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RESTRAINT USAGE AMONG CRASH-INVOLVED MOTOR VEHICLE OCCUPANTS

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16. Abstract
Objectives of this study were to identify recent trends in restraint use in Michigan and assess the effectiveness of mandatory restraint laws in increasing the use of occupant restraint systems and decreasing traffic casualties. All reported crash-involved motor vehicle occupants in Michigan from January 1978 through December 1982 were examined. Box-Jenkins time-series analyses were used to measure trends in restraint use and injuries, and to measure the effects of Michigan's mandatory child restraint law, implemented in April 1982.

Restraint use in Michigan was found to vary considerably by age, alcohol or drug use, seating position, number of vehicle occupants, injury severity, vehicle damage severity, vehicle size and type, time of day, day of week, highway class, and county. Use of restraints decreased from 1978 to 1980, but increased from 1980 to 1982. The mandatory child restraint law was associated with a 208% increase in restraint usage among 1-3-year-olds, a 50% reduction in injuries to infants under age 1, and a 17% reduction in injuries to toddlers age 1-3.

Recommendations include a longer-term followup study of the child restraint law and, based on the demonstrated effectiveness of Michigan's child restraint law, an expansion of the law to cover motor vehicle occupants of all ages.

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EXECUTIVE SUMMARY

Objectives of this study were to identify recent trends in restraint use in Michigan and assess the effectiveness of mandatory restraint laws in increasing the use of occupant restraint systems and decreasing traffic casualties. A review of studies of mandatory adult restraint laws in other countries revealed that the laws have generally been successful. A review of recent studies of mandatory child restraint laws revealed that such laws have frequently increased use to some extent, but a clearly demonstrable effect on child injuries has not yet been documented. Many past studies have major methodological limitations and should therefore be interpreted with caution.

The present study examined all reported crash-involved motor vehicle occupants in Michigan from January, 1978, through December, 1982. Time-series analyses were used to measure trends in restraint use and injuries in recent years, and to measure the effects of Michigan's mandatory child restraint law, implemented in April, 1982.

Major findings are summarized here. The rate of restraint use in Michigan: (1) is higher among young children and lower among teenagers and young adults, (2) is lower among drivers using alcohol or drugs at the time of a crash and higher among drivers not using alcohol or drugs, (3) varies according to seating position, (4) is higher among drivers alone in a vehicle and lower among people in vehicles with multiple occupants, (5) is higher among occupants experiencing no injury and lower among those severely injured or killed, (6) is higher among occupants of vehicles with minor damage and lower among occupants of vehicles experiencing extensive damage, (7) is higher among occupants of small cars and lower among occupants of large cars and pickup trucks, (8) is higher during weekday daytime hours and lower during weekend nighttime hours, (9) is higher on limited-access highways and lower on nonlimited-access highways, and (10) varies

considerably across counties in Michigan. Restraint use decreased from 1978 to 1980 and increased from 1980 to 1982. Use is slightly higher during the winter months than during the summer, but this seasonal cycle was of marginal significance. The number of Michigan residents involved in traffic crashes trended downward from 1978 through 1982. These patterns were controlled when evaluating the effects of Michigan's child restraint law through the use of Box-Jenkins intervention analysis methods.

The main effects of the child restraint law were as follows: (1) a 208% increase in restraint use among 1-3-year-olds, that is, use increased from about 12% to 36%; (2) a 50% reduction in injuries (including all types of reported fatal and nonfatal injuries) to infants under age 1; that is, an estimated 156 infant injuries are prevented per year; and (3) a 17% reduction in injuries to children age 1-3, that is, an estimated 302 toddler injuries are prevented per year. The effects of the law were due primarily to reductions in less severe injuries, and occurred primarily among occupants of crash-involved vehicles experiencing low or moderate damage. The number of children riding in the more-dangerous front-seat and cargo-area positions decreased as a result of the law, with children increasingly riding in the safer rear-seat position. Finally, the law may have had a slight spillover effect in reducing injuries among 25-54-year-olds by about 6%, although this finding must be verified in followup research.

In conclusion, Michigan's mandatory child restraint law has had a significant effect in increasing the proportion of young children who are restrained, and has prevented a substantial number of injuries to young children. Continued public information and enforcement efforts might make the law more effective. Long-term effects of the law should be evaluated in followup studies. Given the demonstrated effectiveness of the child restraint law in Michigan, it is recommended that the mandatory restraint law be expanded to motor vehicle occupants of all ages.

1: INTRODUCTION

Injuries and deaths due to motor vehicle crashes are a major public health problem in the State of Michigan. Accidents, most associated with motor vehicles, are the leading cause of death for residents aged 1-44 (Verway, 1982), and are a frequent cause of disabling injury as well. In 1982 alone, 1,417 people died and 130,061 were injured in motor vehicle crashes. Costs associated with health care and lost productivity are a significant burden to the State of Michigan, both in terms of direct costs paid by the state and costs paid by Michigan residents through numerous other mechanisms (Andary and others, 1981). The pain and suffering caused by traffic accidents is incalculable. Not included in many assessments of costs of automobile crashes are such secondary effects as marital and family instability, psychological stress, and alcohol and drug abuse frequently seen in families where a member has been killed or seriously injured in a crash (Rubin, 1982; Kaufman and Bilge', 1982).

Currently available technology, in the form of occupant restraint systems, can substantially reduce the risk of injury and death associated with motor vehicle travel. Effectiveness of properly used restraint systems in reducing injury among crash-involved automobile occupants is beyond dispute. Current estimates indicate that the use of lap and shoulder belts at the time of a crash reduces the probability of fatality or serious injury by about 30 to 50%. This does not necessarily mean that an increase in restraint use among the motor vehicle occupant population will automatically result in a proportionate reduction in injury and death. The 30 to 50%

estimate represents the effectiveness of restraint technology in a given crash. When the rate of use increases in a specific population of motor vehicle occupants, there are numerous differences between long-term users, new users, and continuing nonusers. The most important difference is the risk of crash involvement. Long-term users are least likely to be crash-involved, new converts are more likely to be crash-involved, and continuing nonusers are those at highest risk for crash involvement. In short, belt users tend to be relatively safe drivers, while those refusing to use belts are those that most need the protection provided by belts. Further discussion of the characteristics differentiating belt users from nonusers and high-risk drivers from low-risk drivers follows in Section 4. For now, it is simply noted that the huge reductions in injury and death possible with widespread belt use are likely to be somewhat smaller when actually implemented, due to such confounding factors. Nevertheless, substantial reductions in motor vehicle casualties are likely if the rate of occupant restraint use were significantly increased.

Of major concern to state health and safety officials is the large proportion of the motoring public in Michigan that does not regularly use occupant restraints. Analyses of self-reported belt use in a recent survey of Michigan residents indicated an average belt use rate of approximately 28% (McGinley Marketing Research, 1982; O'Day and Filkins, 1983). Self-reported belt use typically overestimates actual use. Estimates of observed (rather than self-reported) belt use in Michigan vary from study to study, depending primarily on the sample design. Most studies indicate, however, a rate ranging between 10 and 20% (Grimm, 1980). The most recent observational study of occupant restraint use in Michigan indicates an overall rate of

13.8% (O'Day and Wolfe, 1984).

It is a major priority among state safety officials, public health professionals, and others to increase the proportion of the motoring public that is protected by occupant restraint devices. There are three main approaches designed to increase the use of occupant restraints. One traditional approach relies on public information and education campaigns to persuade individuals to use the seat belt restraint systems already available. The best programs have been able to increase knowledge concerning restraints, and have occasionally changed restraint attitudes. However, few programs have achieved significant increases in restraint-use behavior, particularly when evaluated for long-term effects.

A second major approach to increase the proportion of restraint-using motorists is through the installation of passive or automatic restraint systems in new vehicles. Universal installation of passive restraint systems is likely to significantly reduce injury and death due to motor vehicle crashes (Warner, 1983). A detailed discussion of the debate surrounding mandating passive restraints is beyond the scope of this report. Nevertheless, a few issues should be noted. First, after installation of passive restraints in new vehicles is mandated, it would take ten or more years before the vehicle population completely turned over and passive restraints were available in most vehicles in use. Second, airbag passive restraints are most effective in reducing injury caused by frontal-impact crashes; they are less effective in other crash configurations. Therefore, air bags should be viewed as an important supplement to existing seat belt systems, but not as a replacement for seat belts. Third, it is difficult for the State of Michigan to require installation of passive restraint systems on all vehicles driven in Michigan. Passive restraint installation is best required on all new automobiles by the federal government, resulting in a substantial reduction in per-vehicle cost due to economies of scale. In short, while compulsory installation of passive restraint systems is a potentially fruitful means of reducing crash-related deaths and injuries, it will not eliminate the need to increase use of existing active restraint systems, and is a less convenient focus for policy attention at the state level.

The third major approach to increasing the proportion of motor vehicle occupants that are adequately restrained, compulsory use of existing seat belts, is the focus of this volume. Numerous countries have implemented mandatory adult seat belt use laws. The laws have frequently been associated with increased seat belt use and decreased accident casualty rates. While no state has yet passed a general adult mandatory belt use law, most states, including Michigan, have implemented compulsory restraint use for young children (Table 1.1). Making belt use compulsory for motor vehicle occupants of all ages is currently under debate in Michigan (Michigan State Legislature, 1983).

The pattern of policy changes in most western countries has been the opposite of the United States. Many countries in the 1970s implemented mandatory adult restraint use laws that explicitly excluded young children from the provisions of the laws. After benefits of adult use laws were observed, several jurisdictions then revised their occupant restraint policy by extending mandatory use to young children as well. In contrast, most states have implemented mandatory restraint laws limited to young children in recent years, but none has passed similar legislation applying to adult vehicle occupants. It is apparently politically more acceptable to require young children to be restrained than adults, because they are unable to decide for themselves to use restraints and take the requisite action. Moreover, some advocate child restraint laws as a first step in building public support for mandatory restraint use for occupants of all ages. Early signs that mandatory restraint policy focused on young children is gradually being expanded to other populations is already emerging. New York, for example, began mandating restraint use for young children in April, 1982; the law is gradually being extended to cover children through age 10. In March, 1983, a regulatory change (i.e., without new legislation) made restraint use compulsory for those driving under a learner's permit (New York State Department of Motor Vehicles, 1983).

The main goal of this project is to provide detailed information on the pattern of restraint use over time among crash-involved motor vehicle occupants in Michigan. Effects of the recently enacted child restraint law are assessed, and important background information on adult restraint use is obtained. The findings concerning adult restraint use will function as baseline information needed for adequate evaluation of a mandatory adult restraint use policy, should it become law. Specific questions addressed include: (1) has restraint use increased or decreased over the past several years? (2) do the changes in restraint use over time vary by characteristics of the motorist such as age? (3) how have changes in patterns of restraint use affected injury rates? (4) has the recently enacted mandatory child restraint law significantly increased child restraint use? (5) has the child restraint law significantly reduced child traffic crash injuries? and (6) how might an extension of the child restraint law to motor vehicle occupants of all ages be best evaluated for its effect in casualty reduction? While cross-sectional differences in restraint use and injury patterns between occupants with various characteristics are also examined, the dominant focus of this study is on (1) longitudinal changes in restraint use and injury rates, and (2) the efficacy of compulsory restraint use laws in increasing use and reducing casualties. Therefore, we begin with an extensive review of the extant literature on effects of mandatory restraint use laws (section 2). The research design and analysis methods used in this study are discussed in section 3. Results concerning patterns of restraint use in Michigan are found in section 4. Findings concerning the effects of the child restraint law are presented in section 5. Finally, section 6 includes a discussion of the implications of the results for injury prevention efforts and recommendations for further research.

Table 1.1
States Implementing Mandatory Child Restraint Laws

State	Effective Date	Highest Age Covered
Alabama	1-81	3
Arizona	7-84	4
Arkansas	8-83	5
California	1-83	4
Colorado	1-84	4
Connecticut	10-82	4
Delaware	6-82	4
District of Columbia	7-83	6
Florida	7-83	6
Georgia	7-84	4
Hawaii	7-83	4
Illinois	7-83	3*
Indiana	1-84	5
Kansas	1-82	2
Kentucky	7-82	40 Pounds
Maine	9-83	4
Maryland	1-84	5
Massachusetts	1-82	5
Michigan	4-82	4
Minnesota	1-82	4
Mississippi	7-83	3
Missouri	1-84	4
Montana	1-84	4
Nebraska	9-83	4
Nevada	7-83	5
New Hampshire	7-83	5
New Jersey	4-83	5
New Mexico	6-83	5
New York	4-82	10*
North Carolina	7-82	2
North Dakota	1-84	4
Ohio	3-83	4
Oklahoma	11-83	5
Oregon	1-84	5
Rhode Island	7-80	3
South Carolina	7-84	4
Tennessee	1-78	4
Virgina	1-83	4
West Virginia	7-81	5
Wisconsin	12-82	4

*Age group covered is gradually being expanded up to the age indicated.

Information current as of June 1983. Based on data published in Physicians for Automotive Safety News, Spring, 1983.

2: CURRENT LITERATURE ON MANDATORY OCCUPANT RESTRAINT LAWS

Numerous studies over the past decade have reported on the effects of mandatory restraint use laws. Most of the studies have been conducted outside the United States, since no state has yet implemented an adult restraint use law. Most of the existing studies focus on the effects of adult restraint laws, which have been implemented in a larger variety of jurisdictions than laws limited to very young motor vehicle occupants. Finally, the key variable examined most frequently is observed use of restraint systems, although several studies also examined the impact of restraint laws on traffic injuries and deaths. Keep in mind that many of these studies used nonrandom samples, inadequate control groups, and data analysis methods that are far from state-of-the-art. Therefore, results from any particular study should not be the basis for a determination of the impact of restraint laws. However, the pattern of findings across many studies, in diverse jurisdictions, using different methods, and during different time periods, lends strong support to the proposition that mandatory restraint use laws can significantly increase the proportion of motor vehicle occupants that regularly use restraints, and consequently reduce injury and death caused by motor vehicle crashes. Available findings on effects of compulsory restraint use from individual jurisdictions follow.

Effects of Adult Restraint Use Laws

Australia. The province of Victoria in Australia was the first to implement an adult mandatory restraint use law. In December, 1970, belt use became compulsory for motor vehicle occupants over the age of seven years. Joubert (1979) reports that belt use was about 18% before the law, and increased after the law to 75% in urban areas and 64% in rural areas. Use continued to increase, reaching over 90% in urban areas and 80% in rural areas by 1978. Joubert also examined occupant fatalities and injuries for 1971, the first year with the new law. Fatalities were down 15% among drivers and 19% among passengers; the reductions for nonfatal injuries were 14% for drivers and 10% for passengers. Neither fatalities nor injuries decreased for the rest of Australia, indicating that the reductions in Victoria may have been due to the seat belt law.

Vulcan (1978) summarized surveys conducted by Andreassand which indicated that belt use among Victorian drivers and front passengers increased steadily from 1971 through 1976. Overall use increased from 32-48% in 1971 to 73-88% in 1976. Consistent with the increased use, occupant fatalities were 32% lower and occupant injuries were 44% lower in 1976 than expected given the 1960-1970 trends. In comparison, there were no appreciable changes in nonoccupant (i.e., pedestrian, motorcyclist) traffic fatalities and injuries during the same period. Vulcan notes that other factors, such as the December, 1972, and December, 1973, reductions in speed limit, probably contributed to the casualty reductions.

Trinca and Dooley (1977) also examined traffic deaths and injuries in Victoria. An upward trend throughout the 1960s reversed in 1970, when the belt law was passed. According to these researchers, by 1974 deaths were 37%

lower than in 1970, and injuries were 41% lower. These casualty reductions were not accompanied by similar reductions in the frequency of crashes, indicating that the declines in injury and death were not due to factors associated with reduced crash involvement.

McDermott and Hough (1979) examined annual numbers of traffic fatalities and injuries in the whole of Australia from 1955 through 1977. Beginning with Victoria, all Australian provinces implemented mandatory restraint use laws in the early 1970s. During this period, there was a significant decline in the rate of motor vehicle occupant injuries and deaths per registered vehicle. [Note that determination of the statistically significant decline is based on deviations from linear trends based on ordinary least squares regression. Because the basic assumption of uncorrelated residual errors was violated, the measure of statistical significance is suspect, and results should be interpreted cautiously.] Although the speed limit reduction and fuel shortages of the early 1970s were a confound, there were no comparable reductions in death and injury among motorcyclists and pedestrians, providing support that the observed reductions may be due to the restraint laws.

Bhattacharyya and Layton (1979) conducted perhaps the most sophisticated analyses of Australian seat belt laws, focusing on Queensland, which mandated belt use beginning January, 1972. Using an explicit Box-Jenkins time-series modeling strategy, they found that motor vehicle occupant deaths in the mid-1970s were an estimated 46% less than expected without the belt law. [By using the Box-Jenkins approach, which explicitly takes into account serial correlation in time series, Bhattacharyya and Layton avoided the error made by McDermott and Hough.] Exposure, as measured by gasoline sales, was controlled in the analyses, increasing confidence that the observed effect was due to the seat belt law. Two remaining confounding factors are the reduction in speed limit and significant improvements in traffic control during the 1970s (e.g., installation of traffic lights and stop signs).

Seeney (1977) notes that Queensland "traffic surveys in 1972 indicated that the [seat belt] wear rate rose immediately to about 60% with respect to drivers (90% compliance in the 65% of vehicles then fitted with belts)" after the compulsory belt use law was implemented. Further details were not provided.

According to data reported by Johinke (1977), belt use in Queensland (prior to the law) increased from 8% in 1964 to 23% in 1971. With minimal enforcement of the new law, use increased to 49% after the law took effect (78% of occupants with belts available). Some decline in use occurred in subsequent years, but increased enforcement in 1976 brought use up to 90% for drivers with belts available, according to Johinke. The enhanced enforcement efforts were also associated with a reduction in occupant fatalities of 14%.

Fisher (1980) reviewed the effects of Australian belt laws and concluded that use rates increased from about 25% to 35% before the laws were implemented, to 74% to 95% immediately after, with a partial decay of the laws' effects over time. Noting that methodological details for many studies were not available, Fisher concluded that there was a reduction of about 20% in occupant fatalities after compulsory belt laws were implemented in Australia.

Austria. Austria implemented a mandatory belt use law applying to front seat occupants in July, 1976. Although the law does not have any penalty for noncompliance, belt use increased immediately after passage of the law, according to Fisher (1980). However, no before and after figures were provided.

Belgium. Belgium enacted a compulsory seat belt law for front seat occupants in June, 1975 (Fisher, 1980). No formal studies of belt use were found, but one document obtained by Fisher indicated use of about 17% before the law, increasing to about 87% after. However, belt use decreased gradually after the initial increase. Consistent with the increased belt use after the law was enacted, occupant fatalities decreased 25%.

Canada: British Columbia. In a study of over seven thousand British Columbia drivers, Rockerbie (1983) found an increase in belt use from 20 to 24% before the 1977 mandatory use law, to just over 50% after. Box-Jenkins intervention analyses of occupant fatalities indicated a significant decrease in fatalities beginning nine months after the law was implemented, provided the pattern of fatalities in the mid-1970s was assumed to represent a long-term upward trend. Under a model assuming no long-term trend, no significant impact of the law on fatalities was found. Because a significant fatality reduction was found only with a model including a trend component and a nine-month lag, and not with several other models tested, the study only provided tentative evidence that the restraint law may have reduced traffic fatalities.

Canada: Ontario. Snow (1979) reviewed belt use in Ontario in the 1970s, pointing out that use was about 10 to 15% in the early 1970s, rising to 17% by 1975. These slight increases occurred during a period characterized by mass media campaigns to encourage belt use. In December, 1975, immediately prior to the January 1 implementation of a mandatory belt law, use rose to 21%. After the law took effect use jumped to 77% in February, 1976, declining to just over 50% by June of that year. Simpson and

Warren (1981) argue that the decline in use in mid-1976 was a result of the driving public gradually becoming aware of the low risk of detection for violating the belt law, and decreasing their compliance as a result. Pierce (1979) reported figures similar to Snow, with the addition of a survey of drivers in May, 1978, which revealed that use was up to 65%. The increased use seen in 1978 may have resulted from the strengthened enforcement that began in mid-1977.

Matthews (1982) observed belt use among Ontario drivers from September to December, 1980. Average use was 49% during this period. Matthews points out that this figure is close to the 50% estimate found after the law had been in effect for a year, indicating that belt use may be stabilizing after the temporary jump in use in early 1976 and subsequent partial decay of the legal impact during the following several months.

Consistent with the increase in restraint use in Ontario, fatalities were down 13% and injuries down 18% over the first six months with the new law (Snow, 1979). However, a simultaneous reduction in the province-wide speed limit makes it difficult to attribute observed injury declines to the restraint law.

The Ontario Ministry of Health (n.d.) obtained hospital records of all crash-involved injured motor vehicle occupants in 1975 and 1976. They found a 13% decline in number of victims hospitalized between 1975 and 1976, but the average treatment cost per victim increased from Cn$339.01 to Cn$361.00 in constant dollars. Combining these two effects, there was a net reduction of 7.5% in medical care costs due to traffic injuries after the belt law took effect. These authors also noted the February 1976 reduction in speed limit as a factor confounding interpretation of the results.

Roberts and others (1979) specifically tried to isolate the effects of the restraint law from the speed limit change by analyzing crashes on roads with speed limits of 35 M.P.H. or less in an Ontario city. They found that 11.3% of crash-involved drivers in 1975 were injured, while only 9.9% were injured in 1976, after the belt law was implemented. Figures for passengers were 8.9 injured per 100 crashed vehicles in 1975, and 6.8 per 100 crashed vehicles in 1976. While the study did not include control groups, and was limited to one city, the results do indicate that the belt law apparently had an effect in reducing injuries that was independent of the effect of lowering the speed limit.

Canada: Saskatchewan. Saskatchewan's July, 1977, implementation of a seat belt law resulted in an increase in use from 26% to 78% among drivers, and from 24% to 80% among front seat passengers, according to Simpson and Warren (1981). More detailed data on use among front seat occupants (both drivers and passengers) provided by Sheils (1978) are as follows: 24% in May, 1977; 73% in October, 1977; and 60% in May, 1978. Bergen and others (1979) observed driver belt use and reported the following figures: 52% in July, 1977; 70% in October, 1977; 55% in May, 1978; and 70% in May, 1979. While some of the increase in use immediately following passage of the law decayed a year later, most of the loss was regained by 1979.

Sheils (1978) also analyzed injury and fatality data for one year before and one year after the new law. An inconsistent pattern of changes in injuries and fatalities was found. Nonfatal injuries were down in Saskatchewan after the belt law took effect, and were up in one comparison province, Manitoba. The other comparison province, Alberta, experienced an injury reduction similar to Saskatchewan. Fatalities in Saskatchewan increased slightly after the belt law was implemented, but the increase was less than expected given previous trends and was less than the increase in Alberta. On the other hand, fatalities actually declined in Manitoba, the second comparison province. Given these results, it appears that Saskatchewan's belt law had no clear effect on traffic casualties.

Denmark. Denmark required front seat occupants over the age of 14 to use restraints beginning January, 1976. Nordentoft and others (1978) summarized several studies of the Demark experience. A study of data from 15 hospitals for the fourth quarters of 1975 and 1976 revealed a 16% decline in injured drivers admitted, but a 10% increase in injured passenger admissions; total injuries were down 14%. Data from the Aarhus County hospitals revealed a 15% decrease in injuries and a 25 to 32% decrease in serious lesions after the belt law was implemented. A university hospital treated significantly fewer traffic injuries immediately after the law was implemented, but injuries in 1977 returned to their 1975 prelaw level. In contrast to this finding of an apparent temporary effect of the law based on one hospital's data, belt use data indicated an increase from 20% before to 50% immediately after the law, with use continuing to rise to 75% after two years.

Finland. In July, 1975, Finland mandated belt use for front-seat occupants over the age of 15. Oranen (1977) reported belt use trends before the belt law. In 1966 use was about 15%, in 1967 16%, increasing to 20% by 1968, the rate observed in 1972 as well. Restraint use was observed immediately before (May-June, 1975) and immediately after (August, 1975) the effective date of the new law, as well as one year later. Weekday belt use among highway motorists was 30% before the law, 68% after, and 64% one year later. Sunday use among highway motorists went from 40% before to 71% after and 67% one year later. Restraint use among urban motorists increased from 9% before to 53% immediately after the law, but decayed to 37% one year later. Oranen noted the partial decay in the laws effect on use, and also indicated substantial variation in observed use across regions of the country and across observation sites.

Fisher (1980), citing Berard-Andersen, reported that belt use before the Finland law was 8% in urban areas and 31% in rural areas. The corresponding figures after use was compulsory were 38% and 66%.

France. France has required belt use since July, 1973 for motorists traveling on highways; the law was extended to city driving in 1979. Fisher (1980) reported belt use of 20-25% before the 1973 law and 80% after. Chodkiewicz and Dubarry (1977) provided the following belt use data based on "police controls:" 20% in 1972, 26% in 1973, 67% in 1974, and 80% in 1975. They also report a 21% decline in the number of traffic fatalities between 1972 and 1975.

Gerondeau (1979) has provided the most complete data on belt use on French highways after the law took effect. One week after the July 1 implementation of the law 80% of rural motorists wore belts. By November, 1973, however, use dropped to 50%. Strengthened enforcement brought use back up to 80% in early 1974, but use subsequently declined slightly to 70-75% by 1979. In a later report, Gerondeau (1981) provided use figures for 1975-1979 as follows: belt use was 54% in 1974, 76% in 1975, 79% in 1976, 72% in 1977, 67% in 1978, 69% in 1979, and 79% in 1980. Most of the variation in use estimates during this period may be due to the sampling design (details of which were not provided). However, it does appear that the expansion of mandatory belt use to city driving resulted in more drivers belting up whenever on the road, since use on highways increased 10% at the time of that legal change.

Ireland. Ireland mandated restraint use for front seat occupants effective February, 1979. Hearne (1981) conducted small-scale surveys in the fall of 1978 and the summer of 1979, in an attempt to identify effects of the law. Use among drivers on national roads increased from 19% in 1978 to 46% in 1979, while passenger use increased from 17% to 52%. Similar data for other roads were 9% to 38% for drivers, and 12% to 48% for passengers. Crash data for February-December, 1979 were compared with similar data for 1977 and 1978. Based on these short-term followup data, the restraint law had no effect on the proportion of all crashed drivers that were injured.

Israel. In July, 1975, Israel mandated restraint use for front seat occupants 14 years of age and older traveling on nonurban roads. Hakkert and others (1981) observed belt use on three main roads and at three gasoline stations. Belt use on nonurban roads increased from 6% before to 77% immediately after the law was passed. Use was up to 83% in 1976, but declined somewhat to 70% in 1977. The authors also examined fatality and injury data for urban and nonurban roads for a five-year period after implementation of the belt law. Using urban roads as a control group, net casualty reductions associated with the belt law were 42% for driver fatalities, 44% for passenger fatalities, 18% for driver injuries, and 8% for passenger injuries. Interpretation of the casualty reductions is complicated by fuel shortages and reduced speed limits occurring during the same period.

Luxembourg. Luxembourg made belt use compulsory among drivers and front seat passengers beginning June, 1975. Fisher (1980) noted that some officials indicated that the frequency of fatalities and the severity of injuries declined after the belt law, reports of the research to substantiate such claims are not available.

Netherlands. The Netherlands implemented a mandatory belt law for drivers and front passengers in June, 1975. Fisher (1980) reports that use went from 11 to 58% in urban areas and 24 to 75% in rural areas at the time the law took effect.

New Zealand. New Zealand implemented compulsory belt use in June, 1972. Belt use in May, 1972, immediately before the new law took effect, was 40% (Toomath, 1977). In June, 1972 use jumped to 87%, declining slightly to 83% in 1974, but increasing to 89% in 1975. Assuming the small changes in estimated use between 1972 and 1975 were due to sampling error, it appears that New Zealand's belt law resulted in an immediate and sustained increase in restraint use. A decay in the law's effects after a year or more, as seen in several other jurisdictions, apparently did not occur in New Zealand. Toomath also examined occupant fatalities and found a 3% increase from the two-year period immediately preceding the belt law to the two-year period immediately following. This 3% increase in occupant fatalities was in contrast to the increase in other types of traffic fatalities (i.e., motorcyclists, pedestrians) of almost 40%, and the increase in gasoline sales of over 12%. The very small increase in fatalities among motor vehicle occupants covered by the belt law, during a period in which exposure to crash risk increased (indicated by increased sales of motor fuel) and overall fatalities increased substantially, provides evidence that the belt law contributed to the prevention of fatalities.

Norway. Norway implemented a mandatory belt law for drivers and front seat passengers in September, 1975; however, no penalties were assessed for noncompliance. Use in urban areas increased from about 15% before the law to 30% immediately after. The corresponding figures for rural areas were from 37% to 60% (Fisher, 1980). Use declined somewhat in early 1976, but in 1977 returned to the level observed immediately after the law took effect.

Puerto Rico. Occupant restraint use has been mandatory for motor vehicle drivers and passengers in Puerto Rico since January, 1974. Fisher (1980) reported an increase in belt use from 5% in July, 1973 to 24% in May, 1974. Belt use declined to a low of 7% in September, 1974, then increased gradually to a high of 34% in January, 1976. Use exhibited a downward trend throughout 1976 and the first half of 1977, to 14% by May, 1977. While there was some evidence that traffic fatalities were negatively associated with belt use rates, details were not provided.

South Africa. South Africa began mandating the use of seat belts by front seat occupants in December, 1977. Fernie (1980) reported belt use figures before and after passage of the new legislation. Average use was 6% in 1974, increasing to 11% in 1977, following major publicity campaigns. Use was 18% a month before the law took effect, and jumped to 62% by March, 1978. By September, 1979, use stood at 70%.

Fernie also conducted a preliminary analysis of the effects of the law on traffic injuries and fatalities. Passenger cars (subject to the new law) were compared to light commercial vehicles (not subject to the new law) both before and after December, 1977. No significant change in fatality rates was found to be associated with the belt law, but injuries were down an estimated 20%. The author cautions the reader that major confounding factors, such as a motor fuel shortage and substantially increased fuel prices in 1979, complicate interpretation of the results.

Spain. Compulsory seat belt use on highways in Spain began April, 1974. Fisher's (1980) survey of countries with belt laws revealed no information on effectiveness of Spain's law.

Sweden. Sweden began mandating restraint use in January, 1975, for front seat occupants over 14 years old. Bohlin (1979) reported an increase in belt use among front seat occupants from about 40% in 1974 to 80% in 1975. Belt use among rear seat occupants remained much lower, and stood at about 6% in 1978. Fatalities among motor vehicle occupants decreased 12%, and serious injuries decreased 20% the first year with the new law. Bohlin estimates a cost savings due to the legislation of about US$33 million in 1975 alone.

Fisher (1980), citing Edvardsson and Degermark, provided belt use information for several years prior to and immediately after passage of the belt law. Use rates increased from about 15% in 1971 to 36% in 1974, a period during which several public information and education campaigns were implemented. One month after the law took effect use remained about the same as immediately before.

Additional followup data are also reported by Fisher, based on a report by Tingvall. The more recent data reveal a substantial increase in belt use after the law was implemented, beginning in 1976. By 1978 the figures were 76% in urban areas and 90% in rural areas.

Andreasson and Roos (1977) studied injured motor vehicle occupants treated in 16 hospitals, comparing these data for the fall of 1974, before the law was implemented, to the fall of 1975, after implementation of the law. The number of injured motor vehicle occupants decreased 19%. The reduction is consistent with the increase in belt use from 36% in 1974 to 81% in 1975 reported by Andreasson and Roos. However, casualties in other types of traffic units not affected by the belt law (pedestrians, motorcyclists, etc.) also decreased 6-27%, indicating that observed reductions in injured occupants may be due to factors other than the belt law.

Switzerland. A mandatory seat belt law was implemented in Switzerland in January, 1976. Public opposition to the law was evident soon after it took effect, and the law was challenged in court. In the fall of 1977, the Supreme Court ruled in two separate cases that the mandatory belt law was invalid, having the effect of repealing the law. Swiss government reports summarized by Fisher (1980) indicate that belt use increased from about 35% before to over 90% immediately after implementation of the law, but began to decline after several months. The downward trend continued through 1978; use figures for September, 1978, (almost a year after the law was repealed) were 64% on expressways, 46% on rural roads, and 33% on urban streets. Andreasson (1983) has reported more recent use figures, after the belt law was reinstated in July 1981. Belt use in 1982 was up to 77% on expressways, 76% on rural roads, and 62% on urban streets.

Fisher also described a study in which occupant injuries and fatalities among crash victims were compared for the years 1972, 1973, 1975, and 1976. A 12% decrease in fatalities occurred from 1975 to 1976. The Swiss Bureau of Accident Prevention has said (in an interview reported by Fisher, 1980) that injury severity decreased 9-14% while the seat belt law was in effect, and increased 22% after repeal. No details on the basis for the estimates were available, and others have questioned the accuracy of those estimates.

United Kingdom. The United Kingdom implemented a mandatory belt use law in February, 1983. Andreasson (1983) indicated that belt use in Great Britain in May, 1983, was up to 95%, and mentions that hospitals report fewer and less severe injuries due to the higher belt use rate. No further details were provided.

West Germany. Occupant restraint use was made mandatory for drivers and front seat passengers in West Germany beginning January, 1976. Although no fines for noncompliance were established, some courts have viewed lack of belt use as contributory fault in motor vehicle crash cases. Data collected by the Federal Institute for Streets (reported by Fisher, 1980) indicated that belt use increased substantially after the law was implemented, despite the lack of penalties for noncompliance (a finding also reported by Seidenstecher, 1979). Overall use (i.e., urban, rural, and expressways) averaged 28% in August, 1975, 32% in November, 1975, jumping to 50% in January, 1976, declining slightly to about 46% throughout 1977, and gradually increasing to 58% by September, 1978.

Other studies. In addition to the specific studies reviewed above, the American Seat Belt Council, which has taken a position in support of belt use laws, has surveyed officials in countries that have implemented mandatory use laws (American Seat Belt Council, 1981). While the basis for the estimated legal impacts were not provided, estimates of the effectiveness of mandatory belt use laws in increasing use and reducing occupant fatalities and injuries were provided for many of the countries surveyed. According to these data, seat belt use increased from about 10-30% before the laws to 70-90% after in many jurisdictions.

Effects of Child Restraint Use Laws

Australia. Compulsory use of child restraint devices emerged several years after mandatory adult seat belt laws were implemented. As with adult belt use laws, the first jurisdiction to mandate restraint use for children was Victoria, Australia. In January, 1976 the Victoria adult seat belt law was expanded to include children. Klug (1978) compared children admitted to one hospital because of crash-induced injury in 1972 and 1973 with those admitted in 1976 and 1977. The total number of children admitted for injury was down slightly after the child restraint law, but there was no significant change in injury patterns. There was an increased tendency for injured children to be riding in the rear seat at the time of the crash, but the change in position did not apparently result in significantly fewer or less serious injuries. Vulcan (1977, 1978) surveyed vehicle occupants at six shopping centers and several intersections in the Melbourne area in September, 1975, December, 1976, February, 1977, December, 1977, and February, 1978. Child restraint use increased very slightly after the law was implemented, and the effect of the law on shifting child passengers from the front to rear seats was again noted. Vulcan also compared casualties for 1975 and 1976, finding a 11% decrease for young children, compared to a 4% decrease for older children. Boughton (1978) reported the decrease in youth casualties as an 8% decline for 0-6-year-olds, arguing that it is not significant given the 1971-75 linear trend.

Boughton (1978, 1979) also reported on the experience of New South Wales with mandating child restraint use. A shift in seating position to the rear seats was observed, as well as a 6% increase in restraint use among front seat child passengers. Children under the age of seven also showed 3% fewer casualties the first six months with the law than the corresponding period one year earlier. Reviewing several studies of Australian child restraint laws, Boughton concludes that observed child restraint use was not much different in provinces with mandatory use laws than those without. Therefore, Boughton argues, none of the Australian child restraint laws can be considered effective.

Saunders (1982) studied the May, 1981, reduction in age for compulsory belt use from 5 years old to 1 year old in Western Australia. Observing restraint use at four shopping centers in Perth, Saunders found an increase in restraint use among 1-4-year-olds from 55% the day before the law took effect to 60% the following day. The legal impact decayed slightly nine months later, when use was 57%. These figures were based on small samples and should be interpreted with caution. Saunders also noted that the law had no apparent effect on child fatalities and injuries.

Implementation of mandatory occupant restraint use laws in the United States has diverged from the pattern seen elsewhere. Whereas most countries first mandated restraint use among adults, and only later expanded the laws to include young children, no state has yet made restraint use compulsory for adults (the territory of Puerto Rico might be considered the only exception), but most states in the past few years have implemented mandatory child restraint use laws.

Tennessee. Tennessee was the first state to mandate restraint use for young children. The law applied to children up to the age of four, and took effect in January of 1978. Perry and others (1980) have conducted the most comprehensive evaluation of child restraint laws published to date. Using convenience samples of young motor vehicle occupants, they found that restraint use among 0-3-year-olds before the law was implemented was 11.8% in urban areas and 6.5% in rural areas. These figures apply only to the best restrained child in each vehicle. In vehicles with multiple children, restraint use among secondary children was typically much lower. Followup data were as follows: 17.4% urban and 12.2% rural 6 months after implementation, 13.1% urban and 7.0% rural at 12 months, 16.8% urban and 10.4% rural at 18 months, and 18.8% urban and 15.8% rural at 24 months followup. Thus implementation of the law was associated with a short-term increase in use of about 6 percentage-points, with the size of the increase decaying to only about one percentage-point 12 months after the law took effect. Restraint use subsequently increased; 24 months after the law took effect use was about 8 percentage-points higher than prior to the compulsory use statute.

Perry and others also examined Tennessee accident data for the 1976-79 period, using six-month totals. No significant effect of the child restraint law on the frequency of minor, serious, or fatal injury crashes was found.

Williams and Wells (1981a) conducted an observational survey of child restraint use in four Tennessee cities. Restraint use was 8% five months before implementation of the law, 16% four months after implementation, and 29% 29 months after. Use was also observed in two Kentucky cities five months before and 29 months after the Tennessee law took effect, for comparison with use in Tennessee. Child restraint use increased in Kentucky from 11% to 14% during this period. The much smaller increase in use in Kentucky than in Tennessee indicates that the compulsory child restraint use law in Tennessee resulted in a significant increase in the proportion of young vehicle occupants restrained.

Rhode Island. Williams and Wells (1981b) also studied child restraint use in Rhode Island, where a mandatory child restraint use law was implemented in July, 1980. Use of child restraints increased from 22% to 35%

after the law took effect. While the increased use of child restraints in Rhode Island may be due to the new law, use also increased (from 18% to 26%) in Massachusetts, which had not yet passed child restraint legislation. The increased use in Massachusetts may indicate a spillover effect of the law in Rhode Island, or may be caused by the increased nationwide interest in child safety in recent years. However, the increase in use was larger in Rhode Island with compulsory use than in Massachusetts without compulsory use. This pattern of larger changes in Rhode Island than Massachusetts after the new law was also observed for the increased proportion of children traveling in rear seats, and the reduced proportion of children traveling in someone's arms.

Ain and others (1981) report on a survey of 130 Rhode Island vehicles and 34 Massachusetts vehicles in July, 1980, the month the restraint law took effect. Restraint use among those under 3 years old was about the same in the two samples, 24% in Rhode Island and 21% in Massachusetts. Rhode Island drivers were questioned concerning their knowledge and use of child restraint devices. Ninety-four percent had heard of the new law, but 85% reported no change in their use of child restraints.

Hollingshead and Simon (1982) observed restraint use for newborns discharged from a Rhode Island hospital. Use increased from 25% in 1980 to 51% in 1981 to 70% in October, 1982. The parents were also questioned concerning ownership of a child safety seat. Seventy percent reported ownership in 1981 and 87% in 1982. While based on very limited samples, these findings indicate use of child restraint devices apparently increased after Rhode Island implemented the compulsory use law.

New York. Compulsory restraint use for children up to age 5 began in New York in April, 1982. Friedman (1983) points out the child restraint law caused a significant increase in restraint use ("more than doubled"). No details concerning the basis for this conclusion were provided.

North Carolina. North Carolina made use of a restraint system mandatory for children up to the age of two, beginning July, 1982. Hall and others (1982) conducted a preliminary evaluation of the law, examining police accident reports for 15 weeks prior to and 13 weeks after the law took effect. The percent of 0-1-year-old crashed occupants that were restrained went from 29.7% immediately before the law to 44.1% immediately after. Restraint use among 2-3-year-olds similarly increased from 11.8% to 19.8%, indicating a possible spillover effect of the law. The number of injuries to 0-1-year-old occupants decreased when the law was implemented, but no effect on rate of fatalities was discernable. The very small number of fatalities made identification of any statistically significant effect impossible.

Hall and others (1983) followed up these initial analyses with observation surveys in 1982 and 1983. Restraint use among infants (0-1) increased from 55% before the law to 75% after; figures for 2-3-year-olds were 25% in 1982 and 43% in 1983. The researchers also examined data on crash-involved children through June, 1983. Restraint use among 0-1-year-old crash-involved children leveled off in mid-1983 at about 48%, just slightly higher than the 44% level immediately after the law took effect. Injury data revealed a drop in the percent of all crash-involved children that were seriously injured from 1.7% before the law to 1.0% after.

Kentucky. Kentucky's child restraint law, which took effect in July, 1982, applies to children 40 inches or less in height. Agent (1983) conducted statewide observational surveys before and after the law was implemented. Use of child restraints among children under the age of 4 increased from 14.4% before to 22.7% one year after the law. In addition, the proportion of children restrained in seat belts increased from 1.0 to 1.5%. Unfortunately, of the 22.7% using child seats, 50% were used incorrectly. Effects of the law on child injuries were not examined.

Discussion of Restraint Law Evaluation Literature

Precise estimation of the effects of mandatory restraint laws on the basis of the extant literature is difficult. Many studies have not used carefully planned scientific evaluation designs, and some have used outdated and incorrect data analysis methods. Methodological details are frequently not discussed, making it difficult to evaluate the quality of the information provided. As a result of these factors, findings to date vary significantly from study to study, and the reported data must be interpreted cautiously. Despite these problems, some general statements concerning the effects of compulsory restraint laws seem warrented.

With only one exception, all studies reviewed so far report increased occupant restraint use associated with the implementation of compulsory adult restraint use laws. The one exception is the study by Edvardsson and Degermark (discussed in Fisher, 1980), that found no change in belt use in Sweden in the first month after the law took effect. Other Swedish data, however, indicated substantial increases in use during the three years following passage of the law. Several studies found that increases in use immediately following implementation of an adult restraint law partially decayed in subsequent years if enforcement and/or publicity was minimal. On the other hand, two countries, West Germany and Norway, exhibited increased belt use after passage of compulsory use laws with no penalty for violation. Thus, while public information and enforcement efforts help increase belt use, there also appears to be some effect due simply to the passage of a mandating law, without enforcement or other ancillary efforts.

Most studies of effects of mandatory adult belt laws on restraint use have been limited to drivers and front seat passengers, because most laws apply only to vehicle occupants in these seating positions. Where belt use in rear seats has been surveyed, use was found to be significantly lower.

Effects of compulsory adult belt use laws on traffic casualties are less clear. While most studies that examined injuries or deaths found significant declines associated with belt use laws, some studies found no clear effect. Changes in maximum speed limits, and motor fuel shortages and price increases also confound interpretation of observed changes in traffic casualties during the 1970s. However, the better-designed studies, including analyses of extended time series for multiple comparison groups, have found significant casualty reductions attributable to compulsory adult restraint use laws.

Warren and Simpson (1980) reviewed studies on Canada's experience with restraint laws, and noted that numerous studies have found reductions in crash-related injuries following passage of the laws. They argue, however, that observed injury reductions cannot be attributed to the belt laws without the use of comparison groups and complex time-series models to control for confounding factors. To avoid these problems typical of past studies, the current investigation was carefully designed to include both extensive time-series models and multiple comparison groups.

A few researchers argue that mandatory belt laws are not an effective means of reducing traffic casualties because of risk homeostasis. According to this theory, drivers may have a particular level of risk that is acceptable to them. If required to wear belts, which are viewed as reducing risk of injury, drivers may compensate by increasing their risk in other ways, say, by driving faster. In short, "protecting drivers from the consequences of bad driving encourages bad driving" (Wilde, 1981). Adams (1982) used the risk homeostasis theory to explain the results of a study of the effects of seat belt laws. Adam's study indicated that countries without belt laws (Britain, Italy, United States, and Japan) experienced larger fatality reductions in the mid-1970s than countries with belt laws (Denmark, Finland, France, Germany, Netherlands, Norway, Spain, Switzerland, Sweden, Israel, Australia, and New Zealand). Conybeare (1980) analyzed traffic injuries in Australia in the 1970s and found that occupant injuries were reduced by mandatory belt laws but that non-occupant (cyclist, pedestrian) injuries increased. To explain these results, Conybeare suggests that drivers responded to the reduction in risk caused by the belt law by increasing their "driving intensity."

