD PI&E, January-March 1982	-4.4†	0.42
Effects of CRD Law, April 1982-December 1985*	-27.7	3.31

Baseline time-series model: ARIMA $(0,1,3)(0,0,1)_{12}$

* Effective date of mandatory child restraint law was April 1, 1982.

† Percent change not significantly different from zero, p<.05, one-tailed test.

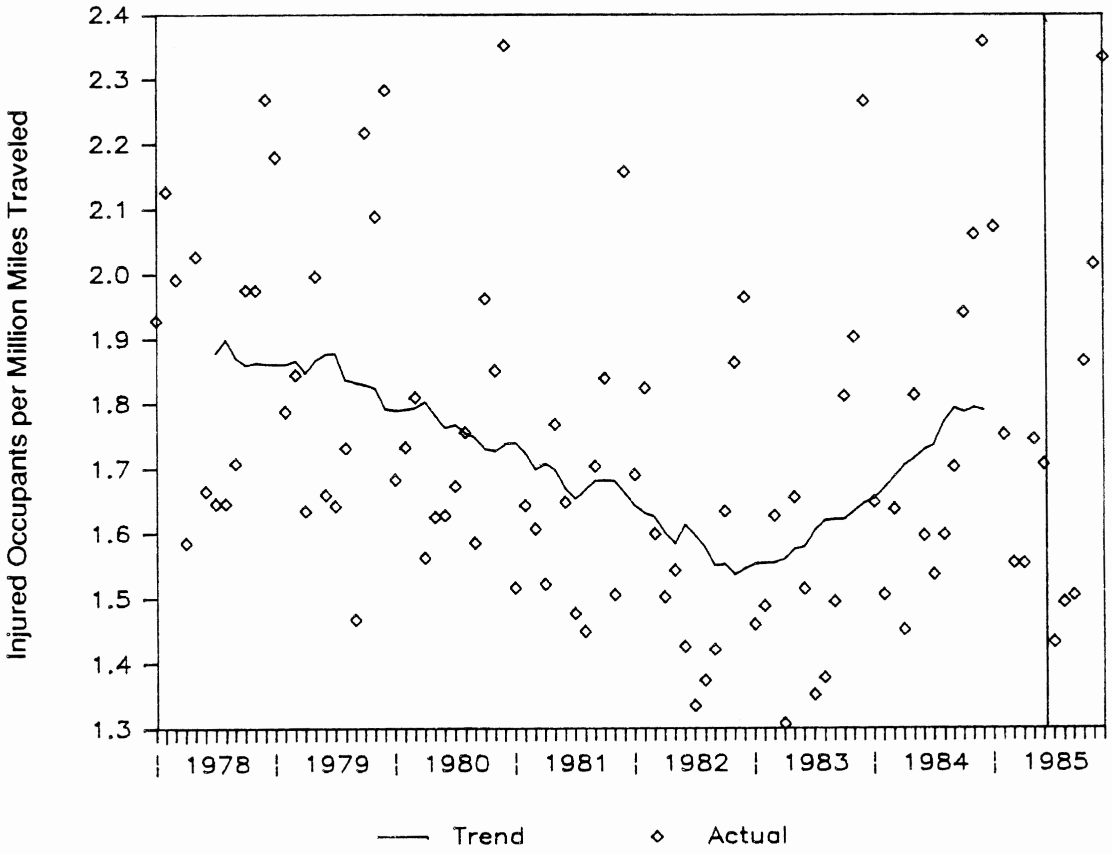

Figure 3.39 Injured Occupants Age 16 and Over per Million Miles Traveled

	Percent Change	t-Ratio
Effects of Adult PI&E, April 1985-June 1985	-4.8†	0.86
Effects of Adult Law, July 1985-December 1985*	-8.7†	1.50

Baseline time-series model: ARIMA (4,0,0) $(0,1,0)_{12}$

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* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

