Technical Report Documentation Page

1. Report No. UMTRI-89-5	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Changes in Police-reported Injuries Associated with Michigan's Safety Belt Law: 1988 Update		5. Report Date March 1989
		6. Performing Organization Code
7. Author(s) Streff, F.M., Schultz, R.H., Wagenaar, A.C.		8. Performing Organization Report No. UMTRI-89-5
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. MDE-89-003A
12. Sponsoring Agency Name and Address Michigan Office of Highway Safety Planning 300 S. Washington Square, Suite 300 Lansing, MI 48913		13. Type of Report and Period Covered Final October 1988 through September 1989
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

We measured intermediate-term effects of Michigan's safety belt law. Monthly frequencies of crash-induced injuries and fatalities from January 1978 through December 1987 were analyzed using time-series methods. Exposure to injury risk was controlled by including aggregate frequency of crashes as a covariate in time-series models. Effects of economic conditions on traffic crashes were controlled by including an index of unemployment as a covariate in the models.

The following statistically significant effects were associated with the safety belt law:

- 14.6% reduction in B-level injuries in crashes of minor severity
- 11.0% reduction in C-level injuries in crashes of minor severity

- 16.8% reduction in A-level injuries in crashes of moderate severity
- 11.6% reduction in B-level injuries in crashes of moderate severity
- 10.7% reduction in C-level injuries in crashes of moderate severity

- 6.3% reduction in fatalities in severe crashes
- 11.8% reduction in B-level injuries in severe crashes
- 4.7% reduction in C-level injuries in severe crashes

- 14.0% reduction in B-level injuries in crashes (all severities)
- 8.3% reduction in C-level injuries in crashes (all severities)
- 6.4% reduction in injuries to front-seat occupants (all severities)

Based on these results, Michigan's adult safety belt law from July 1985 through December 1988 has prevented 31,710 injuries, a cost savings of $734.72 million.

17. Key Words Injuries, Motor vehicle crashes, Occupant restraint laws, Safety belts, Social costs, Time-series analysis	18. Distribution Statement Unlimited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 45	22. Price

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.

Contents

List of Tables

List of Figures

1 INTRODUCTION

This is one of a series of reports on crash-related injuries in Michigan (Wagenaar, 1984b; Wagenaar and Webster, 1985; Wagenaar and Maybee, 1986; Wagenaar, Maybee, and Sullivan, 1987; Wagenaar, Streff, and Liu, 1988). The specific objectives of this report are to evaluate intermediate-term effects of Michigan's adult compulsory safety belt use law on police-reported injuries, and monitor trends in motor vehicle crash injury frequencies and rates. In addition, we estimated aggregate economic savings to the people of the State of Michigan produced by decreased fatalities and injuries following implementation of the law. This report updates information provided in last year's report (Wagenaar, Streff, and Liu, 1988) with the addition of 1987 crash and injury data.

Literature reviewed in previous reports in this series indicates that compulsory occupant restraint use laws can significantly increase the proportion of drivers restrained, and reduce crash-related injuries and deaths. Selected recent reports, which were not available at the time of previous reviews, are briefly summarized here.

A study conducted by the Highway Loss Data Institute (HLDI, 1988) found that the frequency of insurance claims for injuries sustained in motor-vehicle crashes involving model-year 1983 through 1986 cars were reduced by 6 to 17 percent after the implementation of Michigan's safety belt law. Specifically, the HLDI study found that total injury claims were reduced 6%, claims over $250 were reduced 13%, claims over $500 were reduced 16%, and claims above $1000 were reduced 17%. The HLDI report notes that these injury reductions are larger than expected given the increase in belt use due to the law, suggesting that factors other than the belt use law are responsible for some of the change. No hypotheses were provided for these other factors. Injury claims also declined at the time of the Connecticut and New Jersey belt laws, but the effects were smaller than those found in Michigan. No changes or slight increases in injury claims were found in five other states that implemented safety belt laws (New York, Texas, Florida, Kansas, and Maryland). HLDI points out, however, that because the analyses used only comparisons in frequencies of claims before and after the law implementations, normal year-to-year fluctuations in injury claims could mask the 5-15 percent reductions in claims expected following belt law implementation. According to the HLDI, lack of significant reductions in injury claims in most states may be because analyses were limited to late-model vehicles. Because belt use in relatively new cars is higher than in older cars, increases in belt use in new cars due to belt use laws may be smaller than in the overall population of vehicles.

Results of a second insurance industry study of the effects of Michigan's safety belt law were recently released (League General Insurance Company, 1988). This study found that the law reduced the number of front-seat injury claims by 5 percent during the first year and 13 percent during the second year after implementation. Fatal and severe injuries dropped 25 percent from 1984 to 1987, while the number of serious and moderate injuries dropped 20 percent.

Campbell (1988) examined effects of North Carolina's compulsory safety belt law on fatal, severe, and moderate injuries. North Carolina's law, which includes a primary enforcement provision, was implemented in two phases. In the first 15-month phase, enforcement of the law was confined to oral or written warnings. The second phase included full enforcement with citations and a $25 fine. Using time-series analyses, Campbell compared motor-vehicle crash casualty figures from a 57-month baseline period to the 15-month warning-ticket phase of the law. The warning-ticket phase resulted in no significant change in fatalities, a 6.9% decline ($p<.10$) in serious to fatal injuries, and a 3.2% decline ($p<.10$) in moderate to fatal injuries. No details were provided to more fully define criteria for severe or moderate injury. Campbell also compared the 72-month combined baseline and warning-ticket phases to the available 6 months of data for the full enforcement phase. The full enforcement phase resulted in an estimated 7.6% reduction in fatalities ($p=.10$), a 13.6% reduction in serious to fatal injuries ($p<.01$), and a 9.8% reduction in moderate to fatal injuries ($p<.01$).

In a second study of the effects of North Carolina's safety belt use law, Chorba, Reinfurt, and Hulka (1988) found significant reductions in injury due to the law. These researchers examined North Carolina State Police crash data using tests for linear trends in proportions, and chi-square analyses. Trend analyses showed that both the warning-ticket and full-enforcement phases resulted in significant decreasing trends in fatal and severe injuries among front-seat occupants and drivers, but no change in injuries among rear-seat occupants. Injury severity and frequency was analyzed by crash damage severity and impact location using chi-square analyses. The warning-ticket period was found to be responsible for a significant decrease in the proportion of drivers who experienced fatal or severe injuries in nonfrontal crashes of moderate severity. The proportion of right-front-seat occupants who experienced fatal or severe injuries in moderate frontal crashes also decreased compared to pre-law levels. Full-enforcement resulted in significant decreases in the proportion of fatal or severe injuries suffered by drivers in moderately severe frontal crashes, and in the proportion of fatal or severe injuries among front-seat occupants involved in moderately severe frontal and nonfrontal crashes.

Sidhu (1987) examined effects of the first year of the Illinois safety belt law on motor-vehicle crash fatalities. During the period studied, the Illinois law included primary enforcement, although it has since been changed to secondary enforcement only. Using time-series analyses, Sidhu found that the Illinois law resulted in an estimated 6.0% reduction in fatalities.

Using national data from 1983-1987, Partyka (1988) estimated the effects of safety belt laws. Comparisons between fatality frequencies and safety belt use levels between states with and without safety belt use laws showed that states with belt laws have seven percent fewer fatalities than would be expected if these states did not have the laws.

It is virtually impossible to calculate a single "true" safety belt law effect estimate for a variety of reasons. For example, statistical estimates are affected by errors in measurement of the variables on which they are based. The type of statistical methods used to calculate estimates may affect results. Model specification errors may increase an effect estimate for a given variable beyond what its "true" contribution is. Differences in interpreting results from statistical analyses can also cause differences in effect estimates. Although estimates of the effects of compulsory occupant restraint use laws vary, the laws are effective in reducing injuries and fatalities resulting from motor vehicle crashes. Table 1.1 presents findings of the effects of Michigan's safety belt use law on injuries from a variety of studies using different data sets and different analytic methods.

Table 1.1: Alternative Estimates of the Effects of Michigan's Safety Belt Law

Investigators	Source of Data	Analytic Method	Post-Law Months	Injury Severity	Percent Change	Significance[1]
Campbell and others, 1986	FARS	ARIMA-intervention models	6	Fatal	-16	p<.10
Campbell and others, 1987	FARS	ARIMA-intervention models	18	Fatal	-6	p<.01
Lund and others, 1986	FARS	ARIMA-intervention models	6	Fatal	-10	ns
		simple comparison	6	Fatal	-6	ns
Skinner and Hoxie, 1988	FARS	OLS regression	3	Fatal	-25.7	p<.05
			9	Fatal	-17.1	p<.05
			27	Fatal	-9.6	ns
Wagenaar and others, 1987	FARS	ARIMA-intervention model with comparison states	12	Fatal	-4.1	p<.05
Wagenaar and others, 1988	Police report	ARIMA-intervention model	18	Fatal	-19.7	p<.05
Highway Loss Data Institute, 1988	Insurance claims	simple comparison	3	Severe[2]	-24	NA
			15	Severe[2]	-3	NA
League General Insurance, 1988	Insurance claims	simple comparison	12	All	-4.9	NA
			24	All	-13	NA
Wagenaar, Margolis & Liu, 1988	Hospital discharge	ARIMA-intervention models	18	Severe[3]	-43	p<.05

1. ns indicates the result was not statistically significant, NA indicates the statistical significance of the estimate was not tested.

2. Severe is defined in this study to be injury claims greater than $1000.

3. Severe is defined in this study to be injuries which required hospitalization over one week.

2 METHODS

2.1 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 safety belt law were based on a pre-law baseline of 90 months (January 1978 through June 1985), and a post-law period of 30 months (July 1985 through December 1987).

2.2 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. Information was collected on crash damage severity, occupant age, sex, injury severity, and whether occupants were restrained at the time of the crash. Monthly fatality and injury totals were computed for occupants age 16 and over riding in passenger cars, vans, and light trucks. Injuries and fatalities involving ambulances, buses, specialized vehicles, and medium and heavy trucks were excluded as they are either exempt from the provisions of Michigan restraint laws or were covered by pre-existing laws or regulations. Data on vehicle miles traveled and the rate of unemployment were used to control for other changes influencing injury and fatality rates during the 1978-87 period examined. Estimates of vehicle miles traveled per month, based on gasoline sales and traffic counters, were obtained from the Federal Highway Administration. Monthly rates of unemployment among noninstitutionalized Michigan residents age 16 and over were obtained from the U.S. Bureau of Labor Statistics.

2.3 Statistical Analyses

Our goal was to estimate shifts in each injury and fatality time series associated with implementation of the adult safety belt law in July, 1985. Methods of Box and Jenkins (1976) were employed to control for long-term trends and seasonal cycles, and intervention models (Box and Tiao, 1975) were used to estimate any changes beginning the first month after the law took effect. At a conceptual level, the analytic strategy involves explaining as much of the variance in each variable as possible on the basis of its own past history, before attributing any of the variance to another variable, such as passage of a law making restraint use compulsory. The intervention-analysis approach is particularly appropriate for the present study, since the objective was to identify significant shifts in injury and fatality frequencies associated with the belt law, independent of observed regularities in the history of each variable. In short, controlling for baseline trends and cycles with time-series models produces more accurate estimates of the effects of restraint-use legislation. A more detailed discussion of the methods can be found in the first report of this series (Wagenaar, 1984b).

In previous reports (Wagenaar, 1984b; Wagenaar and Webster, 1985; Wagenaar and Maybee, 1986; Wagenaar, Maybee, and Sullivan, 1987; Wagenaar, Streff, and Liu, 1988) we examined monthly injury and fatality frequencies, rates per vehicle mile traveled, rates per population, and rates per crashed vehicle. In previous years we examined multiple rates in addition to simple injury counts to control for influences other than the belt law which may have affected injury frequencies. To eliminate the need to evaluate multiple belt-law-effect estimates based on these three injury rates, we included the aggregate frequency of crashes as a covariate in the time-series models.