Findings concerning the effects of mandatory child restraint use laws are mixed. Most studies to date have reported moderate increases in use after passage of child restraint laws, while a few studies found no changes in use. Similarly, results concerning the effect of child restraint laws on casualties present no clear pattern. Some declines in casualties have been seen following implementation of child restraint laws, but the statistical and substantive significance of the observed changes are not clear. Given that most states have just recently made child restraint use compulsory, the need for additional information derived from controlled studies using state-of-the-art methods is clear. The study reported in the following sections was designed to meet that need.

3: METHODS

The methods used in this study are briefly reviewed here. First, the design of the evaluation of Michigan's child restraint law is discussed. Second, data collection and computer file-building activities are summarized. Finally, a brief introduction to time-series statistical analysis methods is presented. This Section is included to provide adequate documentation on the conduct of the study. Awareness of research design, data collection, and statistical analysis issues is important when assessing the level of confidence that can be placed in the results. As noted in Section 2, many studies of mandatory restraint laws conducted to date were poorly designed and implemented. Interpretation of many studies is complicated by omission of information on methods used. This study was designed to avoid common problems in past studies. Therefore, the material covered here will facilitate understanding of the results presented in Sections 4 and 5. Nevertheless, some readers, interested primarily in the main findings of the study, might proceed directly to Section 4.

Research Design

The design of an evaluation research project such as this is primarily concerned with providing an answer to the following question: Did the intervention (here the mandatory restraint law) cause a reduction in the number of motor vehicle occupants injured in crashes? Finding a reduction in injuries associated with implementation of the law is not adequate. The research should be designed so that the observed decrease in injuries is best explained by the restraint law. Other potential explanations for the observed decrease in injuries should be controlled to the best extent possible.

Two important dimensions of the design of this evaluation are briefly discussed here. First, the study is a monthly time-series design. This rules out possible explanations of observed changes in injury rates based on multi-year trends or cycles due to other factors. The use of monthly data allows identification of changes in restraint use or injury rates the first month the law took effect. Careful measurement of a significant change in restraint use or injury rates beginning the exact month the mandatory restraint law took effect makes it more difficult to argue that the change is due to other influences that did not first appear that particular month.

The second dimension of the design of this study is inclusion of multiple comparison groups. The comparison groups function as controls not directly affected by the "experiment" of mandating restraint use. The main comparison groups consist of motor vehicle occupants other than those under the age of four. If observed changes in restraint use and injuries are due to the child restraint law, the main effects of the law should be limited to the focal age group, children under four. An additional level of control groups, consisting of states that did not implement child restraint laws at the time Michigan did, would further increase confidence that injury reductions in Michigan following implementation of the child restraint law are in fact due to that law. Such multi-state comparisons were not part of the current project, but might be considered in further research on mandatory restraint use laws.

Data Collection

Information on occupants involved in motor vehicle crashes required for this project were obtained from the Michigan State Police. Records were available for all traffic accidents that occurred in the State of Michigan and were reported to local or state police agencies. Data obtained were reformatted into individual records representing accidents, vehicles, and occupants (or pedestrians). Detailed information was available for all accidents, vehicles, and injured occupants. However, the only information available for uninjured occupants was whether or not they were using a restraint at the time of the crash. Information on age, sex, and other characteristics for uninjured occupants other than drivers is not recorded by police officers investigating traffic crashes in Michigan.

The complete data files contained records on three-quarters of a million crash-involved occupants per year. Files for the years 1978 through 1982 were used to calculate the number of crash-involved occupants per month for numerous subgroups of interest. Monthly time-series variables were constructed one year at a time by generating hundreds of bivariate tables containing the number of occupants stratified by (1) month, and (2) a variable or combination of variables of interest (e.g., young injured children in front seat positions in a vehicle experiencing extensive damage). The frequency counts in such tables were extracted to form many individual 12-month time-series. The separate monthly time-series for each year were combined to produce the 60-month-long time-series required for a careful assessment of recent restraint use and injury trends, and evaluation of the effects of Michigan's child restraint law.

Specific variables and code values used to construct the 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, 1982). Variable numbers and code values corresponding to the 1982 codebook are enclosed in parentheses for easy reference. 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 all the 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 not the focus of this study. Passengers on farm equipment, construction equipment, or motorcycles also are 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 the 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) time-series variables were constructed for the period January, 1978, through December, 1982:

A. Total number of crashed vehicles per month for each of nine levels of vehicle damage as measured by the Traffic Accident Damage (TAD) scale (V118).

B. Total number of injured occupants per month by:

   (1) age less than one year (V206:0)
   (2) ages 1 through 3 (V206:1-3)

(3) ages 4 through 15 (V206:4-15)
(4) ages 16 through 17 (V206:16-17)
(5) ages 18 through 24 (V206:18-24)
(6) ages 25 through 34 (V206:25-34)
(7) ages 35 through 54 (V206:35-54)
(8) ages 55 and over (V206:55-98)

C. Total number of injured occupants per month by age groups above and by:

(1) occupant position front seat (V203:0-2)
(2) occupant position rear seat (V203:3-5)
(3) occupant position other (V203:6-9)

D. Total number of injured occupants per month by age groups above and by:

(1) restraints used (V204:2,4)
(2) restraints not used (V204:1,3,5)

E. Total number of injured occupants per month by age groups above and by:

(1) fatal injury severity (V210:1) and minor vehicle damage (V118:1-2)
(2) incapacitating injury severity (V210:2) and minor vehicle damage (V118:1-2)
(3) nonincapacitating injury severity (V210:3) and minor vehicle damage (V118:1-2)
(4) possible injury severity (V210:4) and minor vehicle damage (V118:1-2)
(5) fatal injury severity (V210:1) and moderate vehicle damage (V118:3-4)
(6) incapacitating injury severity (V210:2) and moderate vehicle damage (V118:3-4)
(7) nonincapacitating injury severity (V210:3) and moderate vehicle damage (V118:3-4)
(8) possible injury severity (V210:4) and moderate vehicle damage (V118:3-4)
(9) fatal injury severity (V210:1) and severe vehicle damage (V118:5-8)
(10) incapacitating injury severity (V210:2) and severe vehicle damage (V118:5-8)
(11) nonincapacitating injury severity (V210:3) and severe vehicle damage (V118:5-8)
(12) possible injury severity (V210:4) and severe vehicle damage (V118:5-8)

F. Total number of vehicle occupants (V127), number of restrained vehicle occupants (V135), and vehicle occupants with unknown restraint use (V136). From these data the number of unrestrained occupants was calculated.

Construction of the time-series listed under F above required an additional step. These series included both injured and uninjured occupants. Prior to 1980, separate records were not included in the original data files for uninjured occupants. New occupant-level files were created for 1979 and 1978 using information in vehicle records concerning the number of occupants in each vehicle and restraint use at various seating positions. These files, along with occupant-level files already available for 1980 through 1982, permitted analyses of restraint use among uninjured as well as injured motor vehicle occupants.

Data Analysis Methods

The number of crash-involved occupants per month was examined for an extended time period for each of the categories included in the research design. Long series of observations were required to assess the degree to which restraint usage and injury frequencies in 1982 (after child restraints became mandatory) were different from the level expected, given regular patterns over the previous four-year period. Examination of both the raw plots of injuries and the series smoothed with simple 12-month moving averages provided preliminary evidence concerning effects of the legal change. The moving average also revealed whether long-term baseline trends were present in each series. The figures shown in Chapters 4 and 5 include such a moving average trend line. The line for the first 12 months of each series is simply the mean of those 12 months; beginning the 13th month the line represents a moving average, which for any time point is the average of the actual values for that month and the preceding 11 months.

The main objective of the analyses was to estimate shifts in each injury and restraint-use time series associated with the legal intervention in April, 1982. To estimate such shifts beginning the first month after the law took effect, long-term trends and seasonal cycles must first be controlled. The Box-Jenkins and Box-Tiao (Box and Tiao, 1975; Box and Jenkins, 1976) intervention analysis methods were used to accomplish this. The methods combine baseline modeling techniques with intervention impact models. The time-series (Auto-Regressive Integrated Moving Average) 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.

On a conceptual level, the analytic strategy involves explaining as much of the variance in restraint use or occupant injuries as possible on the basis of the past history of restraint usage or injuries, before attributing any of the variance to another variable such as passage of a law making restraint usage 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 analysis strategies (Reid, cited in Kendall, 1976; Newbold and Granger, 1974; Vigderhous, 1977). This approach of intervention analysis was particularly appropriate for the present study, since the objective was to identify significant shifts in restraint usage and injury rates associated with the child restraint law, independent of observed regularities in the history of each variable. The most important point is that without these methods, incorrect conclusions might be made. For example, a decrease in injuries might be fully attributed to a specific intervention, when in fact it is entirely consistent with a pre-existing multi-year downward trend 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.

4: PATTERNS OF RESTRAINT USE IN MICHIGAN

Before examining in detail the effect of the recently enacted mandatory child restraint use law, trends in crash involvement and restraint use are reported. Two questions are answered in this section. First, in what ways does restraint use vary by characteristics of the occupant, motor vehicle, or travel environment? This information will help OHSP identify subpopulations that may have benefited from previous efforts to increase belt use and decrease casualties, and, more importantly, identify appropriate target populations for further programmatic and policy efforts. Comparisons between reported restraint use among specific subpopulations in the crash-involved population with restraint use measured in on-the-road observational surveys will help identify possible biases in each dataset. This information will be important because measures to decrease casualties through increasing restraint use will continue to be evaluated using these two basic sources of information (i.e., observation surveys and crash reports).

The second major question answered in this section is how has restraint use and crash involvement changed in recent years? Year-to-year changes over the past several years and month-to-month changes within each year were examined. This information is important as broader measures to increase restraint use, such as mandatory belt use for motor vehicle occupants of all ages, are considered. Overall trends in restraint use and crash involvement are examined here; age-specific restraint use and injury rates are discussed in section 5, where the effects of the child restaint law are presented.

Restraint Use Across Subpopulations

Restraint use was examined among all Michigan residents involved in a passenger car or light truck crash in 1982. The relatively small number of non-Michigan residents involved in crashes in the state were purposely filtered out to increase the sensitivity of the analyses. Efforts to increase restraint use are largely focused on the resident population. Public information and education programs are limited to residents of Michigan. Even the child restraint law does not apply to nonresident drivers (Public Law 117 of 1981). Analyses were also limited to the great majority of all vehicles that are passenger cars or light trucks. Passengers of these vehicles are the target population of almost all efforts to increase restraint use. Restraint use among passengers of buses, motor homes, farm equipment, and other miscellaneous vehicles is a separate issue not the focus of this study.

The population under study is crash-involved automobile/light truck occupants. Indicators of the variables under study are based on data recorded by police officers investigating crashes. While Michigan has a well-developed accident data recording system compared to many states, the reliability of each item on the crash report has not been thoroughly investigated. The core dependent variable of this study, restraint use, may have differing degrees of reliability depending on circumstances surrounding the crash. For example, in less serious crashes, police officers may have to rely on the reports of crash-involved individuals for determination of restraint use. In contrast, restraint use might be more obvious to the investigating officer in serious crashes. An additional limitation of the dataset is that measures of individual characteristics such as age and sex are recorded only for injured occupants. Limitations of the data should be kept in mind when considering the results that follow.

Does restraint use in Michigan vary significantly by age? Results shown in Table 4.1 indicate that it does. Among injured infants under age one, 17.5% are restrained with a belt and 23.8% by a child seat (total restraint use 41.3%). Belts are used by 24.6%, and child seats by 11.6% of children age 1-3 (total restraint use 36.2%). In contrast to these relatively high rates of use among young children (largely due to the child restraint law as discussed in section 5), use among 4-15-year-olds is only 10%. Seat belt use remains at 11% or below through the 18-24 age group, but increases to 16.9% among 25-34-year-olds and 17.7% among 35-54-year-olds. Among injured occupants age 55 and over 17.4% use belts. A particularly low rate of restraint use among young people has also been observed by Glauz and others (1982) and Pierce (1979).

Three broad age groups might be distinguished on the basis of their rate of restraint use. First, one-third to one-half of young children (age 0 to 3) use restraints. This is an age group whose use of restraints is currently the focus of tremendous public attention, educational programs, and legal requirements for restraint use. In contrast to young children, only about 10% of older children and young adults (age 4 to 24) use restraints. This group is an important target group for further legal or programmatic efforts to increase restraint use. Measures that have successfully increased use among young children might be expanded to older children. Eighteen-to-twenty-four-year-olds are a particularly important target group given their high rates of crash involvement compared to people of other ages. Finally, although a use rate of about 17% among those age 25 and over might be

Table 4.1

Occupant Restraint Use By Age

Age	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Under 1										
Number	2	33	67	0	45	25	0	17	0	189
Percent	1.1	17.5	35.4	0.0	23.8	13.2	0.0	9.0	0.0	100.0
1 - 3										
Number	23	352	642	0	165	109	0	134	3	1,428
Percent	1.6	24.6	45.0	0.0	11.6	7.6	0.0	9.4	0.2	100.0
4 - 15										
Number	146	845	6,876	0	16	24	0	519	30	8,456
Percent	1.7	10.0	81.3	0.0	0.2	0.3	0.0	6.1	0.4	100.0
16 - 17										
Number	379	3,245	28,537	0	0	2	3	1,309	64	33,539
Percent	1.1	9.7	85.1	0.0	0.0	0.0	0.0	3.9	0.2	100.0
18 - 24										
Number	1,206	13,493	102,058	0	0	2	10	5,868	317	122,955
Percent	1.0	11.0	83.0	0.0	0.0	0.0	0.0	4.8	0.3	100.0
25 - 34										
Number	1,003	19,004	85,644	5	0	1	14	6,521	516	112,708
Percent	0.9	16.9	76.0	0.0	0.0	0.0	0.0	5.8	0.5	100.0
35 - 54										
Number	861	19,081	81,072	5	0	1	4	6,223	510	107,757
Percent	0.8	17.7	75.2	0.0	0.0	0.0	0.0	5.8	0.5	100.0
55 and over										
Number	423	10,852	47,119	1	0	0	2	3,927	215	62,539
Percent	0.7	17.4	75.3	0.0	0.0	0.0	0.0	6.3	0.3	100.0
Unknown or not injured										
Number	2,260	28.901	157,629	20	3,312	721	11	7,115	244	200,213
Percent	1.1	14.4	78.7	0.0	1.7	0.4	0.0	3.6	0.1	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

considered high compared to 4-24-year-olds, it is only a small fraction of that achieved in other countries that have mandated restraint use by automobile occupants of all ages.

Other information of interest in Table 4.1 can be found in the bottom row labeled "Total." Average belt use across all ages including both injured and uninjured occupants was 14.7%; adding the 0.5% that were restrained with a child seat produces an overall estimated restraint use of 15.2% among crash-involved automobile occupants. One percent of the occupants did not have a belt available. Only 44 out of 649,784 crash-involved occupants experienced a failure in the restraint system. Thirty-one out of 649,784 occupants had the protection of an airbag restraint system. Restraint use was coded "unknown" for only 4.9% of all occupants; restraint information was missing for an additional 0.3% of occupants.

Differential belt use for males and females was also of interest. Use rates could not be calculated for males alone because of coding conventions in the available data. As with age, the sex of the person is not recorded for uninjured occupants other than drivers. When keypunching the paper copies of accident reports, the Department of State Police arbitrarily assigns all uninjured occupants the code for "male." A more appropriate practice would be to include a code of "sex unknown," and place all occupants for which sex is not recorded on the accident report form into that category in the crash files. Given the current practice, however, many uninjured females are included in the "male" category, and analyses of these data is therefore not helpful. Restraint use among <u>injured</u> females is properly recorded, however, and is 15.0%. Noting that restraint use is 14.9% among all injured occupants (derived from Table 4.1), one can infer that use among males is slightly lower than among females.

Data on alcohol or drug use at the time of the crash was available for drivers only (Table 4.2). Belt use was considerably lower among drivers that had used alcohol or drugs (7.8%) than among those who had not (16.3%). Since drivers using alcohol or drugs are at significantly higher risk for crash involvement than those that do not, the belt use differential indicates that those most in need of the protection of restraints are least likely to use them.

Restraint use also varies considerably by seating position (Table 4.3). Rear left passengers exhibit the highest rate of belt use (excluding child restraints), 18.0%. Rear right passengers exhibit the second highest belt use rate, 16.5%. Drivers, who make up 67% of all vehicle occupants, wear a safety belt 15.2% of the time. Nine and nine-tenths percent of front center passengers and 14.6% of rear center passengers use belts. The lowest belt use rate, 6.6%, is for occupants classified as occupying an "other or unknown" seating position. These results may seem counter to the usual finding of lower belt use in rear than front seating positions. The relatively high rates of rear-seat restraint usage found here are easy to explain. They are due to high rates of restraint use by young children after the mandatory-use law took effect (see section 5).

The most popular seating position for children that are in a child restraint device is rear right, where 26.1% of such children are located. The rest of the children using a child restraint device are distributed as follows: 23.1% rear left, 19.6% front right, 16.1% front center, and 15.1% rear center.

Some recent campaigns to increase belt use have focused on the driver

Table 4.2

Occupant Restraint Use By
Alcohol or Drug Use at Time of Crash

Alcohol or Drug Use	Occupant Restraint Use							
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Yes								
Number	427	3,189	34,693	1	2	2,521	93	40,926
Percent	1.0	7.8	84.8	0.0	0.0	6.2	0.2	100.0
No								
Number	3,009	60,118	286,064	10	31	18,818	1,486	369,536
Percent	0.8	16.3	77.4	0.0	0.0	5.1	0.4	100.0
Unknown								
Number	129	1,243	7,519	1	2	5,712	195	14,801
Percent	0.9	8.4	50.8	0.0	0.0	38.6	1.3	100.0
TOTAL								
Number	3,565	64,550	328,276	12	35	27,051	1,774	425,263
Percent	0.8	15.2	77.2	0.0	0.0	6.4	0.4	100.0

Table 4.3

Occupant Restraint Use by Seating Position

Seating Position	Occupant Restraint Use									
	Belt Unavailable	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Driver										
Number	3,565	64,550	328,276	12	0	0	35	27,051	1,791	425,280
Percent	0.8	15.2	77.2	0.0	0.0	0.0	0.0	6.4	0.4	100.0
Front center										
Number	454	1,777	14,462	1	570	238	1	486	3	17,992
Percent	2.5	9.9	80.4	0.0	3.2	1.3	0.0	2.7	0.0	100.0
Front right										
Number	1,272	18,469	116,611	5	695	243	7	2,503	42	139,848
Percent	0.9	13.2	83.4	0.0	0.5	0.2	0.0	1.8	0.0	100.0
Rear left										
Number	332	4,245	17,629	1	817	130	0	468	4	23,626
Percent	1.4	18.0	74.6	0.0	3.5	0.6	0.0	2.0	0.0	100.0
Rear center										
Number	297	1,645	8,394	9	534	112	0	253	2	11,246
Percent	2.6	14.6	74.6	0.1	4.7	1.0	0.0	2.2	0.0	100.0
Rear right										
Number	372	5,027	23,216	3	922	162	1	672	14	30,389
Percent	1.2	16.5	76.4	0.0	3.0	0.5	0.0	2.2	0.0	100.0
Other or unknown										
Number	11	93	1,056	0	0	0	0	200	40	1,400
Percent	0.8	6.6	75.4	0.0	0.0	0.0	0.0	14.3	2.9	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

persuading/requiring passengers in the vehicle to wear belts. The goal is to take advantage of the position of the driver in the social network among occupants of an automobile to increase belt use. A broader question is whether the size of the social network in an automobile, that is, the number of persons present, influences belt use behavior. Do people feel pressure to wear belts if there are other people present? Or are people more reluctant to wear belts in presence of others? Analyses of the Michigan data revealed that the number of occupants present in a vehicle does appear to influence belt wearing behavior (Table 4.4). Belt use is highest among drivers alone in a vehicle, 16.1%. Other investigators have also noted that use is highest among single occupants (Perry and other, 1980; Boughton and others, 1981). Use drops to about 13% for people in vehicles with two or three occupants. About 15% use belts if in a vehicle with four or five occupants. Use then decreases as the number of occupants increases, such that vehicles with eight or more occupants show a belt use rate of only 11%. Part of the decrease in use in vehicles with many occupants is due to the increasing proportion of occupants that do not have a belt available.

The most interesting finding is the lower rate of belt use among people in an automobile with two or three occupants than among drivers riding alone. There are multiple possible explanations for this difference. Passengers are more likely to be riding in unfamiliar cars than drivers. Even if the person wears a belt regularly when driving his/her own car, s/he may be less likely to wear a belt when riding as a passenger, particularly if the driver does not use a belt. The belts may not be readily available to the passenger (stored under the seat, for example), and the passenger may not wish to risk offending the driver by using a safety belt (belt use may be perceived as an

Table 4.4

Occupant Restraint Use By Number of Occupants In Vehicle

Number of Occupants	Occupant Restraint Use									
	Belt Unavailable	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
One										
Number	2,225	43,848	204,442	7	0	0	27	20,761	1,109	272,419
Percent	0.8	16.1	75.0	0.0	0.0	0.0	0.0	7.6	0.4	100.0
Two										
Number	1,831	26,927	162,748	7	1,082	222	16	6,201	355	199,390
Percent	0.9	13.5	81.6	0.0	0.5	0.1	0.0	3.1	0.2	100.0
Three										
Number	1,022	11,726	71,418	6	1,339	334	1	2,396	134	88,376
Percent	1.2	13.3	80.8	0.0	1.5	0.4	0.0	2.7	0.2	100.0
Four										
Number	660	8,252	43,011	4	723	204	0	1,349	62	54,265
Percent	1.2	15.2	79.3	0.0	1.3	0.4	0.0	2.5	0.1	100.0
Five										
Number	305	3,373	17,242	6	290	82	0	511	36	21,845
Percent	1.4	15.4	78.9	0.0	1.3	0.4	0.0	2.3	0.2	100.0
Six										
Number	164	1,134	7,142	0	78	29	0	280	13	8,840
Percent	1.9	12.8	80.8	0.0	0.9	0.3	0.0	3.2	0.1	100.0
Seven										
Number	50	340	2,247	0	21	9	0	79	12	2,758
Percent	1.8	12.3	81.5	0.0	0.8	0.3	0.0	2.9	0.4	100.0
Eight										
Number	46	204	1,361	1	5	5	0	54	176	1,852
Percent	2.5	11.0	73.5	0.1	0.3	0.3	0.0	2.9	9.5	100.0
Unknown										
Number	0	2	33	0	0	0	0	2	2	39
Percent	0.0	5.1	84.6	0.0	0.0	0.0	0.0	5.1	5.1	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

indictment of the driver's ability to drive). Finally, a social modeling or imitation effect may contribute to lower belt use in multi-occupant vehicles. Svenson (1978) has noted that road users will accept a higher level of risk if they see others taking those risks.

Because the driver is viewed as the occupant with the most social power in an automobile, current efforts to get belt-using drivers to persuade/require passengers to buckle up are to be encouraged. However, the prominent social position of the driver in a vehicle may implicitly encourage regular belt-users to fail to buckle up when riding with a driver that is not wearing a belt. With less than a fifth of the population regular belt users, those who do use belts are likely to ride with unrestrained drivers from time to time. Until we achieve high rates of belt use, the influence of unrestrained motor vehicle occupants on the belt use behavior of other passengers deserves more attention.

Belt use for motor vehicle occupants at various levels of injury severity was also examined (Table 4.5). Belt use is inversely related to injury severity; that is, as injury severity increases, the proportion using belts decreases. Only 3.8% of fatally injured occupants were wearing a safety belt at the time of the crash. The rate increased to 6.3% of those seriously injured, 9.0% of those moderately injured, 14.0% of those experiencing minor injuries, and 15.4% of crash-involved vehicle occupants not injured. The relationship between belt use and injury severity is the result of two factors. First, the safety benefits of belt use reduces the number of belted vehicle occupants that are fatally or seriously injured. Second, the type of people at high risk for involvement in severe crashes tends to be different on a number of dimensions than those at low risk for

Table 4.5

Occupant Restraint Use By Injury Severity

Injury Severity	Occupant Restraint Use									
	Belt Unavailable	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Fatal										
Number	14	36	807	0	0	4	1	88	3	953
Percent	1.5	3.8	84.7	0.0	0.0	0.4	0.1	9.2	0.3	100.0
A-injury										
Number	172	827	11,116	0	9	15	2	936	29	13.107
Percent	1.3	6.3	84.8	0.0	0.1	0.1	0.0	7.1	0.2	100.0
B-injury										
Number	423	2,931	27,205	0	75	68	2	1,663	79	32,446
Percent	1.3	9.0	83.8	0.0	0.2	0.2	0.0	5.1	0.2	100.0
C-injury										
Number	617	8,837	49,676	0	142	77	1	3,602	182	63,134
Percent	1.0	14.0	78.7	0.0	0.2	0.1	0.0	5.7	0.3	100.0
No injury										
Number	5,077	83,175	420,840	31	3,312	721	38	25,344	1,606	540,144
Percent	0.9	15.4	77.9	0.0	0.6	0.1	0.0	4.7	0.3	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

involvement in severe crashes. They apparently have a higher threshold of acceptable risk, which both increases their chances of involvement in a serious crash and reduces their propensity to use belts. For example, Evans and others (1981) found that riskier drivers, measured by headway distance (i.e., tailgating), were significantly less likely to be belt users. Hurst (1979), evaluating New Zealand's mandatory adult belt use law, notes that those not using belts after the law took effect were particularly high-risk drivers. Finally, Deutsch and others (1980) observed urban intersections and found that drivers running red lights had a significantly lower belt-use rate than those not running red lights.

To separate the effects of belts in preventing injury from the relationship between belt use and severity of crash, differential belt use among occupants involved in crashes at various levels of vehicle damage were examined (Table 4.6). Results confirmed that individuals most at risk for serious injury because of involvement in severe crashes (measured by extent of vehicle damage) are the least likely to use belts. The proportion of occupants wearing belts decreases precipitously from about 13-16% in low- and moderate-damage crashes, to only 7.8% among occupants in maximum-damage crashes. This finding is another example of the general principle that those most in need of the protection afforded by seat belts because of their high risk for sustaining a crash-related injury are those least likely to wear belts.

Rates of seat belt use for various types of vehicles are shown in Table 4.7. Seat belt use increases as the size of the vehicle decreases. Use among occupants in automobiles weighing over 3500 pounds is 13.6%, compared to 15.9% in automobiles between 2500 and 3499 pounds, and 20.8% in automobiles

Table 4.6

Occupant Restraint Use By Vehicle Damage Severity

Vehicle Damage Severity		Occupant Restraint Use									
		Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Tad 1	Number	496	3,763	22,339	0	142	38	3	1,649	206	28,636
	Percent	1.7	13.1	78.0	0.0	0.5	0.1	0.0	5.8	0.7	100.0
Tad 2	Number	1,638	29.808	145,541	7	1,094	210	10	8,029	690	187,027
	Percent	0.9	15.9	77.8	0.0	0.6	0.1	0.0	3	4	100.0
Tad 3	Number	1,584	27,244	134,065	5	1,009	215	15	7,180	431	171,748
	Percent	0.9	15.9	78.1	0.0	0.6	0.1	0.0	4.2	0.3	100.0
Tad 4	Number	1,039	18,069	96,867	9	693	185	4	5,231	213	122,310
	Percent	0.8	14.8	79.2	0.0	0.6	0.2	0.0	4.3	0.2	100.0
Tad 5	Number	678	9,307	56,077	6	337	105	4	3,022	136	69,672
	Percent	1.0	13.4	80.5	0.0	0.5	0.2	0.0	4.3	0.2	100.0
Tad 6	Number	390	4,118	27,417	2	159	60	3	1,669	57	33,875
	Percent	1.2	12.2	80.9	0.0	0.5	0.2	0.0	4.9	0.2	100.0
Tad 7	Number	187	1,512	12,762	0	49	37	3	811	33	15,394
	Percent	1.2	9.8	82.9	0.0	0.3	0.2	0.0	5.3	0.2	100.0
Tad 8	Number	158	775	8,273	0	28	22	2	675	31	9,965
	Percent	1.6	7.8	83.0	0.0	0.3	0.2	0.0	6.8	0.3	100.0
Unknown	Number	133	1,210	6,303	2	27	13	0	3,367	102	11,157
	Percent	1.2	10.8	56.5	0.0	0.2	0.1	0.0	30.2	0.9	100.0
TOTAL	Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
	Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

Table 4.7

Occupant Restraint Use By Type Of Vehicle

Type of Vehicle	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Car, under 1500 pounds										
Number	17	166	927	0	7	0	0	146	26	1,289
Percent	1.3	12.9	71.9	0.0	0.5	0.0	0.0	11.3	2.0	100.0
Car, 1500-2499 pounds										
Number	550	16,456	57,817	4	584	99	4	3,353	226	79,093
Percent	0.7	20.8	73.1	0.0	0.7	0.1	0.0	4.2	0.3	100.0
Car, 2500-3500 pounds										
Number	1,486	32,045	156,883	5	1,278	306	17	9,055	334	201,410
Percent	0.7	15.9	77.9	0.0	0.6	0.2	0.0	4.5	0.2	100.0
Car, over 3500 pounds										
Number	1,598	36,051	210,585	21	1,393	391	14	14,109	468	264,630
Percent	0.6	13.6	79.6	0.0	0.5	0.1	0.0	5.3	0.2	100.0
Station Wagon, etc.										
Number	72	858	3,865	0	25	11	0	240	104	5,175
Percent	1.4	16.6	74.7	0.0	0.5	0.2	0.0	4.6	2.0	100.0
Jeep type										
Number	77	451	1,849	0	13	3	0	119	25	2,537
Percent	3.0	17.8	72.9	0.0	0.5	0.1	0.0	4.7	1.0	100.0
Pickup/panel truck										
Number	1,838	8,131	67,925	1	231	75	6	3,676	204	82,087
Percent	2.2	9.9	82.7	0.0	0.3	0.1	0.0	4.5	0.2	100.0
Stake/dump truck, etc.										
Number	512	810	6,338	0	7	0	3	587	478	8,735
Percent	5.9	9.3	72.6	0.0	0.1	0.0	0.0	6.7	5.5	100.0
Truck-tractor										
Number	153	838	3,455	0	0	0	0	348	34	4,828
Percent	3.2	17.4	71.6	0.0	0.0	0.0	0.0	7.2	0.7	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

between 1500 and 2499 pounds. Belt use in very small cars (under 1500 pounds) is shown in Table 4.7 to be 12.9%; however, this estimate is based on only 166 occupants and should therefore be discounted. Up to this point, we have generally found that those at higher risk for crash-related injury are less likely to use restraints. The findings for vehicle size do not follow this pattern. Those at higher risk of injury, that is, passengers of smaller cars, are more likely to use restraints than passengers of large cars. It is is important to keep in mind, however, that the relationship of car size to both risk of injury and propensity to use belts is a complex one. There are numerous differences between people who regularly ride in small cars and those who regularly ride in large cars (for example, age, socio-economic status, exposure patterns, etc.). For present purposes it is simply noted that belt use among Michigan crash-involved automobile occupants varies by car size in a way similar to that found in previous research (Glauz and others, 1982; Matthews, 1982).

Table 4.7 also reveals that belt use among occupants of station wagons and utility vehicles (e.g., Jeep, Bronco, Blazer) is not substantially different than the average for passenger car occupants. In contrast, belt use is significantly lower among occupants of pickup trucks (9.9%) and stake or dump trucks (9.3%). Belt use among occupants of truck-tractors is similar to that for passenger cars (17.4%).

The degree to which belt use varies by time of day and day of week was also examined. These analyses pointed out the importance of using available crash data to supplement observational studies of belt use. Most observational studies are limited, because of practical considerations, to daytime belt use. Measurement of belt use among crash-involved drivers and passengers provides a continuous indicator of belt-using behavior. In the present analyses, time of day and day of week were combined into four categories: weekday day (Monday through Friday 5:00 a.m. to 7:59 p.m.), weekend day (Saturday and Sunday 5:00 a.m. to 7:59 p.m.), weekday night (Monday through Thursday 8:00 p.m. to 4:59 a.m.), and weekend night (Friday through Sunday 8:00 p.m. to 4:59 a.m.).

Results, shown in Table 4.8, indicate significant differences in belt use according to time of week. The highest rate of belt use, 16.2%, occurs during weekday daytime hours. Weekend daytime hours show only a slightly lower use rate, 15.4%. Belt use during weekday nighttime hours is significantly lower, 12.1%. Weekend nighttime hours have the lowest rate of use, only 10.4%. Belt use is again inversely associated with risk of crash involvement. The risk of being involved in a serious crash (and thus needing the protection of a safety belt) is higher at night than during the day, and particularly high on weekend nights. This effect is not simply a function of time of week, but reflects many factors that vary by time of week. For example, alcohol and other drug use on weekend nights may contribute to both increased risk of crash involvement and decreased propensity to use safety belts.

Variation in belt use on different kinds of roads on which a driver or passenger is traveling is shown in Table 4.9. The main finding is that belt use on limited-access highways is over 20%, compared with use of 14 to 15% on other roads. Higher rates of speed and longer distances typically traveled on limited-access highways apparently lead to increased belt use. Travel on nonlimited-access roads, however, puts one at higher risk for crash involvement and subsequent injury than travel on limited-access highways.

Table 4.8

Occupant Restraint Use by Time of Week

Time of Week	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Weekday Day										
Number	3,3432	59,330	281,163	22	2,389	593	25	18,475	1,331	366,760
Percent	0.9	16.2	76.7	0.0	0.7	0.2	0.0	5.0	0.4	100.0
Weekend Day										
Number	1,126	17,787	90,305	4	700	169	8	5,133	243	115,475
Percent	1.0	15.4	78.2	0.0	0.6	0.1	0.0	4.4	0.2	100.0
Weekday Night										
Number	670	8,522	57,266	0	219	47	8	3,611	150	70,493
Percent	1.0	12.1	81.2	0.0	0.3	0.1	0.0	5.1	0.2	100.0
Weekend Night										
Number	1.070	10.040	80,190	5	227	76	3	4,327	170	96,109
Percent	1.1	10.4	83.4	0.0	0.2	0.1	0.0	4.5	0.2	100.0
Missing Data										
Number	5	127	720	0	3	0	0	87	5	947
Percent	0.5	13.4	76.0	0.0	0.3	0.0	0.0	9.2	0.5	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

Table 4.9

Occupant Restraint Use By Highway Class

Highway Class	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Interstate route										
Number	285	6,465	22,117	1	115	37	2	1,337	80	30,440
Percent	0.9	21.2	72.7	0.0	0.4	0.1	0.0	4.4	0.3	100.0
Other limited access										
Number	56	2,372	6,894	1	33	6	0	434	28	9,824
Percent	0.6	24.1	70.2	0.0	0.3	0.1	0.0	4.4	0.3	100.0
Nonlimited access US route										
Number	483	7,072	36,283	1	234	65	0	1,696	127	45,961
Percent	1.1	15.4	78.9	0.0	0.5	0.1	0.0	3.7	0.3	100.0
Nonlimited access Michigan route										
Number	1,269	20,041	104,506	8	767	171	14	5,653	340	132,769
Percent	1.0	15.1	78.7	0.0	0.6	0.1	0.0	4.3	0.3	100.0
Other arterial										
Number	200	3,041	18,571	0	162	25	2	712	52	22,765
Percent	0.9	13.4	81.6	0.0	0.7	0.1	0.0	3.1	0.2	100.0
Local road or Missing Data										
Number	4,010	56,815	321,273	20	2,227	581	26	21,801	1,272	408,025
Percent	1.0	13.9	78.7	0.0	0.5	0.1	0.0	5.3	0.3	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

Again, the pattern is higher belt use rates among those at lower risk of crash-related injury and lower belt use rates among those at higher risk of injury.

Belt use in small, medium, and large communities is shown in Table 4.10. Use is highest in communities larger than 50,000 population (15.9%). Use is lowest, 13.1%, in medium sized communities (cities under 50,000 population). Small communities (i.e., townships) exhibited a belt use rate of 14.9%. The differences are not large, however, and appear to be of minor significance. The rate at which child restraint devices were used was virtually identical across communities of different sizes. Because the measure of community size used here may not accurately reflect rural/urban differences, the results should be interpreted with care.

Finally, the rate of restraint use was examined separately for each of the 83 counties in Michigan (Table 4.11). Considerable variation in the rate of belt use was evident across counties. Average use statewide was 14.7%. Three counties had use rates over 20% (Midland 26.7%, Oakland 21.4%, and Washtenaw 21.8%). In contrast, six counties had use rates below 8% (Alpena 7.4%, Chippewa 6.3%, Dickinson 4.7%, Gogebic 7.0%, Huron 7.9%, Ontonagon 7.1%). Some of the estimates for rural counties are based on a small number of cases and should therefore be interpreted cautiously. Nevertheless, counties with the lowest rate of seat belt use are predominantly rural, upper-peninsula and northern lower-peninsula counties. Others have also observed that restraint use is typically higher in urban areas (Perry and others, 1980).

In summary, data for crash-involved motor vehicle occupants in Michigan during 1982 revealed significant variations in restraint use across a number

Table 4.10

Occupant Restraint Use By Size Of Community

Size of Community	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Township										
Number	2,483	34,947	189,623	5	1,290	266	7	5,564	586	234,771
Percent	1.1	14.9	80.8	0.0	0.5	0.1	0.0	2.4	0.2	100.0
Population <50,000										
Number	1,822	24,210	148,172	4	1,166	209	9	8,368	527	184,488
Percent	1.0	13.1	80.3	0.0	0.6	0.1	0.0	4.5	0.3	100.0
Population >50,000										
Number	1,998	36,649	171,849	22	1,082	410	28	17,701	786	230,525
Percent	0.9	15.9	74.5	0.0	0.5	0.2	0.0	7.7	0.3	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

Table 4.11

Occupant Restraint Use by County

County	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Alcona										
Number	5	118	461	0	2	1	0	65	2	654
Percent	0.8	18.0	70.5	0.0	0.3	0.2	0.0	9.9	0.3	100.0
Alger										
Number	11	71	474	0	2	1	0	18	3	580
Percent	1.9	12.2	81.7	0.0	0.3	0.2	0.0	3.1	0.5	100.0
Allegan										
Number	93	561	4,130	0	39	5	0	84	11	4,923
Percent	1.9	11.4	83.9	0.0	0.8	0.1	0.0	1.7	0.2	100.0
Alpena										
Number	19	158	1,884	0	19	3	0	40	2	2,125
Percent	0.9	7.4	88.7	0.0	0.9	0.1	0.0	1.9	0.1	100.0
Antrim										
Number	9	162	784	0	4	0	0	28	3	990
Percent	0.9	16.4	79.2	0.0	0.4	0.0	0.0	2.8	0.3	100.0
Arenac										
Number	24	224	1,037	0	3	2	0	27	2	1,319
Percent	1.8	17.0	78.6	0.0	0.2	0.2	0.0	2.0	0.2	100.0
Baraga										
Number	9	55	395	0	6	0	0	9	0	474
Percent	1.9	11.6	83.3	0.0	1.3	0.0	0.0	1.9	0.0	100.0
Barry										
Number	30	277	2,310	1	21	4	0	82	7	2,732
Percent	1.1	10.1	84.6	0.0	0.8	0.1	0.0	3.0	0.3	100.0
Bay										
Number	85	1,130	5,999	0	49	10	0	240	17	7,530
Percent	1.1	15.0	79.7	0.0	0.7	0.1	0.0	3.2	0.2	100.0
Benzie										
Number	19	89	608	0	4	0	0	23	2	745
Percent	2.6	11.9	81.6	0.0	0.5	0.0	0.0	3.1	0.3	100.0
Berrien										
Number	70	1,013	9,061	0	31	15	0	444	36	10,670
Percent	0.7	9.5	84.9	0.0	0.3	0.1	0.0	4.2	0.3	100.0
Branch										
Number	23	179	1837	0	9	1	0	65	8	2122
Percent	1.1	8.4	86.6	0.0	0.4	0.0	0.0	3.1	0.4	100.0
Calhoun										
Number	230	1,062	9,745	0	73	16	0	239	32	11,397
Percent	2.0	9.3	85.5	0.0	0.6	0.1	0.0	2.1	0.3	100.0
Cass										
Number	41	207	2,242	0	9	4	0	70	2	2,575
Percent	1.6	8.0	87.1	0.0	0.3	0.2	0.0	2.7	0.1	100.0

Table 4.11 (continued)

County	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Charlevoix										
Number	33	214	1,154	0	4	2	0	76	2	1,485
Percent	2.2	14.4	77.7	0.0	0.3	0.1	0.0	5.1	0.1	100.0
Cheboygan										
Number	36	134	1,098	0	5	1	0	22	2	1,298
Percent	2.8	10.3	84.6	0.0	0.4	0.1	0.0	1.7	0.2	100.0
Chippewa										
Number	40	112	1,519	0	5	3	0	72	13	1,764
Percent	2.3	6.3	86.1	0.0	0.3	0.2	0.0	4.1	0.7	100.0
Clare										
Number	20	215	1,605	0	15	3	0	30	6	1,894
Percent	1.1	11.4	84.7	0.0	0.8	0.2	0.0	1.6	0.3	100.0
Clinton										
Number	16	480	2,555	3	46	6	0	211	8	3,325
Percent	0.5	14.4	76.8	0.1	1.4	0.2	0.0	6.3	0.2	100.0
Crawford										
Number	5	125	618	0	8	2	0	240	7	1,005
Percent	0.5	12.4	61.5	0.0	0.8	0.2	0.0	23.9	0.7	100.0
Delta										
Number	32	240	2,633	0	22	2	1	45	9	2,984
Percent	1.1	8.0	88.2	0.0	0.7	0.1	0.0	1.5	0.3	100.0
Dickinson										
Number	9	74	1,415	0	9	4	0	54	4	1,569
Percent	0.6	4.7	90.2	0.0	0.6	0.3	0.0	3.4	0.3	100.0
Eaton										
Number	76	941	4,492	0	38	16	0	112	15	5,690
Percent	1.3	16.5	78.9	0.0	0.7	0.3	0.0	2.0	0.3	100.0
Emmet										
Number	31	299	1,700	0	20	1	0	104	0	2,155
Percent	1.4	13.9	78.9	0.0	0.9	0.0	0.0	4.8	0.0	100.0
Genesee										
Number	258	3,632	26,277	2	192	64	0	608	56	31,089
Percent	0.8	11.7	84.5	0.0	0.6	0.2	0.0	2.0	0.2	100.0
Gladwin										
Number	12	183	1,142	0	11	0	0	17	2	1,367
Percent	0.9	13.4	83.5	0.0	0.8	0.0	0.0	1.2	0.1	100.0
Gogebic										
Number	10	77	954	0	4	1	0	54	1	1,101
Percent	0.9	7.0	86.6	0.0	0.4	0.1	0.0	4.9	0.1	100.0
Grand Traverse										
Number	143	1,126	4,373	0	45	4	0	79	29	5,799
Percent	2.5	19.4	75.4	0.0	0.8	0.1	0.0	1.4	0.5	100.0
Gratiot										
Number	20	324	2,374	1	12	8	0	117	11	2,867
Percent	0.7	11.3	82.8	0.0	0.4	0.3	0.0	4.1	0.4	100.0

Table 4.11 (continued)

County	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Hillsdale										
Number	30	239	2,081	0	29	1	0	112	7	2,499
Percent	1.2	9.6	83.3	0.0	1.2	0.0	0.0	4.5	0.3	100.0
Houghton										
Number	63	246	2,067	0	13	2	0	41	8	2,440
Percent	2.6	10.1	84.7	0.0	0.5	0.1	0.0	1.7	0.3	100.0
Huron										
Number	28	176	1,921	0	23	2	0	63	1	2,214
Percent	1.3	7.9	86.8	0.0	1.0	0.1	0.0	2.8	0.0	100.0
Ingham										
Number	193	4,644	18,134	1	239	102	0	324	53	23,690
Percent	0.8	19.6	76.5	0.0	1.0	0.4	0.0	1.4	0.2	100.0
Ionia										
Number	51	388	2,915	0	28	3	0	150	10	3,545
Percent	1.4	10.9	82.2	0.0	0.8	0.1	0.0	4.2	0.3	100.0
Iosco										
Number	24	302	1,538	0	9	5	0	49	2	1,929
Percent	1.2	15.7	79.7	0.0	0.5	0.3	0.0	2.5	0.1	100.0
Iron										
Number	10	75	566	0	7	0	0	34	1	693
Percent	1.4	10.8	81.7	0.0	1.0	0.0	0.0	4.9	0.1	100.0
Isabella										
Number	25	477	3,639	0	30	0	0	68	10	4,249
Percent	0.6	11.2	85.6	0.0	0.7	0.0	0.0	1.6	0.2	100.0
Jackson										
Number	98	1,354	9,098	0	89	6	0	174	39	10,858
Percebnt	0.9	12.5	83.8	0.0	0.8	0.1	0.0	1.6	0.4	100.0
Kalamazoo										
Number	177	2,724	14,383	1	99	11	0	587	74	18,056
Percent	1.0	15.1	79.7	0.0	0.5	0.1	0.0	3.3	0.4	100.0
Kalkaska										
Number	28	221	846	0	11	0	0	13	0	1119
Percent	2.5	19.7	75.6	0.0	1.0	0.0	0.0	1.2	0.0	100.0
Kent										
Number	364	6,964	31,408	1	343	48	0	498	75	39,701
Percent	0.9	17.5	79.1	0.0	0.9	0.1	0.0	1.3	0.2	100.0
Keweenaw										
Number	0	9	87	0	0	0	0	3	1	100
Percent	0.0	9.0	87.0	0.0	0.0	0.0	0.0	3.0	1.0	100.0
Lake										
Number	9	84	602	0	3	1	0	23	2	724
Percent	1.2	11.6	83.1	0.0	0.4	0.1	0.0	3.2	0.3	100.0
Lapeer										
Number	31	407	3,362	0	10	4	0	84	4	3,902
Percent	0.8	10.4	86.2	0.0	0.3	0.1	0.0	2.2	0.1	100.0