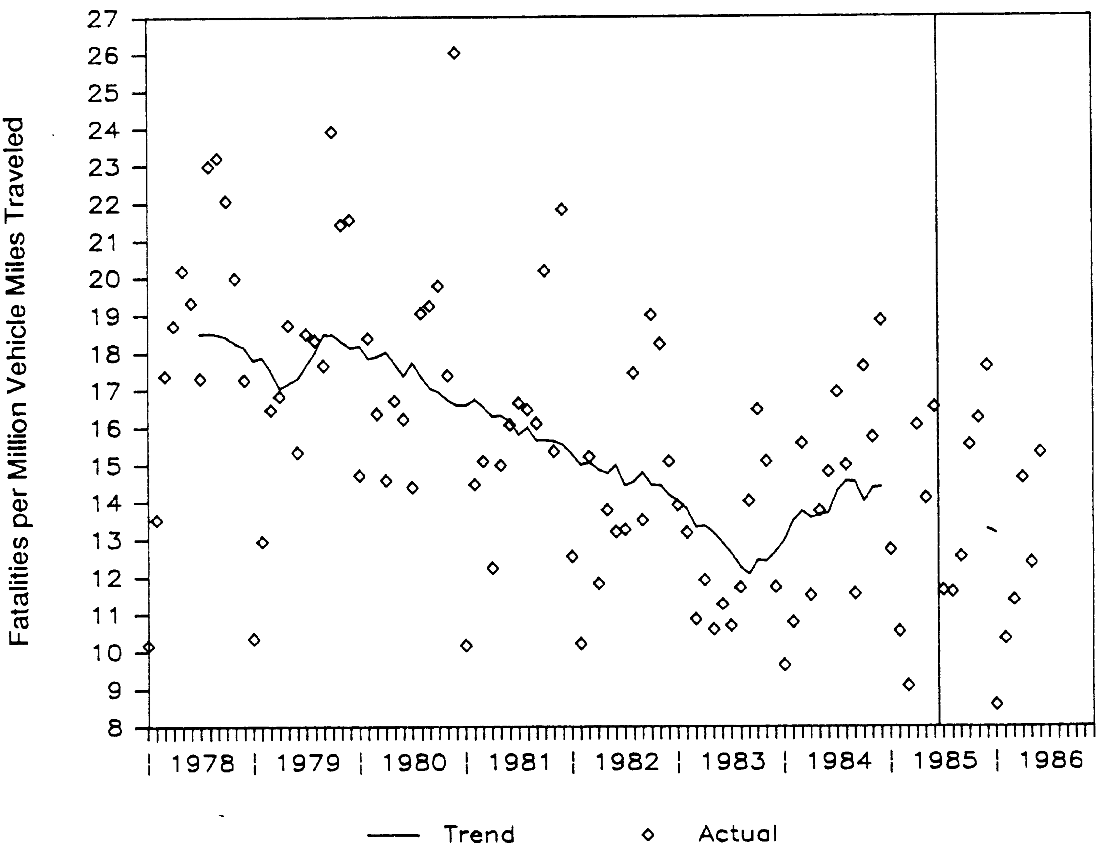

Figure 3.40 Front Seat Fatalities Age 10 and Over per Million Miles

	Percent Change	*t*-Ratio
Effects of Adult PI&E, April 1985-June 1985	1.2†	0.96
Effects of Adult Law, July 1985-June 1986*	-9.3†	0.13

Baseline time-series model: ARIMA $(0,0,1)(0,1,1)_{12}$

* Effective date of adult seat belt law was July 1, 1985.

† Percent change not significantly different from zero, p<.05, one-tailed test.

4 DISCUSSION

Despite the lack of statistical significance of some of the estimates, the results clearly indicate that the Michigan adult and child restraint laws reduced injuries and fatalities. Nonsignificant estimates of the fatality reductions due to the adult restraint law are in the hypothesized direction and within the range of expected effects given the degree to which belt use increased concomitant with the law. Nevertheless, analyses of an extended post-law period are required before we would confidently estimate a specific percentage reduction in fatalities attributable to the effects of Michigan's adult and child restraint laws. Reviewing all the results, with over half of the measures used showing statistically significant declines, and the remainder consistently showing declines though not statistically significant, we conclude that the evidence to date indicates that Michigan's adult and child restraint laws have reduced the aggregate level of injury and death to crash-involved motor vehicle occupants in the state. We now turn to estimating the amount of savings (in dollars) these reductions in injury and fatalities may provide.

4.1 Methods for Valuing Traffic Crash Injuries and Fatalities

Recent studies have proposed alternative approaches to valuing the loss of life and injury resulting from traffic crashes. Kragh and others (1986) compared current approaches to calculating injury costs. They suggest the "willingness to pay" method best represents the totality of costs related to traffic injuries and death. This method involves an assessment of several cost categories: (1) consumption goods (i.e., goods and services not used during the remaining lifetime); (2) human capital costs (loss of ability to perform vocational and avocational work); (3) psychosocial and quality of life costs (mental anguish, drug abuse, family problems, missed opportunities, loss of contact with friends/community); and (4) value placed on life and safety (money, time, freedom, and other measures of what one is willing to pay to reduce injuries). Currently the National Highway Traffic Safety Administration (NHTSA) employs the human capital plus consumption approach to calculate injury costs, whereas the National Safety Council uses only consumption estimates. Clearly, there are numerous estimates of the costs of each crash-related injury or fatality.