In addition to controlling for the risk of injury by including the aggregate frequency of crashes as a covariate in the time-series models, we also included an index of unemployment to statistically control for the effects of changing economic conditions on traffic crashes. Several researchers (e.g., Evans and Graham, 1987; Hoxie, Skinner, and Wang, 1984; Wagenaar, 1984; Wagenaar and Streff, in press) have found that economic conditions can have a significant effect on casualties caused by traffic crashes. Typically, as economic conditions improve (measured by decreases in unemployment, and increases in the production indices, retail sales, and personal income), traffic casualties tend to increase. Precise mechanisms for this relationship have not yet been determined, and continued research is needed to fully understand these effects. Possible explanations for the relationship between improving economic conditions and increased traffic casualties may include increased travel (especially by teenagers, a high risk group), increased alcohol consumption away from home, and increased inclinations for risk-taking during periods of prosperity. It is unlikely that any one of these mechanisms alone is responsible for the observed relationship, and many other factors are probably involved. For the purpose of evaluating effects of Michigan's adult belt use law, it is sufficient to know that there is a relationship between economic indicators and traffic casualty rates, and to note that economic effects were controlled statistically before assessing effects of the safety belt law.

Effects of the safety belt law on injury were examined separately for crashes of various levels of vehicle damage severity. Crash damage severity was divided into three groups using the TAD (Traffic Accident Damage) scale: minor (TAD level 1 and 2), moderate (TAD 3 and 4 level), and severe (TAD level 5 through 8). TAD scale estimates are made by police at the site of the crash, and are determined by the extent of vehicle deformation caused by the crash. Effects of the safety belt law were examined separately for different crash damage severities because it has been found that safety belt effectiveness varies by crash severity (Campbell, 1987; Chorba and others, 1988). Campbell compared the injury experience of unbelted drivers and right-front-seat passengers with that of drivers and right-front-seat passengers who were using safety belts. Although belted occupants were less likely to be killed or severely injured in crashes of every severity, safety belts were found to be more effective in reducing injury in crashes of moderate severity. In an examination of the effects of North Carolina's safety belt law, Chorba and others found significant reductions in fatal and severe injury only for crashes of moderate severity (TAD 3 and 4).

3 RESULTS

3.1 Estimated Reductions in Injury and Fatality Frequencies

Michigan's safety belt law was effective in reducing motor vehicle crash casualties. Injury reductions associated with the adult belt law were examined for each level of injury severity, using the "KABC" injury severity scale. K-level injuries are injuries caused by the crash that resulted in death within 90 days of the incident. A-level injuries are incapacitating injuries which prevent injured persons from continuing activities they were capable of performing prior to the injury. B-level injuries include nonincapacitating injuries that are evident to observers at the scene of the crash in which the injury occurred. C-level injuries are possible injuries reported or claimed but which are not fatal, incapacitating, or nonincapacitating evident injuries (National Safety Council, 1983). Estimates of injury and fatality reductions are presented as percent change figures with their corresponding t-ratio values in Table 3.1. Figure 3.1 summarizes these data graphically with bars representing 95% confidence bands around the estimates. A plot of each outcome measure analyzed is provided in Appendix A.

Overall, there was a significant 6.2% reduction in injury to vehicle occupants associated with the safety belt law. This figure includes fatal, A-level, B-level, and C-level injuries to vehicle occupants regardless of their seating position and crash severity. There was also a significant 6.4% overall reduction in injuries to front-seat occupants associated with the law. No significant reduction in injury was found for rear-seat occupants.

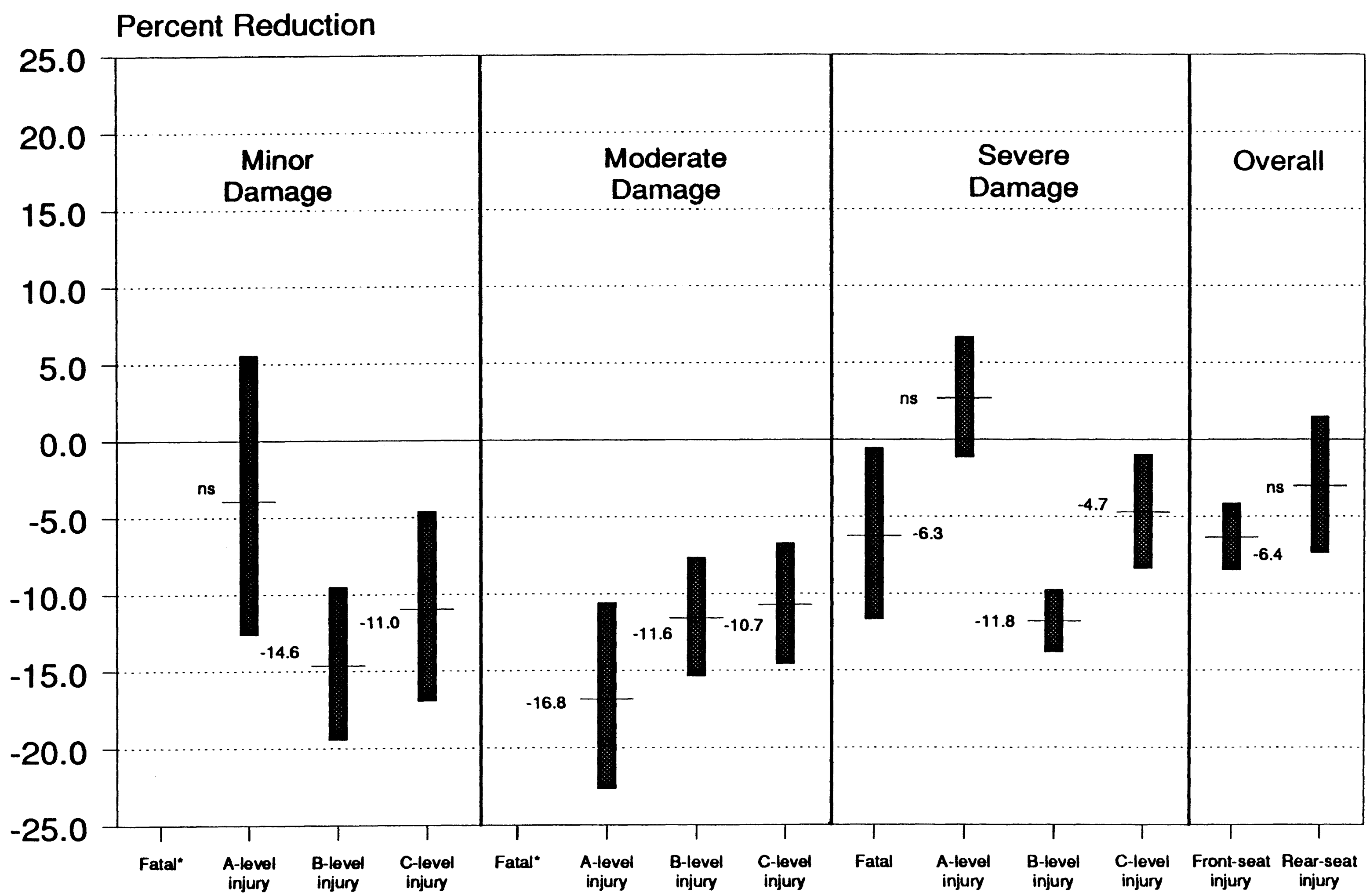
Injury reductions associated with the safety belt law differ by crash damage severity. There is a 6.3% reduction in fatal injuries in severe crashes associated with the safety belt law. Small monthly frequencies of fatal crashes involving minor and moderate vehicle damage preclude analysis of effects of the belt law on fatalities in those crashes. A 16.8% reduction in A-level injuries in crashes of moderate severity is associated with the law; however, there was no statistically significant change in A-level injury frequency in minor or severe crashes. This is consistent with the findings of Campbell (1987) and Chorba and others (1988). Significant B-level and C-level injury reductions are associated with the law for each crash damage severity group. B-level injuries declined 14.6% in minor crashes, 11.6% in moderate crashes, and 11.8% in severe crashes. C-level injuries declined 11.0% in minor crashes, 10.7% in crashes of moderate severity, and 4.7% in severe crashes.

Table 3.1: Effects of Michigan's Safety Belt Law on Injury and Fatality Frequencies

Crash Severity	Injury Severity	Percent Change	*t*-ratio
Minor	Fatal Injuries	NA	NA
	A-level injuries	- 3.9	- 0.83
	B-level injuries	-14.6	- 5.35*
	C-level injuries	-11.0	- 3.30*
Moderate	Fatal Injuries	NA	NA
	A-level injuries	-16.8	- 4.99*
	B-level injuries	-11.6	- 5.54*
	C-level injuries	-10.7	- 5.07*
Severe	Fatal Injuries	- 6.3	- 2.13*
	A-level injuries	2.7	1.37
	B-level injuries	-11.8	-10.70*
	C-level injuries	- 4.7	- 2.45*
All Crashes	Fatal injuries	- 1.5	- 0.37
	A-level injuries	0.3	0.01
	B-level injuries	-14.0	- 7.13*
	C-level injuries	- 8.3	- 3.92*
	All injuries	- 6.2	- 5.16*
	Injuries among front-seat occupants	- 6.4	- 5.54*
	Injuries among rear-seat occupants	- 3.0	- 1.32

* $p<.05$, one-tailed test
NA - insufficient sample size for time-series analysis

Figure 3.1: Effects of Michigan's Safety Belt Law on Injury and Fatality Frequencies: Point Estimates and 95% Confidence Intervals



ns = not statistically significant at p<.05
* - insufficient sample size for time-series analysis

3.2 Economic Benefits from Restraint Laws

Recent studies have proposed alternative approaches to valuing the injury and loss of life 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 U.S. Department of Transportation recommends that state and local highway and safety agencies use the willingness-to-pay approach to estimate cost savings. The U.S. Department of Transportation estimates costs of injury (in 1986 dollars) are: $1.5 million for each fatal injury, $39,000 for each A-level injury, $12,000 for each B-level injury, and $6,000 for each C-level injury (Federal Highway Administration, 1988). These figures were increased 7.8% to account for increases in the U.S. Department of Commerce Consumer Price Index from 1986 to 1988.

Injury reductions and associated cost savings were calculated separately for each injury and crash damage severity level, and these figures were then summed to provide total numbers of injuries prevented for each injury severity level. Table 3.2 shows the number of injuries avoided as well as the cost savings for each level of injury severity using the "KABC" injury severity scale. We adjusted all cost figures to represent current 1988 dollars.

We calculated injury reductions specific to each level of injury severity using results of time-series models specific to each level of injury severity. Annual cost savings produced by Michigan's safety belt law is an estimated $209.92 million based on the willingness-to-pay model. In short, a total of 31,710 injuries have already been prevented as a result of Michigan's safety belt law, representing a total cost savings of 734.72 million dollars to the people of the state.

Table 3.2: Cost Savings from Michigan's Safety Belt Law

	Injuries Prevented	Cost Savings
Fatal	66	$106,722,000
A-level	494	20,768,748
B-level	4,244	54,900,384
C-level	4,256	27,527,808
Annual Savings	9,060	$209,918,940
Savings Since Implementation of Safety Belt Law 1985 through 1988	31,710	$734,716,290

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Appendix A

Time-series Charts

This appendix contains time-series plots of each variable examined. When examining the plots, note that the solid line represents a centered moving average line, which is useful for discerning overall trends. The moving average trend line was created by summing the six data points preceding and the six data points following each point for which the moving average was calculated and dividing this sum by 12 to provide the average. This procedure is replicated for each of the data points in the series with the exception of the first and last six months. These months are omitted since a full set of 12 data points, 6 preceding and 6 following are necessary for calculating the moving average.