Table 4.11 (continued)

County	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Leelanau										
Number	5	120	597	0	1	1	0	5	2	731
Percent	0.7	16.4	81.7	0.0	0.1	0.1	0.0	0.7	0.3	100.0
Lenawee										
Number	67	572	4,937	0	29	9	0	115	22	5,751
Percent	1.2	9.9	85.8	0.0	0.5	0.2	0.0	2.0	0.4	100.0
Livingston										
Number	54	1,063	4,265	0	27	5	0	86	12	5512
Percent	1.0	19.3	77.4	0.0	0.5	0.1	0.0	1.6	0.2	100.0
Luce										
Number	1	63	332	0	2	0	0	40	0	438
Percent	0.2	14.4	75.8	0.0	0.5	0.0	0.0	9.1	0.0	100.0
Mackinac										
Number	10	90	652	0	8	0	0	54	5	819
Percent	1.2	11.0	79.6	0.0	1.0	0.0	0.0	6.6	0.6	100.0
Macomb										
Number	338	7,248	38,796	2	284	56	28	1,390	87	48,229
Percent	0.7	15.0	80.4	0.0	0.6	0.1	0.1	2.9	0.2	100.0
Manistee										
Number	21	183	1,428	0	10	4	0	101	6	1,753
Percent	1.2	10.4	81.5	0.0	0.6	0.2	0.0	5.8	0.3	100.0
Marquette										
Number	45	576	3,988	0	43	6	0	64	7	4,729
Percent	1.0	12.2	84.3	0.0	0.9	0.1	0.0	1.4	0.1	100.0
Mason										
Number	20	244	1,827	0	7	2	0	40	10	2,150
Percent	0.9	11.3	85.0	0.0	0.3	0.1	0.0	1.9	0.5	100.0
Mecosta										
Number	28	480	2,843	0	23	4	0	31	1	3,410
Percent	0.8	14.1	83.4	0.0	0.7	0.1	0.0	0.9	0.0	100.0
Menominee										
Number	9	188	1,706	0	13	1	0	55	2	1,974
Percent	0.5	9.5	86.4	0.0	0.7	0.1	0.0	2.8	0.1	100.0
Midland										
Number	39	1,313	3,462	0	23	6	0	62	12	4,917
Percent	0.8	26.7	70.4	0.0	0.5	0.1	0.0	1.3	0.2	100.0
Missaukee										
Number	12	73	619	0	6	0	0	34	3	747
Percent	1.6	9.8	82.9	0.0	0.8	0.0	0.0	4.6	0.4	100.0
Monroe										
Number	79	600	6,334	0	62	12	0	65	15	7,167
Percent	1.1	8.4	88.4	0.0	0.9	0.2	0.0	0.9	0.2	100.0
Montcalm										
Number	48	350	3,174	0	36	7	0	118	12	3,745
Percent	1.3	9.3	84.8	0.0	1.0	0.2	0.0	3.2	0.3	100.0

Table 4.11 (continued)

County	Occupant Restraint Use									
	Belt Unavailable	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
Montmorency										
Number	0	48	463	0	3	0	0	40	0	554
Percent	0.0	8.7	83.6	0.0	0.5	0.0	0.0	7.2	0.0	100.0
Muskegon										
Number	95	967	10,634	0	47	9	0	332	37	12,121
Percent	0.8	8.0	87.7	0.0	0.4	0.1	0.0	2.7	0.3	100.0
Newaygo										
Number	13	277	2,232	0	16	2	0	49	6	2595
Percent	0.5	10.7	86.0	0.0	0.6	0.1	0.0	1.9	0.2	100.0
Oakland										
Number	593	17,343	59,078	3	408	68	2	3,244	228	80,968
Percent	0.7	21.4	73.0	0.0	0.5	0.1	0.0	4.0	0.3	100.0
Oceana										
Number	14	135	995	0	3	0	0	75	3	1,225
Percent	1.1	11.0	81.2	0.0	0.2	0.0	0.0	6.1	0.2	100.0
Ogemaw										
Number	30	233	1,299	0	6	0	0	32	0	1,600
Percent	1.9	14.6	81.2	0.0	0.4	0.0	0.0	2.0	0.0	100.0
Ontonagon										
Number	5	31	373	0	0	2	0	22	3	436
Percent	1.1	7.1	85.6	0.0	0.0	0.5	0.0	5.0	0.7	100.0
Osceola										
Number	333	206	1,419	0	11	6	0	46	4	1,725
Percent	1.9	11.9	82.3	0.0	0.6	0.3	0.0	2.7	0.2	100.0
Oscoda										
Number	10	68	597	0	4	0	0	13	0	692
Percent	1.4	9.8	86.3	0.0	0.6	0.0	0.0	1.9	0.0	100.0
Ostego										
Number	18	220	1,028	0	6	3	0	40	1	1,316
Percent	1.4	16.7	78.1	0.0	0.5	0.2	0.0	3.0	0.1	100.0
Ottawa										
Number	98	1,242	8,581	0	77	10	0	109	23	10,140
Percent	1.0	12.2	84.6	0.0	0.8	0.1	0.0	1.1	0.2	100.0
Presque Isle										
Number	3	80	684	0	2	0	0	22	3	794
Percent	0.4	10.1	86.1	0.0	0.3	0.0	0.0	2.8	0.4	100.0
Roscommon										
Number	17	204	1,245	0	7	1	0	41	11	1,526
Percent	1.1	13.4	81.6	0.0	0.5	0.1	0.0	2.7	0.7	100.0
Saginaw										
Number	143	2,404	14,484	0	77	31	0	378	41	17,558
Percent	0.8	13.7	82.5	0.0	0.4	0.2	0.0	2.2	0.2	100.0
St. Clair										
Number	91	781	7,831	0	29	17	3	546	30	9,328
Percent	1.0	8.4	84.0	0.0	0.3	0.2	0.0	5.9	0.3	100.0

Table 4.11 (continued)

County	Occupant Restraint Use									
	Belt Unavail-able	Belt Used	Belt Not Used	Airbag	Child Restraint Used	Child Restraint Not Used	Restraint Failure	Restraint Use Unknown	Missing Data	TOTAL
St. Joseph										
Number	33	278	2,957	1	13	6	0	162	5	3,455
Percent	1.0	8.0	85.6	0.0	0.4	0.2	0.0	4.7	0.1	100.0
Sanilac										
Number	36	212	1,815	0	9	5	0	122	16	2,215
Percent	1.6	9.6	81.9	0.0	0.4	0.2	0.0	5.5	0.7	100.0
Schoolcraft										
Number	7	68	520	0	1	0	0	78	2	676
Percent	1.0	10.1	76.9	0.0	0.1	0.0	0.0	11.5	0.3	100.0
Shiawassee										
Number	48	369	3,022	0	26	6	0	133	16	3,620
Percent	1.3	10.2	83.5	0.0	0.7	0.2	0.0	3.7	0.4	100.0
Tuscola										
Number	23	295	2,483	0	14	9	0	60	4	2,888
Percent	0.8	10.2	86.0	0.0	0.5	0.3	0.0	2.1	0.1	100.0
Van Buren										
Number	53	423	3,349	1	30	10	0	98	11	3,975
Percent	1.3	10.6	84.3	0.0	0.8	0.3	0.0	2.5	0.3	100.0
Washtenaw										
Number	124	3,832	13,167	3	67	16	0	338	33	17,580
Percent	0.7	21.8	74.9	0.0	0.4	0.1	0.0	1.9	0.2	100.0
Wayne										
Number	1,469	20,834	106,945	11	451	204	10	17,870	637	148,431
Percent	1.0	14.0	72.1	0.0	0.3	0.1	0.0	12.0	0.4	100.0
Wexford										
Number	31	301	1,960	0	17	3	0	25	10	2,347
Percent	1.3	12.8	83.5	0.0	0.7	0.1	0.0	1.1	0.4	100.0
TOTAL										
Number	6,303	95,806	509,644	31	3,538	885	44	31,633	1,899	649,784
Percent	1.0	14.7	78.4	0.0	0.5	0.1	0.0	4.9	0.3	100.0

of dimensions. The causes of the observed differences are complex and not fully understood. The results, however, indicate important target groups for further efforts to increase restraint use among drivers and passengers in Michigan.

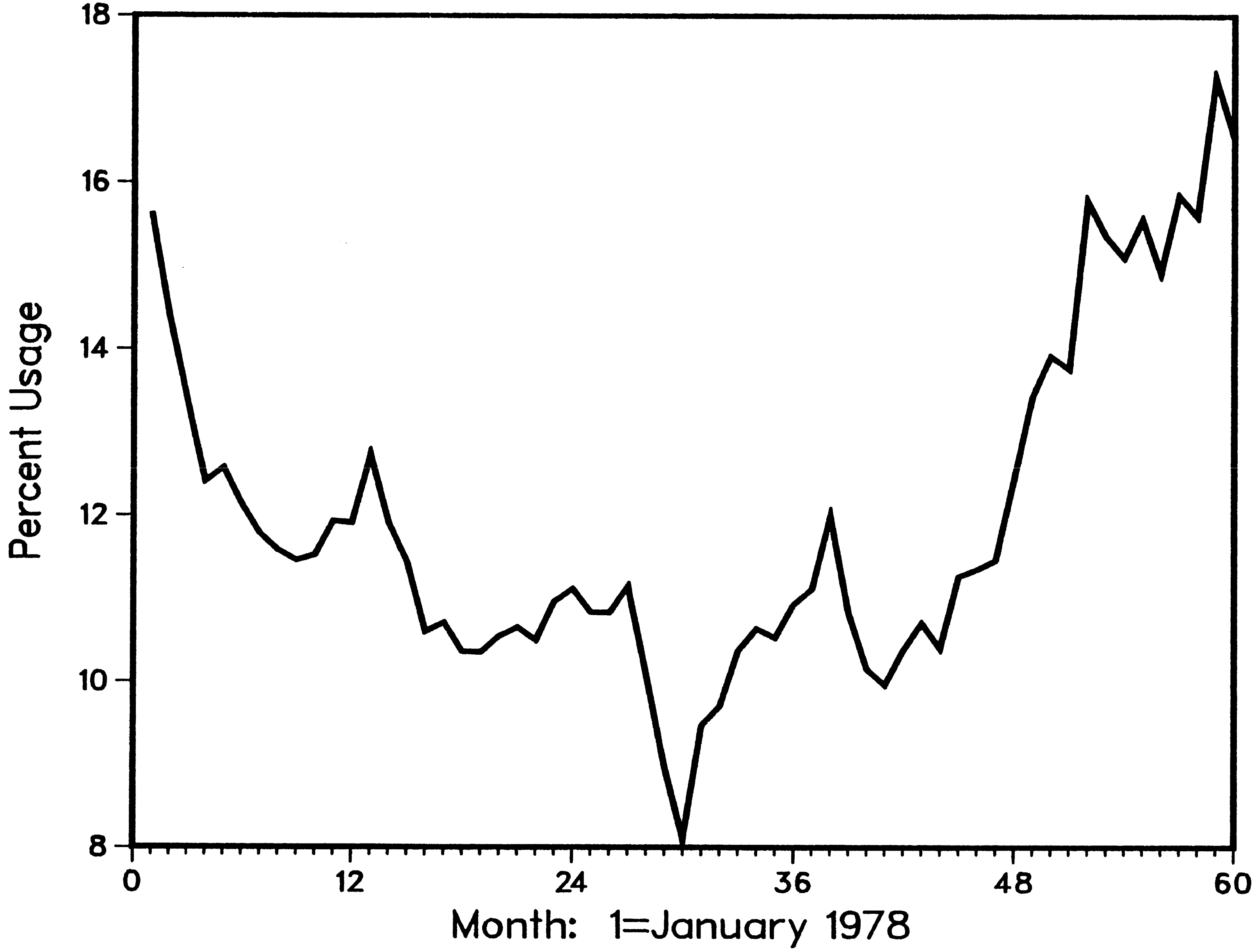
Trends in Restraint Use and Crash Involvement, 1978-1982

In addition to the above analyses of restraint use across a variety of dimensions at one point in time, trends in restraint use and crash involvement over the past five years were examined. An awareness of overall trends in both restraint use and crash involvement will facilitate interpretation of the results reported in section 5, where the specific effects of the mandatory child restraint law are evaluated.

Restraint use among all occupants of crash-involved passenger cars and light trucks was examined first. This is the broadest measure of restraint use in Michigan available on a periodic (i.e., monthly) basis for a multi-year period. Considerable variation in restraint use was evident over the January, 1978, through December, 1982, period (Figure 4.1). Use was over 14% in January and February of 1978, but then decreased to about 12% from mid-1978 through mid-1979. From mid-1979 through 1981 restraint use averaged only about 10.5%. In 1982, however, restraint use increased significantly, averaging about 16% for the last three quarters of the year. In addition to the U-shaped trend in restraint use (high in 1978 and 1982 and low in between), careful examination of Figure 4.1 reveals a potential seasonal cycle in restraint use. That is, use appears to vary according to month of the year in a fairly predictable manner. Restraint use regularly peaks in the December to February winter months, and is at its lowest during the

FIGURE 4.1

Restraint Usage Among Crash-involved Motor Vehicle Occupants



mid-summer months.

Knowledge concerning an underlying seasonal cycle is important for several reasons. First, the nature of the seasonal cycle may point the way to potentially useful ways to increase use. For example, restraint use may be higher in the winter because of an increase in perceived risk of crash involvement when riding on slick roads. If so, perhaps a more realistic assessment of the risk of injury during the summer might help increase restraint use (high-speed, severe-injury crashes are particularly prevalent in the late summer months). Second, awareness of seasonal variation in use is important for the design of observational restraint use surveys, which typically are conducted for a relatively brief time period. Third, significant underlying seasonal cycles must be controlled to obtain an accurate evaluation of the effects of interventions like the child restraint law.

Because of the potential importance of a seasonal cycle in restraint use, and because the cycle in restraint use is not nearly as obvious as that in crash involvement time series, the nature and significance of the apparent seasonal effect in Figure 4.1 was analyzed further by calculating autocorrelations. Autocorrelations represent correlations of a time-series variable with itself at various time lags. For example, if an annual seasonal cycle is present, restraint use in a particular month should be correlated with restraint use 12 months back. To simplify further, the autocorrelation at lag 12 answers questions like the following: if restraint use is higher than average this January, was it also higher than average last January? If use is lower than average this June, was it also lower than average last June? The autocorrelation function provides summary estimates of these relationships for all months across all years in the time series.

For the autocorrelations to accurately measure the significance of seasonal effects, effects of the major U-shaped trend in restraint use over the past several years had to be controlled. This was accomplished by calculating the autocorrelations on the time series after a first difference transformation (i.e., each observation in the series had the previous observation's value subtracted from it). The autocorrelation results are shown in Table 4.12. Results indicated that the lag-12 autocorrelation was only .18, and was not statistically significant. The lag-14 autocorrelation was significant, however, indicating the possibility of a 14-month cycle in this time series.

The immediate practical implications of these results are as follows. Some differences in restraint use according to the month of the year can be seen in Figure 4.1. The differences do not represent a significant annual cycle in this set of data; that is, the seasonal differences are small enough that they may simply be the result of random fluctuations. Further research is needed to clarify whether restraint use in Michigan varies significantly by season of the year. In subsequent analyses evaluating the effects of the child restraint law (section 5), the possibility of controlling for seasonal cycles in restraint use for particularly age groups was considered. No significant seasonal cycles in restraint use for any of the age groups were found, however.

All analyses of effects of the child restraint law were limited to injured motor vehicle occupants only. This was necessary because the age of the occupant is recorded only for injured occupants. Since all the time series examined in section 5 were stratified by age, they are of necessity

TABLE 4.12

AUTOCORRELATIONS FOR RESTRAINT USAGE AMONG CRASH-INVOLVED MOTOR VEHICLE OCCUPANTS

DIFFERENCING	=	$(1 - B)^1$
NUMBER OF OBSERVATIONS	=	59
MEAN OF THE (DIFFERENCED) SERIES	=	0.0157
STANDARD ERROR OF THE MEAN	=	0.0901
T-VALUE OF MEAN (AGAINST ZERO)	=	0.1742

AUTOCORRELATIONS

1- 12	.03	.18	-.04	.08	.02	-.12	.22	-.22	-.06	.15	.14	.18
ST.E.	.13	.13	.13	.13	.14	.14	.14	.14	.15	.15	.15	.15
13- 24	-.04	.32	-.03	.01	-.08	-.05	-.03	-.17	.17	-.08	-.02	-.01
ST.E.	.16	.16	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17

PLOT OF AUTOCORRELATIONS

```
          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   0.029                    +     IX    +
  2   0.175                    +     IXXXX +
  3  -0.043                   +     XI      +
  4   0.075                   +      IXX    +
  5   0.023                   +      IX     +
  6  -0.118                   +   XXXI      +
  7   0.218                   +      IXXXXX +
  8  -0.217                   + XXXXXI      +
  9  -0.061                   +    XXI      +
 10   0.148                   +      IXXXX  +
 11   0.144                   +      IXXXX  +
 12   0.177                  +       IXXXX   +
 13  -0.039                  +      XI       +
 14   0.318                  +       IXXXXXXXX
 15  -0.029                  +      XI       +
 16   0.005                  +       I       +
 17  -0.083                  +     XXI       +
 18  -0.046                  +      XI       +
 19  -0.035                  +      XI       +
 20  -0.171                  +   XXXXI       +
 21   0.172                  +       IXXXX   +
 22  -0.076                 +      XXI        +
 23  -0.017                 +        I        +
 24  -0.014                 +        I        +
```

limited to injured occupants. One question was how this limitation in available data affected the evaluation results. To answer this question, restraint use among injured occupants of all ages (Figure 4.2) was plotted in the same way as restraint use among all occupants (Figure 4.1). The two measures were highly correlated. The U-shaped trend in use over the past five years was clearly evident in both series. Both tended to indicate higher use in the winter than summer months.

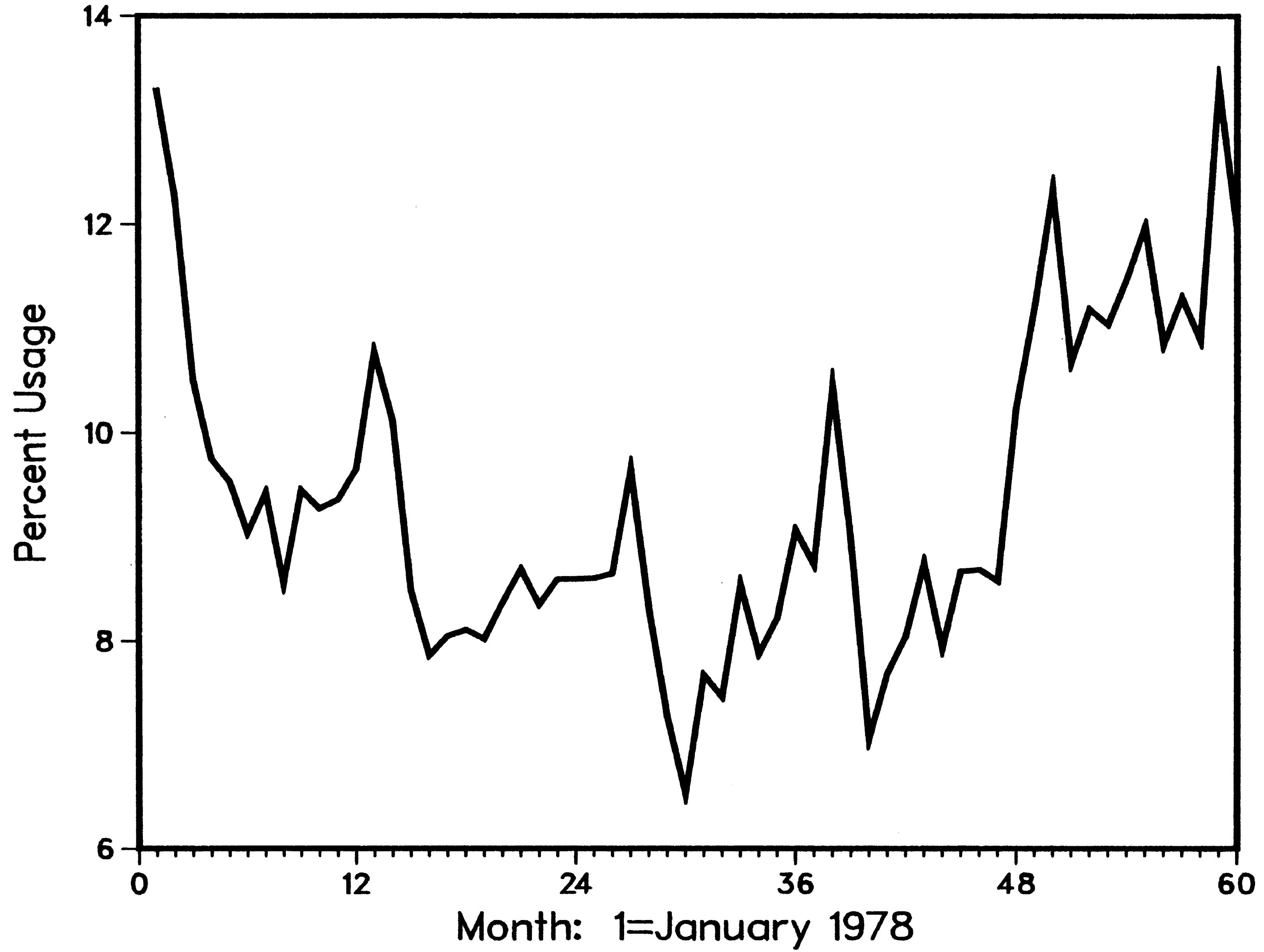
Two differences in the measures might be noted. First, use among injured occupants shows a higher degree of variability from month to month than use among all occupants. This difference was expected, and is due to the smaller number of occupants on which the injury-use plot is based. The implication for subsequent analyses evaluating the child restraint law is that small changes in restraint use that might be due to the law will not be clearly identifiable. That is, they might not be statistically significant because of higher error variance.

A second major difference between Figures 4.1 and 4.2 is a shift downward of about two percentage-points in average restraint use among injured occupants compared to all occupants. Because restraint use as measured by both indicators changes over time in similar ways, the use indicator limited to injured occupants remains a useful measure for evaluation of mandatory restraint use laws. However, it must be kept in mind that the absolute levels of restraint use estimated using injured occupants is about two points lower than an estimate based on all crash-involved occupants.

Because of potential unreliability in the measure of restraint use among crash-involved drivers and passengers, the evaluation of the child restraint

FIGURE 4.2

Restraint Usage Among Injured Motor Vehicle Occupants



law reported in section 5 relies primarily on the changing pattern of traffic injuries in recent years. In this section overall trends in crash involvement and injuries are examined. An understanding of recent general trends facilitated subsequent analyses and interpretation of age-specific trends.

The total number of motor vehicle occupants involved in traffic crashes in Michigan is plotted in Figure 4.3. This figure includes all occupants in recorded crashes, whether the person was injured or not. First, note the general downward trend in crash involvement during the 1978 through 1982 period. Second, note the strong seasonal cycle in crash involvement. Crash involvement regularly peaks in December and January of each year, and is lowest in the mid-summer months. This seasonal cycle in Michigan crash-involvement is longstanding, and has been analyzed in previous studies (Wagenaar, 1983). Further analyses of the significance of the cycle were therefore not necessary. Implications of the downward trend and strong seasonal cycle for evaluation of effects of mandatory restraint use legislation are obvious. These trend and seasonal effects must be controlled to accurately assess the effects of restraint-use interventions.

As noted earlier, information on the age of motor vehicle occupants is recorded only for those injured in crashes. Therefore, evaluations of interventions such as the child restraint law were possible only using data for injured occupants. The total number of injured crash-involved occupants in Michigan is shown in Figure 4.4. The downward trend and seasonal cycle in injuries is very similar to that for total occupants (Figure 4.3). The main difference between Figures 4.3 and 4.4 is that the number of injured occupants is a relatively small proportion of all crash-involved occupants.

FIGURE 4.3

Michigan Total Crash—involved Motor Vehicle Occupants

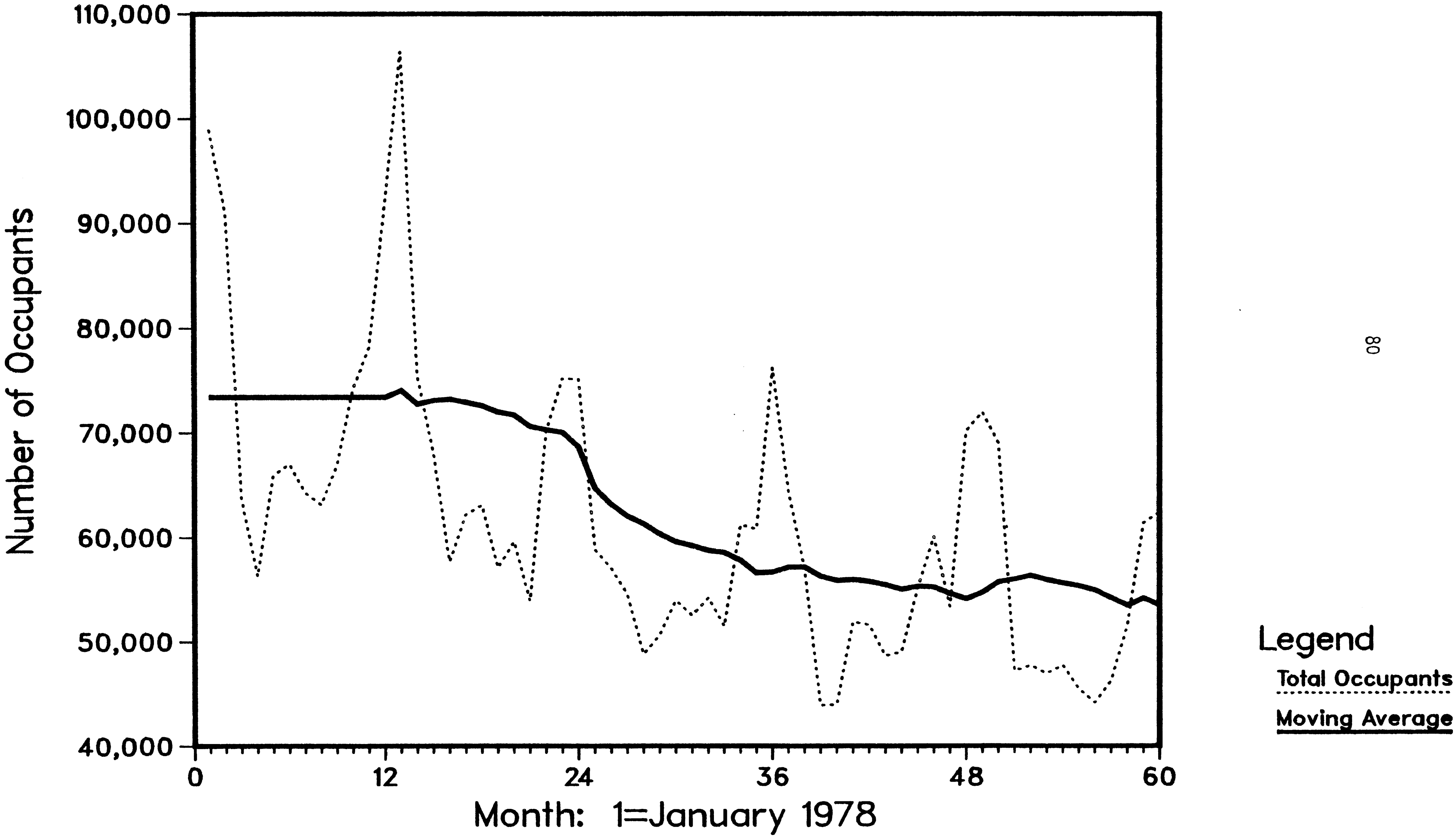
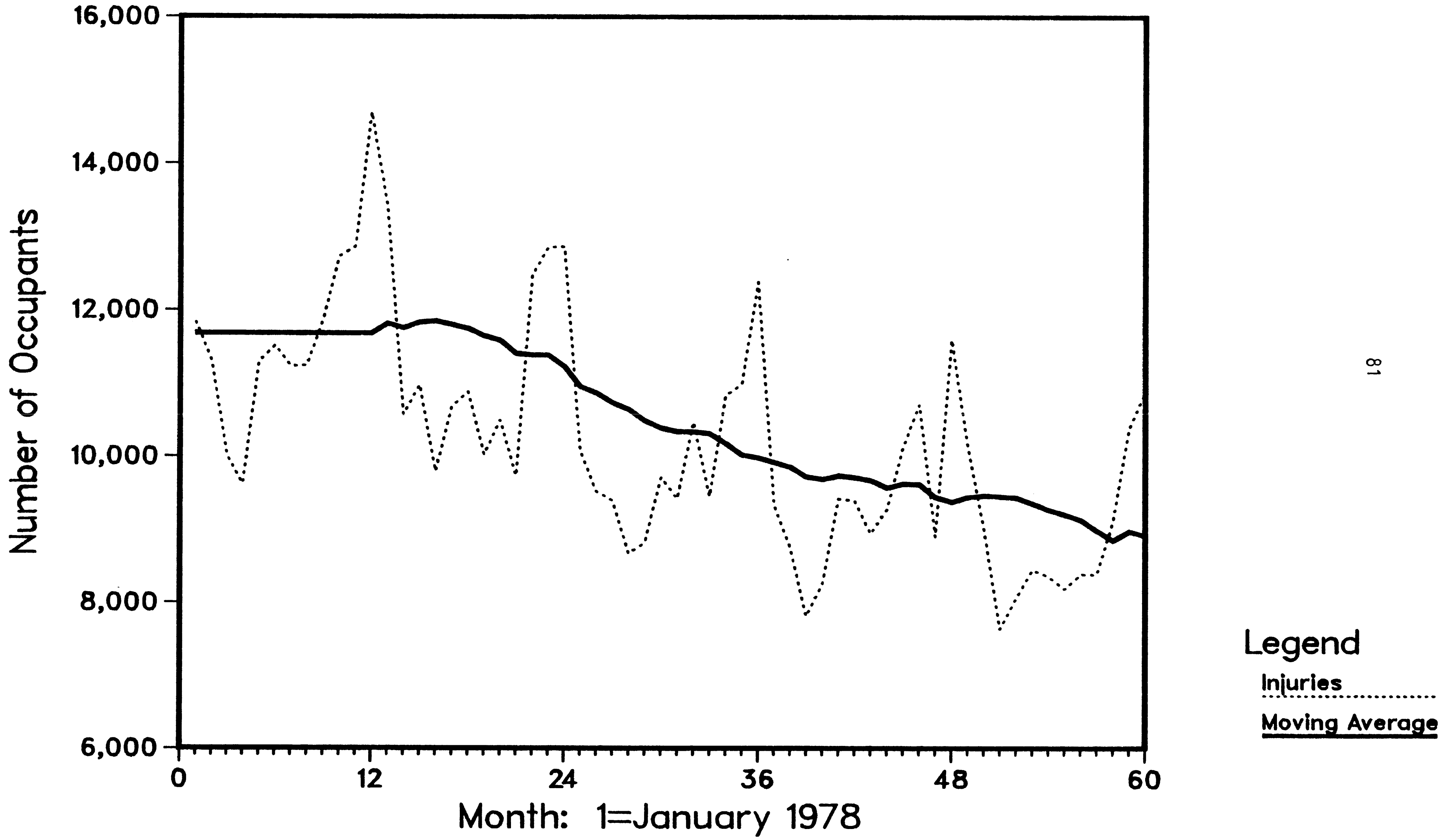


FIGURE 4.4

Michigan Injured Crash-involved Motor Vehicle Occupants



The number of motor vehicle occupants injured averaged under 10,000 per month in 1982 (Figure 4.4), while the number of uninjured crash-involved occupants averaged over 45,000 (Figure 4.5). The lack of data on the majority of crash-involved occupants that are not injured complicates estimation of age-specific exposure to risk of injury. Nevertheless, occupant restraint policies and programs are designed to reduce the aggregate incidence of motor vehicle injury. Data on age-specific injury trends, which are available, are most important for evaluation of the effectiveness of mandatory restraint-use policies.

Restraint-use policies and programs are designed to reduce traffic crash-related casualties by increasing occupant protection when crashed, not by reducing the number or severity of crashes (ignoring a possible small effect of increased restraint use in reducing the number of crashes by improving the ability of drivers to keep their vehicles under control). Major changes in exposure to the risk of injury in recent years, due to changes in the number or severity of crashes, might complicate evaluation of mandatory restraint use laws. If there is a sudden change in number of vehicles crashed, particularly those experiencing extensive vehicle damage, this change may explain observed injury reductions rather than a mandatory use law.

The two dimensions of exposure to risk of injury examined, then, were the number of vehicles involved in crashes and the severity of those crashes (as measured by vehicle damage). Figures 4.6 to 4.13 show the numbers of vehicles involved in crashes from January, 1978, through December, 1982, for each level of vehicle damage, ranging from no damage to maximum damage. All of the plots are similar. The number of crashed vehicles at all levels of

FIGURE 4.5

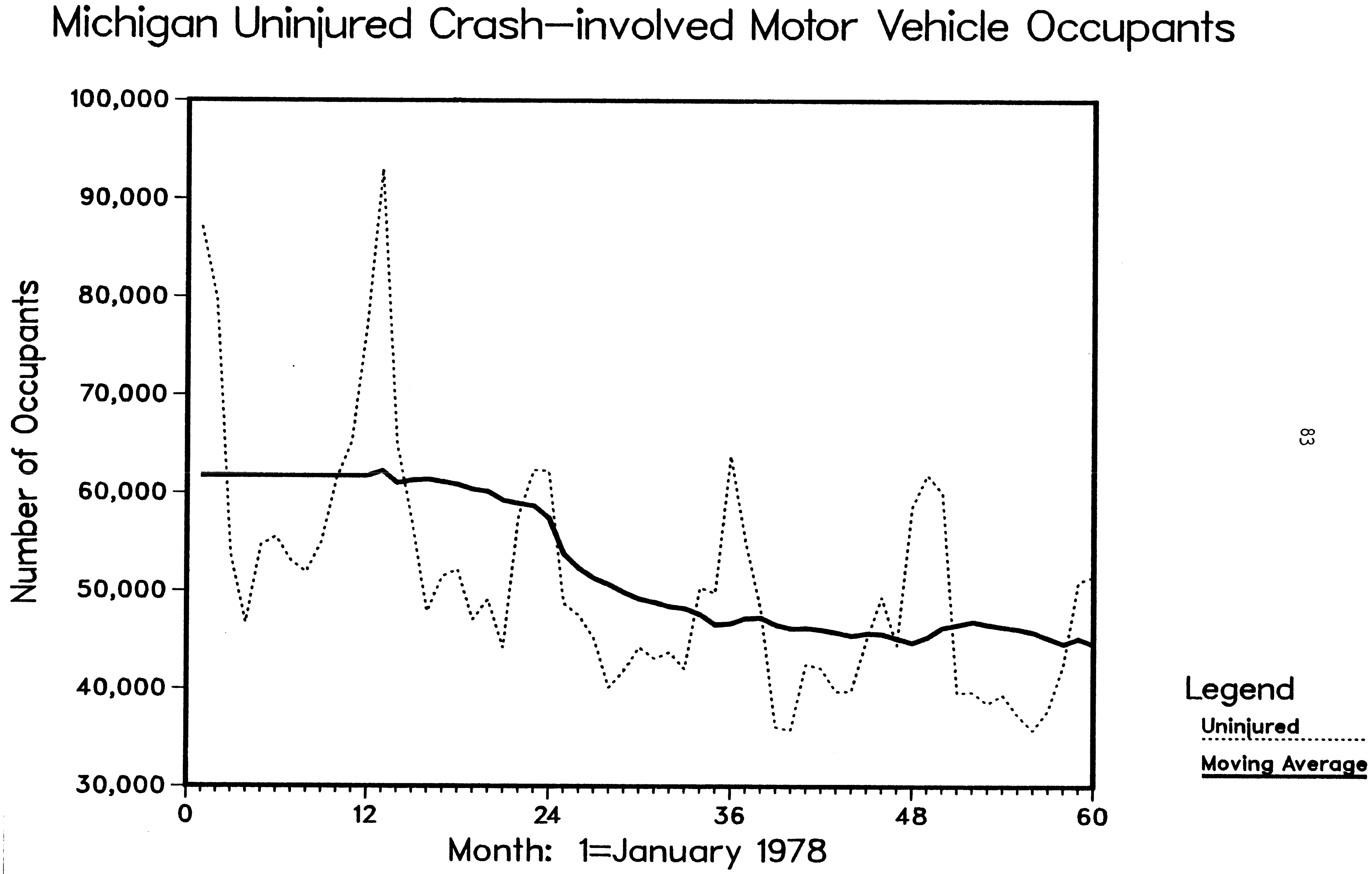

Michigan Uninjured Crash—involved Motor Vehicle Occupants
Number of Occupants
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
0
12
24
36
48
60
Month: 1=January 1978
Legend
Uninjured
Moving Average

FIGURE 4.6

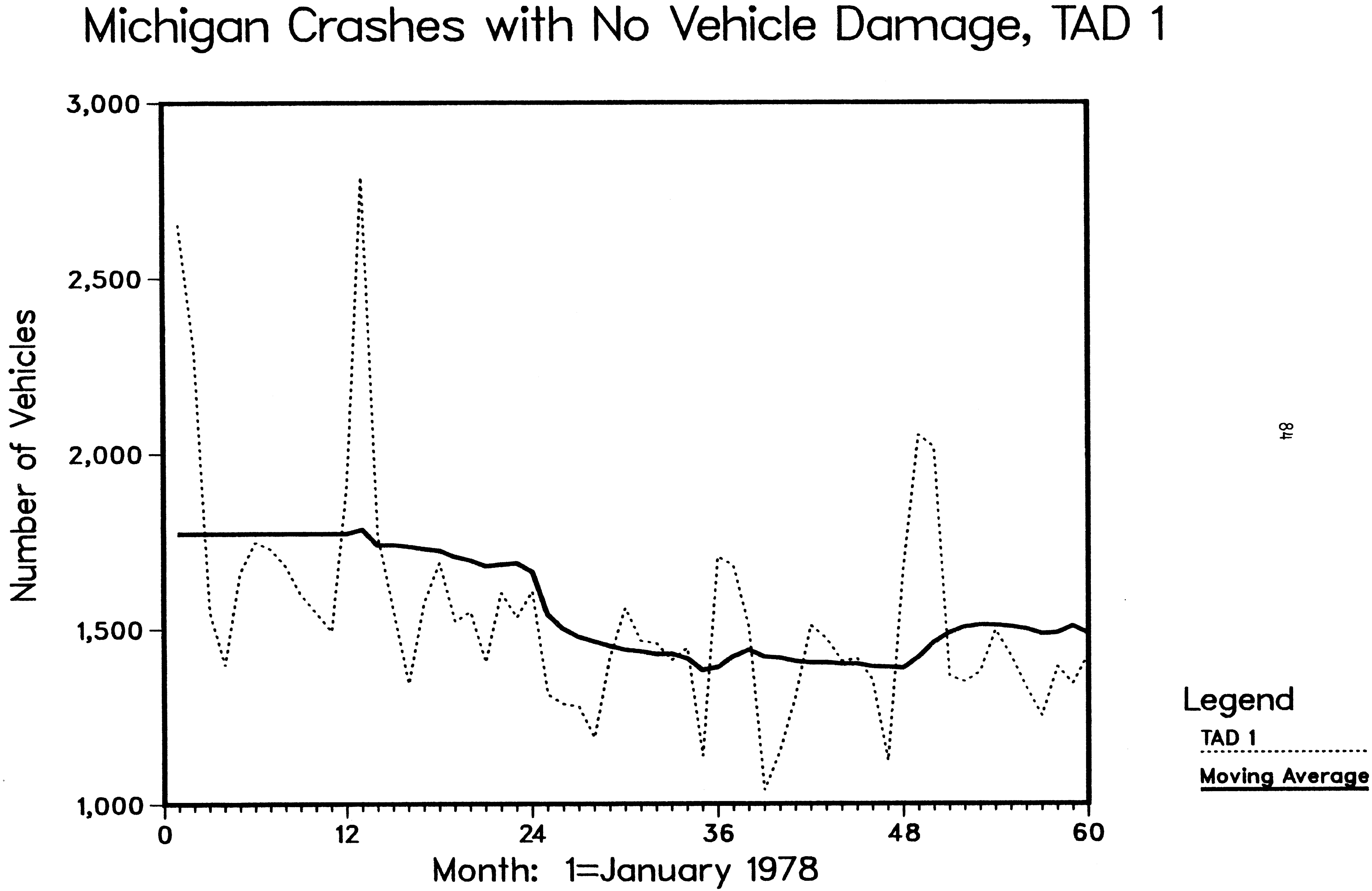

Michigan Crashes with No Vehicle Damage, TAD 1
3,000
2,500
2,000
1,500
1,000
Number of Vehicles
0
12
24
36
48
60
Month: 1=January 1978
Legend
TAD 1
Moving Average