To estimate the savings in dollars to the State of Michigan and its residents, both the "human capital" and the "willingness to pay" approaches were used. As a conservative estimate of injury savings, we selected injury level 1, "minor injury,"[8] of the Maximum Abbreviated Injury Scale (MAIS) developed by the American Association for Automotive Medicine, as our basis for calculation. These figures are conservative since many of the injuries prevented were more serious than MAIS level 1, and the costs of more-severe injuries are considerably higher.[9]

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8. A minor injury is defined as a superficial abrasion or laceration of skin; digit sprain; first degree burn; or head trauma with headache or dizziness (with no other neurological signs).

9. The National Highway Traffic Safety Administration estimates that 18% of injured occupants have more-severe MAIS 2-5 injuries (National Highway Traffic Safety Administration, 1983).

Our approach was to assume that all injuries recorded on police crash reports were level 1 injuries, and calculate the minimum savings associated with the restraint laws. Actual savings are higher than these minimum estimates.

4.2 Effects of the Child Restraint Law on Injuries

It is clear that Michigan's child restraint law, implemented in April 1982, has had a major impact in reducing the number of crash-related injuries to children under four years of age. The number of children not injured each year as the result of the law was estimated using the 28.2% decline in frequency of children under the age of four injured in the post-law period from the number injured during the year immediately prior to the law. Based on these figures, 552 fewer children were injured each year since the child restraint law went into effect. Thus a total of 2,070 children have apparently been spared injury as a result of the law from April 1982 to December 1985. Using these figures, we calculate that using the "willingness to pay" approach, each year $1.7 million was saved, and using the "human capital" approach, each year $1.6 million was saved due to the implementation of the child restraint law (Table 4.1).

Although the reductions cited above appear substantial, a recent study observing child restraint use found that of the 55% of children using child restraint devices, 34% were incorrectly used in such a manner as to reduce the protective effects of the restraint (Wagenaar and others, 1986). Thus, considerable efforts are still needed to further increase **proper** restraint use. One area to be addressed is the improvement of restraint design, reducing the possibility of improper use. In addition, efforts are needed to motivate nonusers to begin using restraints. Programs which stress educating and providing appropriate incentives for target groups with lower than average restraint use are actions which could have a positive influence on the rate of restraint use. According to Wagenaar and others (1986), 75% of Michigan motorists believe that the law is not enforced and 38% believe that if stopped, a ticket is rarely or never issued. In addition 67% of motorists strongly believe that the law should be strictly enforced. These public opinion data show that stepped-up enforcement and penalties for the nonuse of child restraints has public support and therefore may be an effective means to further promote child restraint use.

4.3 Effects of the Adult Seat Belt Law on Nonfatal Injuries

Michigan's seat belt law has significantly reduced nonfatal injuries for motorists traveling on the state's highways. Michigan experienced a 12.1% reduction in the number of injured occupants age 16 and over in the first six months following the adoption of the adult seat belt law. The 12.1% decline translates into 7,278 fewer occupants injured in the first six months with the law. The annual injury cost savings is projected at $43.9 million for the "willingness to pay" model and $42.0 million for the "human capital" model (Table 4.1).

4.4 Effects of Adult Seat Belt Laws on Fatalities

Of the four measured reductions in fatalities, only the 29.9% drop in fatality rate for front-seat occupants age 10 and over per crashed vehicle was statistically significant. In spite of

Table 4.1

Estimated Minimum Cost Savings of Michigan's Restraint Laws

	"Willingness-to-pay" Approach	"Human Capital" Approach
Injuries prevented under age 4	552	552
Cost per minor (MIAS 1) injury	$3,015	$2,888
Total Annual Savings	$1,664,280	$1,594,176
Injuries prevented age 16 and over	14,556	14,556
Cost per minor (MIAS 1) injury	$3,015	$2,888
Total Annual Savings	$43,886,340	$42,037,728
Fatalities prevented age 10 and over	98	98
Cost per fatality	$1,156,164	$436,521
Total Annual Savings	$113,304,072	$42,779,058
Grand Total Annual Savings	$158,854,692	$86,410,962

the lack of statistical significance for three of the four estimates, we conclude that the adult seat belt law has reduced traffic fatalities. All estimates are in the hypothesized direction and within the range of expected effects given the rate of increased belt use. Using the estimate of a 10% reduction in front-seat fatalities, an estimated 98 lives were saved in the first year with the seat belt law. For the two injury cost methods used above, the "willingness to pay" approach estimates that the savings to society is $1,156,164 per fatality and the "human capital" approach estimates a $436,512 savings per fatality. Given an estimated 10% reduction in fatalities, we estimate from $86.4 million to $158.8 million was saved as a result of the reduction in fatalities.