Trend lines are provided to make it easier to determine trends across time and pre-post law differences in frequencies and rates. Patterns of raw data points often have substantial "noise" or variance around a general trend that may mask patterns in the data. Trend lines eliminate much of this "noise," thus making interpretations about general trends and pre-post law differences more straightforward. Note differences in the vertical axis scale across plots. Understanding the scale used is critical for assessing the magnitude of any discontinuities observed.

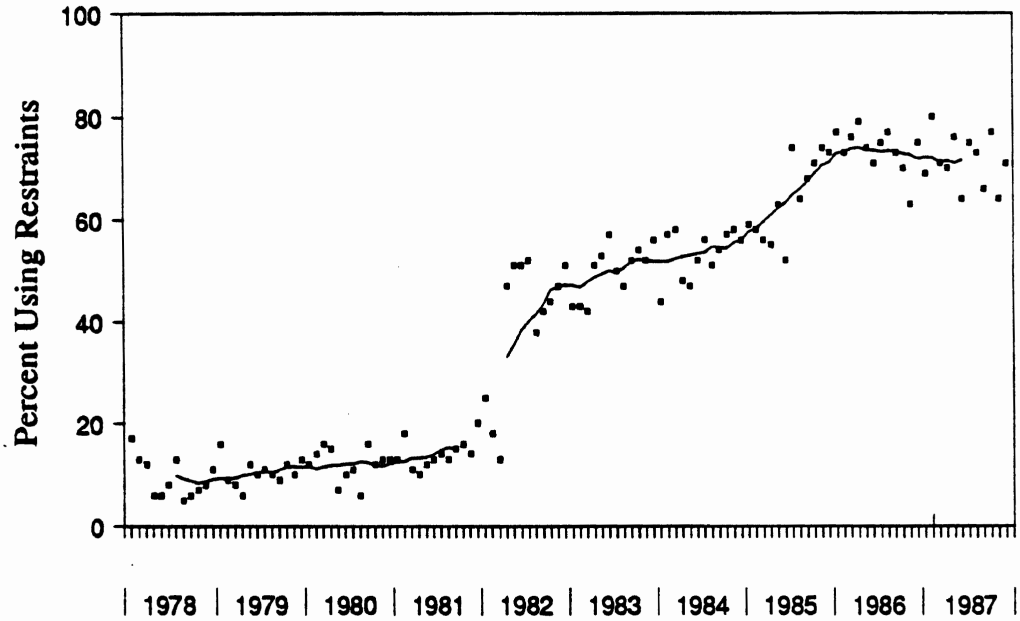

Figure A.1 Reported Restraint Use
Among Injured Occupants Age 1-3

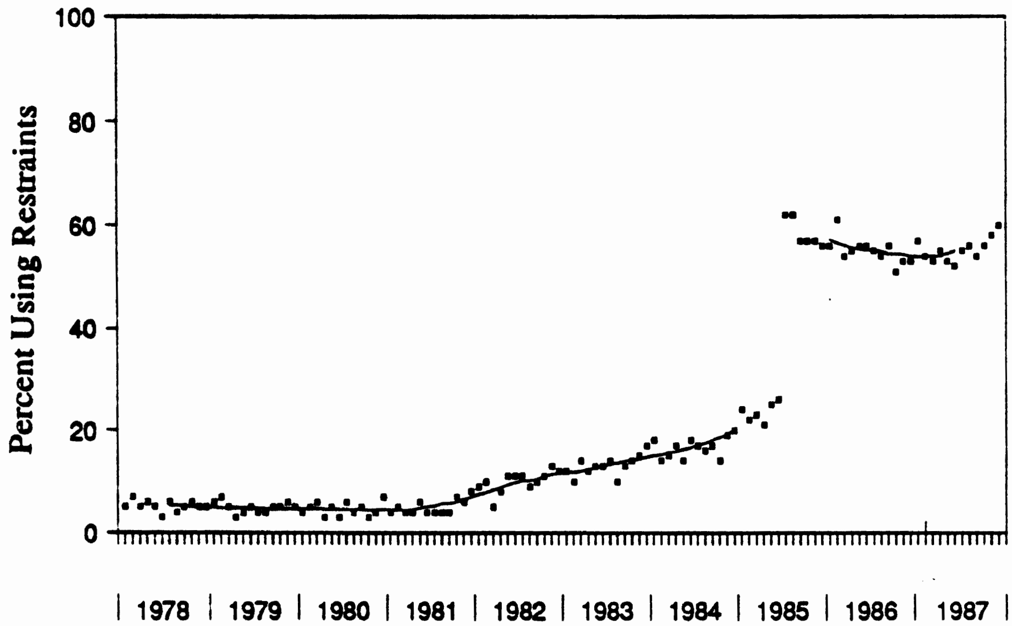

Figure A.2 Reported Restraint Use
Among Injured Occupants Age 4-15