FIGURE 4.7

Michigan Crashes with Minimum Vehicle Damage, TAD 2

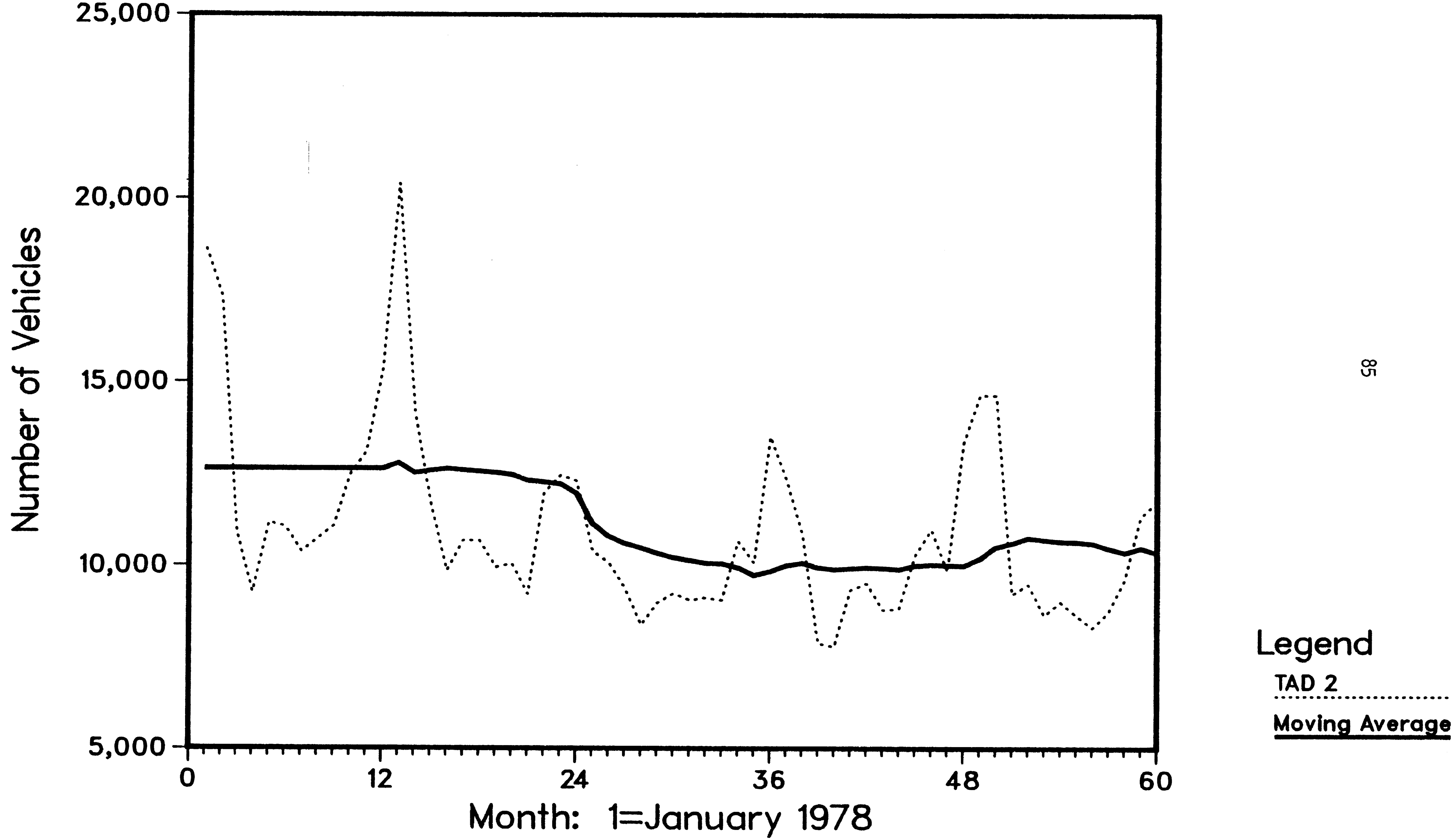


FIGURE 4.8

Michigan Crashes with Limited Vehicle Damage, TAD 3

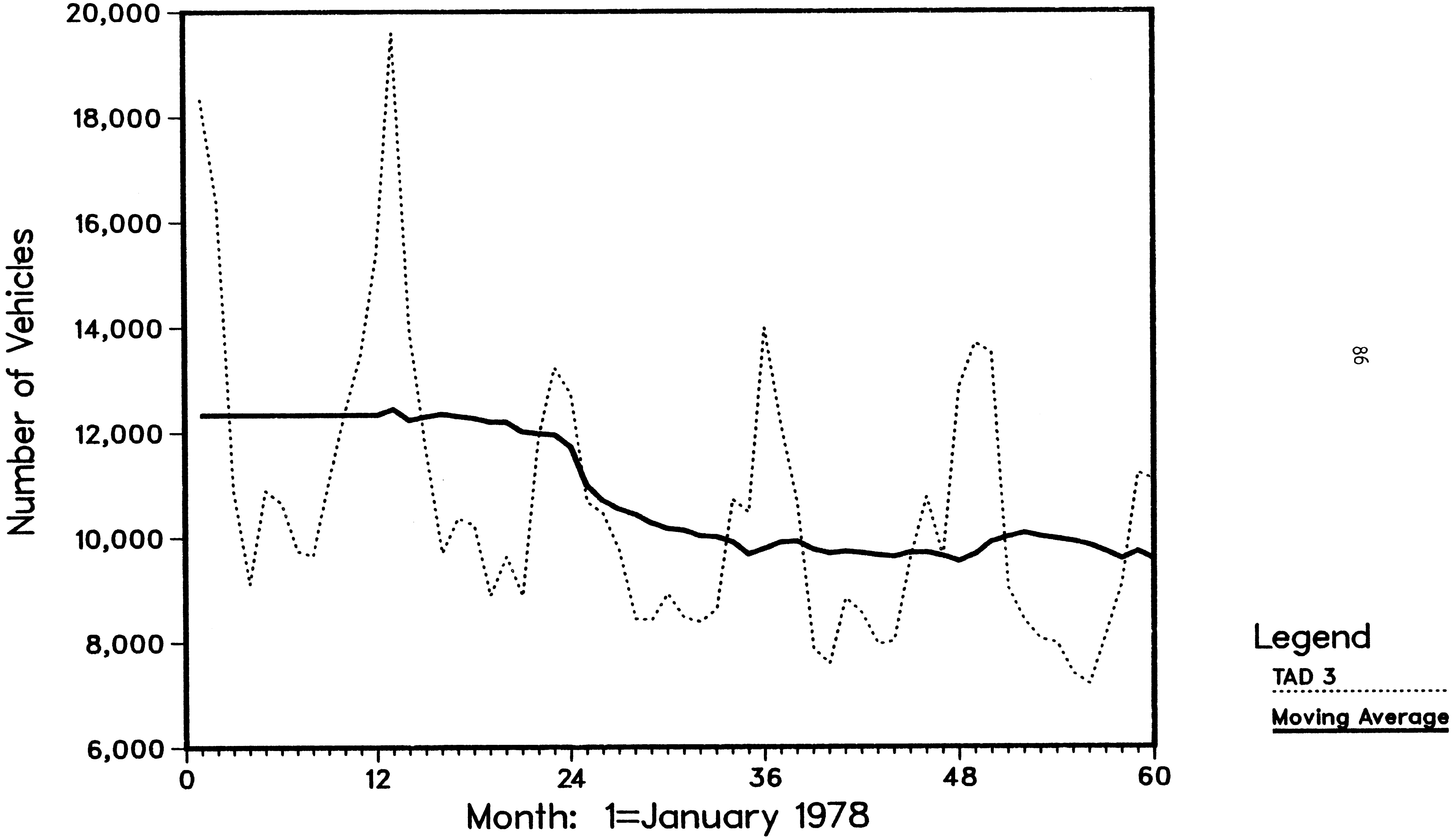


FIGURE 4.9

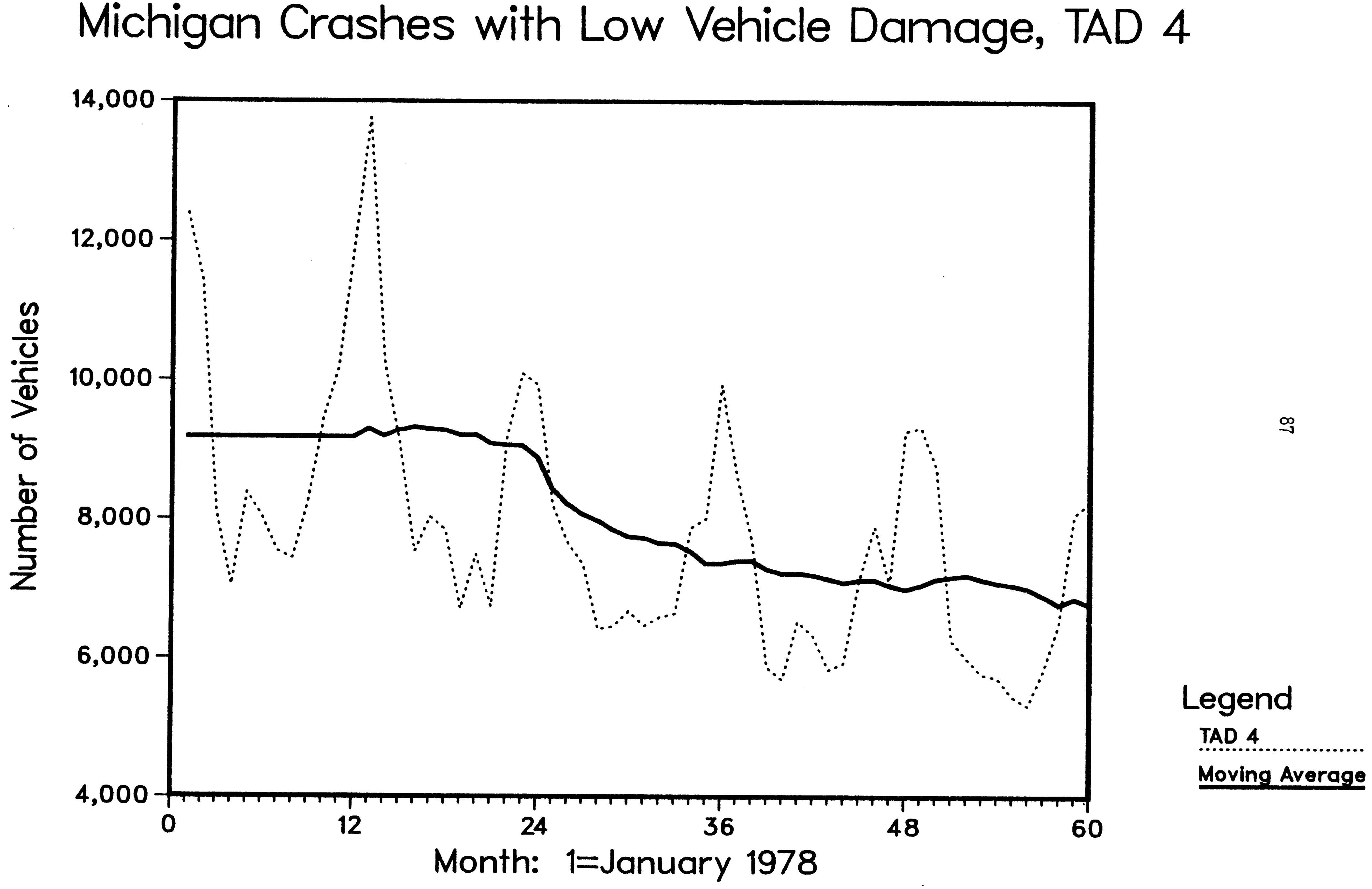

Michigan Crashes with Low Vehicle Damage, TAD 4
14,000
12,000
10,000
8,000
6,000
4,000
Number of Vehicles
0
12
24
36
48
60
Month: 1=January 1978
Legend
TAD 4
Moving Average

FIGURE 4.10

Michigan Crashes with Moderate Vehicle Damage, TAD 5

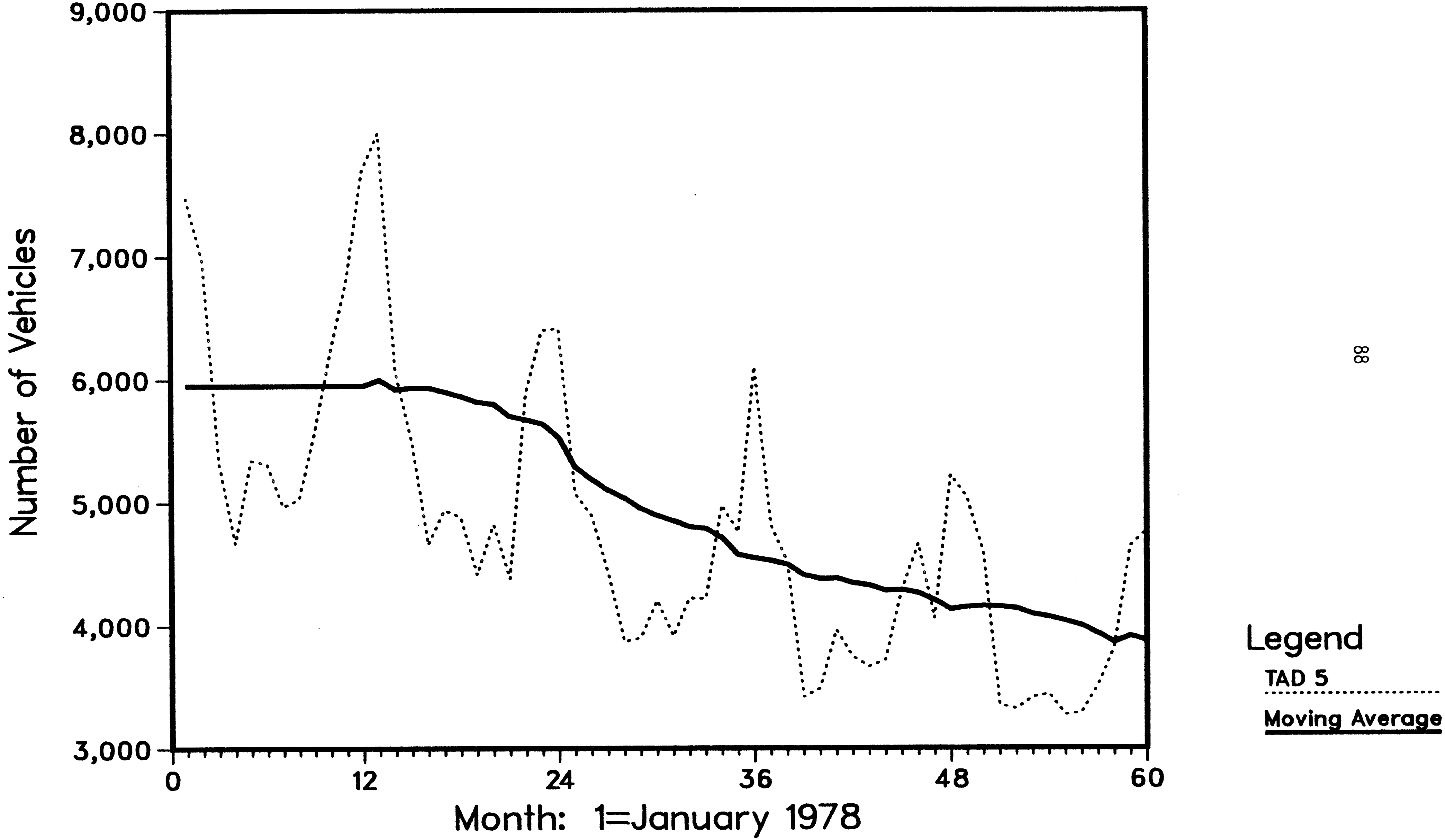


FIGURE 4.11

Michigan Crashes with High Vehicle Damage, TAD 6

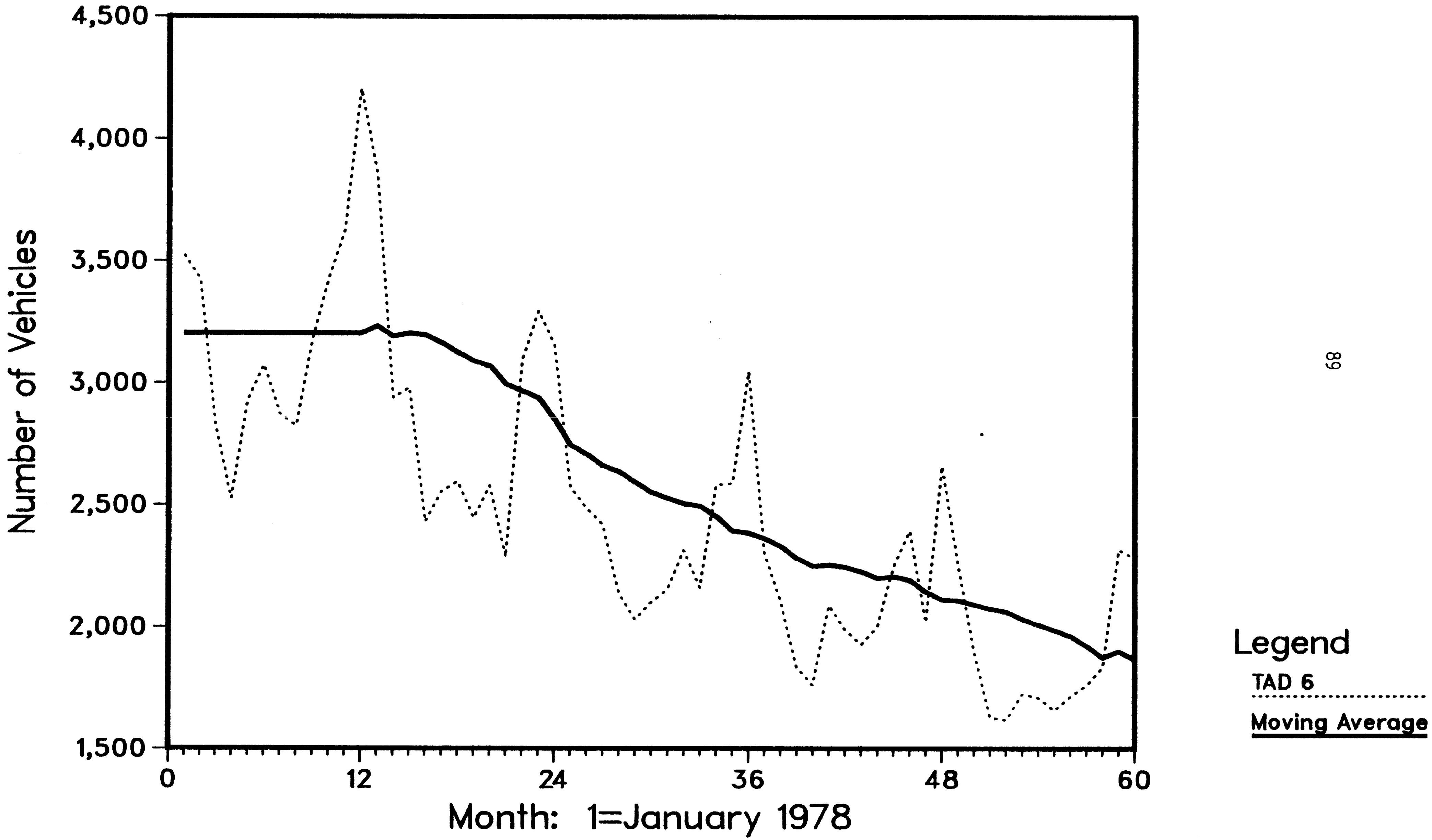


FIGURE 4.12

Michigan Crashes with Extensive Vehicle Damage, TAD 7

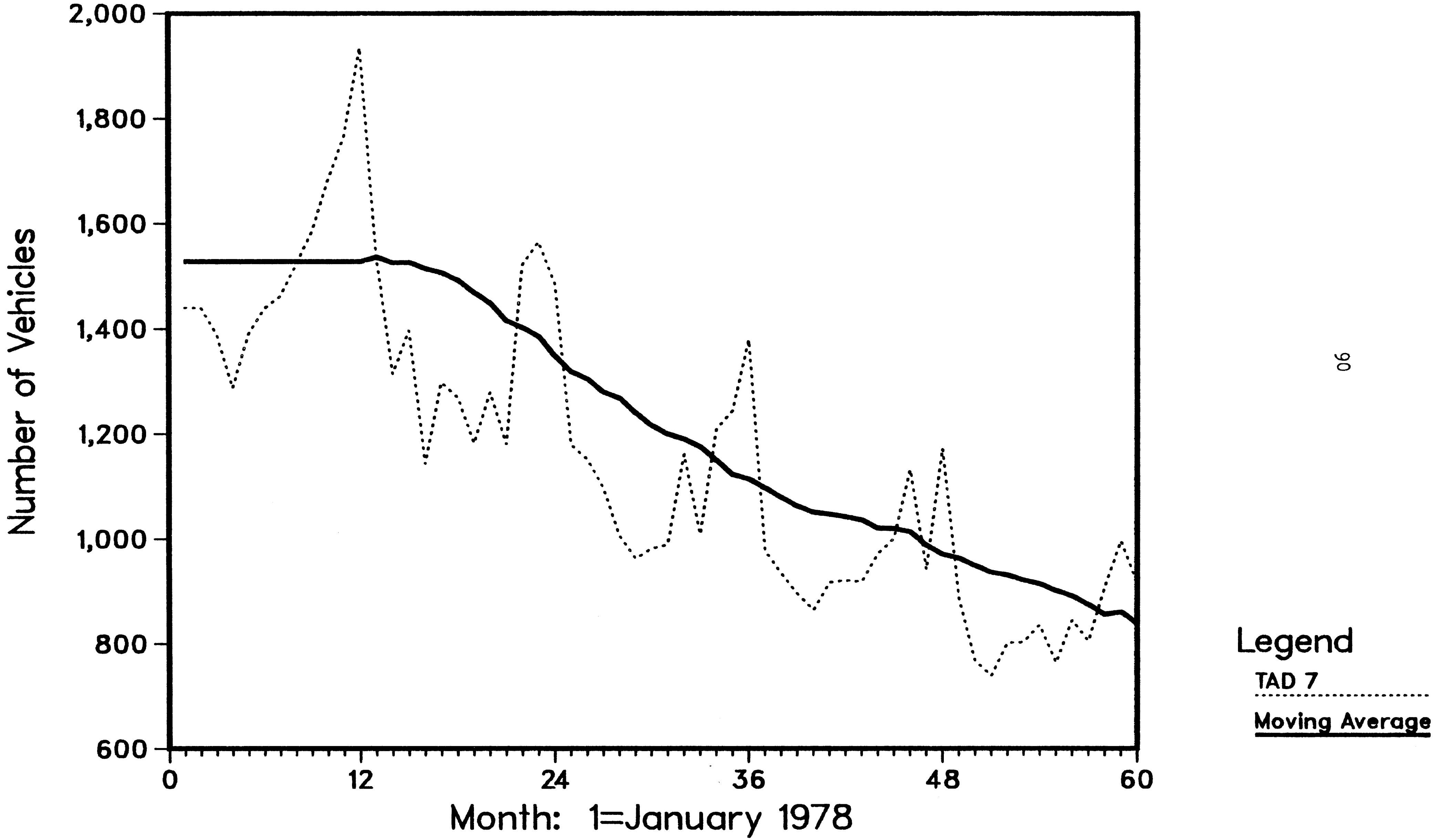
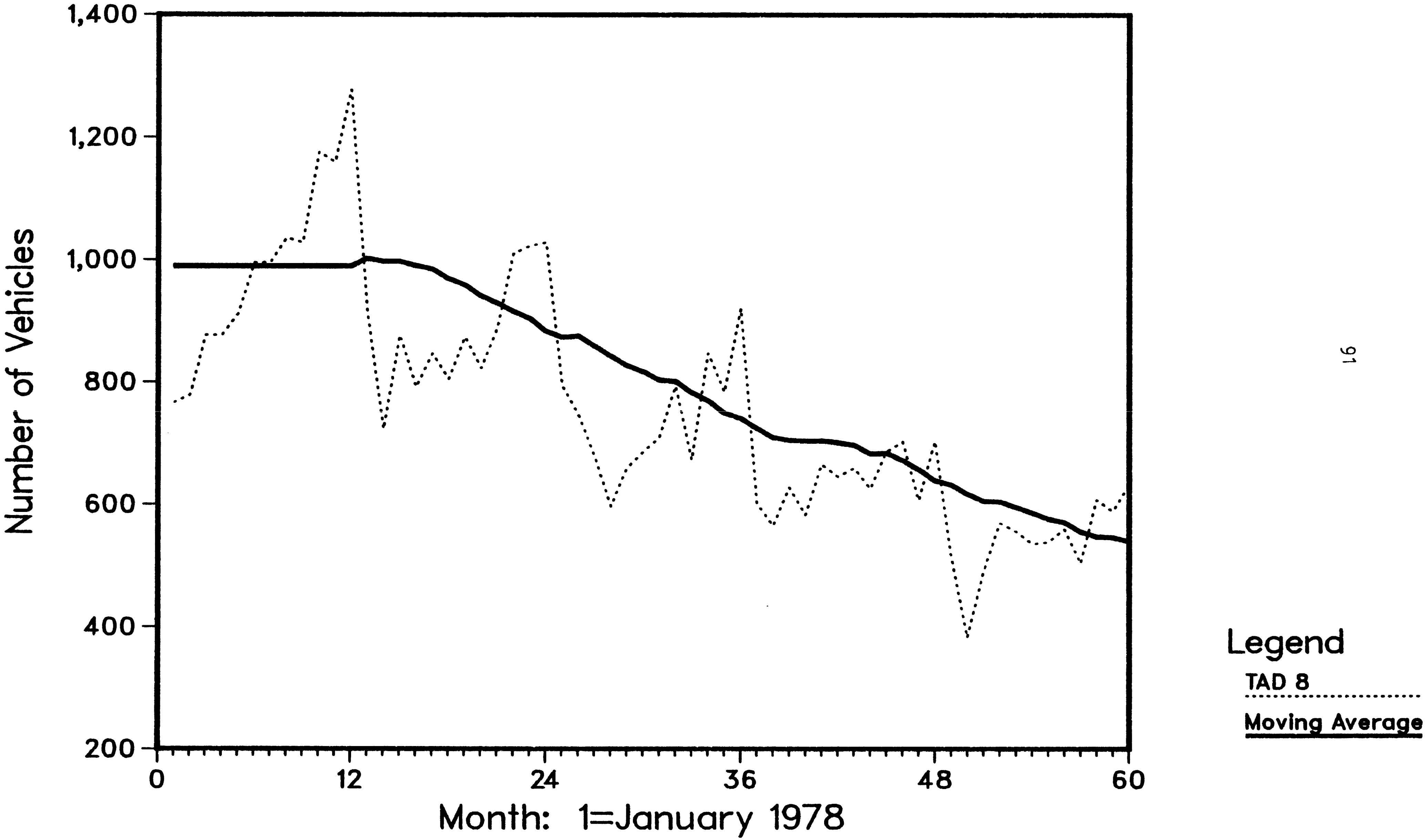


FIGURE 4.13

Michigan Crashes with Maximum Vehicle Damage, TAD 8



damage shows a downward trend from 1978 to 1982. The downward trend is slightly steeper for crashes at higher levels of damage severity. The downward trend in occupant injuries noted above (Figure 4.4) may be due to a reduction in the number of severely damaged vehicles. In any event, there were no sudden changes in the number of vehicles crashed at various damage levels at the time the child restraint law was implemented. The general downward trend in severe crashes and occupant injuries was controlled before assessing the specific effects of the child restraint law.

CHAPTER 5: EFFECTS OF THE MANDATORY CHILD RESTRAINT LAW

Michigan's mandatory child restraint law took effect on April 1, 1982. The law requires children under the age of 4 to be properly restrained by an approved child restraint device. Children age 1 to 3 may be restrained by a conventional adult seat belt, provided they are traveling in the rear seat. A major public information and education (PI&E) effort designed to increase awareness of the new mandatory use law and increase the rate of proper use of child restraints began in January 1982 (Office of Highway Safety Planning, 1981). Effects of these two distinct interventions (law and PI&E program) were assessed separately.

The time-series intervention models included components assessing the impact on restraint use and occupant injuries of (1) the PI&E effort alone (January through March 1982) and (2) the PI&E effort combined with the mandatory child restraint usage law (April through December 1982). A plot of each outcome measure is shown in this chapter, and the net change in each outcome measure associated with these two interventions is discussed. When examining the plots, note that the dotted line represents actual monthly values of restraint use or number of injuries. The solid line represents a smoothed trend line, and is useful to help see the overall trends. The smoothed trend is most helpful for the identification of trends over the multi-year baseline period, while the actual values shown by the dotted line are the most accurate for the post-intervention period. The net change in each outcome measure from previous patterns (trends and cycles) was measured using comprehensive Box-Jenkins time-series models. The statistical time-series modelling results upon which these findings are based are shown in tables found in the Appendix.

If the child restraint law and associated PI&E efforts were successful, the first outcome expected is an increase in the the rate of restraint usage (either with an approved child restraint device or adult seat belt) among children covered under the new law (i.e., those age 0 to 3 inclusive). The focal age group was split into two segments for analysis: children under the age of 1, and children age 1 to 3. This age cutpoint was chosen because of the differential treatment of infants under age one required by the new law.

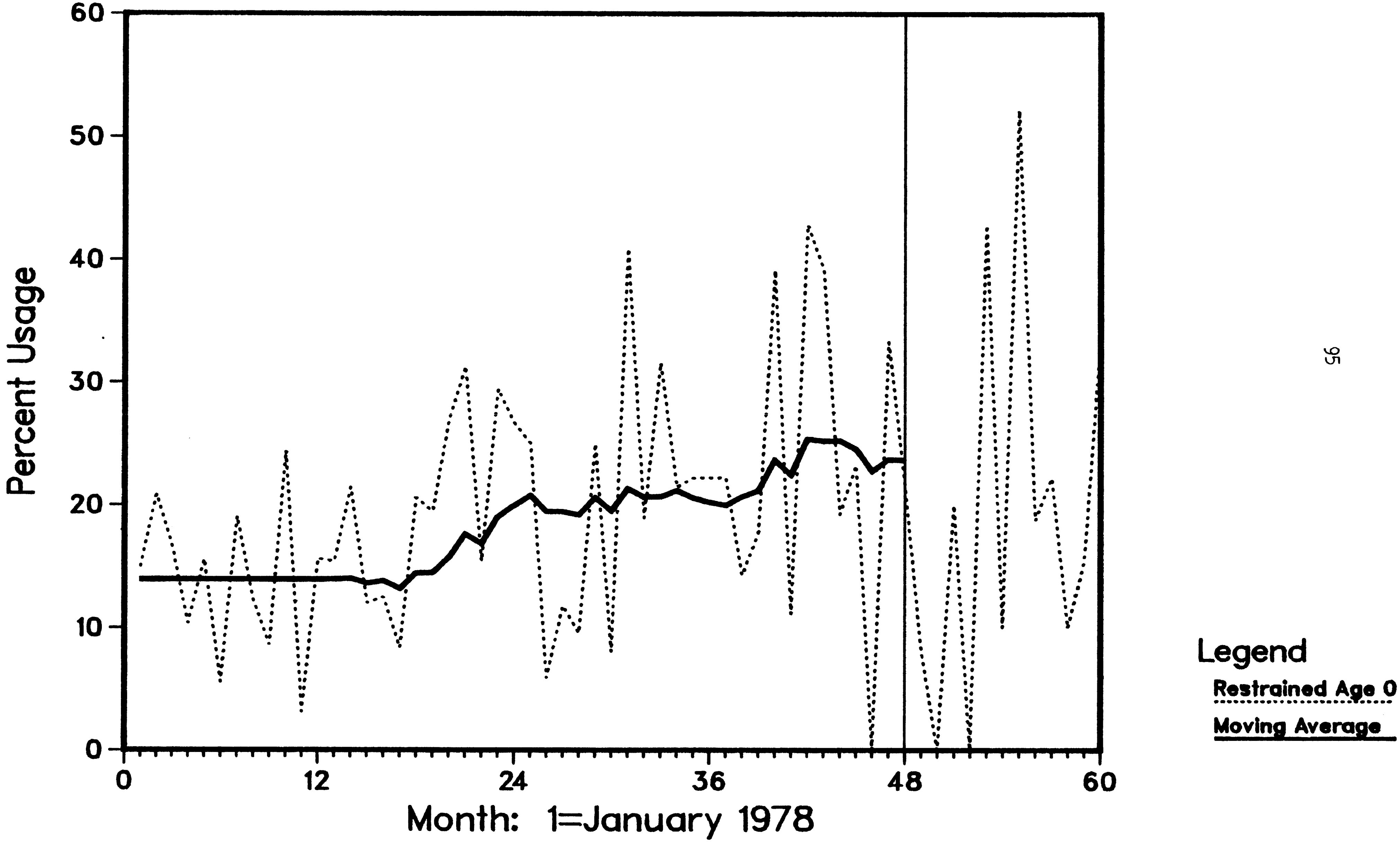
The rate of restraint usage among injured motor vehicle occupants less than one year old is shown in Figure 5.1. There was a moderate upward trend in usage from 1979 through 1981. The upward trend is not consistent, and the usage rate varies dramatically from month to month. Restraint usage in 1981, before the PI&E and mandatory-use interventions, averaged about 21%.

Results of time-series modeling (Table A.1) revealed what appeared to be a significant 72% decrease in restraint usage among infants during the January to March 1982 PI&E-only period. The 72% reduction in the usage rate represents a decrease in usage from 21% in late 1981 to about 7% in early 1982. An increase in restraint usage is evident after the law was implemented, but was not significant (Figure 5.1).

These results are contrary to the hypothesis that both the PI&E efforts and the child restraint law increased restraint usage. However, they cannot be taken at face value because of the nature of the measure on which they are based. The restraint usage indicator for infants under the age of one year is based on a monthly incidence of 0 to 12 restrained crash-involved infants per month. For a month in which no crash-involved infants were restrained,

FIGURE 5.1

Michigan Restraint Usage Among Injured Occupants Age 0



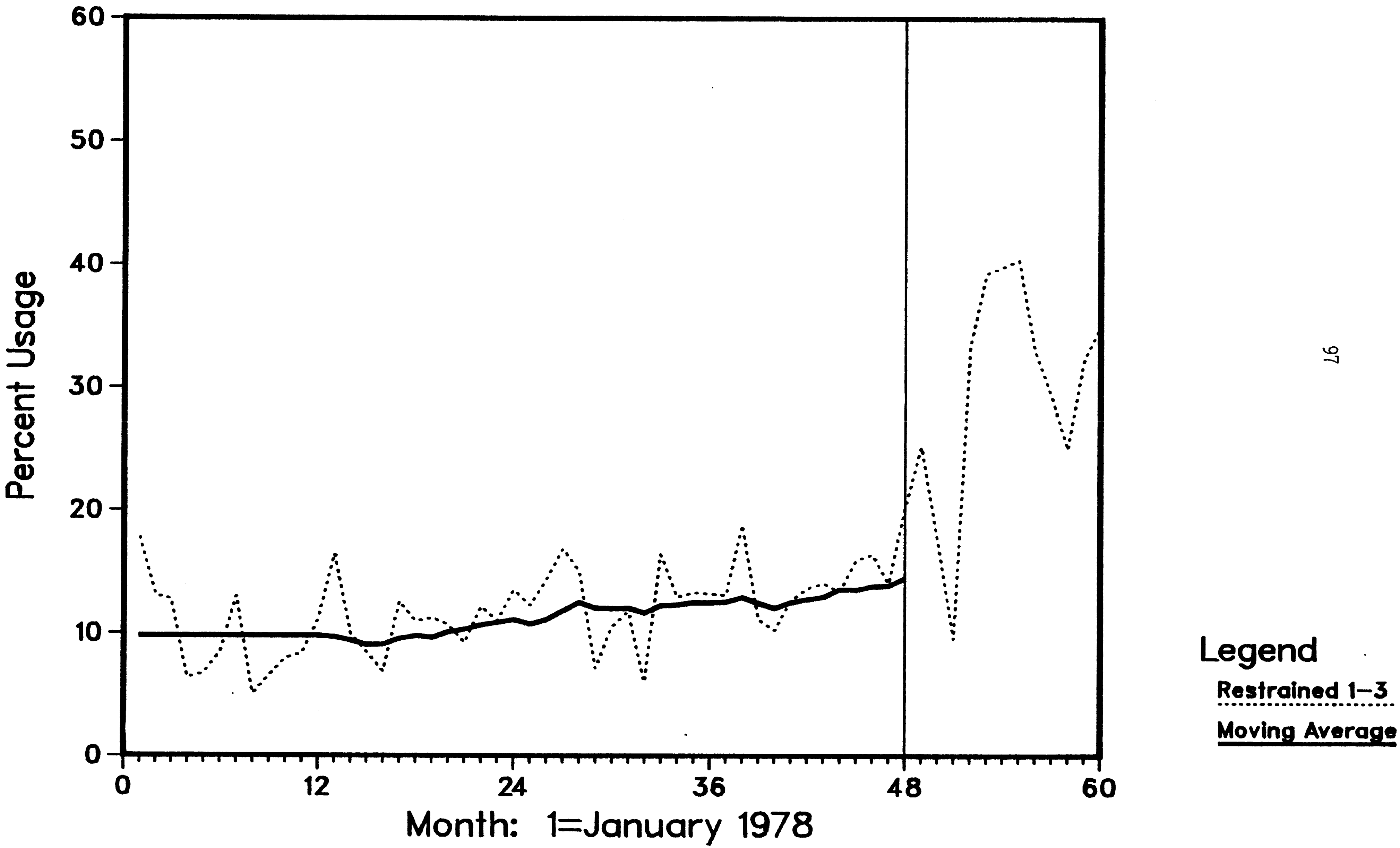
the percent of all crashed infants using restraints is zero. Basing the percent usage indicator on such a small number of cases produces an unstable indicator. The large month-to-month variation in usage noted earlier is an indication of the instability of this measure. Because of these inadequacies in measurement, the time-series model results should be discounted. In short, these data provide little information concerning the effect of the 1982 interventions on restraint usage among Michigan infants.

The small-sample problem did not arise with the rest of the population covered by the child restraint law. Restraint usage among crash-involved children age 1 to 3 is shown in Figure 5.2. There was a slight increase in restraint usage from 1979 to 1981. Time-series modeling results indicated no significant effect of the PI&E efforts alone on restraint usage (Table A.2). The effect of implementation of the child restraint law, in contrast, was dramatic. Usage among 1-3-year-olds was 208% higher during the April-December 1982 period than expected given the multi-year baseline trends. The usage rate tripled from about 12% before the law to about 36% after. In contrast to the analyses of restraint usage among infants under 1, analyses of the larger age group of 1-3-year-olds provided a more stable restraint use indicator, and documented the substantial increase in restraint usage associated with implementation of the mandatory-use law.

Restraint usage among motor vehicle occupants of other ages was also analyzed. Objectives in analyzing occupants of other ages were twofold. First, to identify possible spillover effects of the child restraint law. Second, to ensure that significant increases in usage found among young children were not simply a reflection of other factors influencing all motor vehicle occupants in Michigan, but were in fact due to implementation of the

FIGURE 5.2

Michigan Restraint Usage Among Injured Occupants Age 1 to 3



child restraint law.

Average restraint usage among injured motor vehicle occupants age 4 to 15 was consistently 5 to 6% from 1978 through 1982, shown by the moving average trend in Figure 5.3. A significant 55% increase in usage occurred in early 1982, when the PI&E effort was underway (Table A.3). Implementation of the child restraint law increased usage 102%, twice as much as the PI&E efforts alone. The 102% increase in usage among 4-15-year-olds is significant from both a statistical and substantive point of view. However, it is only half as large as the percent increase in usage exhibited by 1-3-year-olds, who were directly the focus of the new law. Furthermore, because usage prior to 1982 was higher among those age 1-3 than those age 4-15, the percentage-point increase among 1-3-year-olds was several times that among 4-15-year-olds (i.e., a change from 12 to 36% usage among those age 1-3 versus a change from 6 to 12% among those age 4-15). In short, the child restraint law appears to have increased usage among 4-15-year-olds, but the size of the effect is significantly smaller than that among focal 1-3 age group.

Restraint use among automobile occupants age 16 and 17 was quite constant over the 1978 through 1981 period, and increased slightly in 1982 (Figure 5.4). However, the increase in 1982 was not significantly greater than the normal month-to-month variation evident during the baseline period (indicated by the insignificant estimates for both the PI&E-only and child-restraint-law parameters in the time-series model shown in Table A.4).

Vehicle occupants age 18 to 24 exhibited a very slight downward trend in restraint use from 1978 through 1981 (Figure 5.5). No significant change in use occurred in the first three months of 1982. After the child restraint

FIGURE 5.3

Michigan Restraint Usage Among Injured Occupants Age 4 to 15

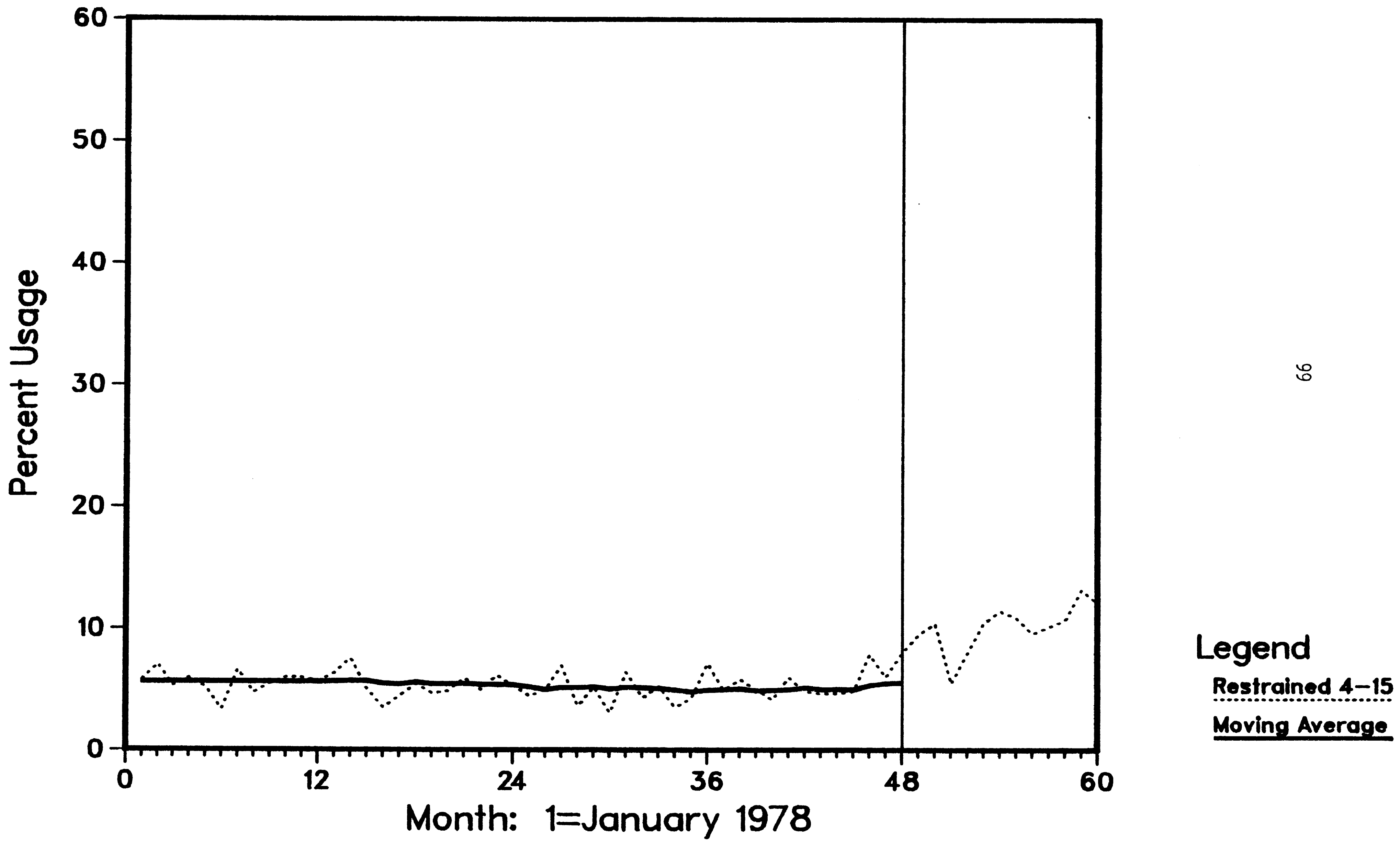


FIGURE 5.4

Michigan Restraint Usage Among Injured Occupants Age 16 and 17

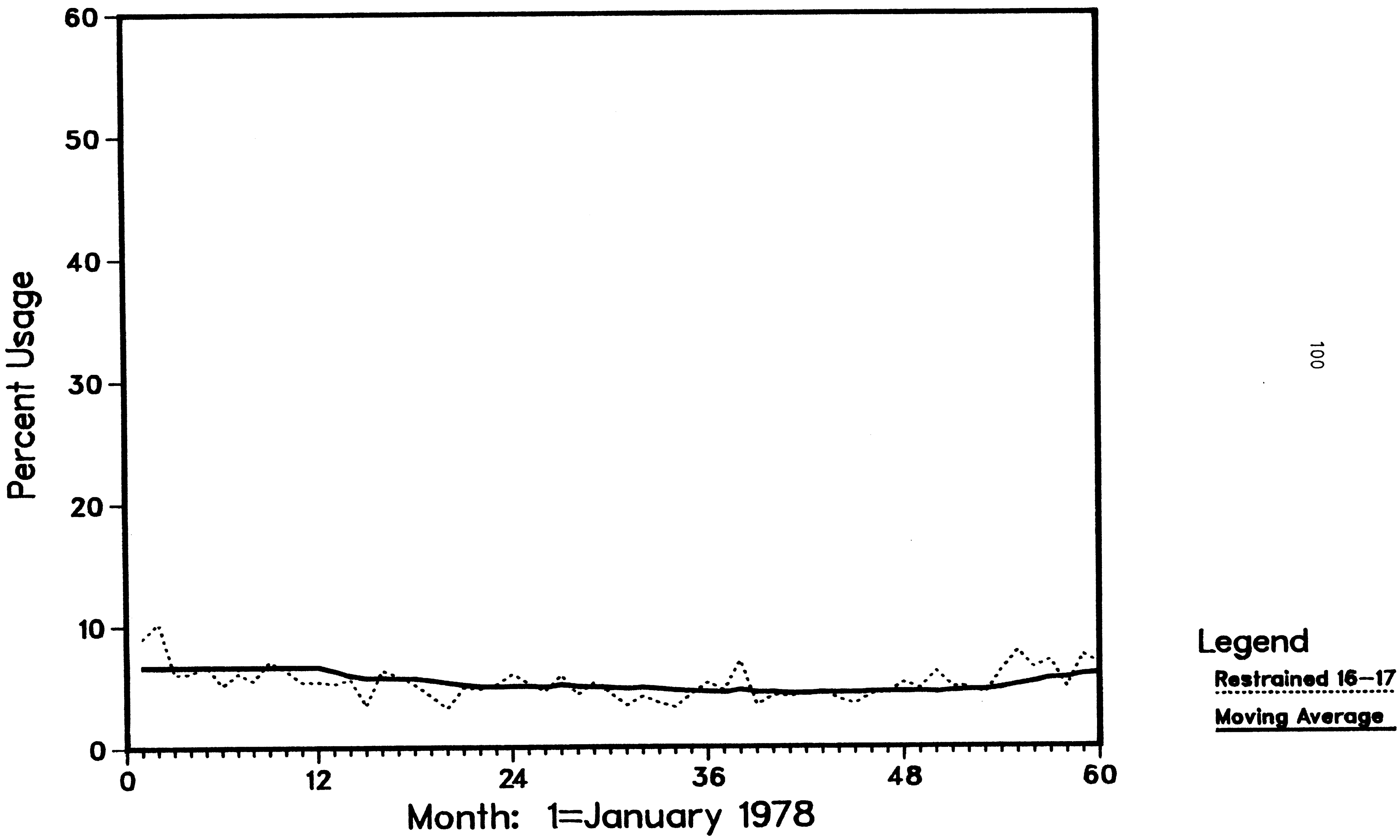
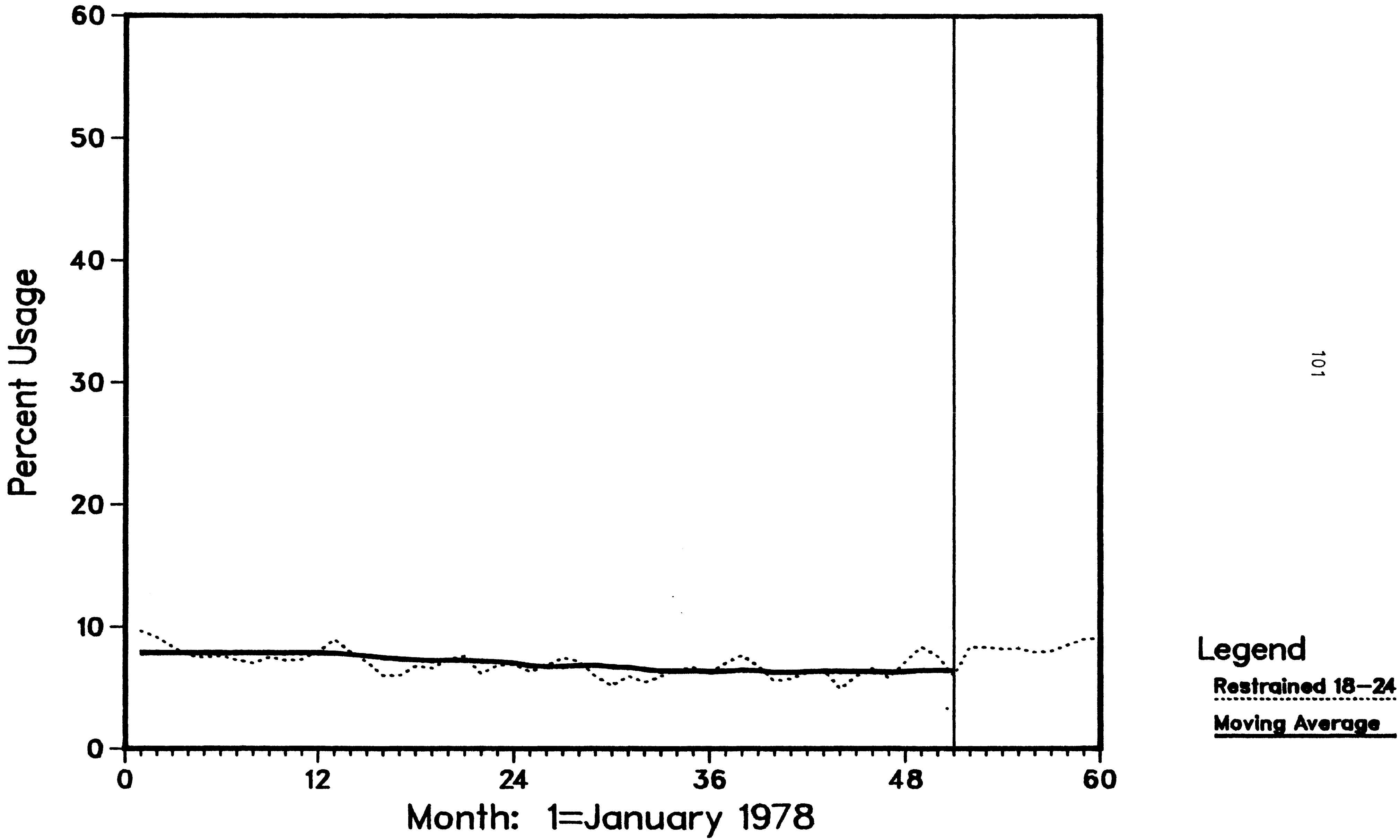


FIGURE 5.5

Michigan Restraint Usage Among Injured Occupants Age 18 to 24



law took effect, however, restraint use increased by 30%, a statistically significant change (Table A.5). Because of the low baseline usage rate, the 30% increase in usage represents an absolute change in usage of about 2 percentage-points (i.e., from 6 to 8%).