4.5 Primary Versus Secondary Enforcement of the Seat Belt Law

Twenty-four states and the District of Columbia now have mandatory adult restraint laws in effect as of February 1987. In only eight of these states, however, does the law provide for primary enforcement by law enforcement officers (Connecticut, Hawaii, Iowa, Minnesota, New Mexico, New York, North Carolina, and Texas; Williams and Lund, 1986). According to Campbell and others (1986), the highest belt use levels attained in the United States to date have been in those states with primary enforcement provisions of the law (Connecticut, 64%; Hawaii, 76%; Texas, 75%; and New York, 69%). Belt use rates in New York have declined substantially in the two years since the law went into effect; although in Elmira, NY, the site of an intensive publicity and enforcement campaign, belt use increased to 77% while statewide use was 44%. Similarly in Texas, where state troopers issued 28,000 citations for seat belt violations in the first four months of 1986, seat belt use rates have been increasing (Williams and Lund, 1986; Bunch and others, 1986, Campbell and others, 1986).

Although Michigan's seat belt use rate has reached a plateau of approximately 44% since December 1985, belt use may increase above this plateau if a primary enforcement provision were implemented, giving law enforcement officials additional opportunity to enforce the law. A primary enforcement clause has the potential effect of increasing the motivation of nonusers to comply out of a heightened concern of being stopped. Results of the child restraint use study by Wagenaar and others (1986) support the notion that belief that one can be stopped for failure to use restraints increases compliance.

Our findings on the effects of the child restraint and adult seat belt laws on traffic injuries and fatalities clearly support the value of such legislation. Michigan's restraint laws have reduced the aggregate level of injury and death to motorists in the state. Nevertheless, improving the compliance of the motoring public to these laws remains as a major task of government and private traffic safety groups. Finally, the current study was limited to the short-term effects of the adult seat belt law. Continuing studies are necessary to assess the longer-term effects of this legislation.

5 REFERENCES

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Appendix A

Methods

This appendix reviews methods and procedures used to measure the effects of Michigan's compulsory restraint policies. Included is a review of the basic design and analytic approach, data collection and processing procedures, and statistical techniques used. The presentation here is brief, with extensions and additions from earlier projects noted. A more detailed discussion of the methods used can be found in the first report of this series (Wagenaar, 1984a).

A.1 Research Design

A monthly **time-series** design was used to control for numerous factors influencing the number of crash injuries and fatalities that were evident in multi-year trends, cycles, or other patterns.

Analyses of the effects of the child restraint law reported here were based on the same 51-month baseline (January 1978 through March 1982) used in previous studies of the short- and intermediate-term effect of the child restraint law (Wagenaar, 1984b; Wagenaar and Webster, 1985; and Wagenaar and Maybee, 1986). However, 45 months of post-child-restraint-law data are reported here, prepared to 33 months of post-law data examined in the 1986 report (Wagenaar and Maybee, 1986), 21 months in the 1985 report (Wagenaar and Webster, 1985) and only 9 months in the 1984 report (Wagenaar, 1984b).

Analyses of the effects of the adult seat belt law were based on a pre-law baseline of 90 months (January 1978 through June 1985). Only six months of post-law data on nonfatal injuries were available (July 1985 through December 1985); this study is therefore limited to the immediate effects of Michigan's adult seat belt law on nonfatal injuries. Twelve months of post-law data were available for traffic fatalities (July 1985 through June 1986).

Multiple age groups were examined to increase confidence that observed changes in injuries and fatalities were, in fact, due to the restraint laws, not other coincidental factors. The age-group comparisons were particularly important in assessing the effects of the child restraint law, given that any changes in injuries attributable to that law should only be seen for those covered by the law, with the exception of the possible spill-over effects on older children. Age-group categories were identical to previous studies in this series, except that injured occupants age 16 and over were summed to assess the overall effects of the adult seat belt law. Finally, frequencies and rates of fatalities were summed for occupants age 10 and over, to further measure the effects of the adult seat belt law. Because the fatality time series were constructed for the first time for this study, an age cut-off point of 10 rather than 16 was chosen because there is little evidence that the child restraint law had spill-over effects on children age 10 and over.