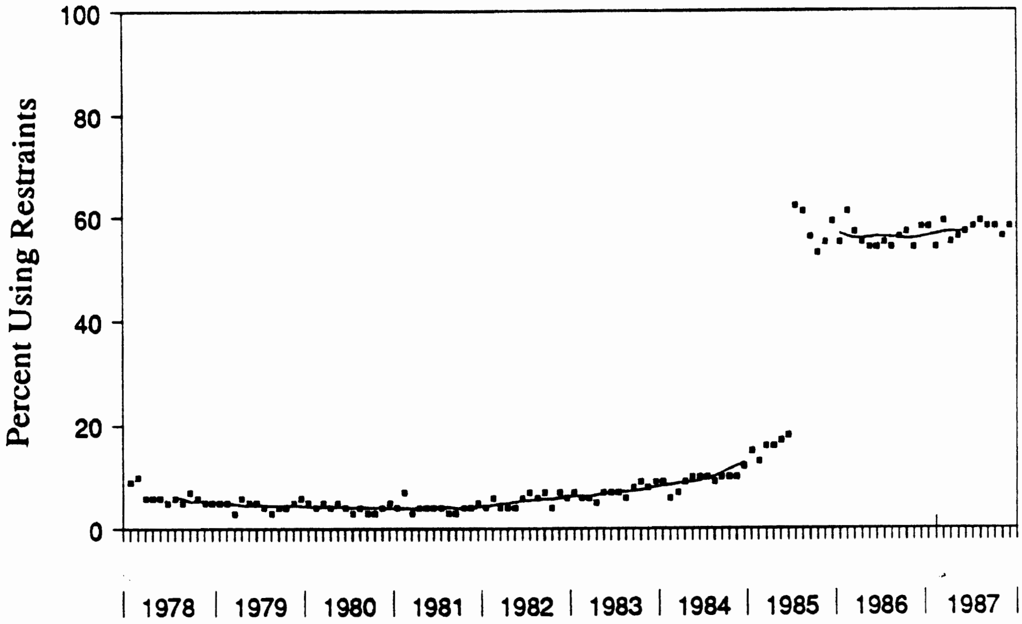

Figure A.3 Reported Restraint Use
Among Injured Occupants Age 16-17

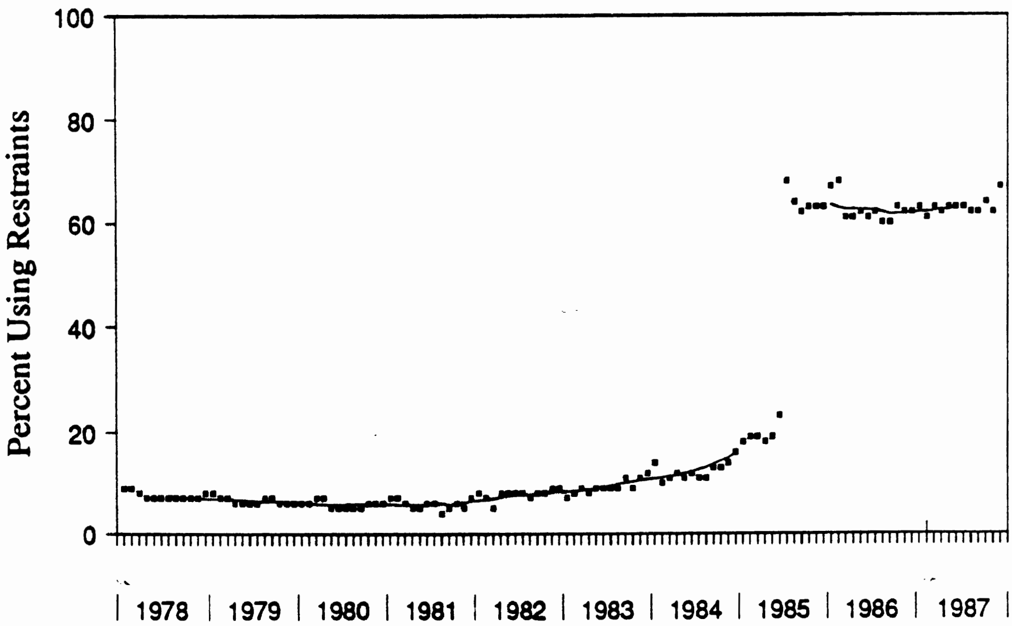

Figure A.4 Reported Restraint Use
Among Injured Occupants Age 18-24

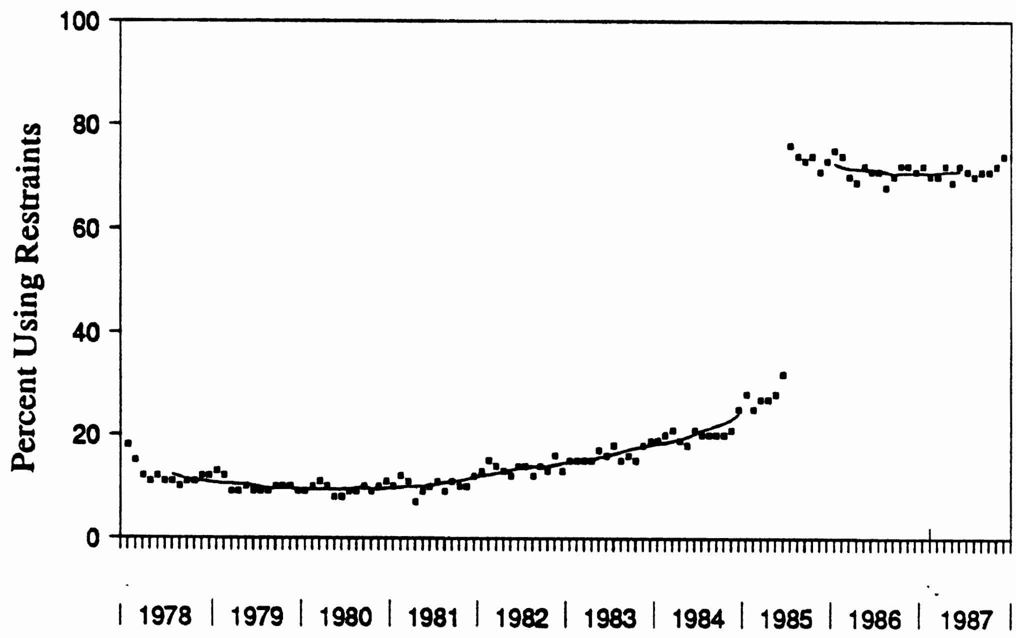

Figure A.5 Reported Restraint Use
Among Injured Occupants Age 25-34

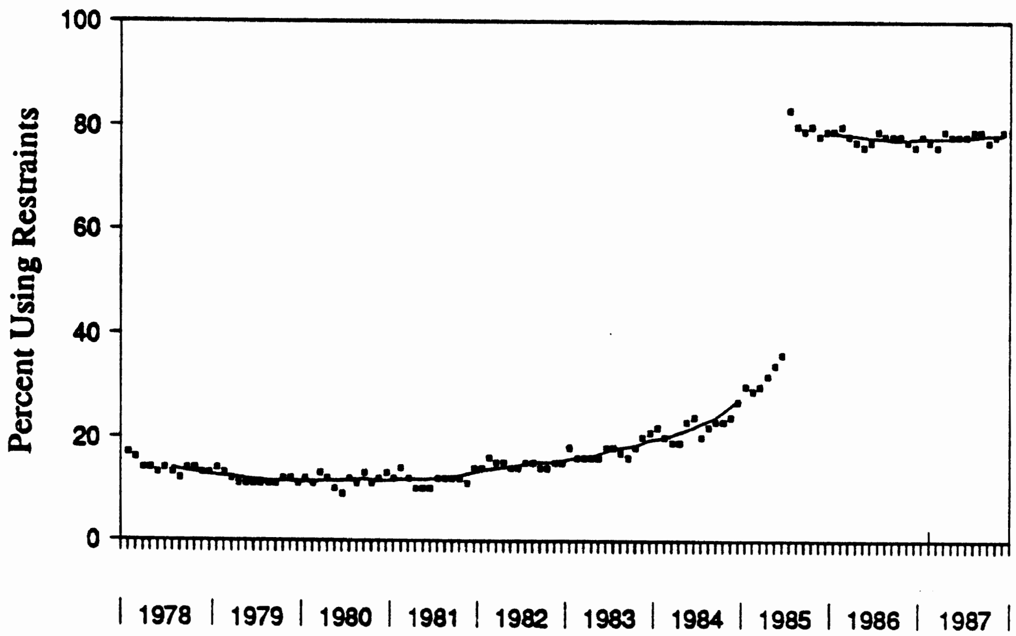

Figure A.6 Reported Restraint Use
Among Injured Occupants Age 35-54

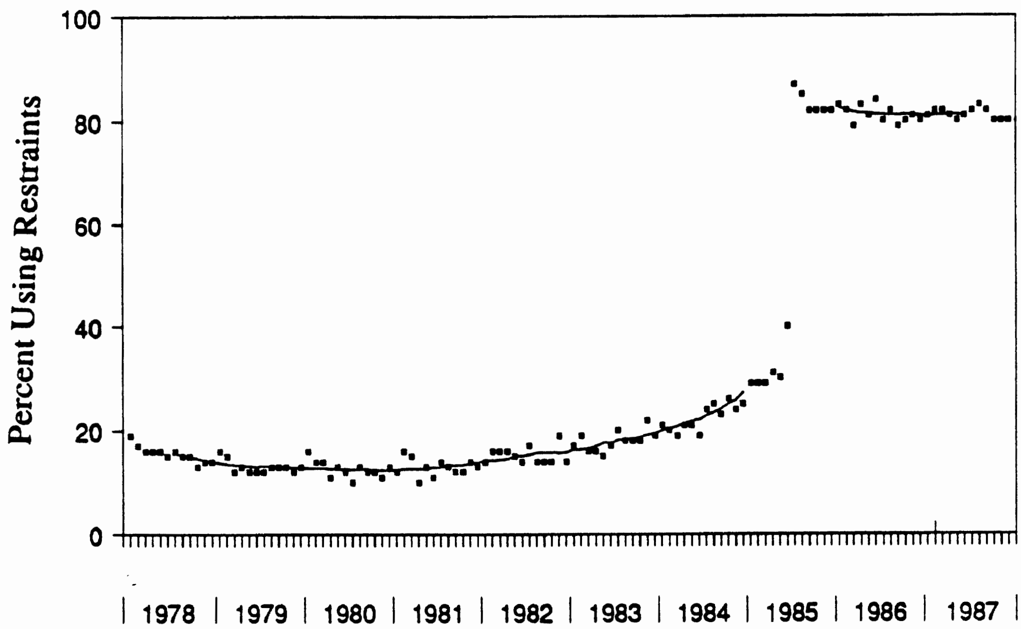

Figure A.7 Reported Restraint Use
Among Injured Occupants Age 55 and Over

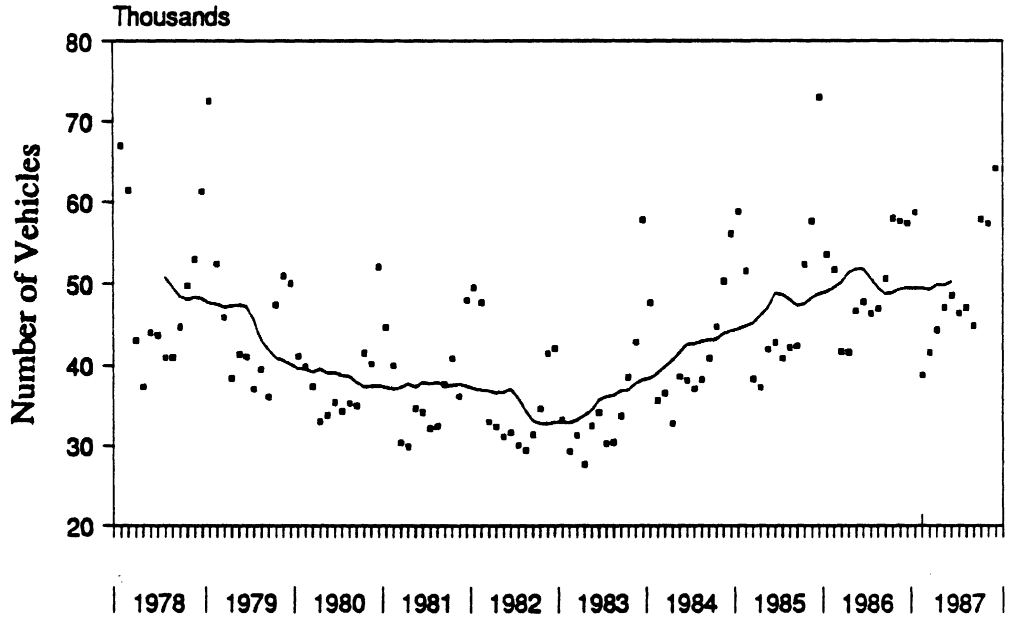

Figure A.8 Number of Vehicles Involved in Crashes

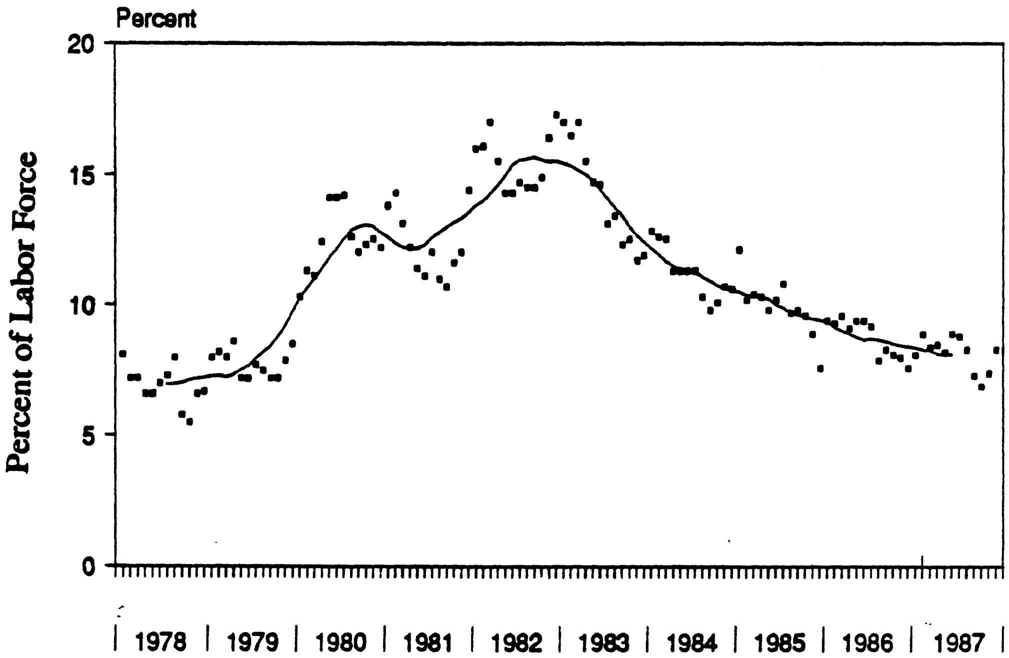

Figure A.9 Michigan Unemployment Rate