Similar analyses were conducted for motor vehicle occupants age 25 to 34. Use of occupant restraints among those in this age group decreased slightly from 1978 to 1981, and increased slightly in 1982 (Figure 5.6). The increase is most pronounced in February 1982, perhaps a result of the increased PI&E efforts. However, usage in 1982 was within the rates expected, given the variation evident over the baseline period; that is, the increase is not statistically significant (Table A.6).

Vehicle occupants age 35 to 54 increased their use of restraints 14% (i.e., about 2 percentage-points) in the first three months of 1982 (Figure 5.7). Again, the increase in adult restraint use may be related to the PI&E efforts in early 1982. But the increase is significant only at the .10 probability level, not at the conventional .05 level (Table A.7). [In other words, a change in restraint use among 35-54-year-olds of two or more percentage-points is expected 10% of the time just by chance.] The increased restraint usage is evident in Figure 5.7, and represents a possible effect of the PI&E efforts in early 1982. Restraint usage during April-December 1982 was not significantly different from pre-1982 levels.

The last age category examined included all injured motor vehicle occupants age 55 and over. Restraint usage rates for this age group decreased slightly from 1978 to 1980, and were constant from 1980 to 1981 (Figure 5.8). The first quarter of 1982, however, was characterized by a significant 16% increase in the usage rate (Table A.8). After the child

FIGURE 5.6

Michigan Restraint Usage Among Injured Occupants Age 25 to 34

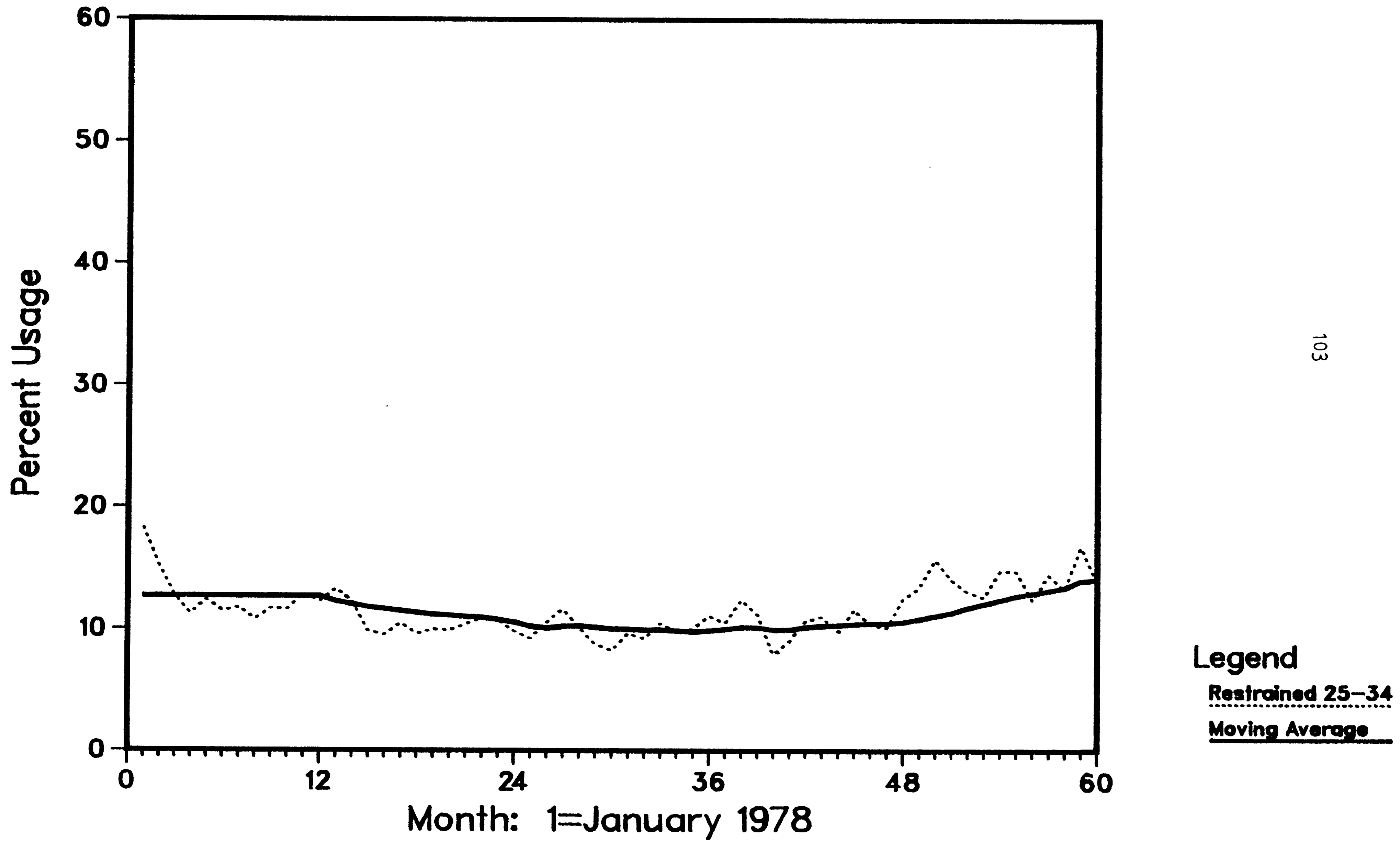


FIGURE 5.7

Michigan Restraint Usage Among Injured Occupants Age 35 to 54

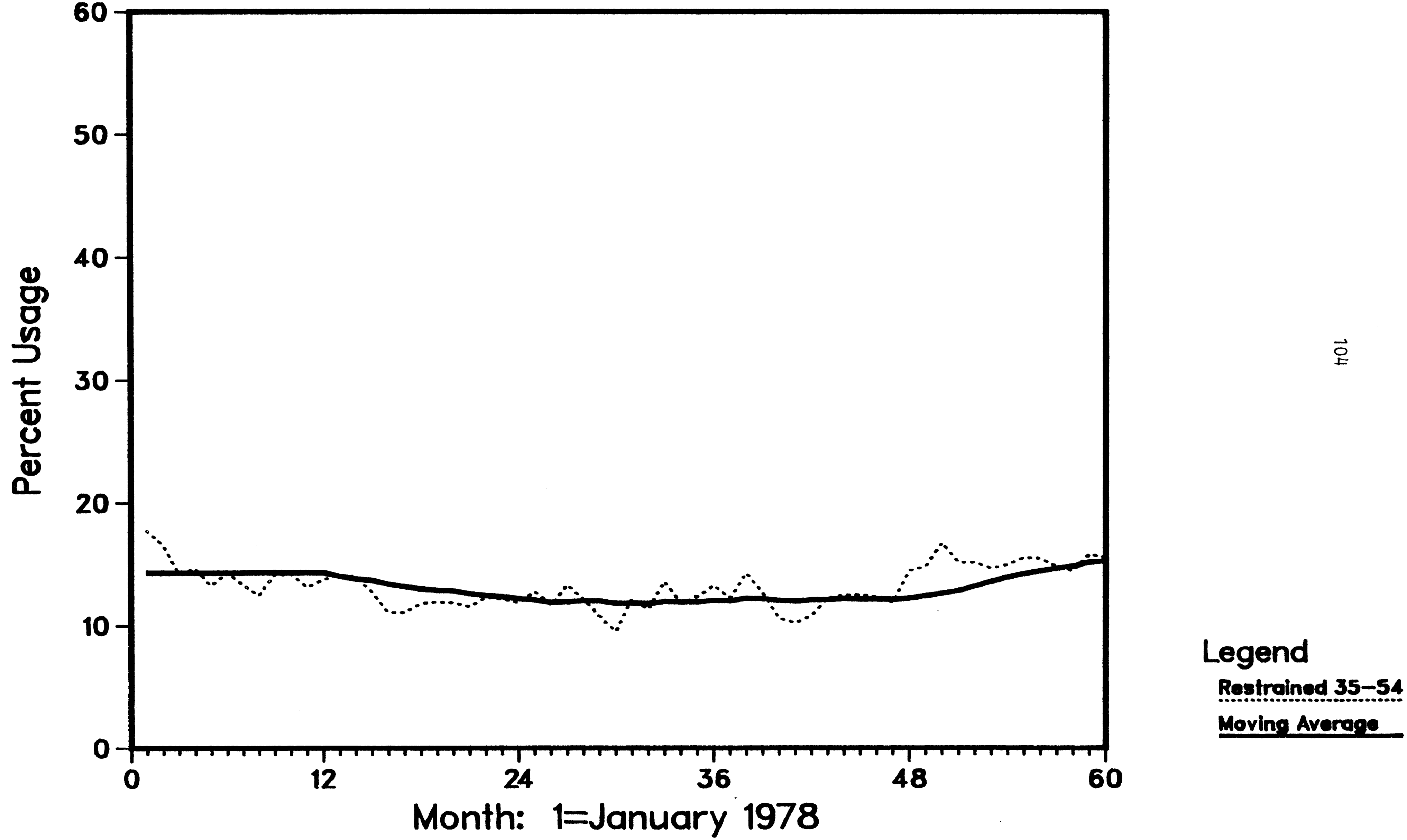
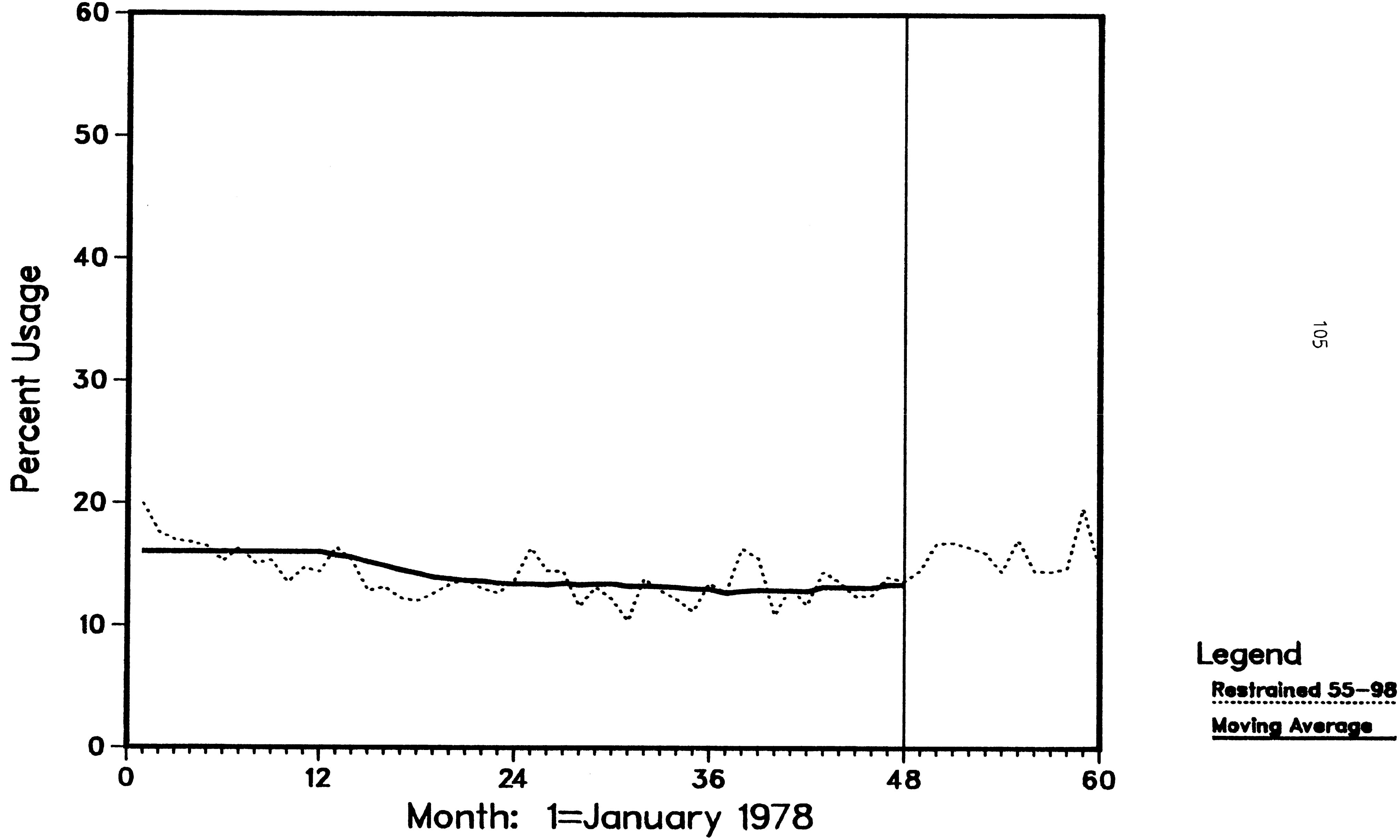


FIGURE 5.8

Michigan Restraint Usage Among Injured Occupants Age 55 and Over



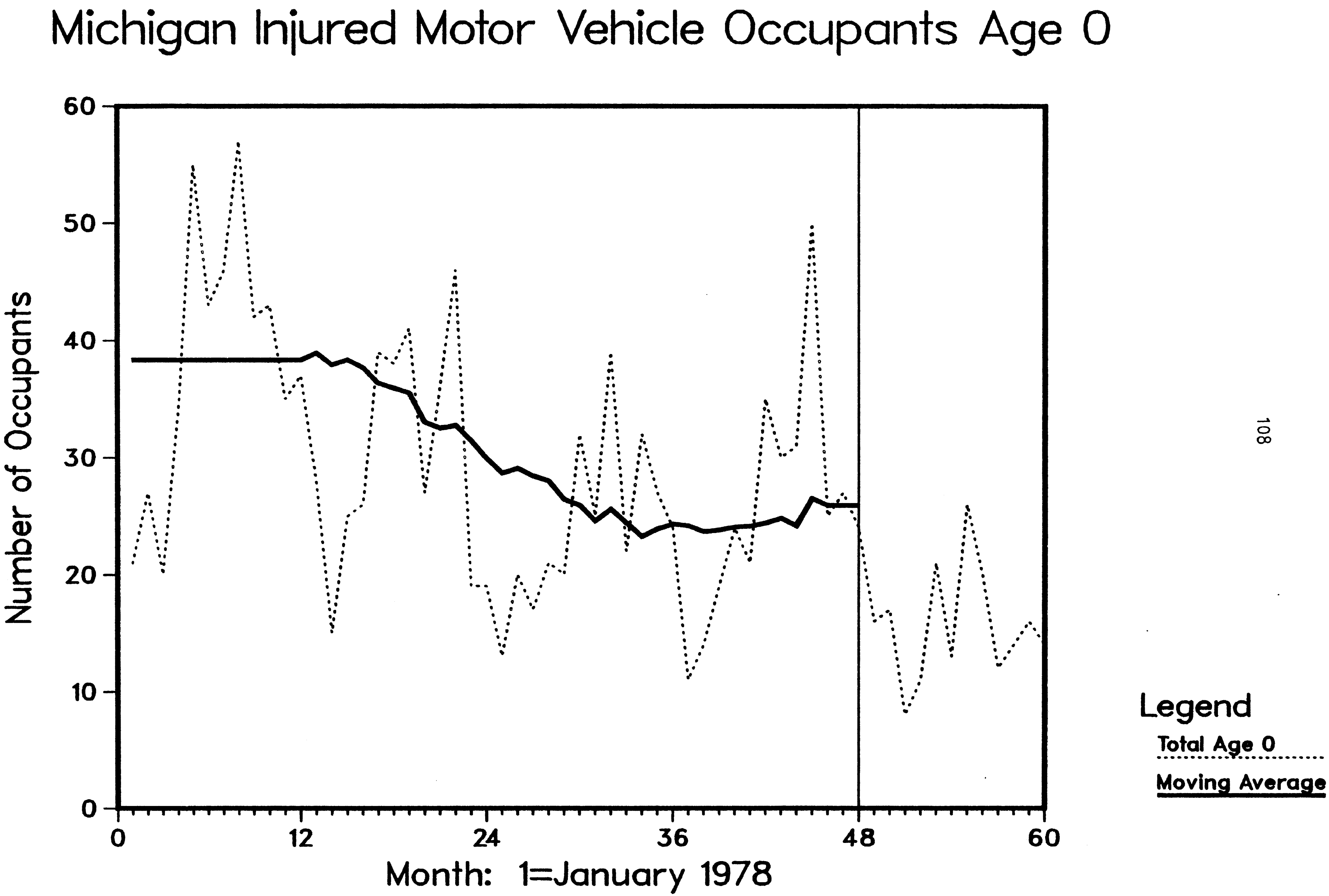
restraint law was implemented in April 1982, restraint usage among those 55 and over increased 20% (i.e., from about 13% usage in 1981 to 16% in the last three quarters of 1982).

A summary of recent changes in restraint use among injured motor vehicle occupants of various ages may be helpful. PI&E efforts designed to increase child restraint use were implemented from January through March 1982. Effects of this intervention on infants under age 1 were not discernable with the data available. No significant changes in the rate of usage during the PI&E-only period was found for the 1-3, 16-17, 18-24, and 25-34 age groups. The PI&E program apparently increased restraint use among the 4-15, 35-54, and 55-and-over age groups. The combination of PI&E efforts with the child restraint law during the last nine months of 1982 had much larger effects than the PI&E efforts alone. A dramatic increase in restraint use was found for passengers age 1 to 3. Much smaller but still significant increases in restraint use after the mandatory child use law took effect occurred for those age 4-15, 18-24, and 55 and older. These changes in restraint use may be a spillover effect resulting from the increased interest in occupant restraints for all vehicle passengers in 1982. The most dramatic increase in restraint usage occurred among the 1-3 age group in April 1982, the first month the new law was in effect. It appears, therefore, that the child restraint law had its intended effect in increasing the proportion of child automobile occupants that are restrained.

The results presented thus far are based on police-reported restraint use among motor vehicle occupants that were injured in a crash. These findings cannot unambiguously indicate the effect of the child restraint law because of questions about the measure. If the use of a restraint is not obvious to the police officer investigating the crash, the officer may rely on the self-report of the drivers involved. One effect of the child restraint law may have been to increase the number of crashed drivers who report that their child was restrained when in fact the child had not been restrained. Correct versus incorrect use of child restraint devices is another confounding factor. The degree to which restraint devices are being used correctly is not assessed and recorded by police officers. Incorrect usage significantly lowers the protection provided by child seats. Surveys have indicated that incorrect usage is a major problem; up to 70% of all child restraint devices are used incorrectly (Shelness and Jewett, 1983). Finally, recall that Michigan's police crash-report form was changed in January 1982 to include a separate category for child restraint device use (added to existing seat-belt-use codes). The addition of child seat codes may have increased awareness of child restraints among police officers, and may have caused an increase in police-reported child seat use, independent of any change in actual usage rates. To avoid problems with the measurement of restraint usage, this study focused on the effects of the PI&E efforts and child restraint law in reducing the ultimate outcome of interest, the number of children injured in crashes.

The number of infants under age 1 injured in motor vehicle crashes is shown in Figure 5.9. The average number of injured infants per month decreased from 1978 to 1980, and changed little in 1981. An obvious discontinuity occurred in early 1982, however. The number of injured infants in the first three months of 1982, when increased PI&E efforts were underway, decreased 30% from the levels expected given the baseline period (time-series modelling results are shown in Appendix Table A.9). After the mandatory use

FIGURE 5.9

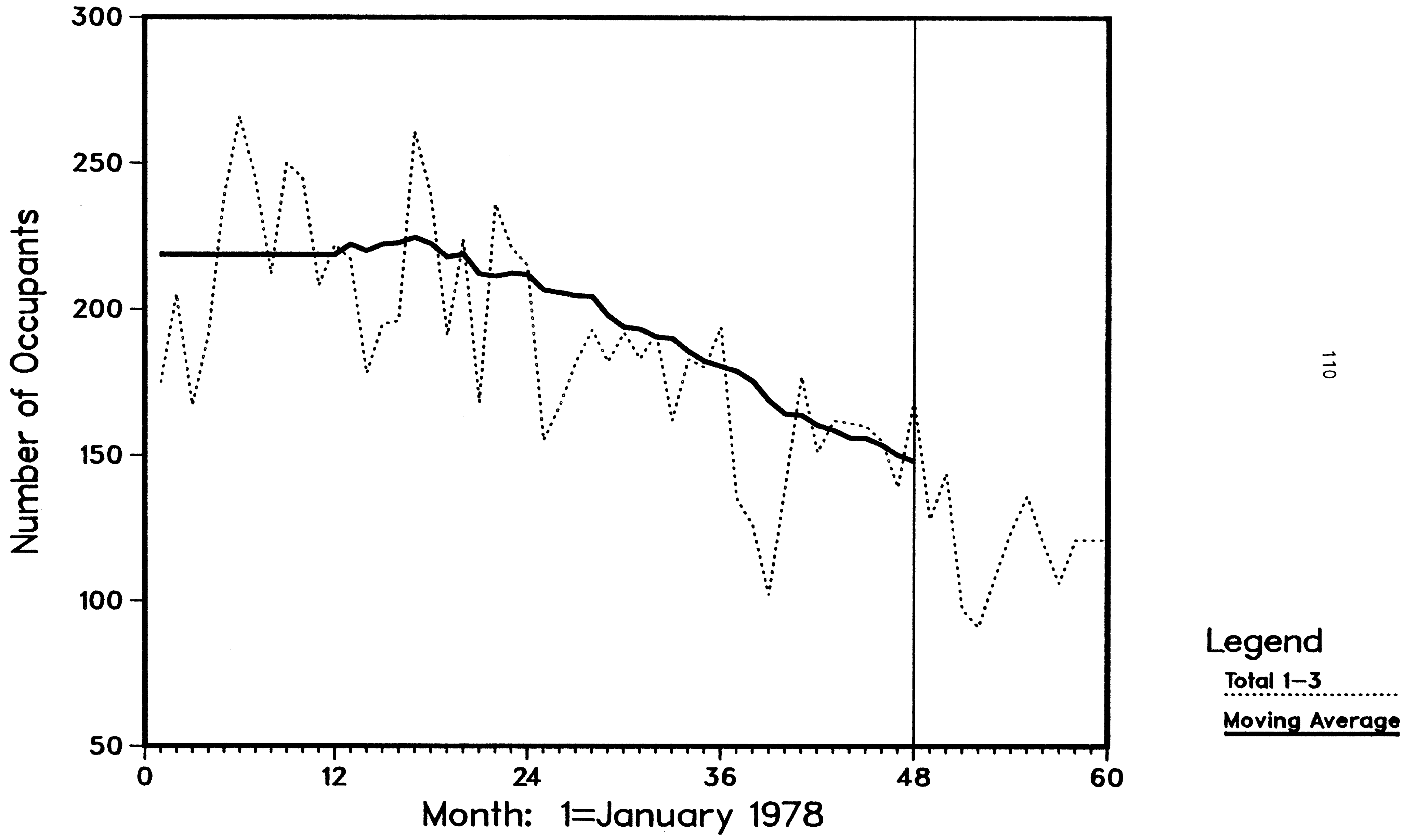

Michigan Injured Motor Vehicle Occupants Age 0
Number of Occupants
0
10
20
30
40
50
60
Month: 1=January 1978
0
12
24
36
48
60
Legend
Total Age 0
Moving Average

law went into effect in April 1982, injuries among infants under age 1 were 50% lower than would have been expected without the law. These results were obtained assuming no long-term downward trend influenced injury figures in 1982. Since the earlier downward trend had leveled out by 1981, this is the most reasonable assumption. Even if one assumes a downward trend in 1982, a significant 29% reduction in injuries is still attributable to the child restraint law (Table A.10).

Significant reductions in the number of injuries also occurred among children age 1 to 3. The number of 1-3-year-olds injured in motor vehicle crashes trend downward from 1979 through 1981 (Figure 5.10). This downward trend is consistent with the overall decrease in traffic crashes for all age groups during this period due to several factors including the economic recession, increased attention to drinking drivers, and other highway safety programs (Wagenaar, in press). If one assumes that this downward trend in injuries among 1-3-year-olds would have stopped without the child restraint law, the estimated effect of the PI&E efforts alone (January-March 1982) is a 20% reduction in children injured, and the effect of the law is a 26% reduction in children injured (Table A.11). A more conservative estimate of the effects of the child restraint law is derived under the reasonable assumption that the downward trend over the 1979-1981 period would have continued even without the child restraint law and associated PI&E efforts. Even after factoring out the effects of the downward trend, a significant 17% reduction in the number of children injured is attributable to the effects of the child restraint law (Table A.12). The PI&E efforts alone, however, had no significant impact on injuries under the assumption that the downward injury trend would have continued without the program.

FIGURE 5.10

Michigan Injured Motor Vehicle Occupants Age 1 to 3

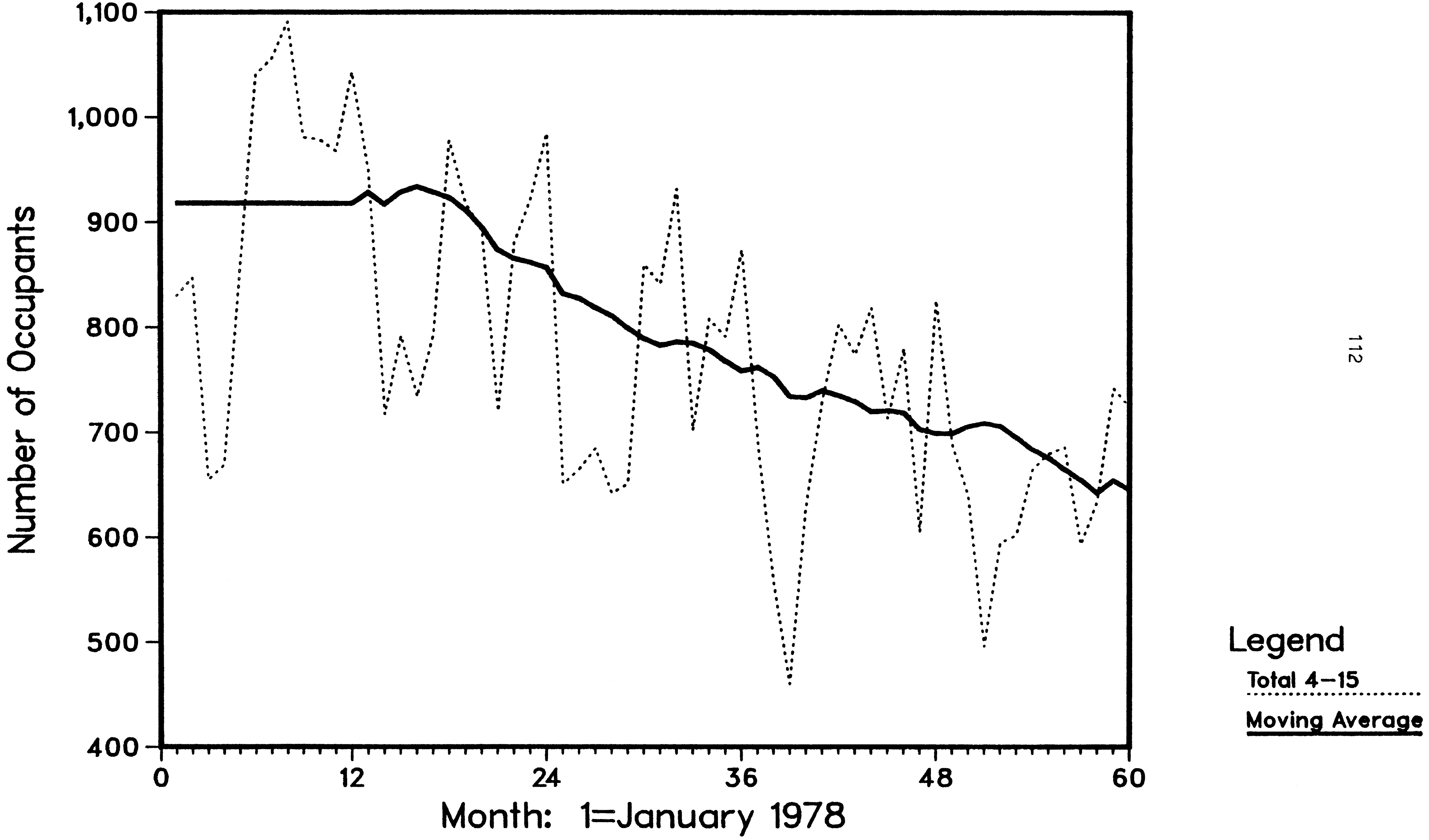


Based on these results, it is clear that the child restraint law substantially reduced the number of traffic casualties among children. In 1981 there were 311 car and light truck passengers under age 1 injured in crashes (excluding out-of-state residents). A 50% reduction associated with the child restraint law means that 156 infant injuries per year are apparently prevented by implementation of the law. Among children age 1 to 3, 1776 were injured in 1981. A 17% reduction attributable to the law represents 302 childhood injuries per year apparently prevented by the law. The magnitude of the effect of the law in reducing injuries is much larger than I expected. Although use of restraints increased substantially in 1982, even after the law less than 40% of injured children were restrained (see Figure 5.2 above). This usage estimate might be further discounted by (1) expected overreporting of use to police officers because of the legal requirement, and (2) portion of children correctly recorded as restrained but who are restrained in an improper manner. In spite of these considerations, substantial casualty reductions occurred after implementation of the mandatory use law. Taking such factors into account, it is apparent that substantially larger reductions in casualties may be achievable if correct use of child restraint systems continues to increase. Whether these substantial short-term effects of the law increase or decay over time will be the subject of a planned second-year followup study.

In addition to analyzing injury trends for infants and young children covered by the law, other age groups were examined for comparison. The number of injured passengers age 4 to 15 exhibited a downward trend from 1979 through 1982 (Figure 5.11). There were no significant discontinuities in 1982, in contrast to the experience of infants and children age 1 to 3. That

FIGURE 5.11

Michigan Injured Motor Vehicle Occupants Age 4 to 15



is, the reduction in injuries in 1982 is not larger than expected, given the 1979-81 downward trend. In short, while there appeared to be a spillover effect of the law in increasing restraint use among 4-15-year-olds (Figure 5.3), the observed increase in usage from 4 to 10% was apparently too small to lead to a measurable reduction in casualties.

The number of injured 16- and 17-year-olds trend downward from 1979 to 1982, consistent with overall crash trends in Michigan (Figure 5.12). No significant discontinuities from pre-existing trends were observed in 1982.

Similarly, no significant changes from overall trends were found in the number of injured 18- to 24-year-olds (Figure 5.13). This age group did exhibit a significant increase in restraint use beginning in April 1982 (see Figure 5.5 above). However, the increase in usage from 8 to 10% was apparently not large enough to result in a measurable casualty reduction.

In contrast, fewer than expected 25-34-year-olds were injured in crashes after April 1982 (Figure 5.14). Controlling out the effects of the slight downward trend over the 1978-1981 period, a 5% decrease in injuries occurred after the child restraint law took effect. This relatively small reduction in casualties is statistically significant at the .10 level, but not at the conventional .05 level (Table A.13). Because the apparent downward trend is slight, some might argue that it does not represent a long-term trend. The analyses were repeated under the assumption that there is no long-term downward trend. Under this assumption, a 13% injury reduction estimate was obtained (significant at .05; Table A.14).

The number of injuries among 35-54-year-olds decreased from 1978 to 1980, but held constant from 1980 to 1981 (Figure 5.15). After April 1982, however, injuries decreased 6%. This reduction is significant at the .05

FIGURE 5.12

Michigan Injured Motor Vehicle Occupants Age 16 and 17

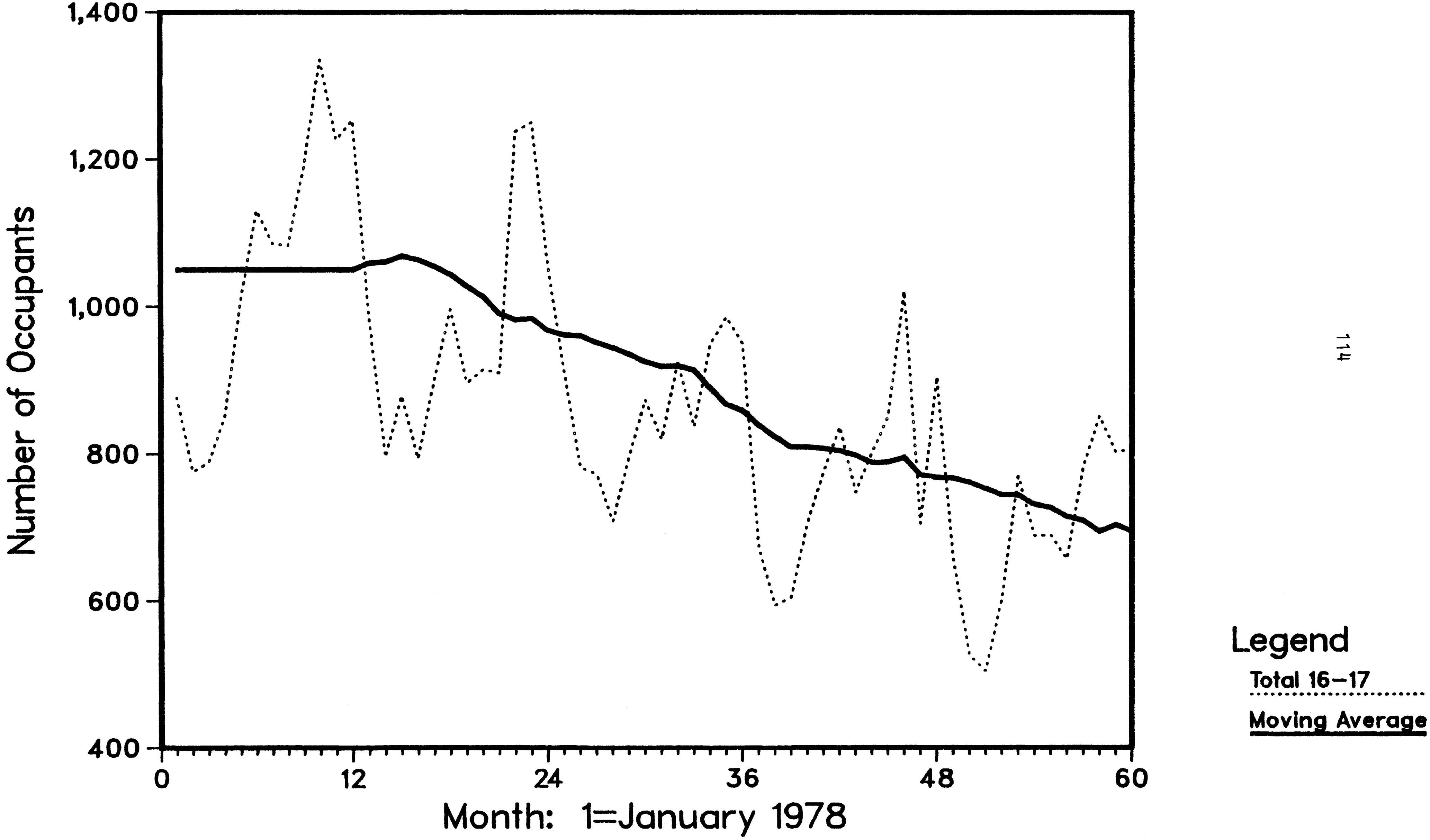


FIGURE 5.13

Michigan Injured Motor Vehicle Occupants Age 18 to 24

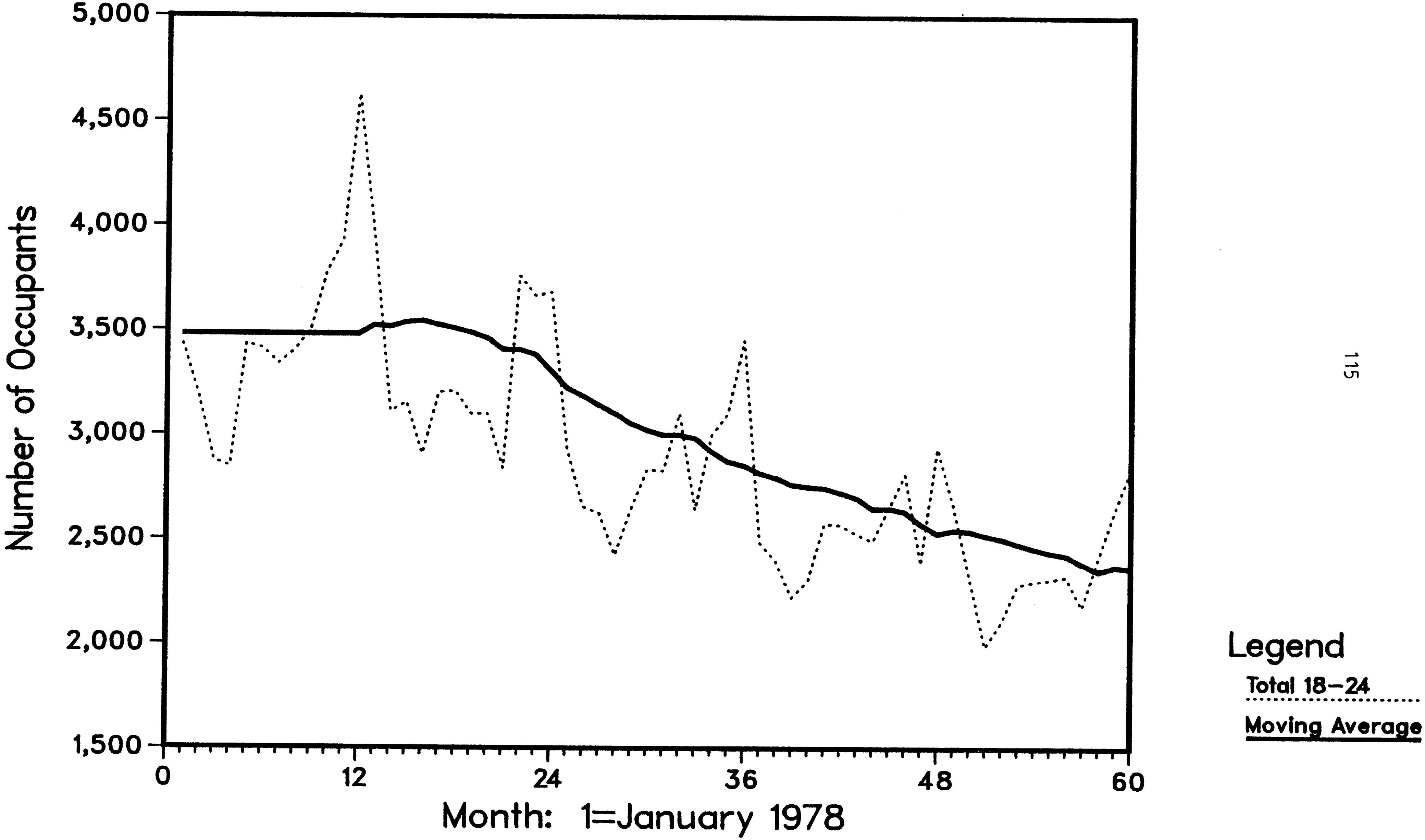


FIGURE 5.14

Michigan Injured Motor Vehicle Occupants Age 25 to 34

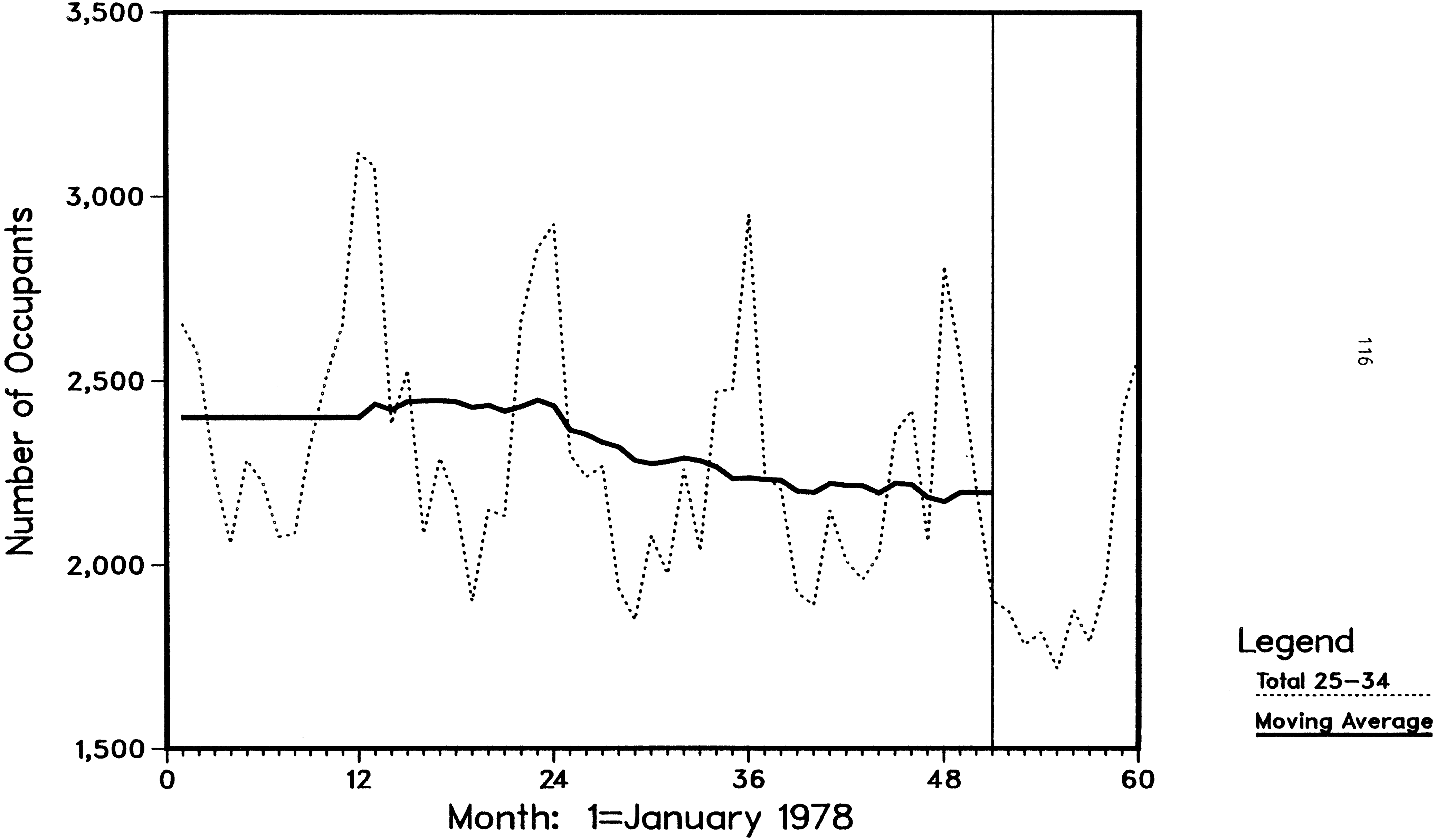
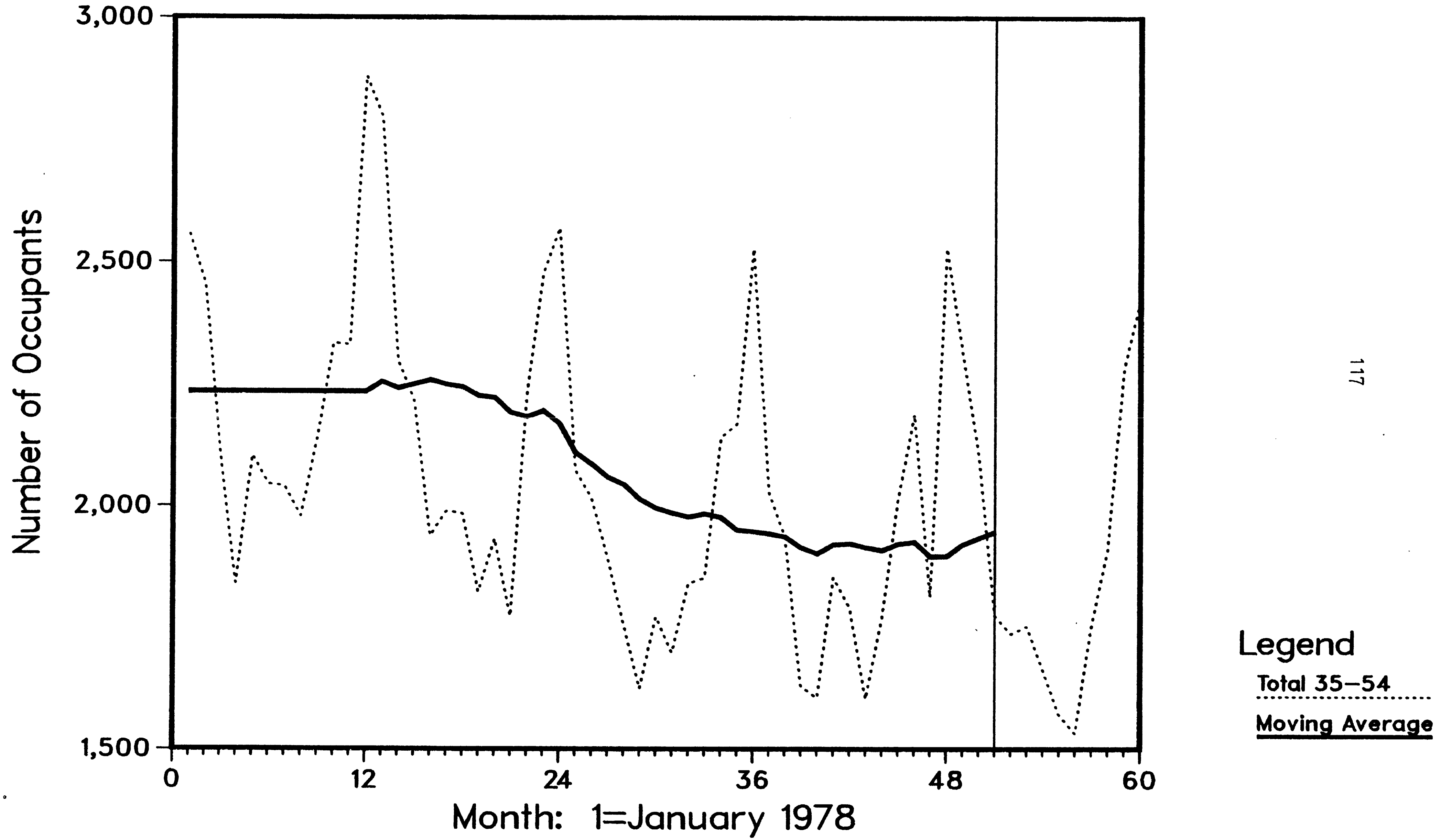


FIGURE 5.15

Michigan Injured Motor Vehicle Occupants Age 35 to 54



level (Table A.15).