A.2 Data Collection

Data on **injured occupants** involved in motor vehicle crashes were obtained from the Michigan State Police. Records were obtained for all traffic crashes in the State of Michigan reported to local or state police agencies. Individual records were developed for each crash, vehicle, and injured occupant. Information was collected on occupant age, sex, injury severity, and whether they were restrained at the time of the crash.

The complete data files contain records on approximately three-quarters of a million crash-involved occupants per year. Files for the years 1978 through 1985 were used to calculate the number of crash-involved injured occupants per month for the subgroups of interest. Monthly time-series variables were constructed one year at a time by generating bivariate frequency tables containing the number of occupants stratified by: (1) year, (2) month, and (3) a variable or combination of variables of interest (e.g., injury by age). Separate monthly time series for each year were combined to produce a 96-month time series required for an assessment of the effects of Michigan's child restraint and adult seat belt laws on aggregate frequencies and rates of injuries.

Specific variables and code values used to construct the crash-involved injury time series are summarized here. For a complete description of each variable, see the codebooks for these data (prepared and published by The University of Michigan Transportation Research Institute). Variable numbers and code values corresponding to the 1982 codebook are enclosed in parentheses for easy reference (The University of Michigan Transportation Research Institute, 1984). For example, "V1:1-2" refers to variable number one, code values one and two as documented in the 1982 Michigan codebook.

Cases included in the Michigan injury time series were first filtered to include only passenger cars and light trucks (V104:1-7). These global filters were employed to limit the data analyzed to the target population of recent restraint use efforts. Restraint use by occupants of buses and motor homes, for example, is a separate issue and not the focus of this study. Passengers on farm equipment, construction equipment, or motorcycles are also not subject to the provisions of mandatory restraint use laws. Likewise, Michigan's child restraint law applies only to Michigan residents; therefore, the time series were filtered to include only occupants of vehicles with a driver possessing a Michigan driver license (V151:1-2). Nonresidents were not exposed to the major public information and education efforts that accompanied implementation of either law. This focus on the relevant target group increased the accuracy of the assessment of the effects of recent restraint use efforts.

The following monthly (V2) crash-related injury time-series variables were constructed for the period January, 1978, through December, 1985:

A. Total number of injured occupants per month by:

(1) ages 0 through 3 (V206:0-3)
(2) ages 4 through 15 (V206:4-15)
(3) ages 16 through 17 (V206:16-17)
(4) ages 18 through 24 (V206:18-24)
(5) ages 25 through 34 (V206:25-34)
(6) ages 35 through 54 (V206:35-54)
(7) ages 55 and over (V206:55-98)
(8) ages 16 and over (sum of numbers 3-7 above).

B. Total number of injured occupants per month by age groups in A above and by:

(1) restraints used (V204:2,5)
(2) restraints not used (V204:1,3,6).[10]

E. Number of occupants injured divided by total estimated vehicle miles traveled (rate of injured occupants per million VMT).

F. Total number of injured occupants per month by age groups noted above divided by total number of crashed passenger cars and light trucks driven by Michigan residents (rate of injured occupants per 10,000 crashed vehicles).

G. Total number of injured occupants per month by the age groups noted above divided by total number of persons in that age group residing in the State of Michigan (rate of injured occupants per population).

Fatality data was obtained from the Fatal Accident Reporting System maintained by the National Highway Traffic Safety Administration. Monthly front-seat fatality totals were computed for occupants ages 10 and over riding in passenger cars, vans, and light trucks. Fatalities involving ambulances, buses, specialized vehicles, medium and heavy trucks were excluded as they are either exempt from the provisions of Michigan restraint laws or are covered by pre-existing laws or regulations.

Monthly fatal crash time series from January 1978 through June 1986 were constructed for front-seat occupants (V205:01-03) age 10 and over (V202:10-97) in passenger cars and light trucks (V104:1-10, 39-41, 43, 50-52) involved in crashes involving drivers with a Michigan drivers license (V151:1-2). Specific code values are defined in the 1986 FARS codebook (The University of Michigan Transportation Research Institute, 1986b).