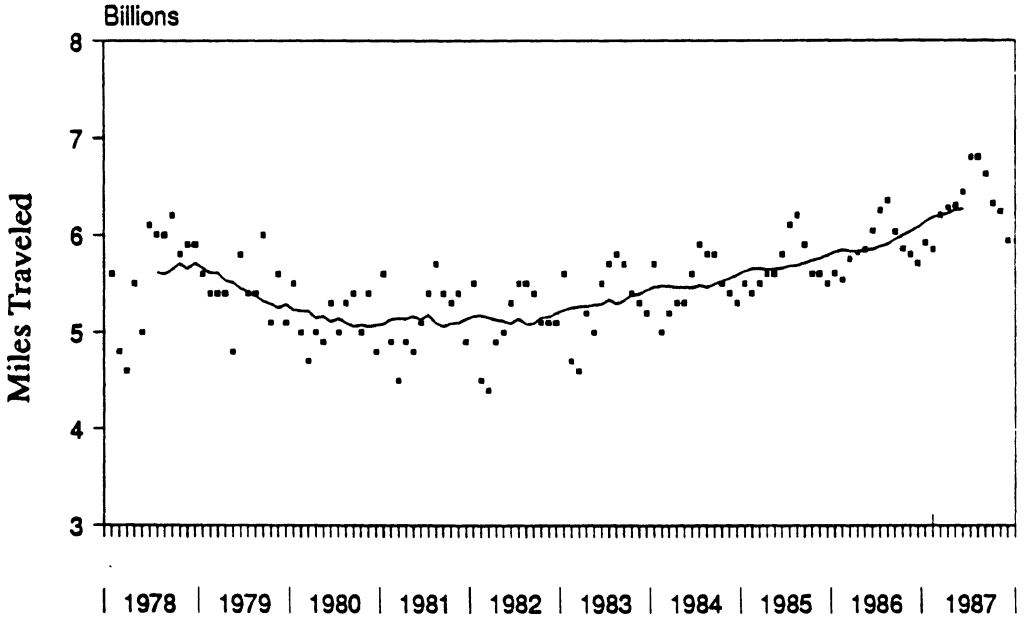

Figure A.10 Vehicle Miles Traveled
in Michigan

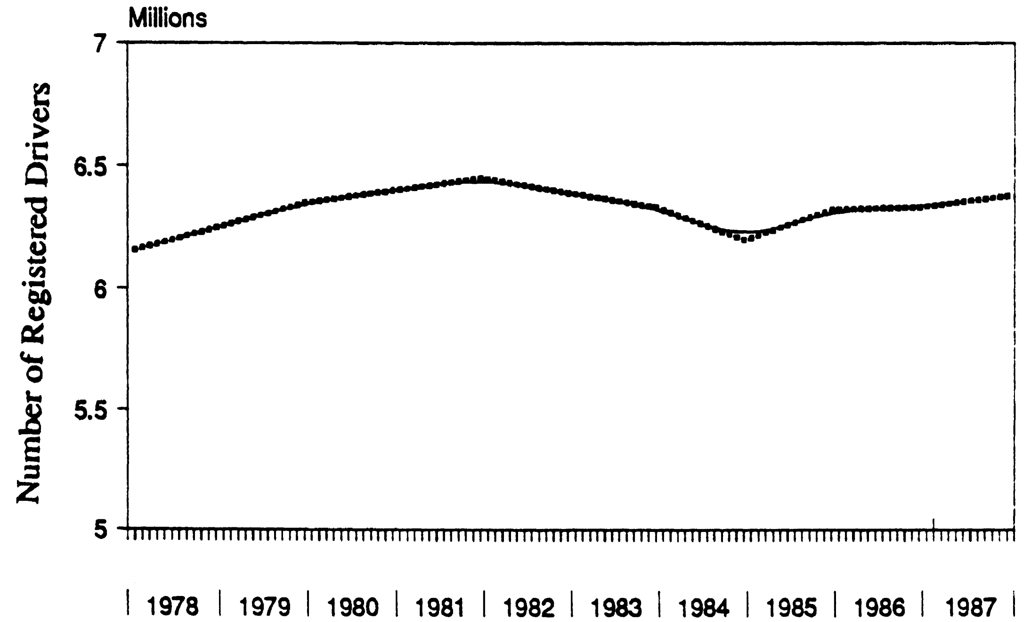

Figure A.11 Number of Licensed
Drivers in Michigan

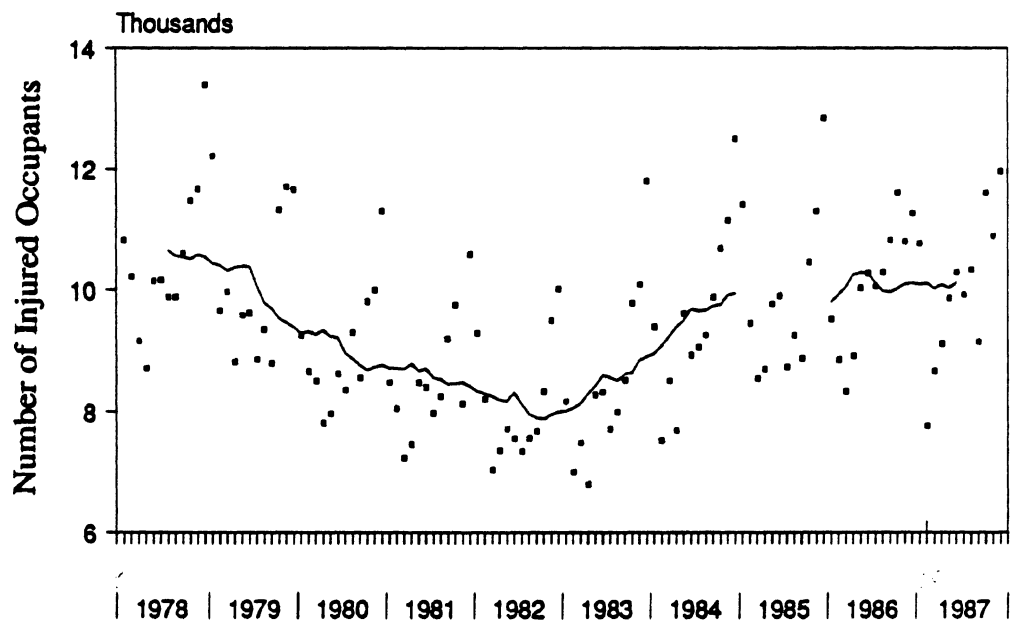

Figure A.12 Number of Injured Occupants Age 16+

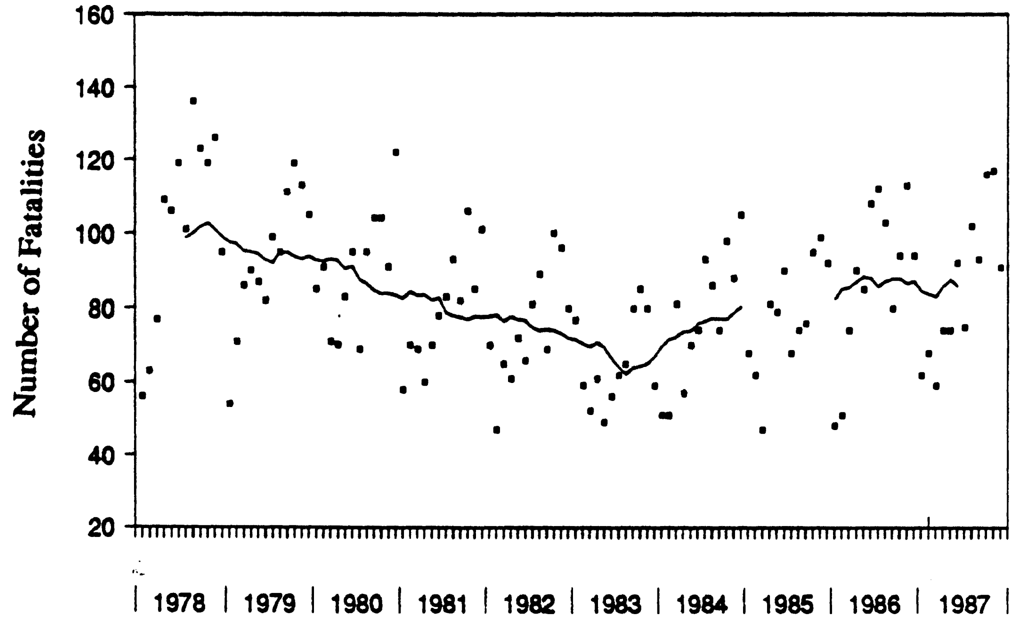

Figure A.13 Number of Fatalities Age 16+

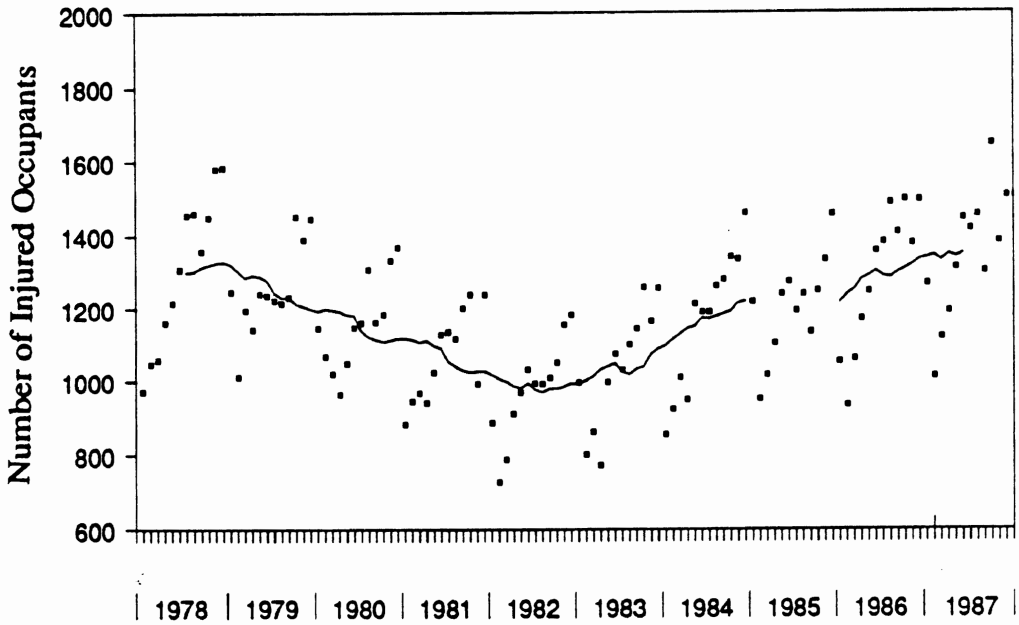

Figure A.14 Number of A-level Injured Occupants Age 16+

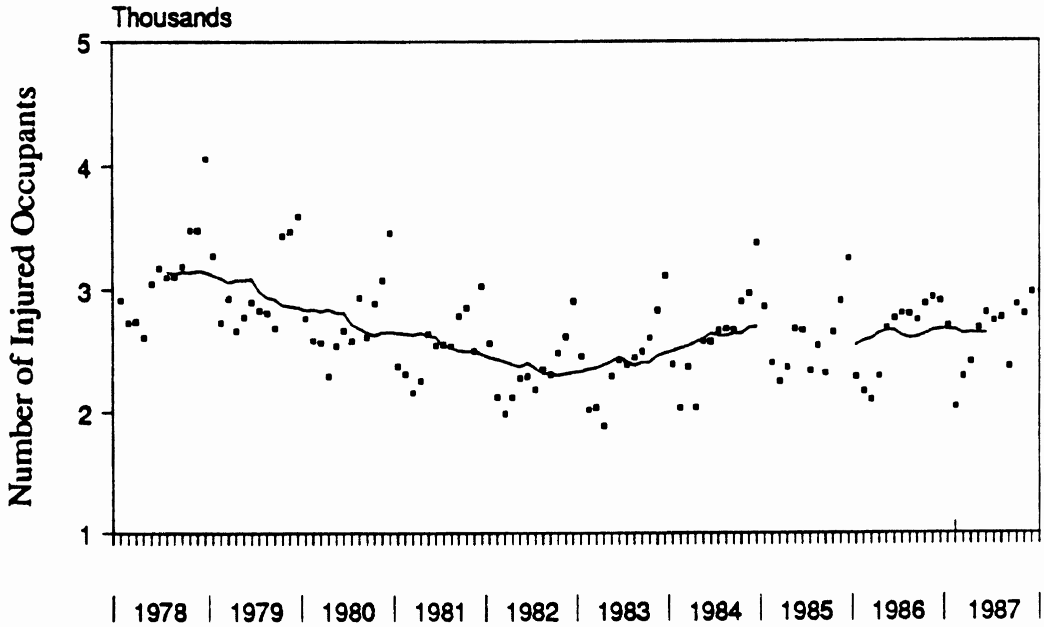

Figure A.15 Number of B-level Injured Occupants Age 16+

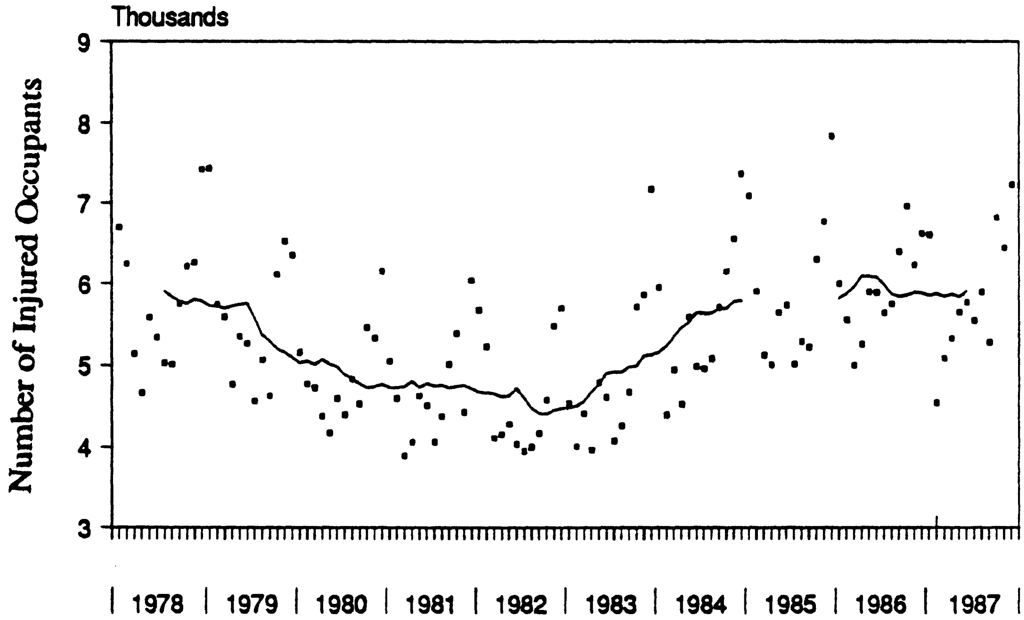

Figure A.16 Number of C-level Injured Occupants Age 16+

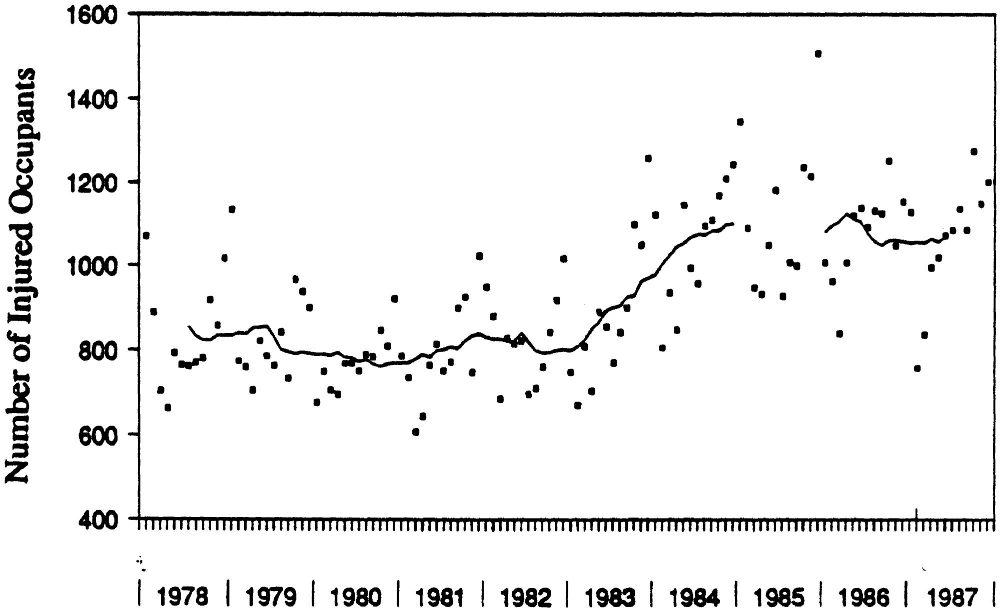

Figure A.17 Number of Occupant Injuries Age 16+ in Crashes with Minor Vehicle Damage