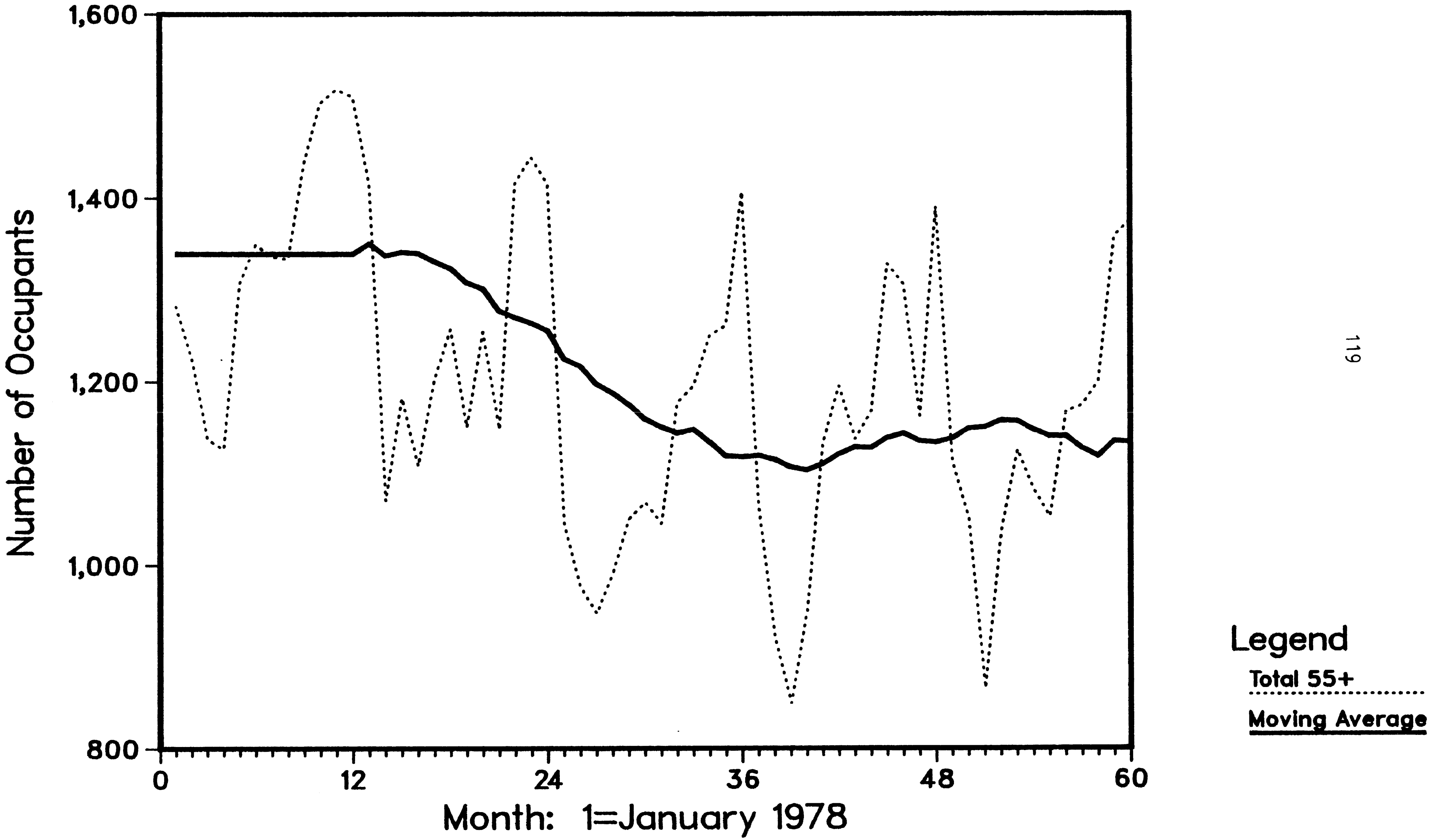
It appears that the mandatory child restraint law had a spillover effect on adults age 25 to 54. The spillover effect is substantially smaller than the main effect of the law in reducing injuries among children, and is of marginal statistical significance. The apparent spillover effect may be due to the response of two distinct populations to the child restraint law and associated public attention. First, parents of young children may be more likely to use restraints after being informed of the legal mandate to restrain their children and the efficacy of restraint systems in preventing injury. Second, adults without children in the age cohort may increase their use of restraints as a result of increased awareness of the importance of restraints both through mass media communication and influence of associates who have young children and have increased their restraint use. In any event, an additional year of followup data will clarify the significance of the apparent effect of the child restraint law on injuries among 25-54-year-olds.

The number of motor vehicle occupants age 55 and over injured in crashes decreased in 1979 and 1980, but has remained quite constant from 1980 through 1982 (Figure 5.16). As expected, there were no significant changes in injury frequency associated with implementation of the child restraint law among those age 55 and over.

Results thus far indicate that the mandatory restraint use law is associated with substantial injury reductions among children subject to the law and small but potentially significant reductions in injuries among those age 25 to 54. To ensure that the observed injury reductions were not due to a sudden change in exposure to the risk of injury rather than the child

FIGURE 5.16

Michigan Injured Motor Vehicle Occupants Age 55 and Over



restraint law, rates of injured occupants per 1000 crashed vehicles were examined for each age group. If the child restraint law reduced the number of injured occupants by increasing restraint use, the number of injured occupants is expected to decrease even when the number of crashed vehicles is held constant. The total number of crashed vehicles in Michigan (including occupants of all ages) is not an ideal exposure index. The number of crashed vehicles stratified by age of the occupants would be better. However, information on the age of uninjured occupants was not available. As a result, exposure to the risk of injury was measured by the total number of crashed vehicles.

The number of injured occupants per 1000 crashed vehicles was calculated for each age group for the January 1978 through December 1982 period. Analyses of these injury rates confirmed the effect of the child restraint law found in the analyses of the frequency of injuries discussed above. The injury rate for occupants under age 1 (Figure 5.17) and age 1 to 3 (Figure 5.18) revealed obvious declines in 1982 after the PI&E efforts and child restraint law were implemented. The injury rate for 4-15-year-olds (Figure 5.19) and 16-17-year-olds (Figure 5.20) are slightly lower in 1982, but there is no obvious discontinuity from the previous four years.

Interpretation of the injury rate plots for those age 18 and over is complicated by the aging of Michigan's population. As the "baby boom" generation born between 1947 and 1959 ages, a smaller proportion of all crashed vehicles will injure young adults, and a larger proportion of all crashed vehicles will injure middle-aged occupants. The changing age structure of the population may explain the decrease in the injury rate among 18-24-year-olds in 1981 and 1982 (Figure 5.21). It may also explain the

FIGURE 5.17

Michigan Motor Vehicle Injury Rate for Occupants Age 0

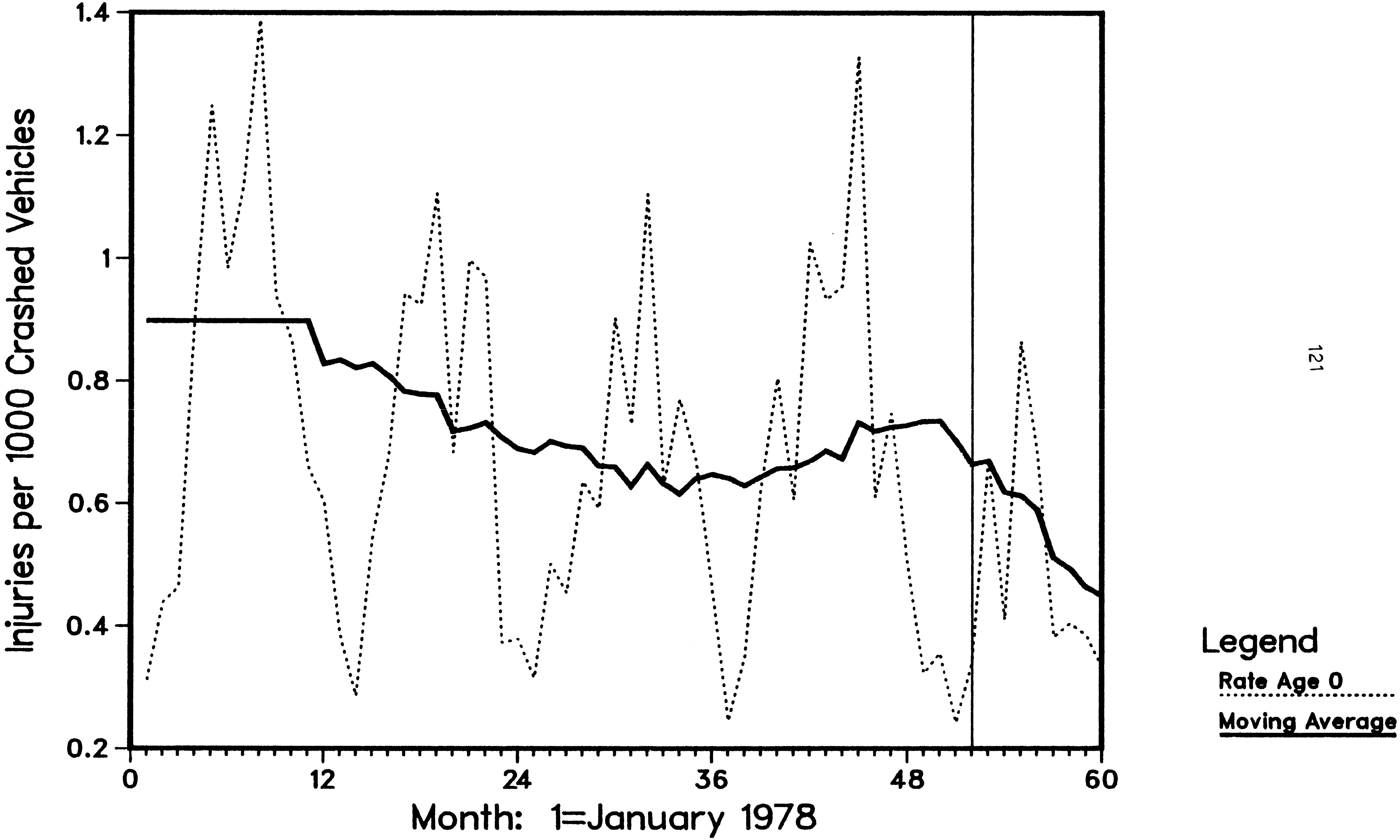


FIGURE 5.18

Michigan Motor Vehicle Injury Rate for Occupants Age 1 to 3

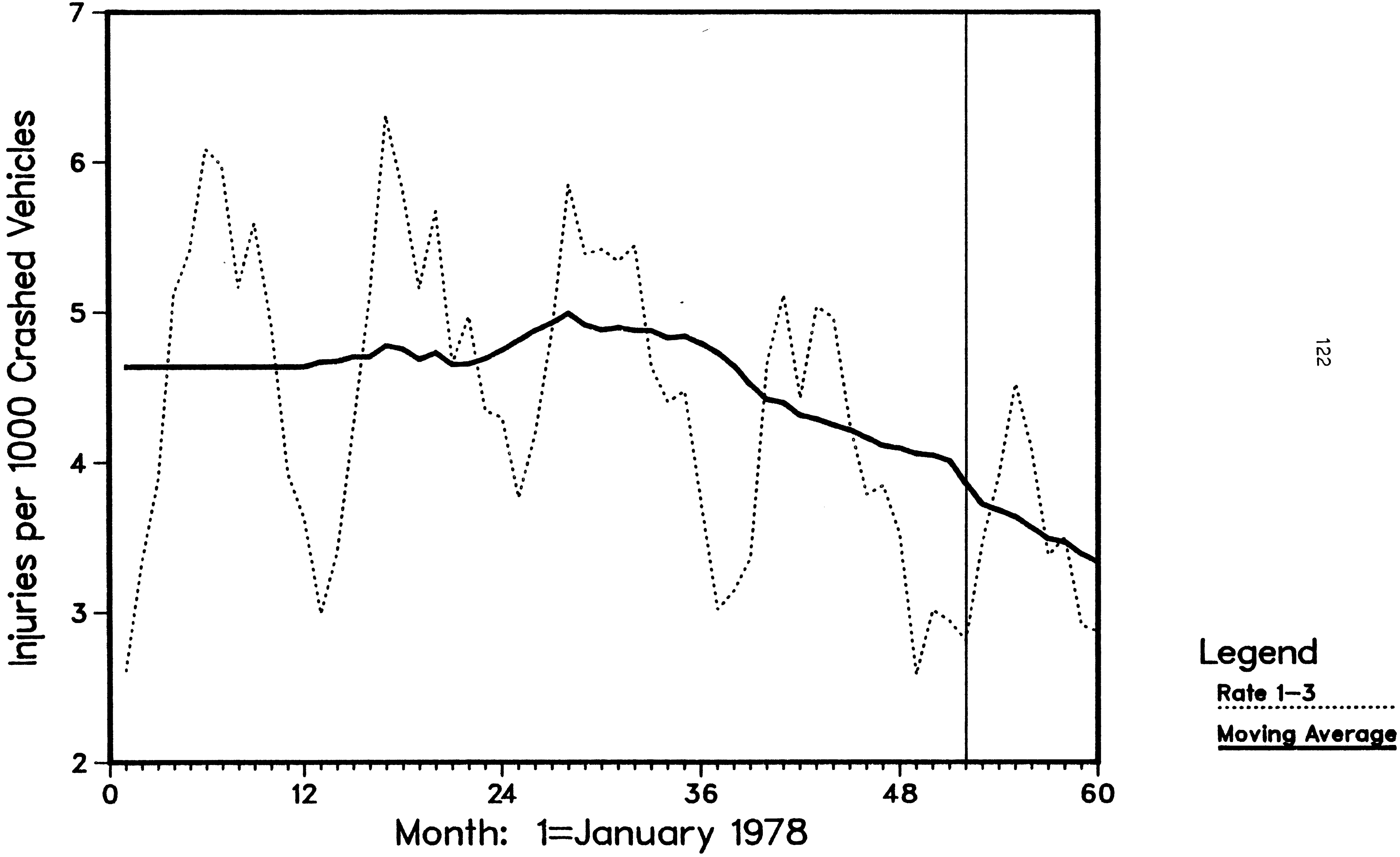


FIGURE 5.19

Michigan Motor Vehicle Injury Rate for Occupants Age 4 to 15

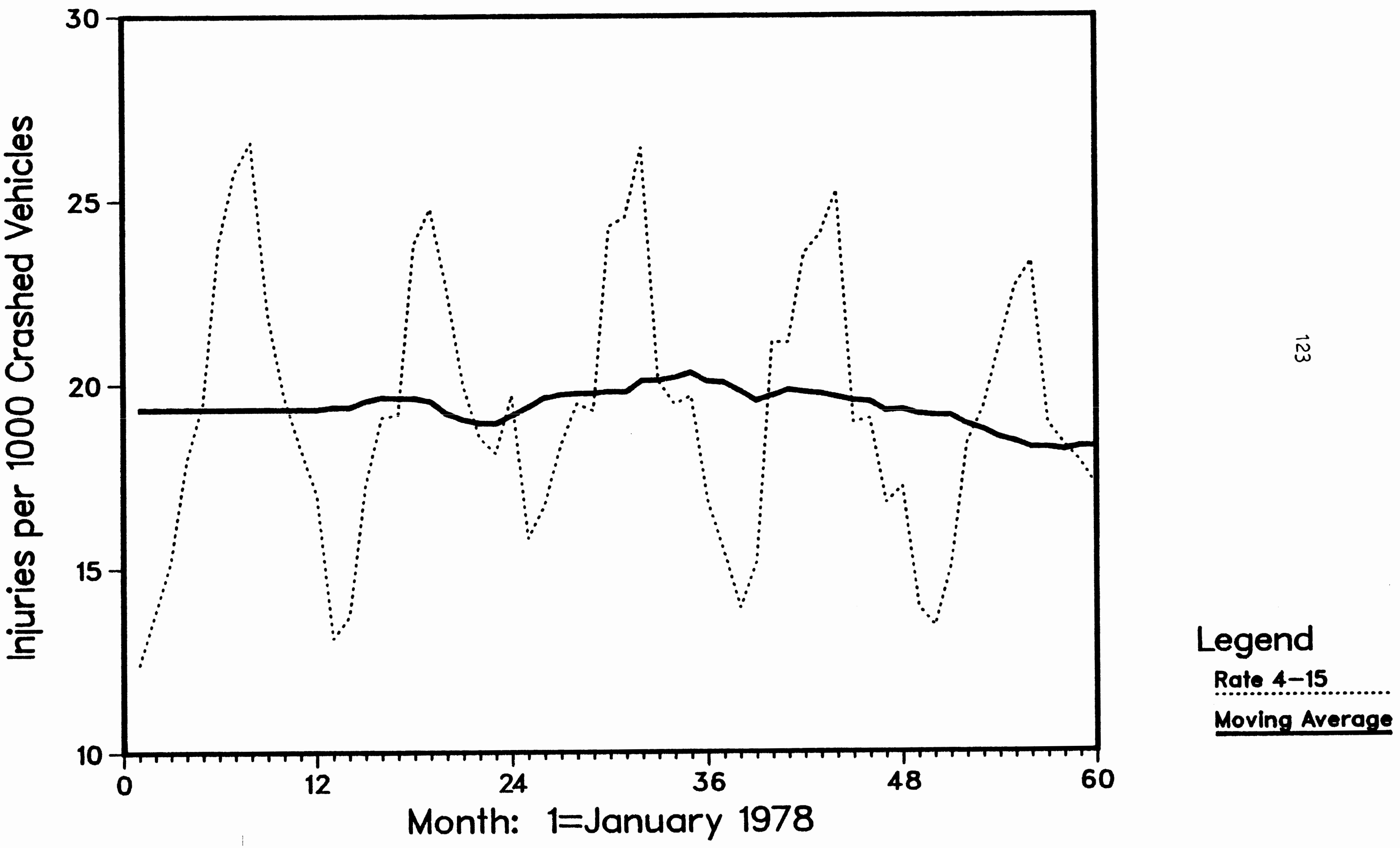


FIGURE 5.20

Michigan Motor Vehicle Injury Rate for Occupants Age 16 and 17

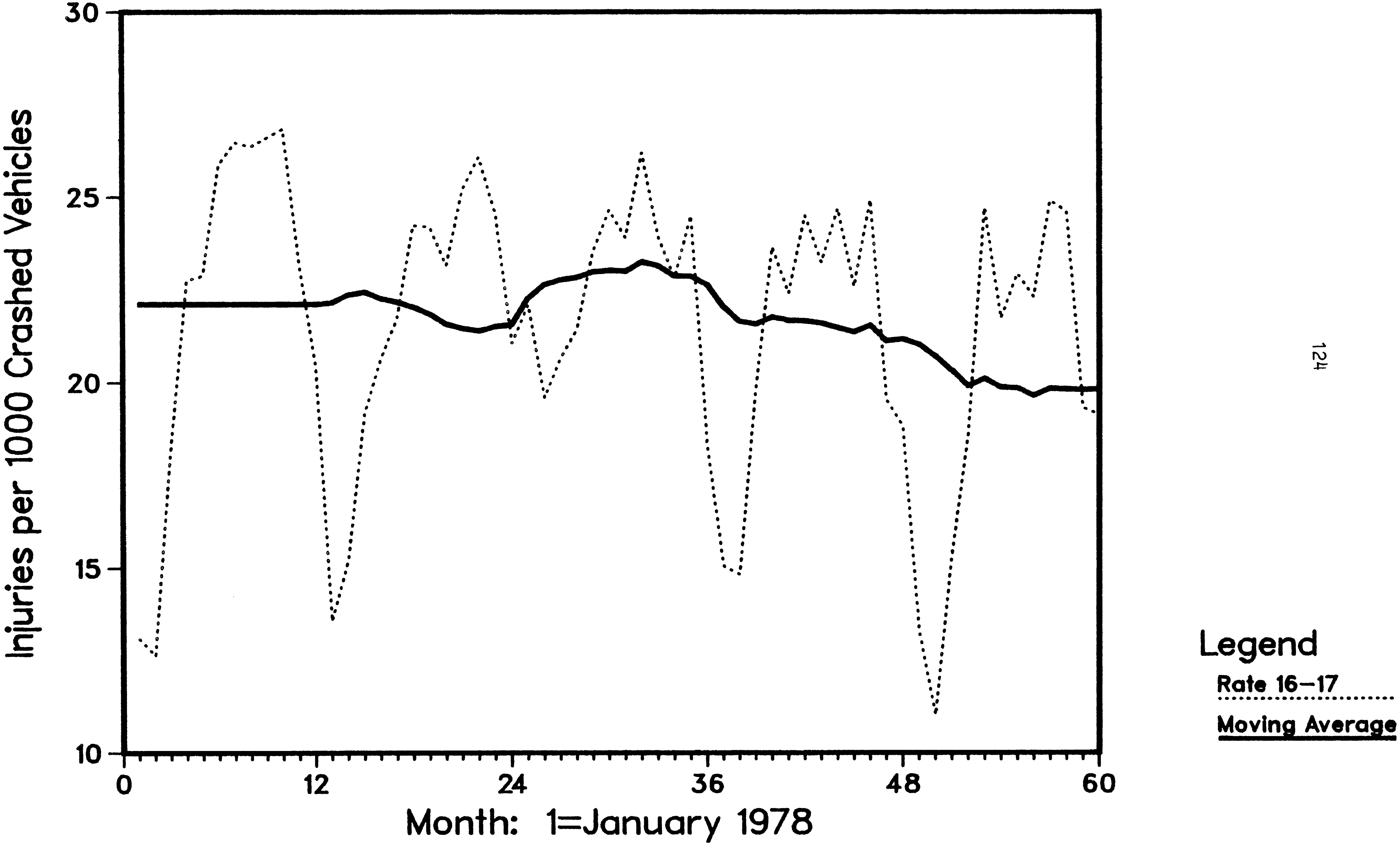
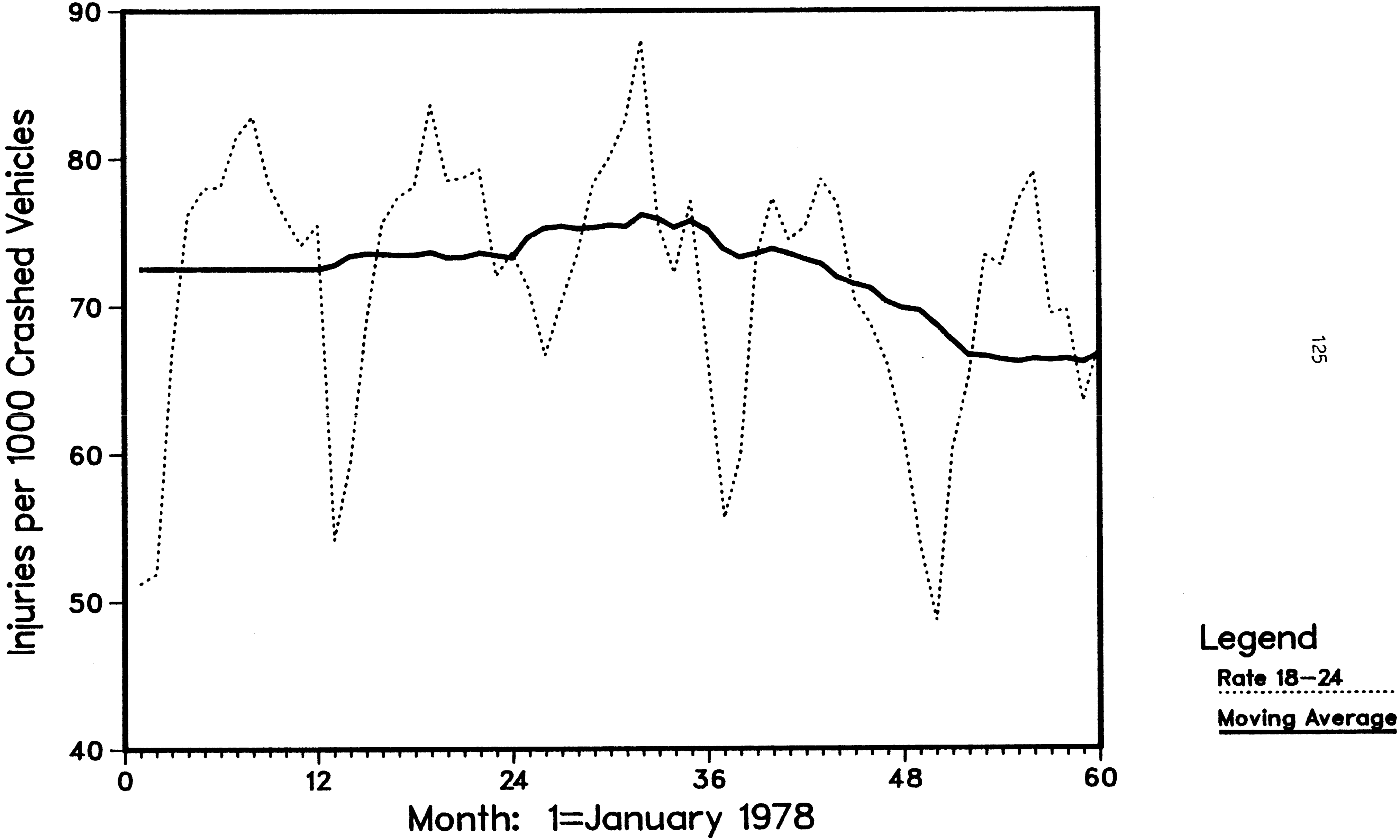


FIGURE 5.21

Michigan Motor Vehicle Injury Rate for Occupants Age 18 to 24



increased injury rate from 1979 to 1981 among those age 25 to 34 (Figure 5.22). The small decrease in the injury rate for 25-34-year-olds in 1982 might reflect the possible spillover effect of the child restraint law noted above. The injury rates for occupants age 35-54 (Figure 5.23) and 55 and over (Figure 5.24) show a gradual upward trend from 1979 through 1982. Increased numbers of motor vehicle occupants in these age groups is a possible explanation of the observed trend.

Observed changes in age-specific injury rates must be interpreted cautiously because the denominator upon which the rate was based is not age-specific. The need for regularly collected (i.e., monthly or quarterly) age-specific information on the exposure to risk of motor vehicle crash-related injury is again apparent. The most important point here, however, is that the injury rate for young children exhibited a noticeable decline after the child restraint law and related PI&E programs were implemented, consistent with the more direct analyses of the frequency of injury discussed earlier. We now return to the analyses of injury frequencies.

The initial analyses split the age group to which the law applied into two segments: infants under age 1, and children age 1 to 3. Both of these segments experienced significant reductions in injuries. Further clarification of the nature of the child restraint law effect was achieved through separate analyses of injury trends across several variables of interest. To maintain a sufficient number of cases in subsequent analyses for the accurate detection of the law's effects, all children under age 4 were examined as a single group.

The first classification of injured children was according to their

FIGURE 5.22

Michigan Motor Vehicle Injury Rate for Occupants Age 25 to 34

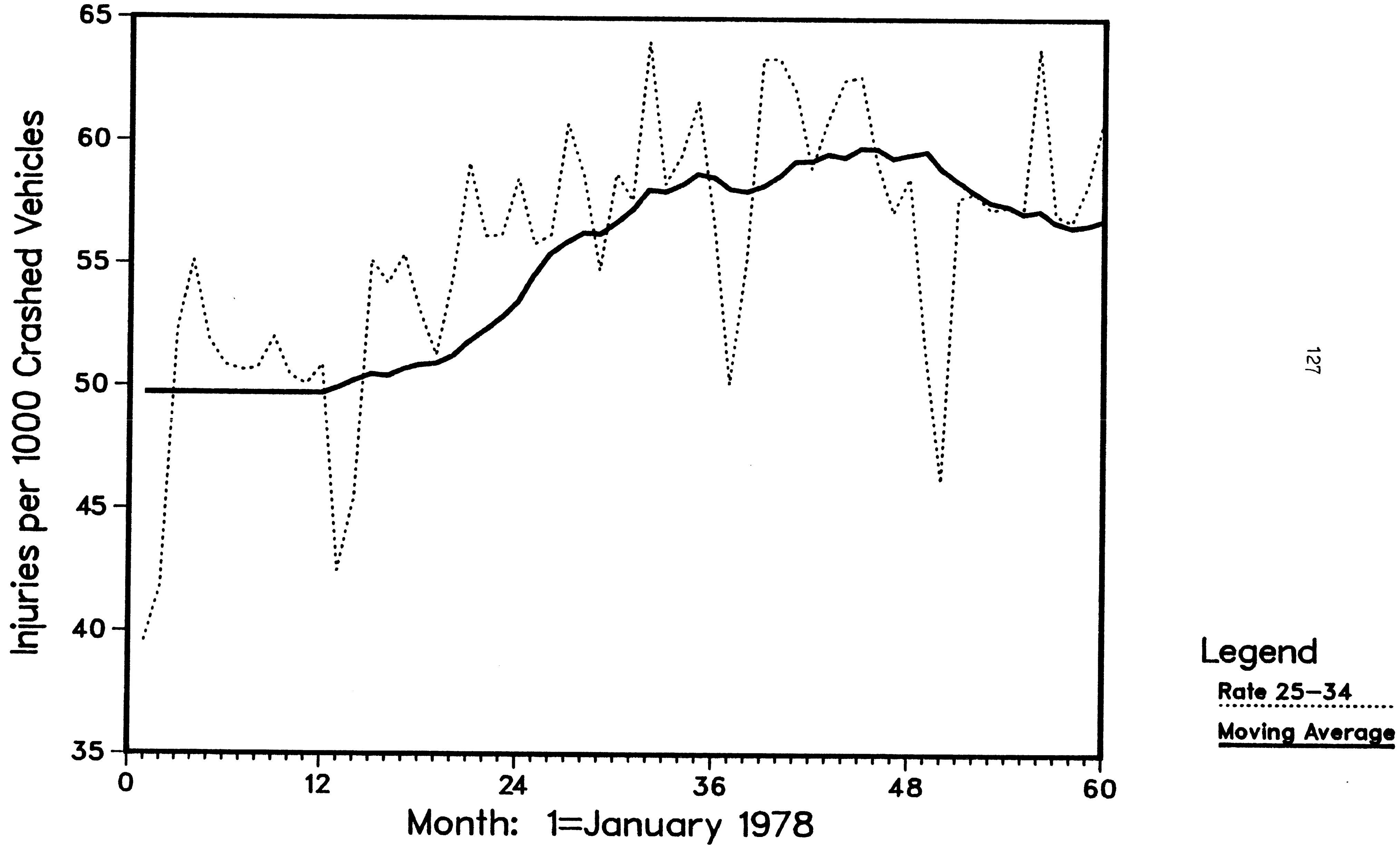


FIGURE 5.23

Michigan Motor Vehicle Injury Rate for Occupants Age 35 to 54

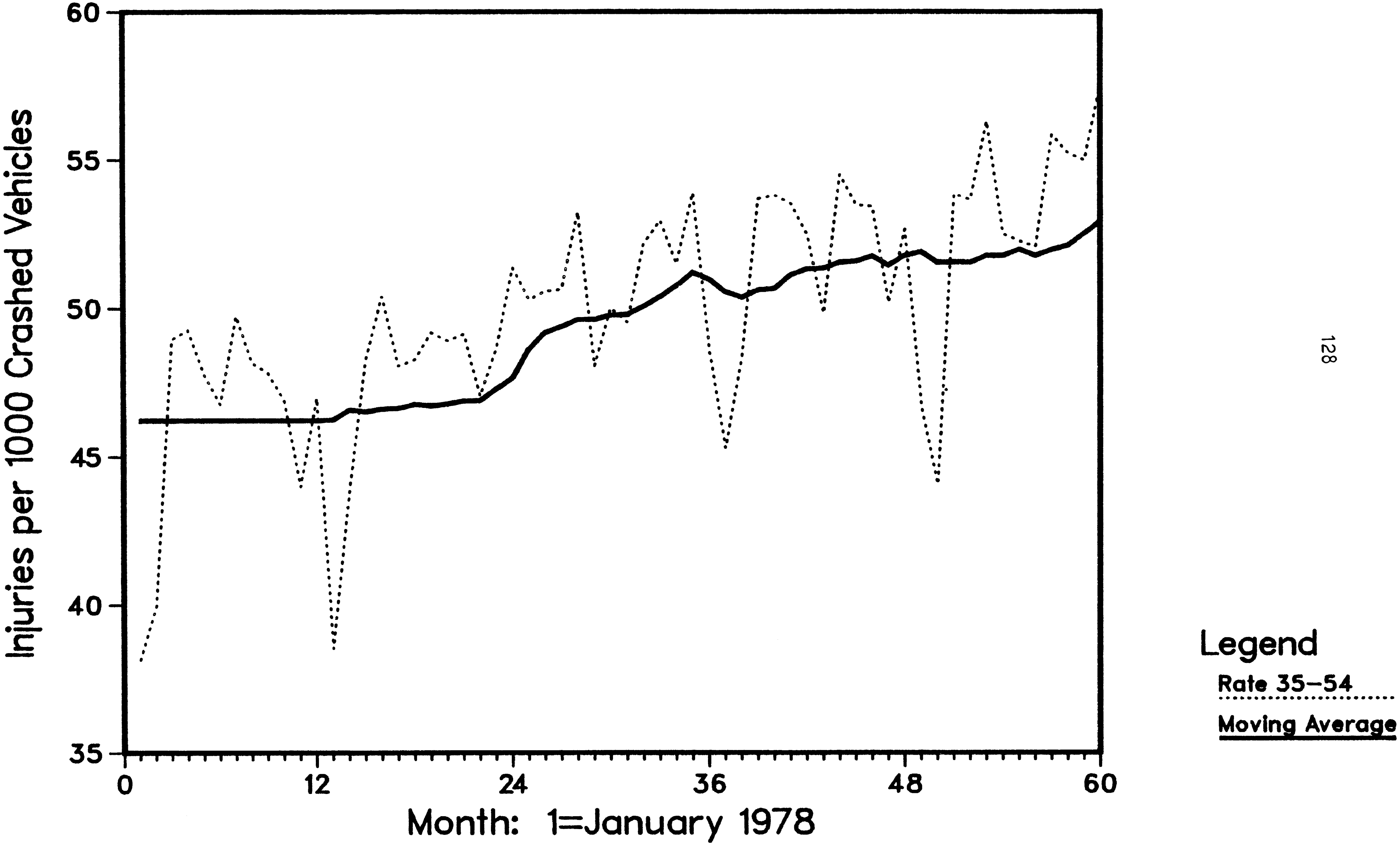
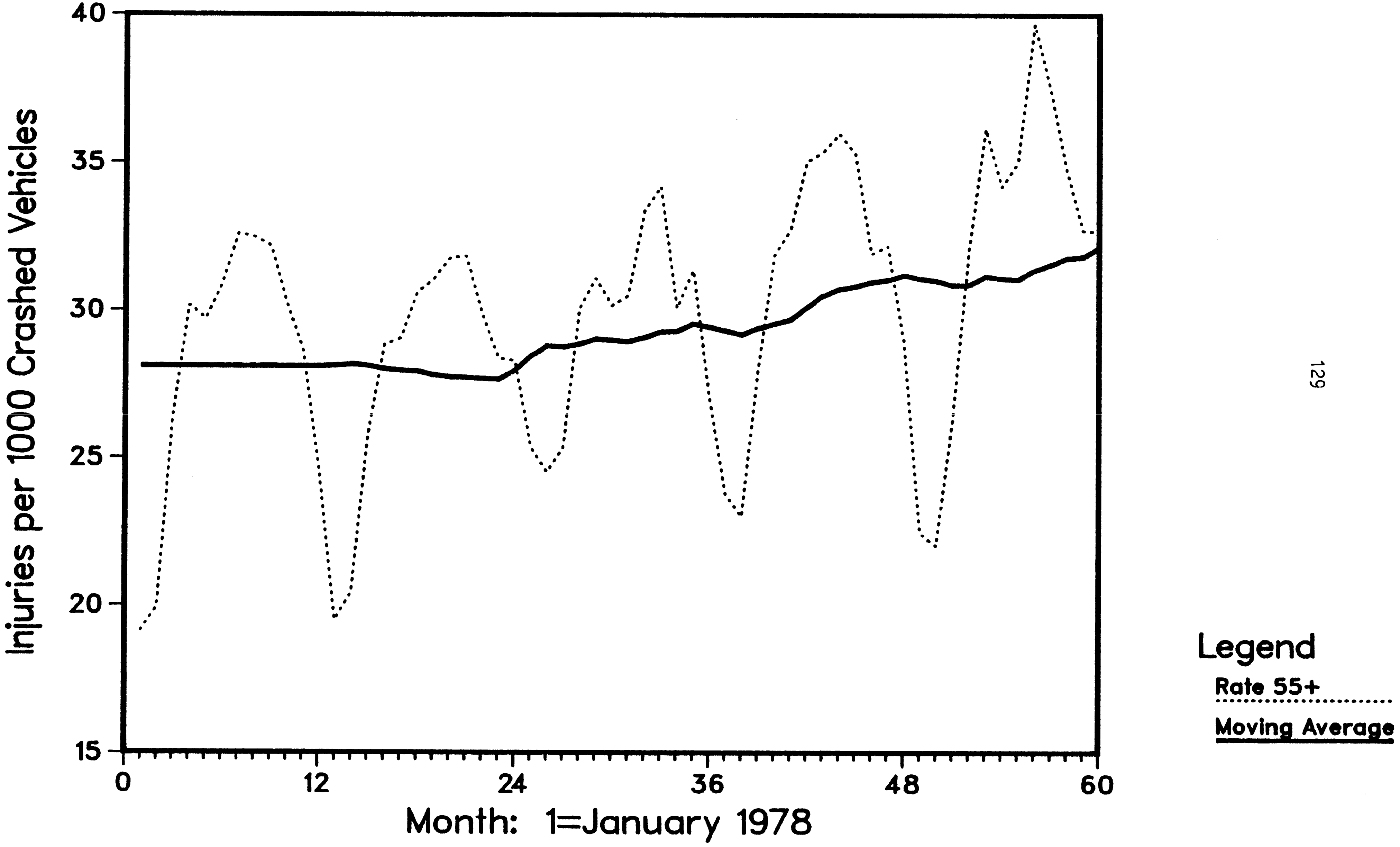


FIGURE 5.24

Michigan Motor Vehicle Injury Rate for Occupants Age 55 and Over



restraint use at the time of the crash. The restraint law significantly increased the percent of child occupants using restraints (see Figures 5.1 and 5.2 above). Consistent with the findings based on the restraint usage rate, separate analyses of restrained and unrestrained children revealed a 45% increase in the number of children restrained and a 40% reduction in the number unrestrained (Figures 5.25 and 5.26; time-series model results are in Appendix Tables A.17 and A.18). Thus the law apparently shifted a significant proportion of crash-involved children from the unrestrained to the restrained category. Recalling possible problems with the measurement of restraint use discussed above, these findings should be viewed cautiously.

The second classification examined was injury severity. Severity of injuries to children were divided into two groups. The first group consisted of moderately injured children, and included those recorded as having a "possible" or "nonincapacitating" injury. The second group consisted of severely injured children, and included fatalities and those recorded as sustaining an "incapacitating" injury. After controlling for the downward trend from 1979 through 1981, the number of children experiencing moderate injuries dropped an estimated 22% when the child restraint law took effect (Figure 5.27; Table A.19). In contrast, severe injuries did not decrease significantly, after accounting for the moderate negative trend over the baseline period (Figure 5.28, Table A.20). If one disregards the moderate baseline trend, an estimated 24% reduction in severe injuries is associated with the child restraint law (Table A.21). In short, it appears that the child restraint law had its main effect in reducing moderate injuries, and less effect in reducing severe injuries and death.