In addition, three fatality rate variables were created using the number of front-seat fatalities per month among those age 10 and over divided by: (1) Michigan resident population 10 and over; (2) number of crashed passenger cars and light trucks in Michigan; and (3) estimated vehicle miles traveled.

Estimated **vehicle miles traveled** data was obtained from the Federal Highway Administration. These estimates are based on traffic counter and motor fuel data provided by the state. The estimated travel mileage figures include all types of vehicles on all classes of roads.

Resident population for Michigan by age from 1978 through 1985 was obtained from the U.S. Bureau of the Census (U.S. Department of Commerce, 1986). Population estimates for certain individual ages were not available; for example ages 0-2 and 3-4 were separately grouped in the data provided. To estimate population figures for the 0-3 age group, the number of live births (Michigan Department of Public Health, 1985; 1986) four years prior to a given year was subtracted from the sum of age groups 0-2 and 3-4 for that year. The first six months of 1986

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10. Due to a change in the crash report format, restraint use coding from 1975 to 1981 was: (1) restraints used, V204:2,4; (2) restraints not used, V204:1,3,5.

Michigan resident population figures for each age group were derived through extrapolation from trends in the previous eight years. The resulting annual population estimates were then used to linearly interpolate monthly population figures for the entire January 1978 through June 1986 period.

A.3 Statistical Analyses

The number of crash-involved occupants injured or killed per month was examined for an extended period for each of the variables included in the research design. A long series of observations was required to assess the degree to which injury and fatality frequencies and rates for post-law periods were different from the level expected, given regular patterns over the previous years. Examination of both the raw plots of injuries and fatalities as well as the series smoothed with simple 12-month moving averages provided preliminary evidence concerning effects of the legal changes. The moving average also revealed whether long-term baseline trends were present in each series. The figures shown in Section 3 include such a moving average trend line, which for any time point equals the average of the actual values for the preceding six months, that specific month, and the subsequent five months.

The primary goal of these analyses was to estimate shifts in each injury and fatality time series associated with the child restraint law in April, 1982 and the adult seat belt law in July, 1985. The Box-Jenkins and Box-Tiao (Box and Tiao, 1975; Box and Jenkins, 1976) methods were employed to control for long-term trends and seasonal cycles and to estimate any changes beginning the first month after the laws took effect. These methods combine baseline modeling techniques with intervention-impact models. The baseline Auto-Regressive Integrated Moving Average (ARIMA) models are developed iteratively, repeatedly going through cycles of specifying a model, estimating it, and evaluating its adequacy. The Box-Jenkins approach is a versatile time-series modeling strategy that can model a wide variety of trend, seasonal, and other recurring patterns.

At a conceptual level, the analytic strategy involves explaining as much of the variance in each variable as possible on the basis of its past history, before attributing any of the variance to another variable, such as passage of a law making restraint use compulsory. Comparative studies have found that, in most cases, the Box-Jenkins methods more accurately account for regularities in time series (as reflected in lower residual error variances) than alternative analytic strategies (Newbold and Granger, 1974; Vigderhous, 1977). The intervention-analysis approach is particularly appropriate for the present study, since the objective was to identify significant shifts in injury and fatality rates associated with the child restraint and adult seat belt laws, independent of observed regularities in the history of each variable. Without these methods, incorrect conclusions can be made. For example, a change in injuries could be fully attributed to a specific intervention, when in fact it is entirely consistent with a pre-existing multi-year cycle in injuries. In short, controlling for baseline trends and cycles with time-series models produces more accurate estimates of the effects of restraint use legislation.

The final form of each baseline Box-Jenkins time-series model is noted on the plots in Section 3. All time series were logarithmically transformed to reduce heteroscedasticity before the parameters were estimated. All results presented in Section 3 are based on final models that were carefully evaluated to ensure low correlations among parameter estimates, significant noise model parameters that met requirements for invertability or stationary, insignificant residual autocorrelations over the first 24 lags, and a parsimonious model accounting for a high proportion of the total time-series variance. Intervention components were added to each baseline model to measure an abrupt, permanent effect of the two restraint policies. Our previous results indicated that an abrupt, permanent model was most appropriate for the child restraint law, and the post-law period covered for the adult belt law (six months for most of these series) was too short to reliably estimate other possible impact forms. Because the models were estimated from the logarithmically transformed series, each parameter estimate from the intervention models was converted into a percent figure that estimates the percent change in the series from baseline to post-intervention. These percent change figures and the t-ratios associated with the underlying time-series model parameter estimates are presented in Section 3.