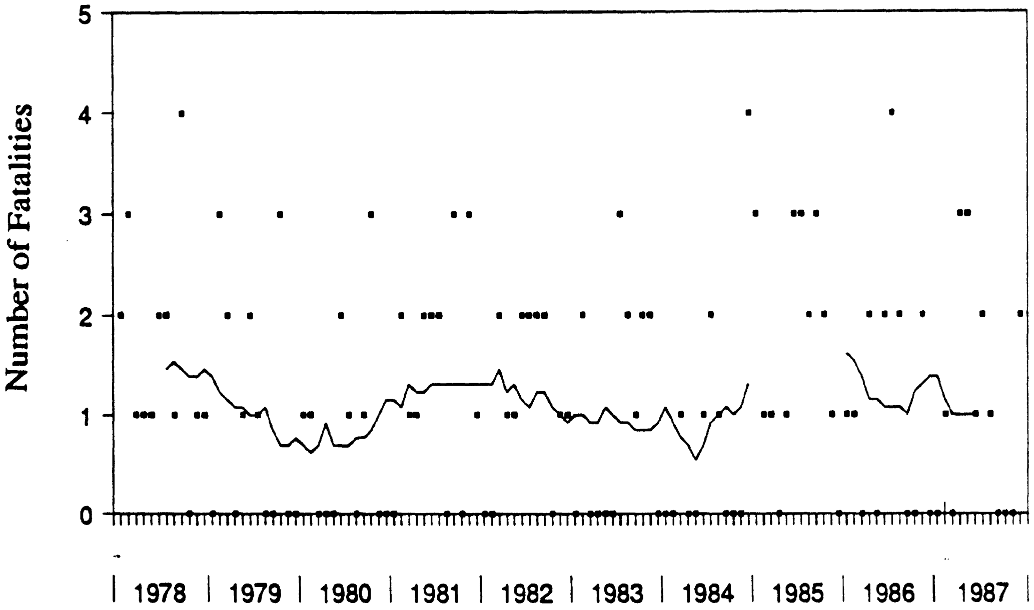

Figure A.18 Number of Fatal Occupant Injuries Age 16+ in Crashes with Minor Vehicle Damage

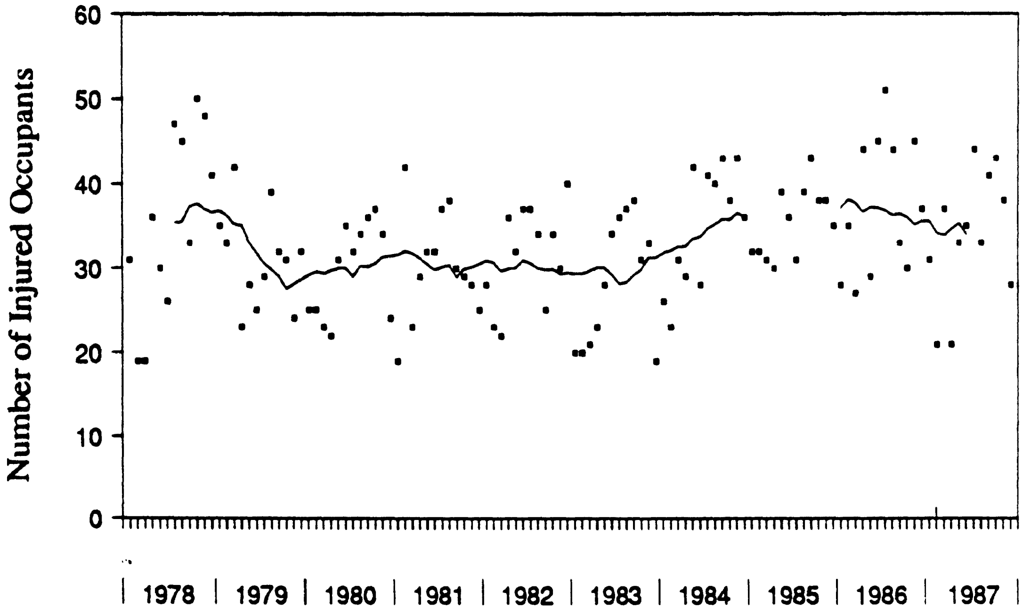

Figure A.19 Number of A-level Occupant Injuries Age 16+ in Crashes with Minor Vehicle Damage

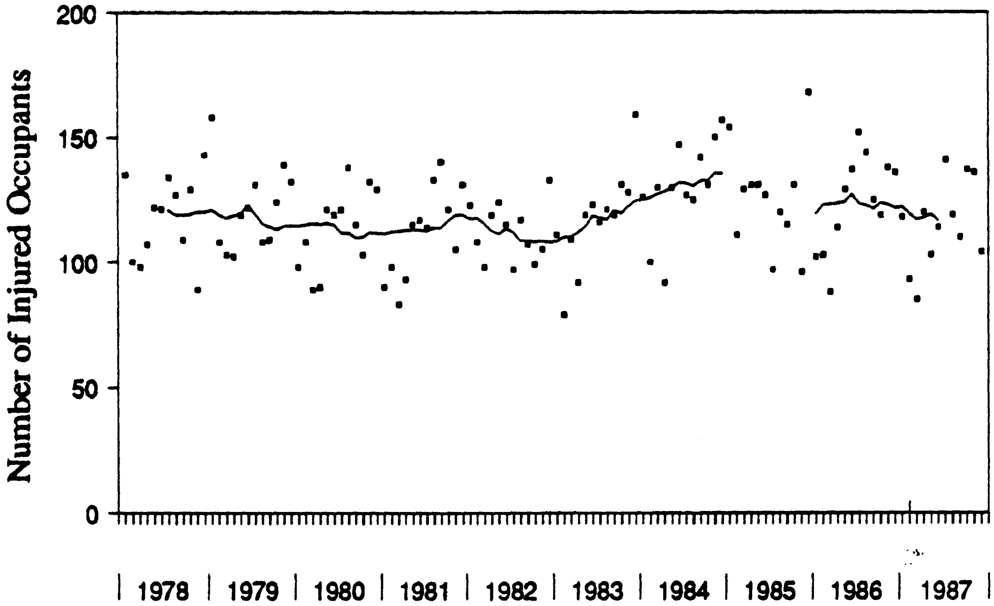

Figure A.20 Number of B-level Occupant Injuries Age 16+ in Crashes with Minor Vehicle Damage

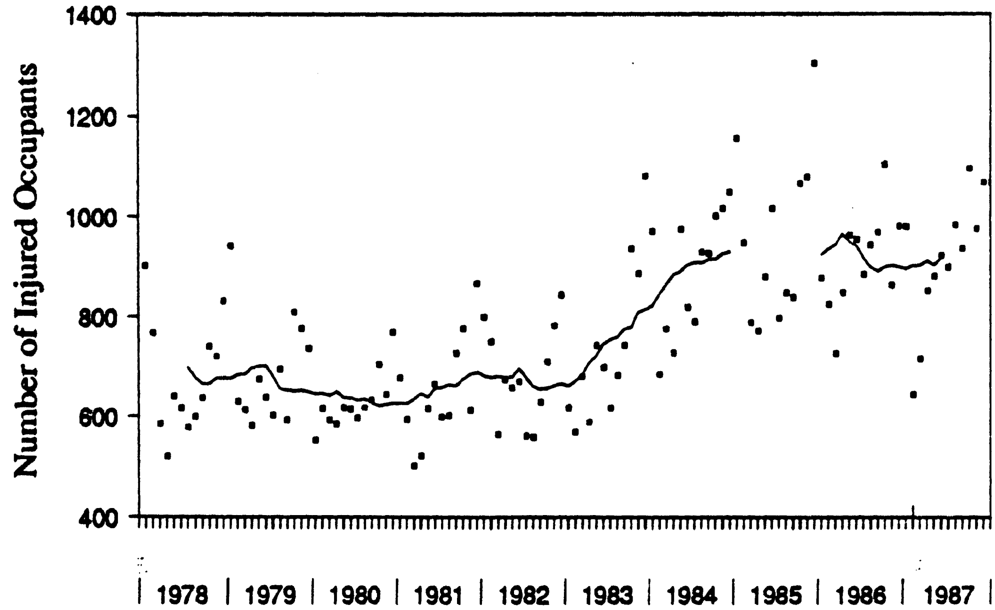

Figure A.21 Number of C-level Occupant Injuries Age 16+ in Crashes with Minor Vehicle Damage

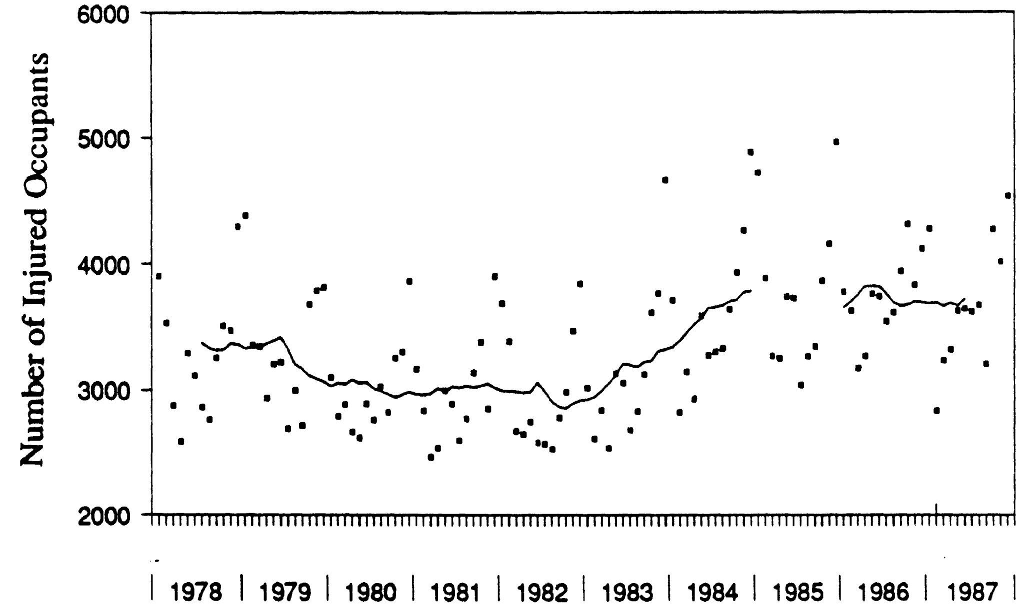

Figure A.22 Number of Occupant Injuries Age 16+ in Crashes with Moderate Vehicle Damage