While a small proportion of crashes are unsurvivable even with

FIGURE 5.25

Michigan Restrained Injured Occupants Age 0 to 3

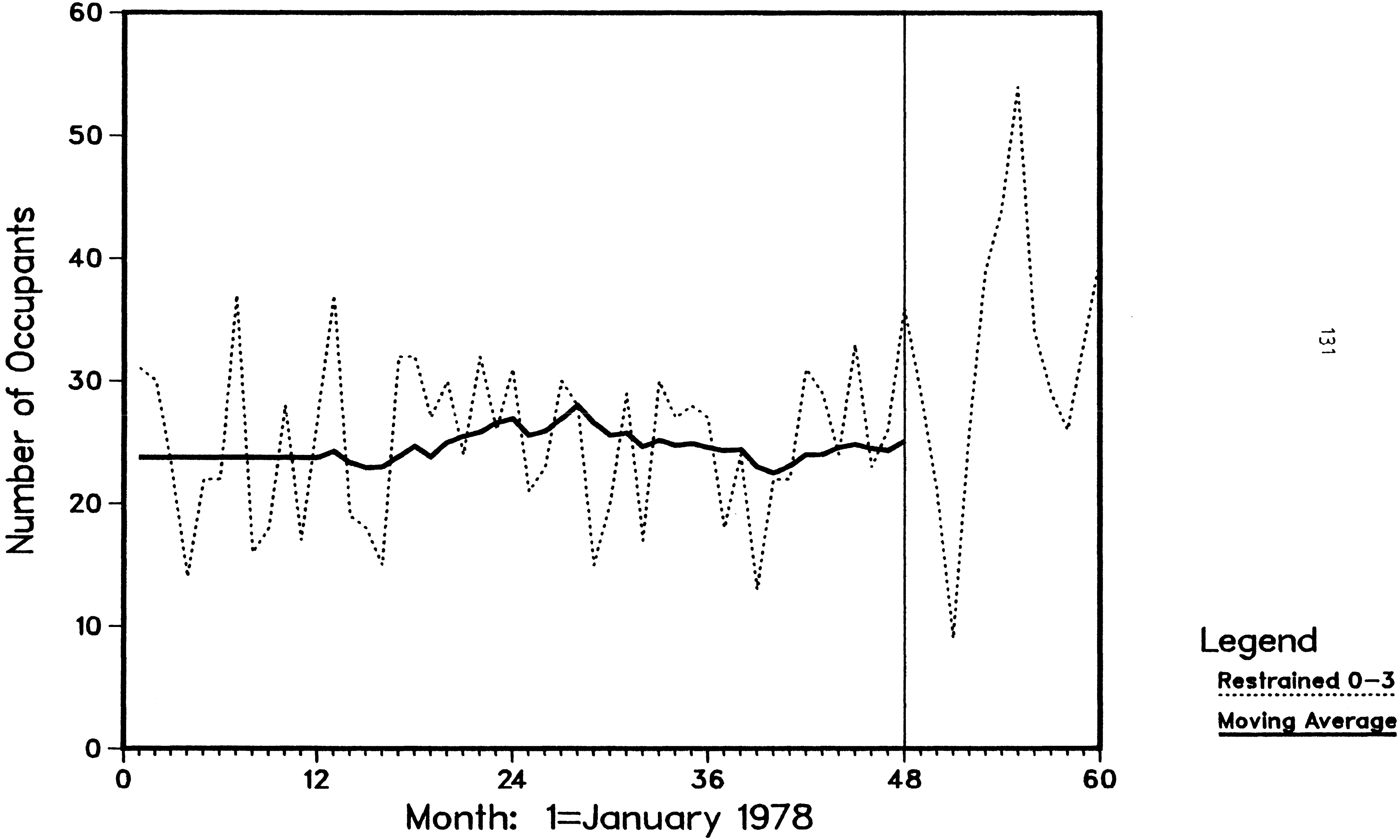


FIGURE 5.26

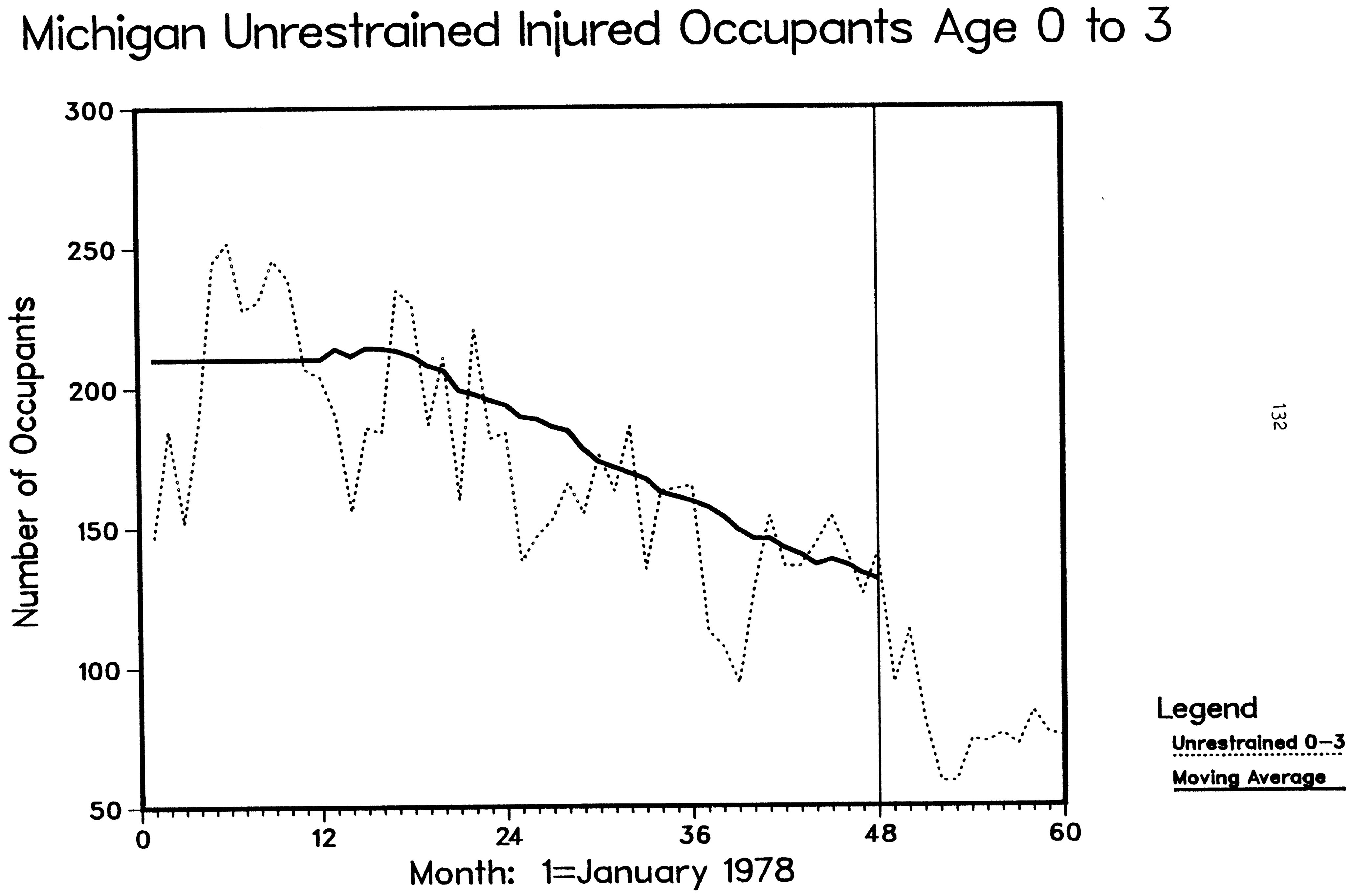

Michigan Unrestrained Injured Occupants Age 0 to 3
Number of Occupants
300
250
200
150
100
50
0
12
24
36
48
60
Month: 1=January 1978
Legend
Unrestrained 0-3
Moving Average

FIGURE 5.27

Michigan Moderately Injured Motor Vehicle Occupants Age 0 to 3

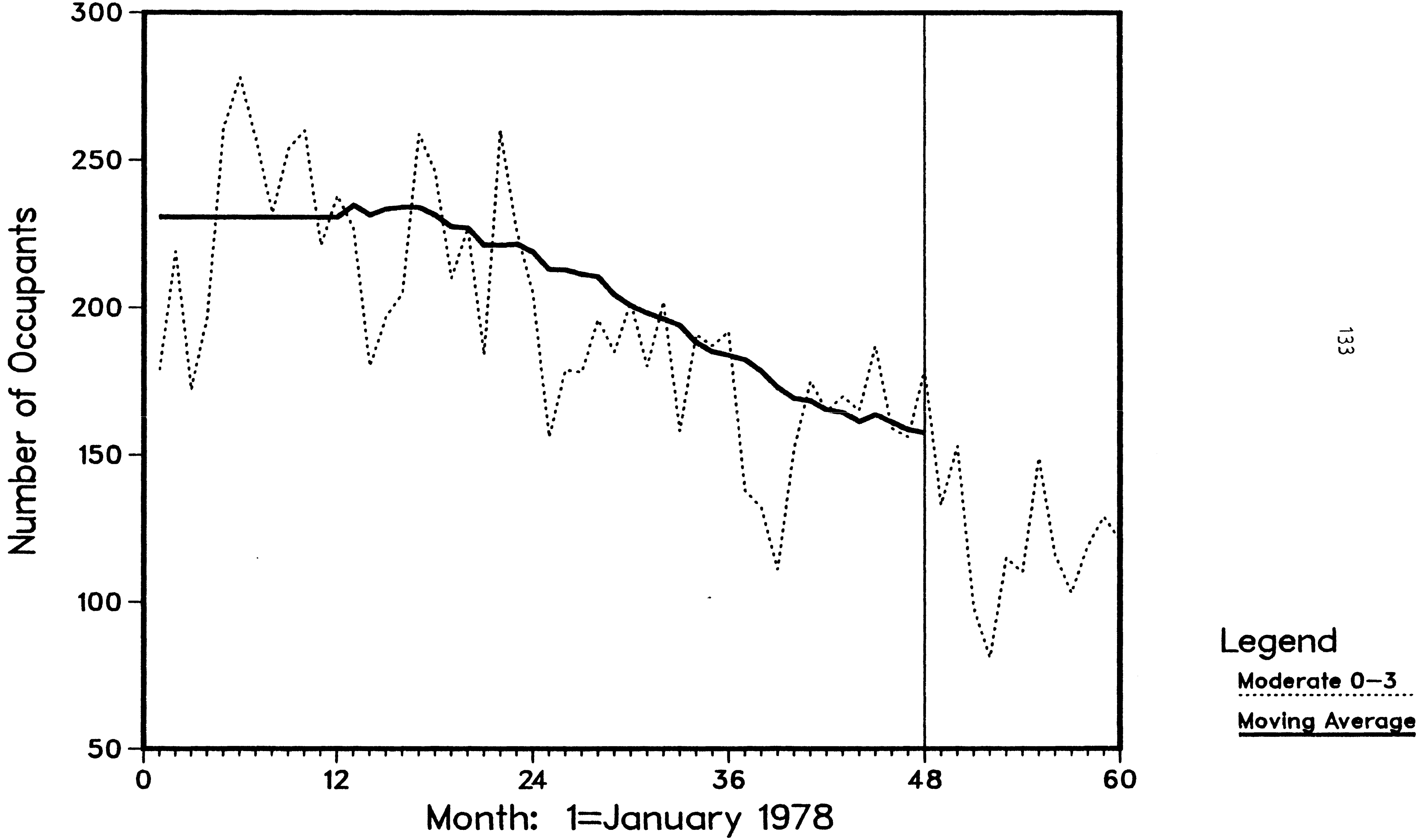
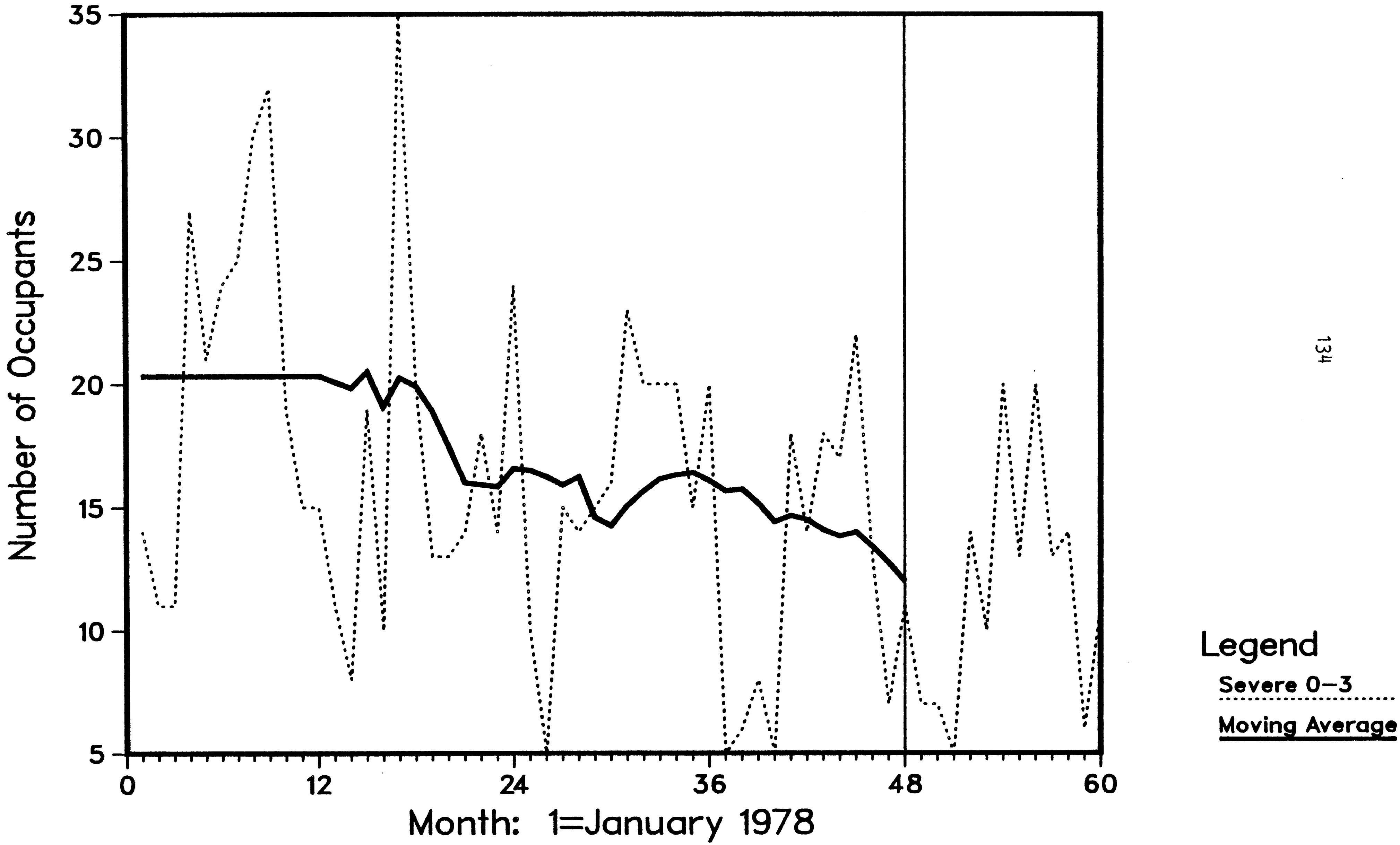


FIGURE 5.28

Michigan Severely Injured Motor Vehicle Occupants Age 0 to 3



restraints, the larger effect of the law on moderate injuries than severe injuries is not due to lower effectiveness of restraints in more severe crashes. The larger effect of the child restraint law in reducing moderate injuries is most likely due to higher restraint use among those involved in less severe crashes than among those involved in severe crashes (see Table 4.5 above). As noted earlier, those at greatest risk of severe injury are the ones that are least likely to change their (non)restraint-using behavior as a result of PI&E efforts and mandating legislation. This proposition was explicitly tested by time-series analyses of childhood injuries categorized by severity of the crash, as measured by extent of vehicle damage. Vehicle damage provides a measure of the seriousness of a crash independent of injuries sustained.

The Traffic Accident Damage (TAD) scale is used by investigating officers to rank the extent of damage to a vehicle on an eight-point scale (scoring ranges from one--no damage to eight--maximum damage). The TAD scale was recalculated into three categories to ensure adequate number of cases for analysis. Low damage represents TAD scores one and two, medium damage TAD three and four, and high damage TAD five through eight. The mandatory child restraint law is associated with a 41% reduction in childhood injuries in low-damage crashes (Figure 5.29, Table A.23), a 20% reduction in medium-damage crashes (Figure 5.30, Table A.24), and a 12% reduction in high-damage crashes (Figure 5.31, Table A.25). These result confirm the expectation that the child restraint law was most effective in increasing restraint use among those at lower levels of risk of serious injury, and least effective among those most at risk of serious injury. Nevertheless, the child restraint law was associated with significant reductions in

FIGURE 5.29

Michigan Injured Occupants Age 0 to 3 in Low Damage Vehicles

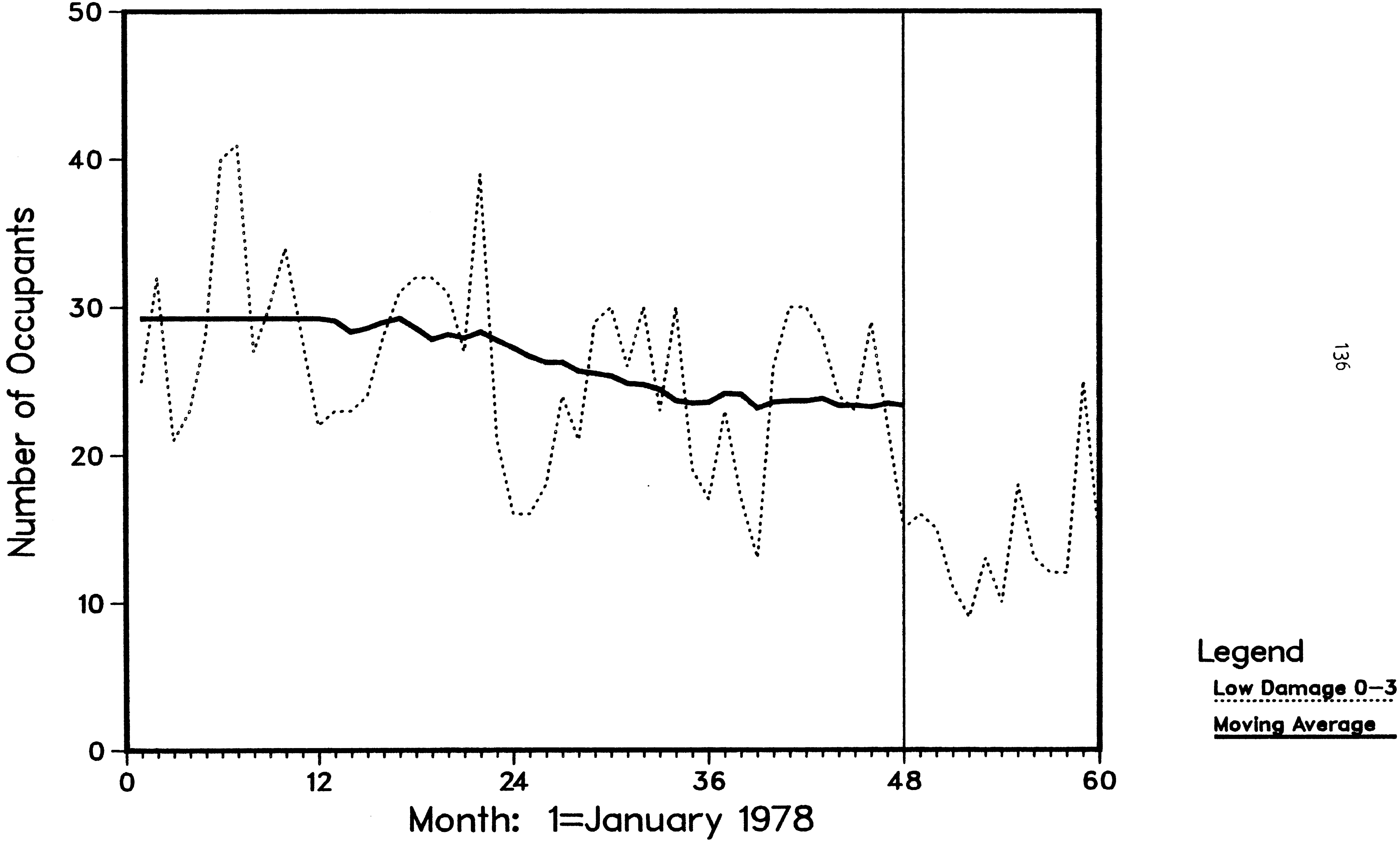


FIGURE 5.30

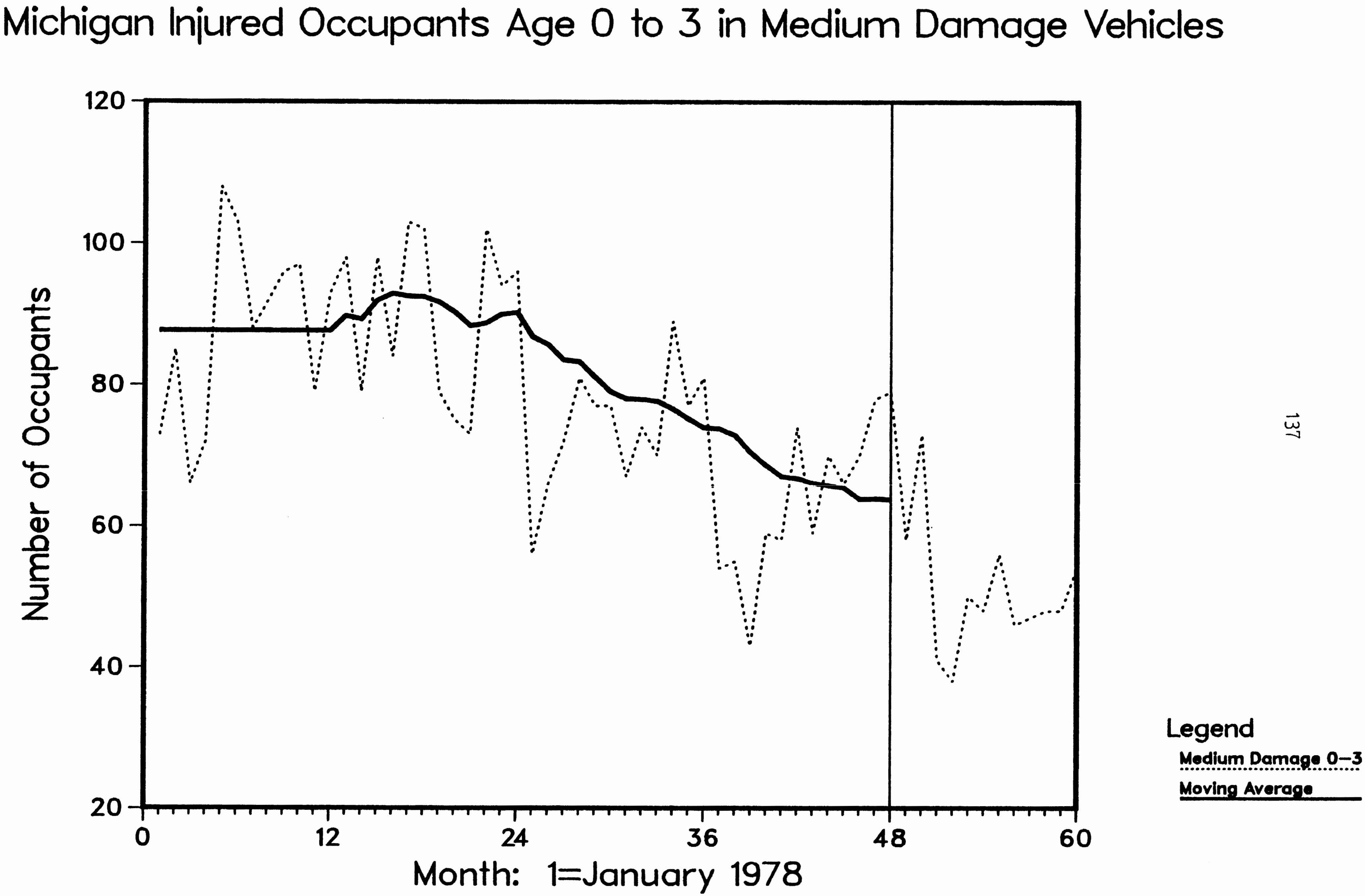
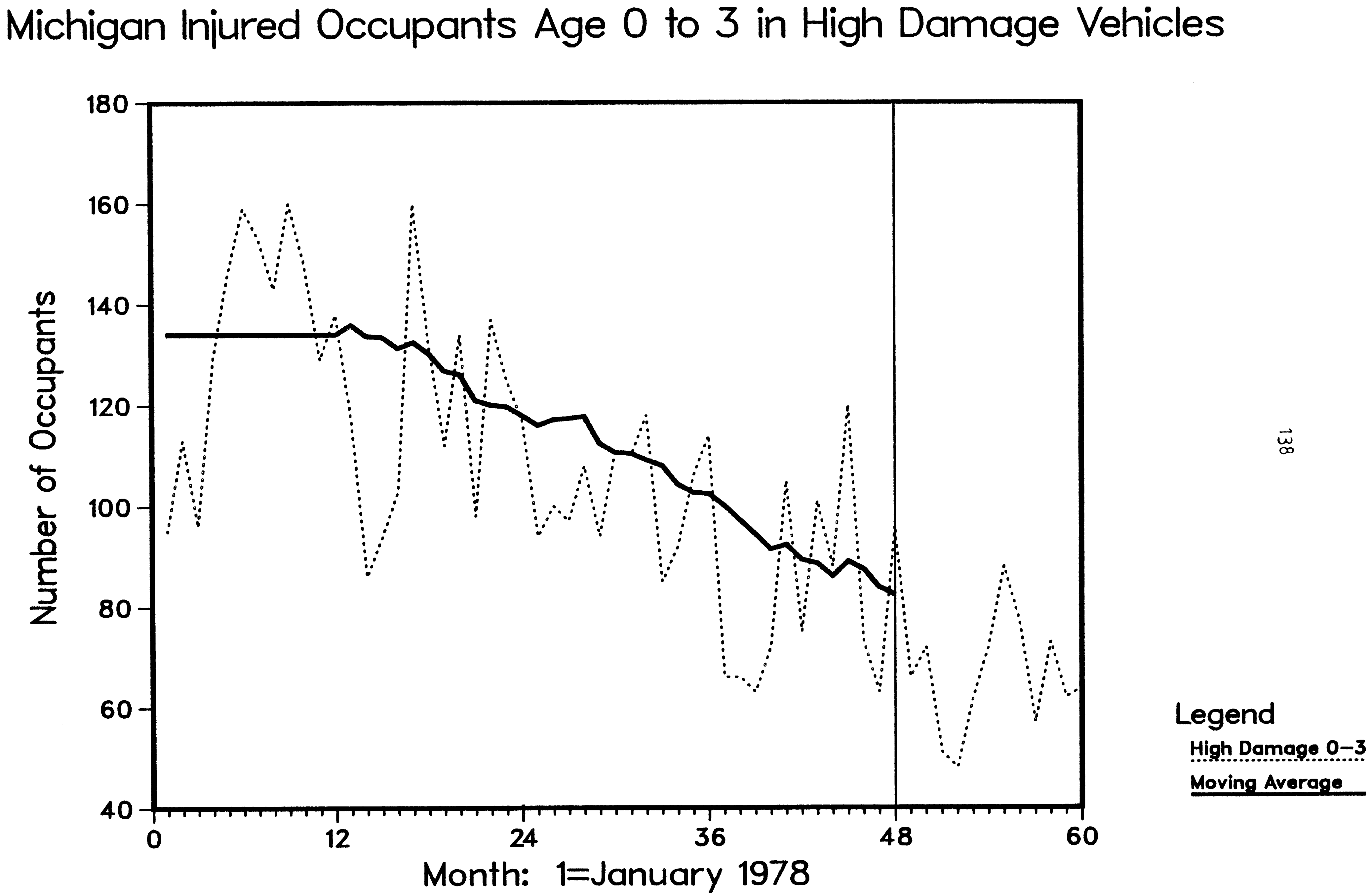

Michigan Injured Occupants Age 0 to 3 in Medium Damage Vehicles
Number of Occupants
120
100
80
60
40
20
0
12
24
36
48
60
Month: 1=January 1978
Legend
Medium Damage 0-3
Moving Average

FIGURE 5.31

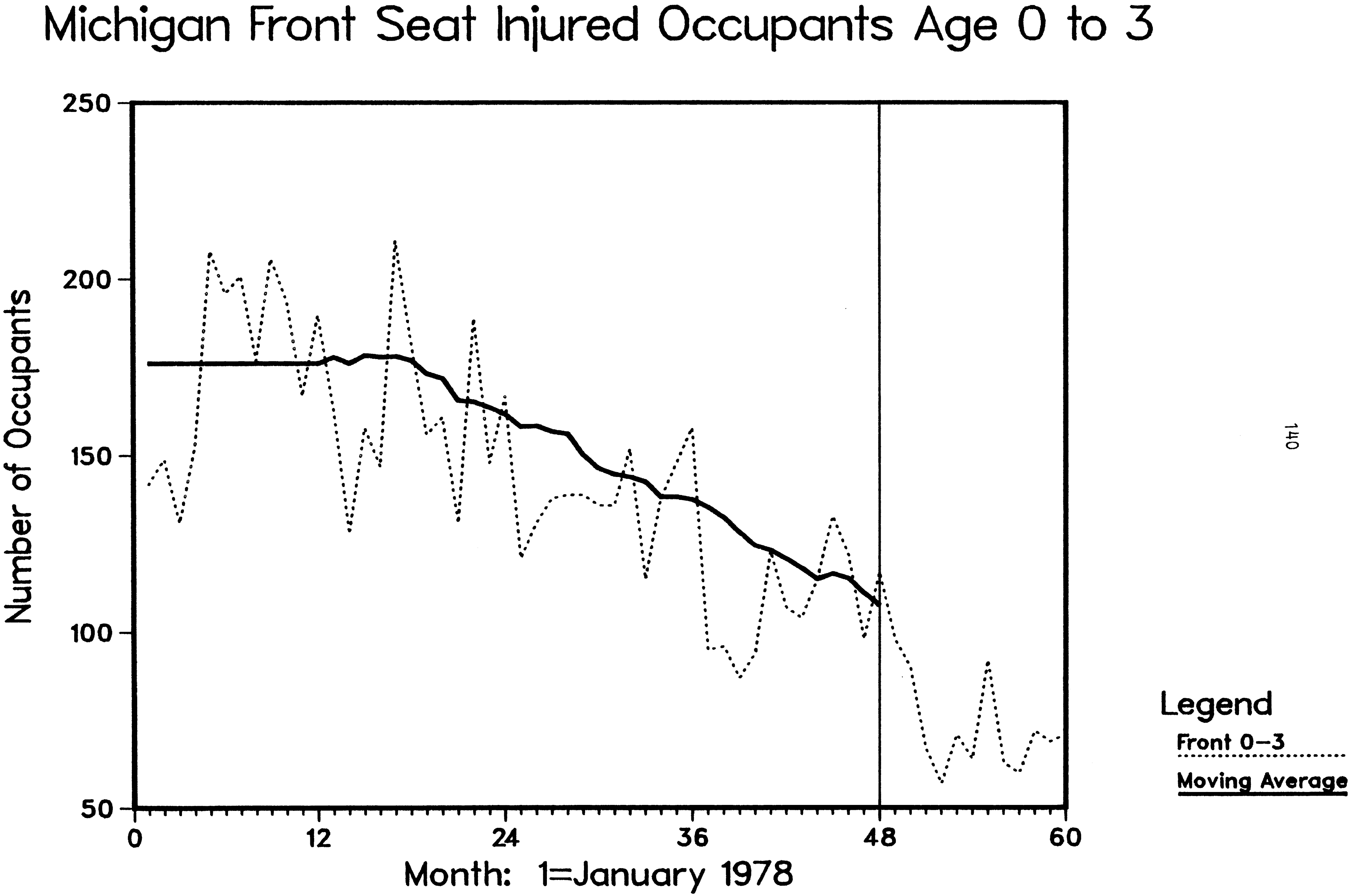

Michigan Injured Occupants Age 0 to 3 in High Damage Vehicles
180
160
140
120
100
80
60
40
Number of Occupants
0
12
24
36
48
60
Month: 1=January 1978
Legend
High Damage 0-3
Moving Average

childhood injuries even among high-risk, difficult-to-change drivers involved in severe crashes. Furthermore, many childhood injuries occur in crashes that involve low or moderate levels of vehicle damage; the child restraint law dramatically reduced injuries in such crashes.

Finally, effects of the child restraint law on injuries among children were examined for various seating positions. There are two dimensions of the new law and associated publicity that may influence seating position of children in automobiles. First, the law states that a child age 1 through 3 must be restrained in an approved child restraint device if riding in the front seat, but use of adult lap belt is legally adequate in the rear seat. Second, publicity and education efforts surrounding the law informed drivers that the safest place for children is in the rear seat.

Time-series analyses were conducted for childhood injuries in three categories of seating position: front seat, rear seat, and other positions primarily consisting of cargo area passengers. After controlling for the downward trend during the baseline period, injuries among children riding in front seats decreased 28% when the child restraint law took effect (Figure 5.32, Table A.26). In contrast, children riding in rear seats experienced no change in injuries (Figure 5.33, Tables A.27 and A.28). The substantial decrease in front-seat injuries is probably due to a decrease in the number of young children riding in the front seat, and an increase in the proportion of those riding in the front seat that are restrained. No net change in the number of children injured in the rear seat is probably the result of two effects. First, some children who before the law rode in the front seat may have been moved to the rear seat. Second, the increased number of children riding in rear seats did not lead to increased rear-seat injuries because a

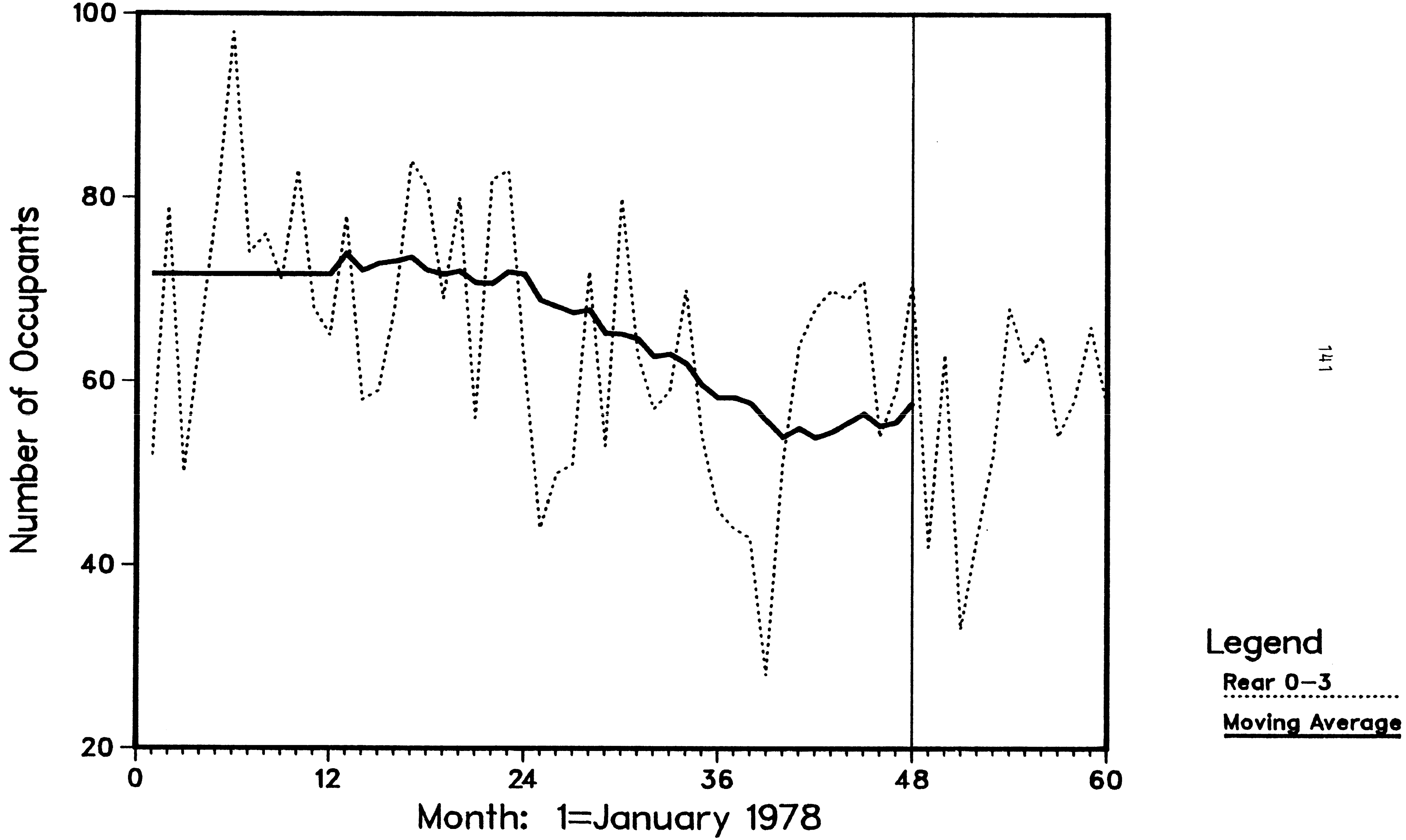
FIGURE 5.32



Michigan Front Seat Injured Occupants Age 0 to 3
Number of Occupants
250
200
150
100
50
0
12
24
36
48
60
Month: 1=January 1978
Legend
Front 0-3
Moving Average

FIGURE 5.33

Michigan Rear Seat Injured Occupants Age 0 to 3



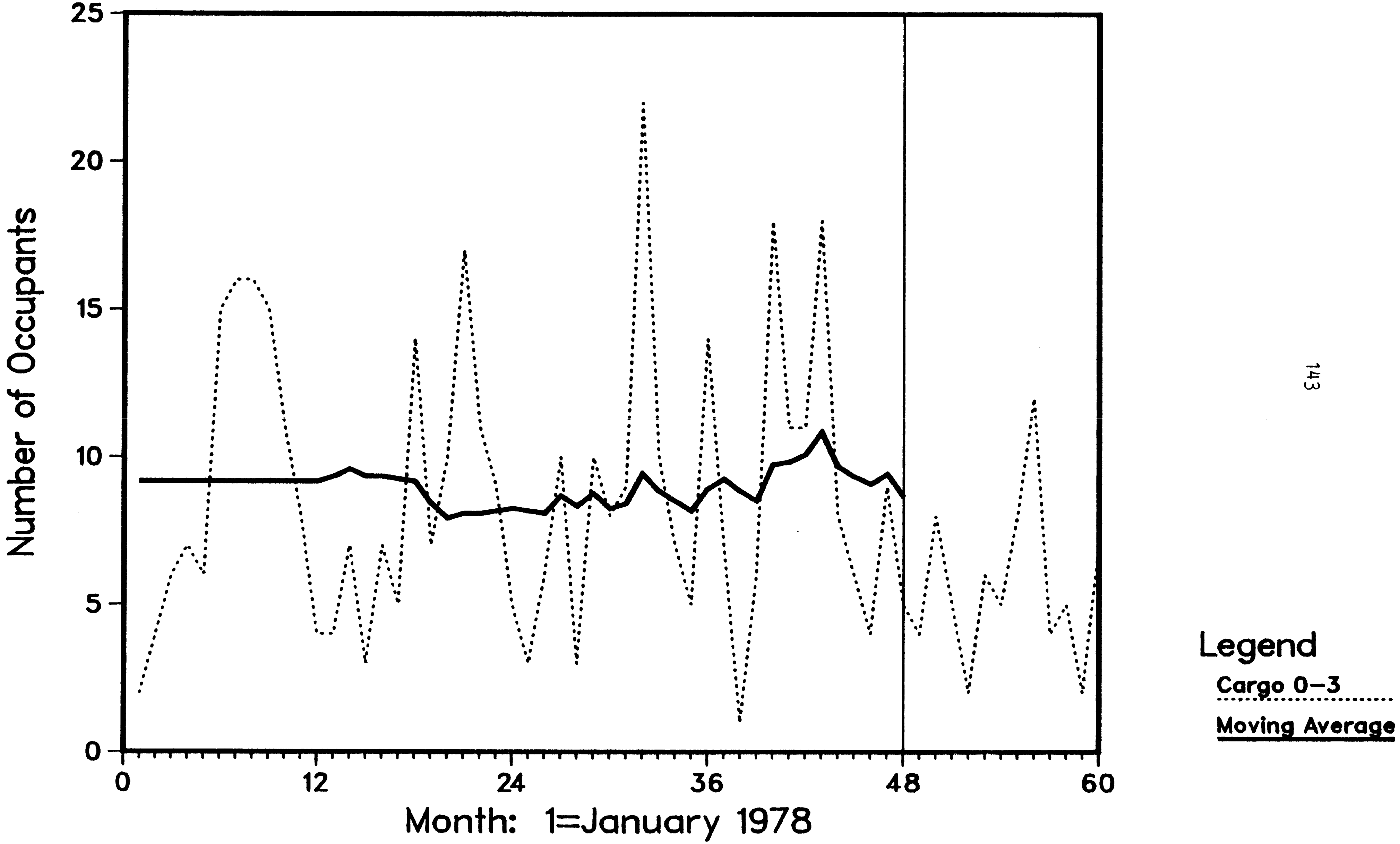
higher proportion were restrained after the law.

The number of children riding in positions other than front or rear seats (i.e., cargo areas) declined substantially after implementation of the child restraint law. Injuries among children riding in cargo areas decreased 45% immediately after the law took effect (Figure 5.34, Table A.29). Thus, in addition to reducing childhood injuries by increasing restraint use, the law apparently moved children riding in automobiles from the more-vulnerable front-seat and cargo-area positions to the safer rear-seat position. This effect, along with increased restraint use, presumably contributed to the overall injury reductions associated with implementation of the child restraint law.

The effects of the child restraint law are now summarized. The law is associated with significantly higher rates of restraint use among young children; this finding should be interpreted cautiously because of potential unreliability of the police-report measure of restraint use. The most important findings are based on detailed analyses of injuries among crash-involved children both before and after the law took effect. The analyses controlled for effects of pre-existing trends in childhood injuries. Key findings are that injuries to infants under age 1 decreased 50%, and injuries to children age 1-3 decreased 17% immediately after implementation of the child restraint law in April 1982. The PI&E efforts implemented the few months before the law took effect apparently had some beneficial effects. However, the combination of PI&E efforts with the mandatory law produced major reductions in childhood injuries in the last nine months of 1982. A possible spillover effect of the law in reducing injuries among adult motor vehicle occupants was also found. Occupants age 25-54 experienced a 6%

FIGURE 5.34

Michigan Cargo Area Injured Occupants Age 0 to 3



reduction in injuries after the law was implemented. The significance of this spillover effect should be clarified with further study of an additional year of followup data. Separate analyses of restrained and unrestrained crash-involved children revealed a 45% increase in the former and a 40% decrease in the latter. The effect of the law was primarily seen in a 22% reduction in moderate childhood injuries. Analyses of severe injuries (a smaller number of cases than moderate injuries) revealed no statistically significant change after controlling for a downward trend over the baseline 1978-1981 period. Analyses of crashes with varying levels of vehicle damage confirmed that the law had its smallest effect among those most at risk for severe injury. Childhood injuries among occupants of vehicles experiencing low damage were down 41% after the law took effect; children in moderately damaged vehicles experienced 20% fewer injuries; finally, children in severely damaged vehicles experienced 12% fewer injuries. A change in childhood seating positions also occurred when the child restraint law took effect. Children were apparently moved from the more-hazardous front seat and cargo area locations to the safer rear seat position. Childhood injuries decreased 28% among front seat occupants and 45% among cargo area occupants, while rear seat injuries held constant.

6: DISCUSSION

This study clearly shows significant declines in crash-related injuries among young children after Michigan's mandatory child restraint law was implemented. These injury reductions can be viewed as a direct result of the law, and do not appear to be the result of other factors. Three main features of the design of this study strengthen the conclusion that observed injury reductions are in fact due to the child restraint law. First, injury data over a five-year period was examined, and the decreased level of child injuries after the law took effect was above and beyond the decreased level expected given a downward trend in injuries in recent years. Second, monthly data on traffic crashes were examined, and significant child injury reductions began the first month the child restraint law was in force. Third, comparisons were made between changes in the number of child injuries and changes in the number of injuries among motor vehicle occupants of other ages. Those comparisons revealed that major reductions in injuries were limited to children under 4 years old, that is, to those covered by the new restraint law.

The state of the economy is one factor influencing the frequency of automobile crashes that might explain recent declines in traffic casualties. The observed reductions in injuries following implementation of the mandatory child restraint law are apparently not due to the effects of economic conditions for three reasons. First, injury reductions identified here were beyond those expected given a downward trend in injuries in the early 1980s. If the downward trends during the baseline (pre-1982) period were due to poor economic conditions, the effects of economic conditions were controlled in the analyses by controlling for the baseline trends. Second, a slowdown in crash involvement and injury rates that might result from poor economic conditions is likely to affect motor vehicle occupants of all ages. The major injury reductions beginning in April, 1982, were limited to children under 4. Finally, the general effects of economic conditions on crash involvement in Michigan were examined as part of this project, and only a small part of the variation in casualties in recent years can be clearly attributed to the effects of economic conditions (as measured by the rate of unemployment). Results of these analyses are discussed in a separate report, to which the reader is referred for additional details (Wagenaar, 1983b, in press).

If occupant restraint systems are properly used, they effectively reduce injuries in a particular crash. However, those not using restraints tend to be at higher risk for crash involvement and injury than those who do use restraints (Robertson, 1978; Campbell, 1979; O'Day and Flora, 1982). By examining crash-involved automobile occupants, this study was focused on a high-risk group of road users. Although crash-involved road users are a primary target population, a mandatory-use law is likely to be less effective in increasing restraint use among this high-risk group than in increasing restraint use among the general population. Therefore, the size of the estimated effect of the law in increasing restraint use obtained here is most likely smaller than an estimate based on before-and-after observational surveys of restraint use among the general road-user population. This difference points to the need to conduct periodic statewide observational surveys of restraint use in addition to continuing analyses of crash-involved motor vehicle occupants. Each type of study has its strengths and weaknesses, and a combination of both will provide the most accurate information concerning the effects of continuing efforts to increase restraint use and decrease casualties.

The size of the effect of Michigan's child restraint law, a 17% injury reduction among 1-3-year-olds and a 50% reduction among infants under 1, is larger than I expected. Hearne (1981) has argued that a mandatory restraint law has to increase use to over 80% before reaching those most at risk for injury; only then will a law significantly reduce the total number of injuries. Results of the current study, however, indicate that a much smaller increase in restraint use significantly reduces casualties. An increase in restraint use from 12 to 36% among crash-involved children resulted in a 17% decline in injuries. In other words, a 0.7% reduction in injuries occurred for each 1.0 percentage point increase in use. Given that those most influenced by the law are at lower risk of injury, a further increase in use of 24 percentage points is likely to result in a larger-than-17% decline in injuries. The potential benefits in reduced injuries of further increases in restraint use are dramatic. What can be done to continue and enhance the success Michigan has experienced thus far?

First, public information and education efforts should continue. Results reported in Section 5 indicate that Michigan's PI&E efforts apparently had some effect in increasing child restraint use even before the law took effect. Effects attributed to the law in much of this discussion really refers to the combined effect of the law with major PI&E efforts. Other research has also found that comprehensive PI&E programs can significantly affect motorists' awareness of the need for restraints (Philpot and others, 1980). Because significant changes in restraint-using behavior are difficult to achieve via PI&E efforts, perhaps the focus of these efforts should be to build public support for mandatory restraint use laws and automatic restraint systems, two ways that significant increases in occupant protection are likely to be achieved.

Second, enforcement of the current child restraint law should be strengthened. Available evidence indicates that major enforcement efforts can increase restraint use. For example, Roberts (1981) notes that child restraint use in Tennessee "doubled" after a stepped-up enforcement program was initiated (although no data were provided to substantiate the claim). Jonah and others (1982) compared two Ontario cities, one of which implemented a selective belt-use enforcement program (including publicity about the increased enforcement). Belt use increased from 58% before to 80% during the program, declining to 70% six months after program termination. Resource limitations constrain the extent to which Michigan's child restraint law can be enforced. However, a moderate level of enforcement is needed to persuade Michigan residents that the state is serious about protecting children while they are riding in motor vehicles.

Third, the legal system should be used in other ways to encourage use of restraints. For example, failure to use an available occupant restraint device might be considered contributory negligence. As a result, compensation for crash-related damages awarded in the course of civil suits would be reduced if the plaintiff had not used a restraint device. Mackay (1981) notes that the seat belt defense is routine in Great Britain, and Green and Sharpe (1981) note that its use is growing in Canada.

Finally, the most obvious recommendation emerging from this study is that Michigan's child restraint law should be extended to motor vehicle occupants of all ages. Werber (1980) and Wanebo (1982) reviewed the legal issues surrounding mandatory restraint use laws, and concluded that such laws are clearly constitutional. Fuchs (1978) argued that mandatory belt use laws are the best way to reduce highway casualties because they reallocate responsibility for preventing serious injury to those best able to so do. Based on results of this study of the child restraint law, a mandatory adult restraint law in Michigan will significantly reduce crash-related injuries, even if the high rates of restraint use (i.e., 80% or over) typical in other countries with mandatory laws are not achieved. A more modest increase in use (i.e., to about 50%) is still likely to have a significant effect in reducing injuries. The potential benefits of an 80% or more use rate are immense; such high levels of use should continue to be the goal.

There appears to be considerable public support for a mandatory adult restraint law. In 1982 a survey of Michigan residents revealed 62% favored a law that would require front-seat occupants to wear seat belts (O'Day and Filkins, 1983). Similarly, a 1982 survey of Illinois residents found 54% in favor of a mandatory-use law (Mortimer, 1983). Furthermore, public support for mandatory-use laws appears to increase after they are implemented (Shiels, 1978; Cunningham and others, 1981), and motorists have more positive attitudes toward belts after use is legally required (Fhaner and Hane, 1979). Given the high level of current support for a mandatory adult belt law, and the likelihood that support would increase after implementation of such a law, passage of such a law in Michigan may be achievable. It should be noted, however, that those opposed to a mandatory adult seat belt law are typically strongly opposed, and their attitudes toward the law are likely to become even more negative after the law takes effect (Fhaner and Hane, 1979).

This minority presents a major obstacle to passage of a mandatory adult restraint law.

Specific suggestions for further scientific evaluation of restraint use in Michigan are also offered. First, a second-year followup study of the effects of the child restraint law is critically important. The most important question is whether the beneficial short-term effects identified in this study are temporary or permanent. Are the injury reductions identified here solely a result of intense interest in child safety the first few months after the law took effect? If so, the effectiveness of the law may decrease over time. In contrast, the effects identified here may be significantly smaller than the permanent effect of the child restraint law. Residents may become more favorably disposed toward the law as time passes, and may therefore increase their use of restraints. Rockerbie (1983) found that a significant effect of British Columbia's mandatory belt law did not begin until nine months after the law was implemented. A followup study would reveal whether such a delayed effect enhanced the initial effect in Michigan. Finally, the current study found a possible effect of Michigan's child restraint law in reducing crash-related injuries among 25-54-year-olds, using the nine months of post-law data available. An additional year of data is required to verify such spill-over effects of the law.

Periodic observational surveys of road users in Michigan should also be conducted. These regular surveys would provide information on changes in restraint use among noncrash-involved motorists, and could also collect detailed data on the many factors influencing exposure to risk of a motor vehicle injury. Availability of additional exposure data would increase the level of confidence to which observed changes in injury rates can be attributed to specific policies and programs. Better data on restraint use over time would facilitate continuing evaluation of policy or programmatic changes designed to increase restraint use.

If mandatory adult belt use legislation currently under debate in Michigan is implemented, effects of the law should be carefully evaluated. The multiple data files constructed for the present study include automobile occupants of all ages (see Section 3 for details). These data files should be updated with new crash-involvement information as it becomes available, and the mandatory adult belt law should be thoroughly evaluated employing time-series design and analysis methods similar to those used in the present study.

APPENDIX

TIME-SERIES MODELING RESULTS

TABLE A.1

TIME-SERIES MODEL FOR RESTRAINT USAGE AMONG INJURED OCCUPANTS AGE 0

OUTPUT VARIABLE -- Belt0000 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt0000	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt0000	MA	1	1	0.2130	0.1342	1.59
2	Belt0000	MA	1	2	-0.2245	0.1364	-1.65
3	Belt0000	MEAN	1	0	2.804	0.1131	24.80
4	Step52	UP	1	0	-0.3914E-01	0.2798	-0.14
5	Puls4951	UP	1	0	-1.285	0.4367	-2.94

RESIDUAL SUM OF SQUARES = 33.066849 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.601215
R-SQUARE (ADJUSTED) = .14

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0011
STANDARD ERROR OF THE MEAN = 0.0966
T-VALUE OF MEAN (AGAINST ZERO) = -0.0115
Q-STATISTIC (WITH 21 D.F.) = 16

AUTOCORRELATIONS

1- 12	-.06	.06	-.26	.06	-.02	.22	-.05	-.01	-.11	-.16	.17	.04
ST.E.	.13	.13	.13	.14	.14	.14	.14	.15	.15	.15	.15	.15
13- 24	-.01	-.14	-.03	.01	-.04	.03	.05	.14	-.10	.04	-.05	.13
ST.E.	.15	.15	.15	.16	.16	.16	.16	.16	.16	.16	.16	.16

TABLE A.2

TIME-SERIES MODEL FOR RESTRAINT USAGE AMONG INJURED OCCUPANTS AGE 1 TO 3

OUTPUT VARIABLE -- Belt0103 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt0103	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt0103	AR	1	1	0.4035	0.1280	3.15
2	Belt0103	MEAN	1	0	2.439	0.0688	35.46
3	Step52	UP	1	0	1.124	0.1637	6.87
4	Puls4951	UP	1	0	0.2173	0.2341	0.93

RESIDUAL SUM OF SQUARES = 4.583659 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.083339
R-SQUARE (ADJUSTED) = .66

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0041
STANDARD ERROR OF THE MEAN = 0.0365
T-VALUE OF MEAN (AGAINST ZERO) = -0.1127
Q-STATISTIC (WITH 22 D.F.) = 10

AUTOCORRELATIONS

1- 12	-.02	-.01	.03	.05	.06	.07	.10	-.01	-.17	.10	.19	.03
ST.E.	.13	.13	.13	.13	.13	.13	.13	.13	.13	.14	.14	.14
13- 24	-.08	0.0	.01	-.01	-.08	-.05	-.06	-.06	.18	-.06	-.06	.09
ST.E.	.14	.14	.14	.14	.14	.14	.14	.14	.14	.15	.15	.15

TABLE A.3

TIME-SERIES MODEL OF RESTRAINT USAGE AMONG INJURED OCCUPANTS AGE 4 TO 15

OUTPUT VARIABLE -- Belt0415 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt0415	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt0415	MEAN	1	0	1.662	0.0310	53.60
2	Step52	UP	1	0	0.7044	0.0781	9.03
3	Puls4951	UP	1	0	0.4398	0.1279	3.44

RESIDUAL SUM OF SQUARES = 2.631495 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 57
RESIDUAL MEAN SQUARE = 0.046167
R-SQUARE (ADJUSTED) = .59

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = 0.0000
STANDARD ERROR OF THE MEAN = 0.0273
T-VALUE OF MEAN (AGAINST ZERO) = 0.0000
Q-STATISTIC (WITH 23 D.F.) = 18

AUTOCORRELATIONS

1- 12	.02	.10	-.16	-.06	-.02	-.13	-.10	-.11	.10	.21	.03	.14
ST.E.	.13	.13	.13	.13	.13	.13	.14	.14	.14	.14	.15	.15
13- 24	.07	-.01	-.11	-.20	.04	-.08	.02	-.21	-.08	.11	.07	.09
ST.E.	.15	.15	.15	.15	.15	.15	.16	.16	.16	.16	.16	.16

TABLE A.4

TIME-SERIES MODEL FOR RESTRAINT USAGE AMONG INJURED OCCUPANTS AGE 16 AND 17

OUTPUT VARIABLE -- Belt1617 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt1617	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt1617	AR	1	1	0.4407	0.1087	4.05
2	Belt1617	MEAN	1	0	1.632	0.0530	30.80
3	Step52	UP	1	0	0.1731	0.1245	1.39
4	Puls4951	UP	1	0	0.4279E-01	0.1626	0.26

RESIDUAL SUM OF SQUARES = 2.401797 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.043669
R-SQUARE (ADJUSTED) = .27

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0061
STANDARD ERROR OF THE MEAN = 0.0272
T-VALUE OF MEAN (AGAINST ZERO) = -0.2240
Q-STATISTIC (WITH 22 D.F.) = 16

AUTOCORRELATIONS

1- 12	-.14	.11	.03	-.06	.20	.02	.03	.14	.07	-.15	.16	.04
ST.E.	.13	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14	.15
13- 24	.04	.09	-.05	-.03	-.01	-.22	.18	-.05	-.03	.07	-.14	0.0
ST.E.	.15	.15	.15	.15	.15	.15	.15	.16	.16	.16	.16	.16

TABLE A.5

TIME-SERIES MODEL OF RESTRAINT USEAGE AMONG OCCUPANTS AGE 18 TO 24

OUTPUT VARIABLE -- Belt1824 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt1824	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt1824	MA	1	1	-0.8803	0.1319	-6.67
2	Belt1824	MA	1	2	-0.2370	0.1306	-1.82
3	Belt1824	MEAN	1	0	1.926	0.0302	63.84
4	Step52	UP	1	0	0.2466	0.0698	3.53
5	Puls4951	UP	1	0	-0.5201E-01	0.0796	-0.65

RESIDUAL SUM OF SQUARES = 0.559816 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.010178
R-SQUARE (ADJUSTED) = .56

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0033
STANDARD ERROR OF THE MEAN = 0.0126
T-VALUE OF MEAN (AGAINST ZERO) = -0.2600
Q-STATISTIC (WITH 21 D.F.) = 21

AUTOCORRELATIONS

1- 12	-.05	.05	.14	.07	-.09	-.01	.09	.14	-.14	.20	.16	.19
ST.E.	.13	.13	.13	.13	.13	.13	.13	.14	.14	.14	.14	.15
13- 24	-.11	.17	.08	-.11	-.05	-.02	-.09	-.10	-.12	.21	-.12	-.04
ST.E.	.15	.15	.16	.16	.16	.16	.16	.16	.16	.16	.17	.17

TABLE A.6

TIME SERIES MODEL FOR RESTRAINT USAGE AMONG OCCUPANTS AGE 25 TO 34

OUTPUT VARIABLE — Belt2534 (log transformed)
INPUT VARIABLES — NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt2534	RANDOM		1- 60	$(1-B^1)$
Step52	BINARY		1- 60	$(1-B^1)$
Puls4951	BINARY		1- 60	$(1-B^1)$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Step52	UP	1	0	-0.3099E-02	0.1755	-0.02
2	Puls4951	UP	1	0	0.7060E-01	0.1240	0.57

RESIDUAL SUM OF SQUARES = 0.876761 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 57
RESIDUAL MEAN SQUARE = 0.015382
R-SQUARE (ADJUSTED) = .48

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0046
STANDARD ERROR OF THE MEAN = 0.0160
T-VALUE OF MEAN (AGAINST ZERO) = -0.2855
Q-STATISTIC (WITH 24 D.F.) = 20

AUTOCORRELATIONS

1- 12	-.20	-.09	-.14	.06	.09	-.02	.06	-.25	.09	0.0	.05	.24
ST.E.	.13	.14	.14	.14	.14	.14	.14	.14	.15	.15	.15	.15
13- 24	-.18	.05	-.03	.18	-.01	-.11	-.09	-.09	.12	.07	-.08	.02
ST.E.	.16	.16	.16	.16	.16	.16	.16	.16	.17	.17	.17	.17

TABLE A.7

TIME-SERIES MODEL FOR RESTRAINT USAGE AMONG OCCUPANTS AGE 35 TO 54

OUTPUT VARIABLE -- Belt3554 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt3554	RANDOM		1- 60	$(1-B^{1})$
Step52	BINARY		1- 60	$(1-B^{1})$
Puls4951	BINARY		1- 60	$(1-B^{1})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt3554	MA	1	1	0.4256	0.1193	3.57
2	Step52	UP	1	0	0.1052	0.1114	0.94
3	Puls4951	UP	1	0	0.1356	0.0834	1.63

RESIDUAL SUM OF SQUARES = 0.441505 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 56
RESIDUAL MEAN SQUARE = 0.007884
R-SQUARE (ADJUSTED) = .54

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0054
STANDARD ERROR OF THE MEAN = 0.0112
T-VALUE OF MEAN (AGAINST ZERO) = -0.4838
Q-STATISTIC (WITH 23 D.F.) = 23

AUTOCORRELATIONS

1- 12	.04	.01	-.24	-.08	.12	-.03	-.14	-.13	-.08	.06	.22	.24
ST.E.	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14	.14	.15
13- 24	.16	-.01	-.08	-.09	.06	-.07	-.05	-.22	.09	-.08	.15	.11
ST.E.	.16	.16	.16	.16	.16	.16	.16	.16	.17	.17	.17	.17

TABLE A.8

TIME-SERIES MODEL FOR RESTRAINT USAGE AMONG OCCUPANTS AGE 55 AND OVER

OUTPUT VARIABLE -- Belt5598 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Belt5598	RANDOM		1- 60	$(1-B^{1})$
Step52	BINARY		1- 60	$(1-B^{1})$
Puls4951	BINARY		1- 60	$(1-B^{1})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Belt5598	MA	1	1	0.7058	0.0823	8.58
2	Belt5598	MA	2	12	-0.8036	0.0488	-16.46
3	Step52	UP	1	0	0.1797	0.0752	2.39
4	Puls4951	UP	1	0	0.1479	0.0658	2.25

RESIDUAL SUM OF SQUARES = 0.445594 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.008102
R-SQUARE (ADJUSTED) = .57

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0090
STANDARD ERROR OF THE MEAN = 0.0112
T-VALUE OF MEAN (AGAINST ZERO) = -0.8048
Q-STATISTIC (WITH 22 D.F.) = 20

AUTOCORRELATIONS

1- 12	-.08	-.04	-.15	-.01	.16	-.04	-.07	-.22	.12	-.22	.12	-.03
ST.E.	.13	.13	.13	.13	.13	.14	.14	.14	.14	.14	.15	.15
13- 24	.09	.18	-.15	.11	-.15	.07	-.13	.05	-.07	0.0	.09	-.15
ST.E.	.15	.15	.16	.16	.16	.16	.16	.16	.16	.16	.16	.17

TABLE A.9

TIME-SERIES MODEL FOR INJURED MOTOR VEHICLE OCCUPANTS AGE 0 (WITHOUT TREND)

OUTPUT VARIABLE -- InjL0000 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL0000	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL0000	MA	1	3	-0.2539	0.1389	-1.83
2	InjL0000	MA	1	4	-0.3043	0.1397	-2.18
3	InjL0000	MA	2	12	0.7761	0.0687	11.30
4	Step52	UP	1	0	-0.6992	0.1390	-5.03
5	Puls4951	UP	1	0	-0.3706	0.1608	-2.31

RESIDUAL SUM OF SQUARES = 3.987526 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 43
RESIDUAL MEAN SQUARE = 0.092733
R-SQUARE (ADJUSTED) = .53

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0304
STANDARD ERROR OF THE MEAN = 0.0350
T-VALUE OF MEAN (AGAINST ZERO) = -0.8684
Q-STATISTIC (WITH 21 D.F.) = 18

AUTOCORRELATIONS

1- 12	-.01	.03	.06	.04	.31	.24	.03	.09	-.05	.15	.03	-.16
ST.E.	.13	.13	.13	.13	.13	.14	.15	.15	.15	.15	.15	.15
13- 24	.13	-.04	.04	-.20	.05	-.11	-.15	-.10	-.07	-.14	.05	-.14
ST.E.	.15	.16	.16	.16	.16	.16	.16	.16	.17	.17	.17	.17

TABLE A.10

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 0 (WITH TREND)

OUTPUT VARIABLE -- InjL0000 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL0000	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL0000	MA	1	12	0.8069	0.0630	12.80
2	InjL0000	TRND	1	0	-0.1434	0.0352	-4.07
3	Step52	UP	1	0	-0.3432	0.1255	-2.74
4	Puls4951	UP	1	0	0.8811E-02	0.1815	0.05

RESIDUAL SUM OF SQUARES = 3.742319 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.085053
R-SQUARE (ADJUSTED) = .57

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0332
T-VALUE OF MEAN (AGAINST ZERO) = -0.0003
Q-STATISTIC (WITH 22 D.F.) = 18

AUTOCORRELATIONS

1- 12	-.08	-.05	.15	.09	.17	.17	-.06	.02	-.03	.09	-.07	-.23
ST.E.	.13	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14
13- 24	.12	-.07	-.09	-.29	.08	-.11	-.16	-.10	-.07	-.15	.08	-.09
ST.E.	.15	.15	.15	.15	.16	.16	.16	.17	.17	.17	.17	.17

TABLE A.11

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 1 TO 3 (WITHOUT TREND)

OUTPUT VARIABLE -- InjL0103 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL0103	RANDOM		1- 60	$(1-B^1)$
Step52	BINARY		1- 60	$(1-B^1)$
Puls4951	BINARY		1- 60	$(1-B^1)$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL0103	MA	1	1	0.3599	0.1125	3.20
2	InjL0103	MA	1	3	0.4051	0.1118	3.62
3	Step52	UP	1	0	-0.3054	0.1365	-2.24
4	Puls4951	UP	1	0	-0.2290	0.1353	-1.69

RESIDUAL SUM OF SQUARES = 1.138571 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 55
RESIDUAL MEAN SQUARE = 0.020701
R-SQUARE (ADJUSTED) = .70

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0169
STANDARD ERROR OF THE MEAN = 0.0179
T-VALUE OF MEAN (AGAINST ZERO) = -0.9434
Q-STATISTIC (WITH 22 D.F.) = 22

AUTOCORRELATIONS

1- 12	-.06	-.17	-.08	.06	.13	-.05	.02	-.01	-.11	.07	-.05	.10
ST.E.	.13	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14
13- 24	.11	.21	-.11	-.28	-.05	.27	-.14	-.15	-.03	-.08	.04	.03
ST.E.	.14	.14	.15	.15	.16	.16	.16	.17	.17	.17	.17	.17

TABLE A.12

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 1 TO 3 (WITH TREND)

OUTPUT VARIABLE -- InjL0103 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL0103	RANDOM		1- 60	$(1-B^{1})$
Step52	BINARY		1- 60	$(1-B^{1})$
Puls4951	BINARY		1- 60	$(1-B^{1})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL0103	MA	1	1	0.4988	0.0888	5.62
2	InjL0103	MA	1	3	0.4694	0.0903	5.20
3	InjL0103	TRND	1	0	-0.8487E-02	0.0026	-3.26
4	Step52	UP	1	0	-0.1899	0.1096	-1.73
5	Puls4951	UP	1	0	-0.1647	0.1265	-1.30

RESIDUAL SUM OF SQUARES = 1.008038 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 54
RESIDUAL MEAN SQUARE = 0.018667
R-SQUARE (ADJUSTED) = .73

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0072
STANDARD ERROR OF THE MEAN = 0.0172
T-VALUE OF MEAN (AGAINST ZERO) = -0.4193
Q-STATISTIC (WITH 21 D.F.) = 25

AUTOCORRELATIONS

1- 12	-.03	-.21	-.10	.04	.08	-.07	.02	-.06	-.13	.09	-.05	.09
ST.E.	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14	.14	.14
13- 24	.15	.22	-.12	-.30	-.03	.28	-.14	-.15	-.05	-.08	.04	.07
ST.E.	.14	.14	.15	.15	.16	.16	.17	.17	.17	.17	.17	.17

TABLE A.13

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 25 TO 34 (WITH TREND)

OUTPUT VARIABLE -- InjL2534 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL2534	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL2534	MA	1	12	0.8363	0.0633	13.22
2	InjL2534	TRND	1	0	-0.3772E-01	0.0090	-4.21
3	Step52	UP	1	0	-0.4935E-01	0.0314	-1.57
4	Puls4951	UP	1	0	0.2299E-01	0.0451	0.51

RESIDUAL SUM OF SQUARES = 0.240299 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.005461
R-SQUARE (ADJUSTED) = .74

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0086
T-VALUE OF MEAN (AGAINST ZERO) = -0.0001
Q-STATISTIC (WITH 22 D.F.) = 20

AUTOCORRELATIONS

1- 12	-.05	-.13	-.06	.16	-.09	-.25	.02	-.04	.03	.14	.04	-.21
ST.E.	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14	.15	.15
13- 24	-.07	.09	-.13	-.20	-.02	.24	.06	-.20	.08	.02	.06	-.20
ST.E.	.15	.15	.15	.15	.16	.16	.16	.17	.17	.17	.17	.17

TABLE A.14

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 25 TO 34 (WITHOUT TREND)

OUTPUT VARIABLE -- InjL2534 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL2534	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL2534	MA	1	12	0.8502	0.0654	13.01
2	Step52	UP	1	0	-0.1413	0.0259	-5.45
3	Puls4951	UP	1	0	-0.6945E-01	0.0455	-1.53

RESIDUAL SUM OF SQUARES = 0.321388 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.007142
R-SQUARE (ADJUSTED) = .66

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0064
STANDARD ERROR OF THE MEAN = 0.0100
T-VALUE OF MEAN (AGAINST ZERO) = -0.6380
Q-STATISTIC (WITH 23 D.F.) = 30

AUTOCORRELATIONS

1- 12	.20	.09	.15	.31	.12	.01	.19	.16	.22	.28	.17	-.04
ST.E.	.13	.13	.14	.14	.15	.15	.15	.15	.16	.16	.17	.17
13- 24	0.0	.10	-.10	-.17	-.05	.13	.01	-.21	0.0	-.08	-.10	-.31
ST.E.	.17	.17	.17	.18	.18	.18	.18	.18	.18	.18	.18	.19

TABLE A.15

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 35 TO 54 (WITHOUT TREND)

OUTPUT VARIABLE -- InjL3554 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL3554	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL3554	MA	1	1	-0.1837	0.1201	-1.53
2	InjL3554	MA	1	4	-0.2343	0.1294	-1.81
3	InjL3554	MA	2	12	0.8439E-01	0.0690	1.22
4	InjL3554	MA	2	24	0.7542	0.0626	12.05
5	Step52	UP	1	0	-0.6478E-01	0.0316	-2.05
6	Puls4951	UP	1	0	0.1031E-01	0.0467	0.22

RESIDUAL SUM OF SQUARES = 0.210761 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 42
RESIDUAL MEAN SQUARE = 0.005018
R-SQUARE (ADJUSTED) = .78

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0028
STANDARD ERROR OF THE MEAN = 0.0087
T-VALUE OF MEAN (AGAINST ZERO) = -0.3210
Q-STATISTIC (WITH 20 D.F.) = 23

AUTOCORRELATIONS

1- 12	.04	.08	.11	.06	.15	-.18	.19	.22	.03	.23	0.0	-.18
ST.E.	.13	.13	.13	.13	.13	.13	.14	.14	.15	.15	.15	.15
13- 24	.06	.02	-.04	-.16	-.08	.26	-.07	-.20	.01	-.09	-.06	-.26
ST.E.	.16	.16	.16	.16	.16	.16	.17	.17	.17	.17	.17	.17

TABLE A.16

TIME-SERIES MODEL OF INJURED MOTOR VEHICLE OCCUPANTS AGE 35 TO 54 (WITH TREND)

OUTPUT VARIABLE -- InjL3554 (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjL3554	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjL3554	MA	1	1	-0.9475E-01	0.1277	-0.74
2	InjL3554	MA	1	4	-0.2205	0.1385	-1.59
3	InjL3554	MA	2	12	0.1124	0.0753	1.49
4	InjL3554	MA	2	24	0.7421	0.0690	10.75
5	InjL3554	TRND	1	0	-0.4390E-01	0.0133	-3.30
6	Step52	UP	1	0	0.7597E-02	0.0363	0.21
7	Puls4951	UP	1	0	0.7611E-01	0.0462	1.65

RESIDUAL SUM OF SQUARES = 0.196261 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 41
RESIDUAL MEAN SQUARE = 0.004787
R-SQUARE (ADJUSTED) = .79

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = 0.0009
STANDARD ERROR OF THE MEAN = 0.0081
T-VALUE OF MEAN (AGAINST ZERO) = 0.1096
Q-STATISTIC (WITH 19 D.F.) = 21

AUTOCORRELATIONS

1- 12	.02	-.01	.03	.04	.06	-.24	.14	.14	-.03	.15	-.06	-.26
ST.E.	.13	.13	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14
13- 24	-.01	.03	-.06	-.22	-.09	.26	-.07	-.23	-.02	-.06	-.04	-.21
ST.E.	.15	.15	.15	.15	.16	.16	.17	.17	.17	.17	.17	.17

TABLE A.17

TIME-SERIES MODEL FOR RESTRAINED OCCUPANTS AGE 0 TO 3

OUTPUT VARIABLE -- Restrain (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
Restrain	RANDOM		1- 60	
Step52	BINARY		1- 60	
Puls4951	BINARY		1- 60	

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Restrain	MEAN	1	0	3.189	0.0410	77.71
2	Step52	UP	1	0	0.3705	0.1033	3.59
3	Puls4951	UP	1	0	-0.3190	0.1692	-1.89

RESIDUAL SUM OF SQUARES = 4.606869 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 57
RESIDUAL MEAN SQUARE = 0.080822
R-SQUARE (ADJUSTED) = .21

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0361
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 23 D.F.) = 22

AUTOCORRELATIONS

1- 12	.13	-.16	-.25	-.16	.16	.04	.17	-.16	-.25	0.0	.05	.08
ST.E.	.13	.13	.13	.14	.14	.15	.15	.15	.15	.16	.16	.16
13- 24	-.07	.03	-.06	-.15	-.07	-.01	-.09	-.05	.19	.05	.04	-.01
ST.E.	.16	.16	.16	.16	.16	.17	.17	.17	.17	.17	.17	.17

TABLE A.18

TIME-SERIES MODEL FOR UNRESTRAINED OCCUPANTS AGE 0 TO 3 (WITH TREND)

OUTPUT VARIABLE -- NotRestr (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
NotRestr	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	NotRestr	TRND	1	0	-0.1558	0.0255	-6.10
2	Step52	UP	1	0	-0.5130	0.0571	-8.99
3	Puls4951	UP	1	0	0.5883E-01	0.0921	0.64

RESIDUAL SUM OF SQUARES	=	1.056090 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM	=	45
RESIDUAL MEAN SQUARE	=	0.023469
R-SQUARE (ADJUSTED)	=	.84

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS	=	48
MEAN OF THE (DIFFERENCED) SERIES	=	-0.0000
STANDARD ERROR OF THE MEAN	=	0.0216
T-VALUE OF MEAN (AGAINST ZERO)	=	-0.0000
Q-STATISTIC (WITH 23 D.F.)	=	26

AUTOCORRELATIONS

1- 12	.05	.14	-.10	.24	.13	-.23	-.14	-.09	.27	.10	-.05	-.23
ST.E.	.14	.14	.15	.15	.16	.16	.17	.17	.17	.18	.18	.18
13- 24	.22	.06	.03	-.30	-.01	.11	.04	-.15	-.15	-.03	.03	-.13
ST.E.	.19	.19	.19	.19	.20	.20	.20	.20	.20	.21	.21	.21

TABLE A.19

TIME-SERIES MODEL FOR MODERATELY INJURED OCCUPANTS AGE 0 TO 3 (WITH TREND)

OUTPUT VARIABLE -- InjMod (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjMod	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjMod	TRND	1	0	-0.1270	0.0256	-4.97
2	Step52	UP	1	0	-0.2516	0.0572	-4.40
3	Puls4951	UP	1	0	0.1223	0.0922	1.33

RESIDUAL SUM OF SQUARES = 1.058634 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.023525
R-SQUARE (ADJUSTED) = .70

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 48
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0217
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 23 D.F.) = 22

AUTOCORRELATIONS

1- 12	.02	-.05	-.05	.17	.23	-.14	-.12	-.03	.09	.17	-.08	-.18
ST.E.	.14	.14	.14	.15	.15	.16	.16	.16	.16	.16	.17	.17
13- 24	.20	.10	.02	-.34	-.02	.09	0.0	-.16	-.14	0.0	.04	-.18
ST.E.	.17	.18	.18	.18	.19	.19	.19	.19	.19	.20	.20	.20

TABLE A.20

TIME-SERIES MODEL FOR SERIOUSLY INJURED OCCUPANTS AGE 0 TO 3 (WITH TREND)

OUTPUT VARIABLE -- InjSer (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjSer	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjSer	MA	1	12	0.8186	0.0623	13.13
2	InjSer	TRND	1	0	-0.1782	0.0415	-4.29
3	Step52	UP	1	0	0.1517	0.1470	1.03
4	Puls4951	UP	1	0	0.3877E-01	0.2122	0.18

RESIDUAL SUM OF SQUARES = 5.193568 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.118036
R-SQUARE (ADJUSTED) = .49

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = 0.0000
STANDARD ERROR OF THE MEAN = 0.0397
T-VALUE OF MEAN (AGAINST ZERO) = 0.0001
Q-STATISTIC (WITH 22 D.F.) = 18

AUTOCORRELATIONS

1- 12	-.19	.17	-.20	.01	-.27	-.03	.06	.05	.03	.06	.09	-.17
ST.E.	.13	.13	.14	.14	.14	.15	.15	.15	.15	.15	.15	.15
13- 24	-.05	.03	-.25	-.04	-.03	.13	.11	.08	.14	-.07	-.08	-.07
ST.E.	.16	.16	.16	.16	.16	.16	.16	.17	.17	.17	.17	.17

TABLE A.21

TIME-SERIES MODEL FOR SERIOUSLY INJURED OCCUPANTS AGE 0 TO 3 (WITHOUT TREND)

OUTPUT VARIABLE -- InjSer (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjSer	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	InjSer	MA	1	12	0.8332	0.0618	13.47
2	Step52	UP	1	0	-0.2793	0.1217	-2.30
3	Puls4951	UP	1	0	-0.3933	0.2084	-1.89

RESIDUAL SUM OF SQUARES = 6.628578 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.147302
R-SQUARE (ADJUSTED) = .37

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0337
STANDARD ERROR OF THE MEAN = 0.0465
T-VALUE OF MEAN (AGAINST ZERO) = -0.7242
Q-STATISTIC (WITH 23 D.F.) = 13

AUTOCORRELATIONS

1- 12	.09	.28	.04	.14	-.04	.12	.17	.13	.05	.06	.08	-.10
ST.E.	.13	.13	.14	.14	.14	.14	.14	.15	.15	.15	.15	.15
13- 24	-.04	.03	-.19	-.03	-.06	.08	.08	.07	.13	-.01	-.05	-.06
ST.E.	.15	.15	.15	.16	.16	.16	.16	.16	.16	.16	.16	.16

TABLE A.22

TIME-SERIES MODEL FOR MODERATELY INJURED OCCUPANTS AGE 0 TO 3 (WITHOUT TREND)

OUTPUT VARIABLE -- InjMod (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
InjMod	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	Step52	UP	1	0	-0.3785	0.0629	-6.02
2	Puls4951	UP	1	0	-0.4693E-02	0.1090	-0.04

RESIDUAL SUM OF SQUARES	=	1.638864 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM	=	46
RESIDUAL MEAN SQUARE	=	0.035627
R-SQUARE (ADJUSTED)	=	.54

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS	=	48
MEAN OF THE (DIFFERENCED) SERIES	=	-0.0952
STANDARD ERROR OF THE MEAN	=	0.0231
T-VALUE OF MEAN (AGAINST ZERO)	=	-4.1219
Q-STATISTIC (WITH 24 D.F.)	=	33

AUTOCORRELATIONS

1- 12	.15	.03	.03	.30	.33	-.01	-.04	.04	.16	.18	-.10	-.19
ST.E.	.14	.15	.15	.15	.16	.17	.17	.17	.17	.18	.18	.18
13- 24	.14	.05	-.03	-.37	-.09	0.0	-.09	-.26	-.22	-.08	-.02	-.24
ST.E.	.19	.19	.19	.19	.20	.20	.20	.20	.21	.22	.22	.22

TABLE A.23

TIME-SERIES MODEL FOR OCCUPANTS AGE 0 TO 3 IN LOW DAMAGE VEHICLES (WITH TREND)

OUTPUT VARIABLE -- LowDamage (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
LowDamage	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	LowDamage	TRND	1	0	-0.7888E-01	0.0420	-1.88
2	Step52	UP	1	0	-0.5350	0.0939	-5.70
3	Puls4951	UP	1	0	-0.1395	0.1514	-0.92

RESIDUAL SUM OF SQUARES = 2.856902 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.063487
R-SQUARE (ADJUSTED) = .50

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 48
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0356
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 23 D.F.) = 12

AUTOCORRELATIONS

1- 12	.12	-.14	-.09	.10	.11	-.14	-.23	-.15	-.03	.09	-.12	-.16
ST.E.	.14	.15	.15	.15	.15	.15	.16	.16	.17	.17	.17	.17
13- 24	.06	.05	.05	-.08	-.13	.01	.10	.05	-.04	.02	.07	.03
ST.E.	.17	.17	.17	.17	.17	.18	.18	.18	.18	.18	.18	.18

TABLE A.24

TIME-SERIES MODEL FOR OCCUPANTS AGE 0 TO 3 IN MEDIUM DAMAGE VEHICLES

OUTPUT VARIABLE -- MedDamage (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
MedDamage	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	MedDamage	MA	1	12	0.8156	0.0587	13.88
2	MedDamage	TRND	1	0	-0.1164	0.0177	-6.57
3	Step52	UP	1	0	-0.2265	0.0628	-3.61
4	Puls4951	UP	1	0	0.9223E-01	0.0911	1.01

RESIDUAL SUM OF SQUARES = 0.944655 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.021469
R-SQUARE (ADJUSTED) = .69

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0173
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 22 D.F.) = 12

AUTOCORRELATIONS

1- 12	.15	.12	-.10	-.16	.06	-.07	-.02	.01	-.07	.09	-.13	-.03
ST.E.	.13	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14	.14
13- 24	.06	-.08	-.02	-.19	-.06	.02	.06	.04	0.0	0.0	-.14	-.26
ST.E.	.14	.14	.14	.14	.15	.15	.15	.15	.15	.15	.15	.15

TABLE A.25

TIME-SERIES MODEL FOR OCCUPANTS AGE 0 TO 3 IN HIGH DAMAGE VEHICLES

OUTPUT VARIABLE -- HighDamage (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
HighDamage	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	HighDamage	MA	1	12	0.8333	0.0595	14.00
2	HighDamage	TRND	1	0	-0.1622	0.0188	-8.64
3	Step52	UP	1	0	-0.1243	0.0659	-1.89
4	Puls4951	UP	1	0	0.4986E-01	0.0942	0.53

RESIDUAL SUM OF SQUARES = 1.055386 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.023986
R-SQUARE (ADJUSTED) = .75

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = 0.0000
STANDARD ERROR OF THE MEAN = 0.0182
T-VALUE OF MEAN (AGAINST ZERO) = 0.0001
Q-STATISTIC (WITH 22 D.F.) = 25

AUTOCORRELATIONS

1- 12	-.06	-.12	-.19	.11	.20	-.17	-.14	-.11	.13	.15	-.06	-.22
ST.E.	.13	.13	.13	.14	.14	.14	.15	.15	.15	.15	.15	.15
13- 24	.26	.01	-.02	-.25	.01	.22	.05	-.10	-.13	0.0	.17	-.17
ST.E.	.16	.17	.17	.17	.17	.17	.18	.18	.18	.18	.18	.18

TABLE A.26

TIME-SERIES MODEL FOR FRONT SEAT OCCUPANTS AGE 0 TO 3 (WITH TREND)

OUTPUT VARIABLE — FrontPos (log transformed)
INPUT VARIABLES — NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
FrontPos	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	FrontPos	TRND	1	0	-0.1633	0.0283	-5.77
2	Step52	UP	1	0	-0.3325	0.0632	-5.26
3	Puls4951	UP	1	0	0.6507E-01	0.1020	0.64

RESIDUAL SUM OF SQUARES = 1.295947 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.028799
R-SQUARE (ADJUSTED) = .77

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 48
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0240
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 23 D.F.) = 29

AUTOCORRELATIONS

1- 12	.07	-.12	-.07	.20	.05	-.13	-.13	-.08	.30	.29	-.09	-.25
ST.E.	.14	.15	.15	.15	.15	.15	.16	.16	.16	.17	.18	.18
13- 24	.16	.06	-.11	-.28	.06	.20	.15	-.02	-.15	-.02	.08	-.18
ST.E.	.19	.19	.19	.19	.20	.20	.21	.21	.21	.21	.21	.21

TABLE A.27

TIME-SERIES MODEL FOR REAR SEAT OCCUPANTS AGE 0 TO 3 (WITH TREND)

OUTPUT VARIABLE -- RearPos (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
RearPos	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	RearPos	MA	1	12	0.8438	0.0596	14.15
2	RearPos	TRND	1	0	-0.9134E-01	0.0210	-4.35
3	Step52	UP	1	0	0.6647E-01	0.0731	0.91
4	Puls4951	UP	1	0	0.9088E-01	0.1048	0.87

RESIDUAL SUM OF SQUARES = 1.312947 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 44
RESIDUAL MEAN SQUARE = 0.029840
R-SQUARE (ADJUSTED) = .46

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0000
STANDARD ERROR OF THE MEAN = 0.0199
T-VALUE OF MEAN (AGAINST ZERO) = -0.0000
Q-STATISTIC (WITH 22 D.F.) = 18

AUTOCORRELATIONS

1- 12	.02	0.0	.16	0.0	-.05	-.11	.11	-.21	-.26	.05	.01	-.12
ST.E.	.13	.13	.13	.13	.13	.13	.13	.14	.14	.15	.15	.15
13- 24	.04	.11	.11	-.20	.09	.06	-.25	-.01	-.01	-.10	-.17	-.13
ST.E.	.15	.15	.15	.15	.16	.16	.16	.17	.17	.17	.17	.17

TABLE A.28

TIME-SERIES MODEL FOR REAR SEAT OCCUPANTS AGE 0 TO 3 (WITHOUT TREND)

OUTPUT VARIABLE -- RearPos (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
RearPos	RANDOM		1- 60	$(1-B^{1})(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{1})(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{1})(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	RearPos	MA	1	1	0.8067	0.0960	8.41
2	RearPos	MA	2	12	0.8250	0.0588	14.03
3	Step52	UP	1	0	-0.1367	0.1154	-1.19
4	Puls4951	UP	1	0	-0.6544E-01	0.1248	-0.52

RESIDUAL SUM OF SQUARES = 1.247577 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 43
RESIDUAL MEAN SQUARE = 0.029013
R-SQUARE (ADJUSTED) = .48

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = 0.0128
STANDARD ERROR OF THE MEAN = 0.0207
T-VALUE OF MEAN (AGAINST ZERO) = 0.6147
Q-STATISTIC (WITH 22 D.F.) = 17

AUTOCORRELATIONS

1- 12	-.05	-.07	.12	.02	0.0	-.05	.21	-.13	-.19	.13	.06	-.12
ST.E.	.13	.13	.13	.13	.13	.13	.13	.14	.14	.14	.15	.15
13- 24	.05	.11	.12	-.21	.10	.07	-.26	0.0	.03	-.04	-.17	-.16
ST.E.	.15	.15	.15	.15	.16	.16	.16	.16	.16	.16	.17	.17

TABLE A.29

TIME-SERIES MODEL FOR CARGO AREA OCCUPANTS AGE 0 TO 3 (WITHOUT TREND)

OUTPUT VARIABLE -- CargoPos (log transformed)
INPUT VARIABLES -- NOISE Step52 Puls4951

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
CargoPos	RANDOM		1- 60	$(1-B^{12})$
Step52	BINARY		1- 60	$(1-B^{12})$
Puls4951	BINARY		1- 60	$(1-B^{12})$

PARAMETER	VARIABLE	TYPE	FACTOR	ORDER	ESTIMATE	ST. ERR.	T-RATIO
1	CargoPos	MA	1	12	0.8362	0.0573	14.59
2	Step52	UP	1	0	-0.6030	0.1657	-3.64
3	Puls4951	UP	1	0	0.2573	0.2868	0.90

RESIDUAL SUM OF SQUARES = 13.143752 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 45
RESIDUAL MEAN SQUARE = 0.292083
R-SQUARE (ADJUSTED) = .24

ANALYSIS OF RESIDUALS

NUMBER OF OBSERVATIONS = 60
MEAN OF THE (DIFFERENCED) SERIES = -0.0041
STANDARD ERROR OF THE MEAN = 0.0649
T-VALUE OF MEAN (AGAINST ZERO) = -0.0627
Q-STATISTIC (WITH 23 D.F.) = 21

AUTOCORRELATIONS

1- 12	-.18	-.22	.05	.05	-.05	-.12	.15	-.04	-.24	.13	-.02	-.27
ST.E.	.13	.13	.14	.14	.14	.14	.14	.14	.14	.15	.15	.15
13- 24	.18	.19	-.08	.05	-.15	.12	.07	-.03	.03	-.18	.07	-.03
ST.E.	.16	.16	.17	.17	.17	.17	.17	.17	.17	.17	.18	.18

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