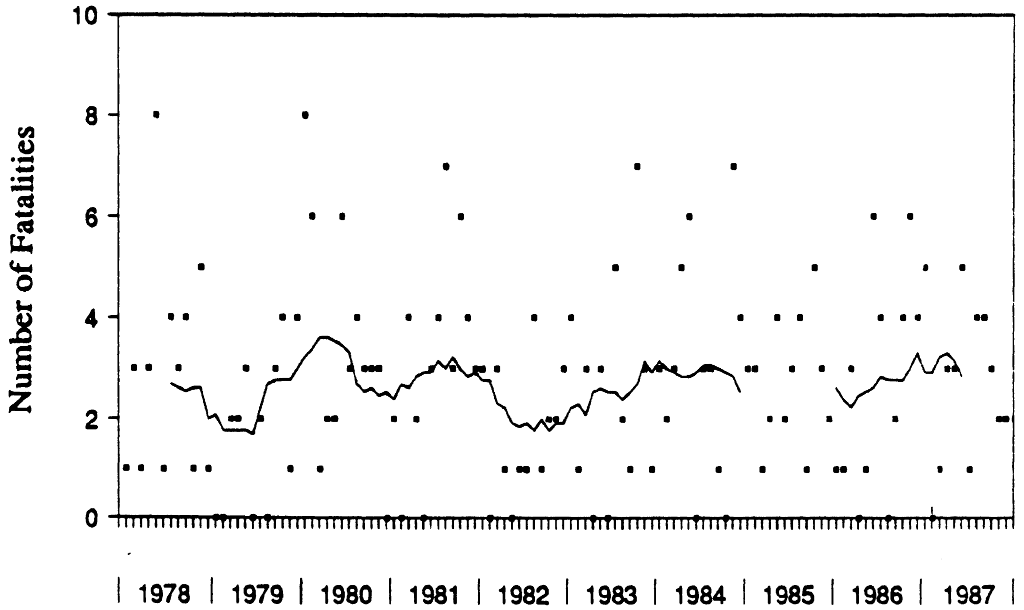

Figure A.23 Number of Fatal Occupant Injuries Age 16+ in Crashes with Moderate Vehicle Damage

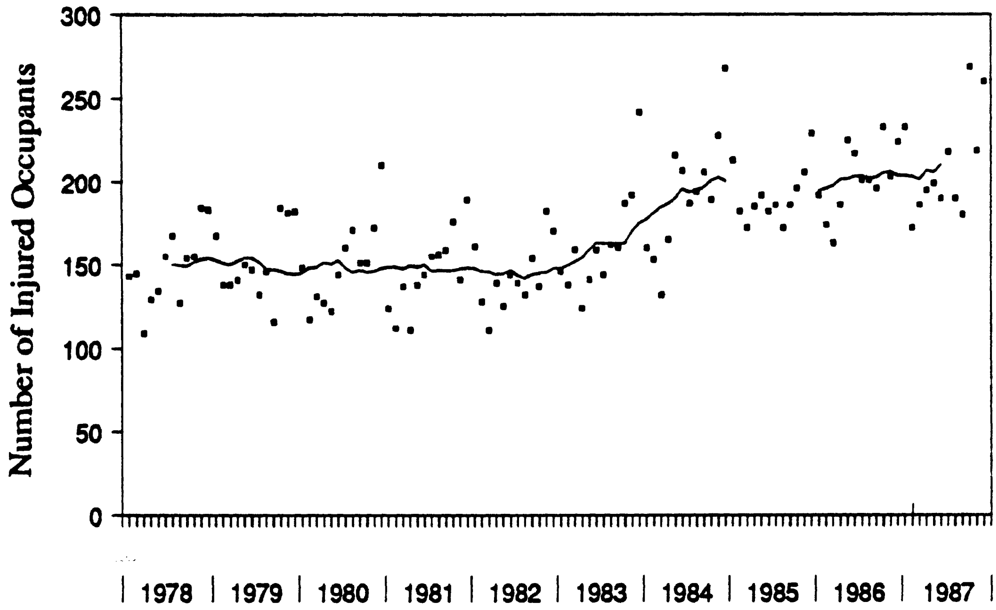

Figure A.24 Number of A-level Occupant Injuries Age 16+ in Crashes with Moderate Vehicle Damage

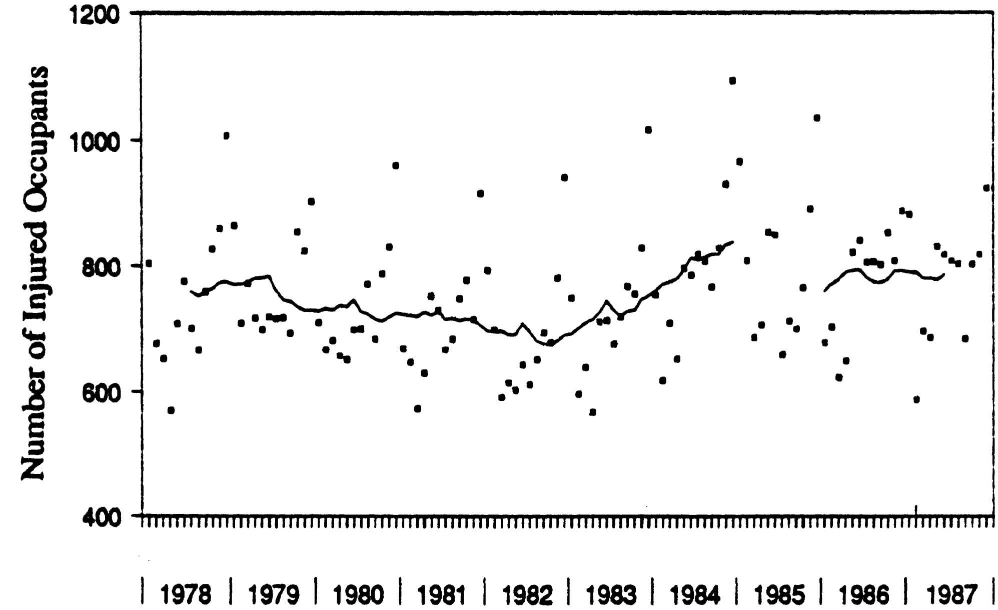

Figure A.25 Number of B-level Occupant Injuries Age 16+ in Crashes with Moderate Vehicle Damage

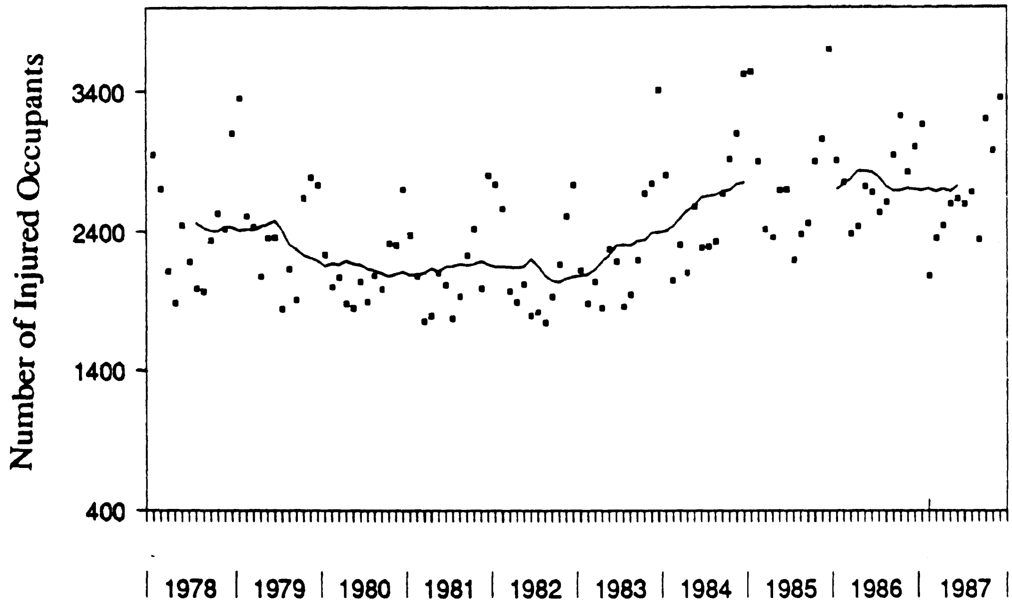

Figure A.26 Number of C-level Occupant
Injuries Age 16+ in Crashes with
Moderate Vehicle Damage

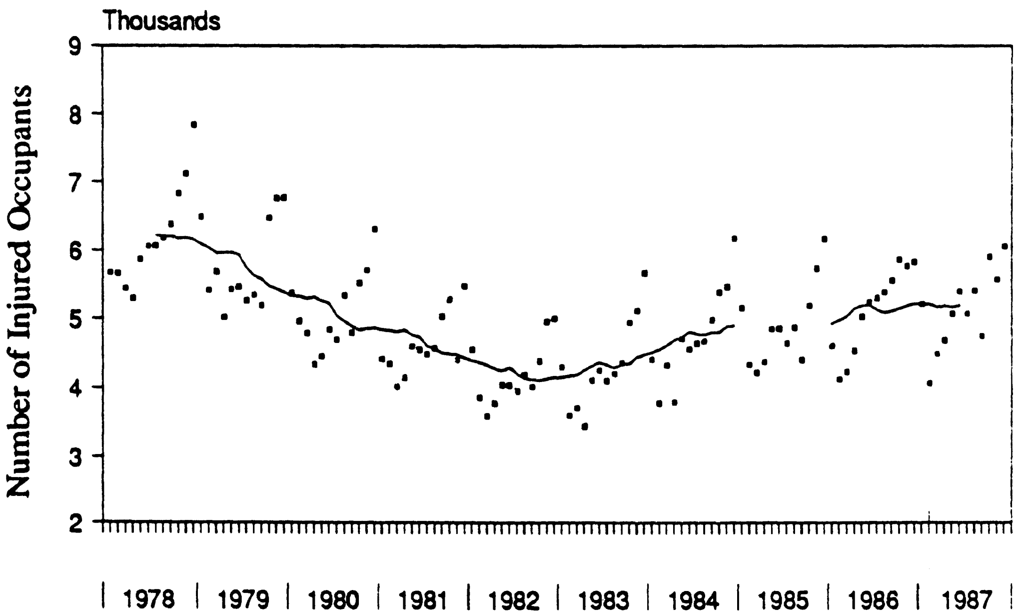

Figure A.27 Number of Occupant
Injuries Age 16+ in Crashes with
Severe Vehicle Damage

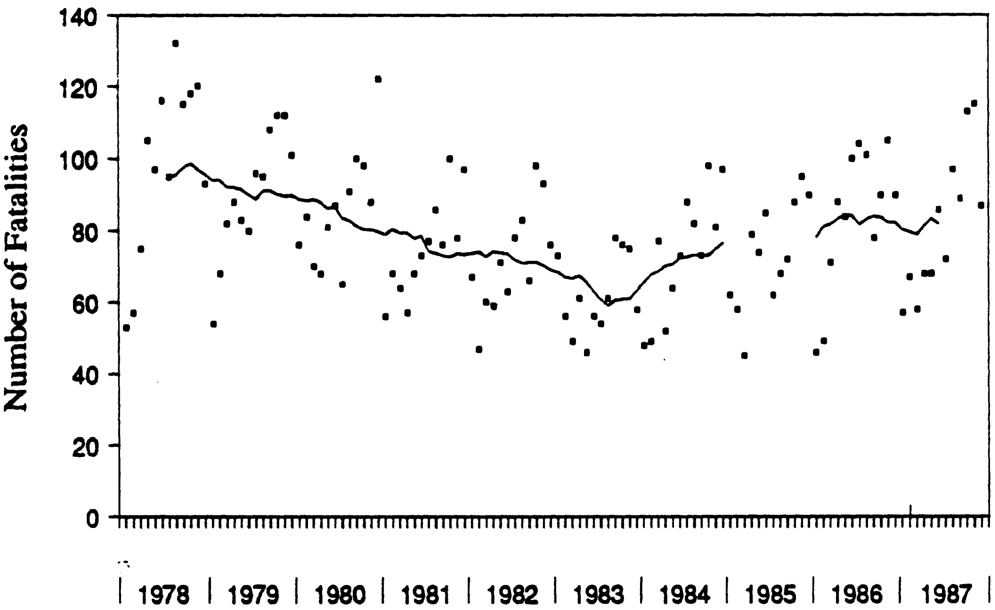

Figure A.28 Number of Fatal Occupant Injuries Age 16+ in Crashes with Severe Vehicle Damage

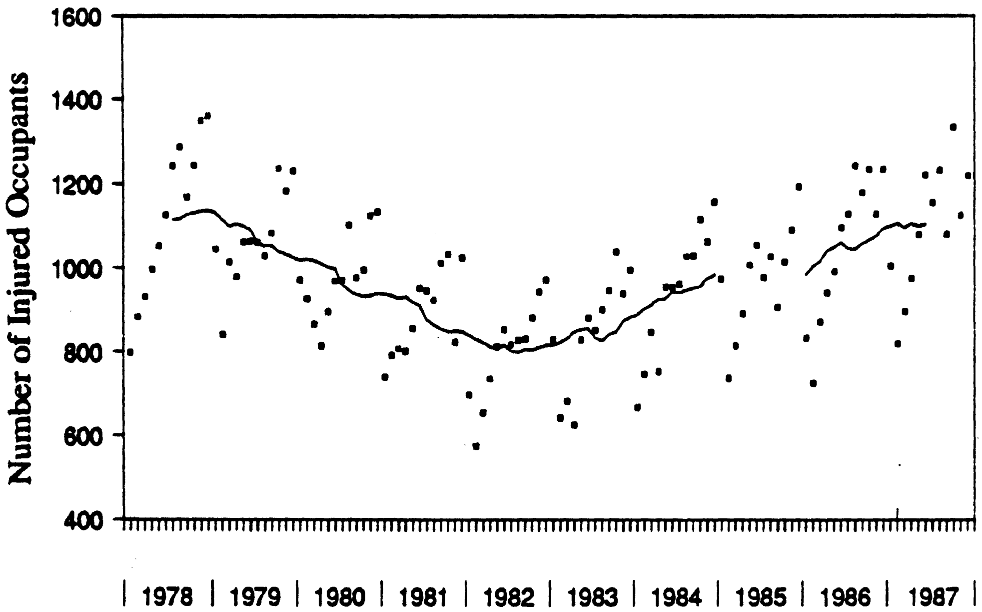

Figure A.29 Number of A-level Occupant Injuries Age 16+ in Crashes with Severe Vehicle Damage

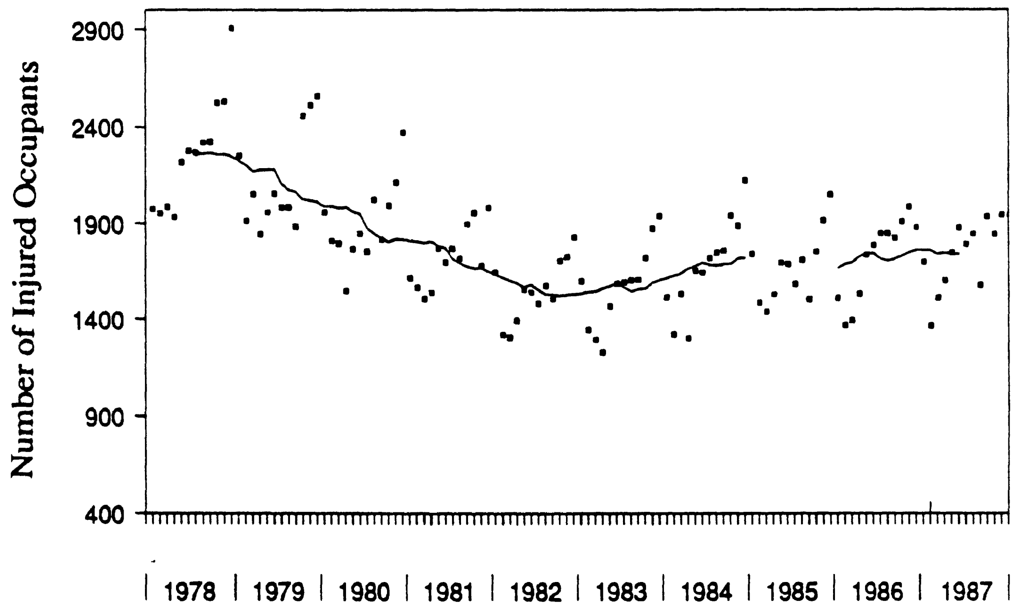

Figure A.30 Number of B-level Occupant Injuries Age 16+ in Crashes with Severe Vehicle Damage

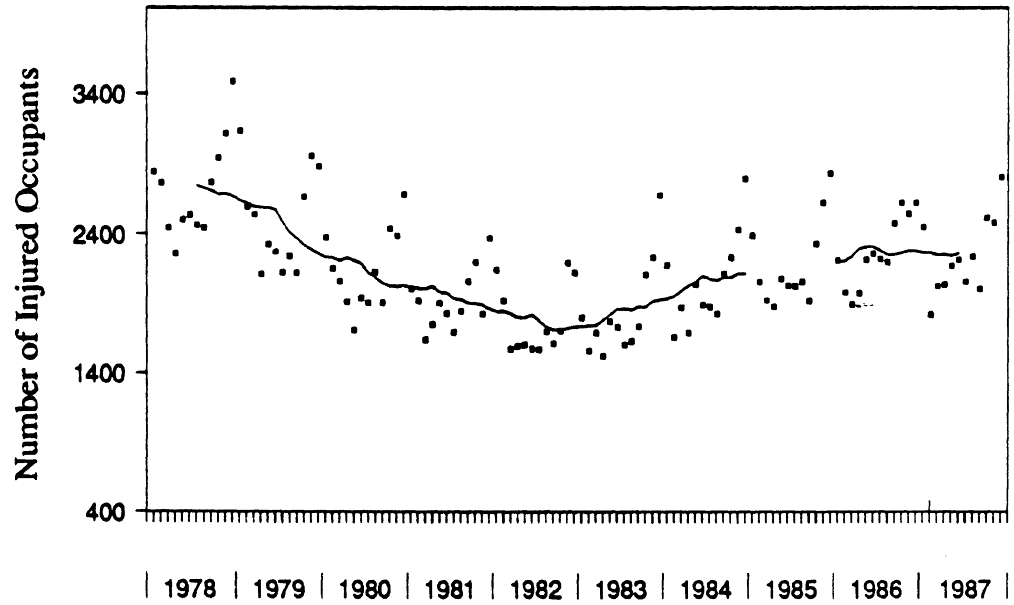

Figure A.31 Number of C-level Occupant Injuries Age 16+ in Crashes with Severe Vehicle Damage

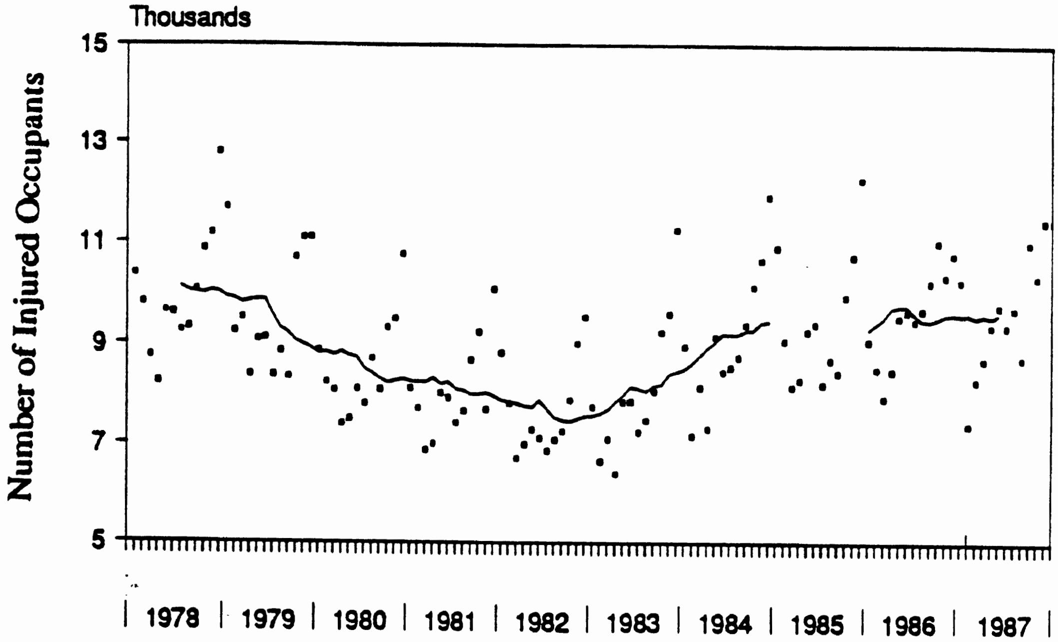

Figure A.32 Number of Front-seat
Injuries Age 16+

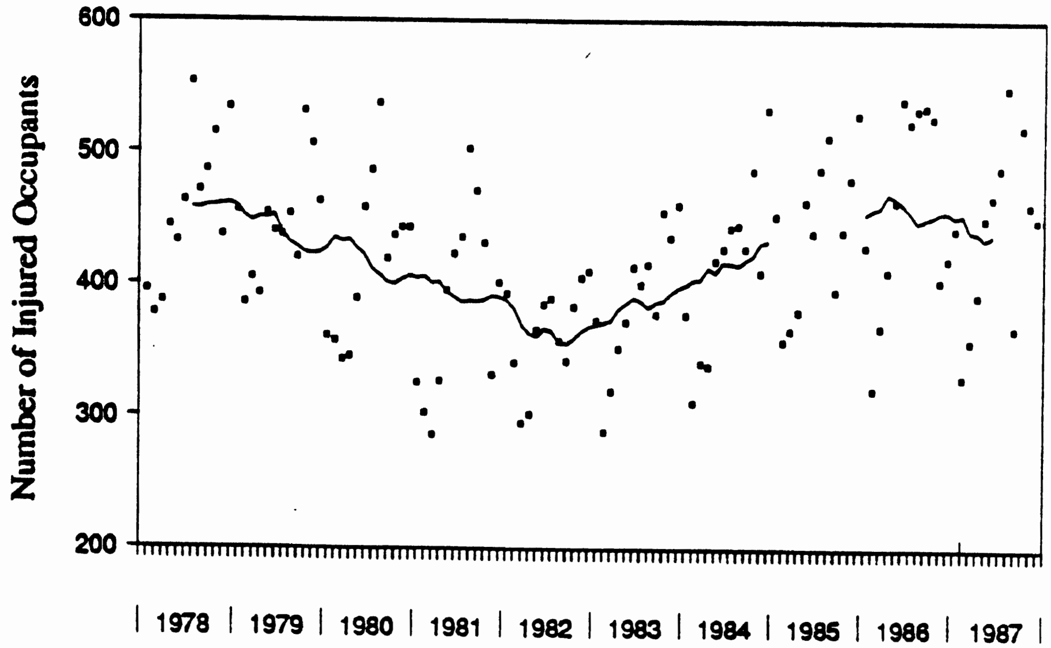

Figure A.33 Number of Rear-seat
Injuries Age 16+