Report No. K-TRAN: KSU-98-3
Final Report

Impact of New Speed Limits on Kansas Highways

Yacoub M. Najjar
Robert W. Stokes
Eugene R. Russell
Hossam E. Ali
Xiaobin "Carol" Zhang
Kansas State University
Manhattan, Kansas

November 2000

K-TRAN

A COOPERATIVE TRANSPORTATION RESEARCH PROGRAM BETWEEN:
THE KANSAS DEPARTMENT OF TRANSPORTATION
KANSAS STATE UNIVERSITY
THE UNIVERSITY OF KANSAS

1. Report No. K-TRAN: KSU-98-3	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle IMPACT OF NEW SPEED LIMITS ON KANSAS HIGHWAYS		**5 Report Date** November 2000
7. Author(s) Yacoub M. Najjar, Robert W. Stokes, Eugene R. Russell, Hossam E. Ali and Xiaobin "Carol" Zhang		**6 Performing Organization Code** **8 Performing Organization Report No.**
9 Performing Organization Name and Address Kansas State University Department of Civil Engineering Manhattan, Kansas 66506		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.** C-1057
12 Sponsoring Agency Name and Address Kansas Department of Transportation Docking State Office Bldg. Topeka, Kansas 66612		**13 Type of Report and Period Covered** Final Report Dec 1997 to Nov 2000 **14 Sponsoring Agency Code** 106-RE-0127-01

15 Supplementary Notes

Partial funding provided by the Mid-America Transportation Center (MATC).

16 Abstract

On November 28, 1995, the National Highway System (NHS) Designation Act abolished the federal mandate for the National Maximum Speed Limit (NMSL) and returned the authority of establishing speed limits to the states. By the end of 1996, 32 states had passed laws to raise speed limits on various highways. Accordingly, Kansas' law increased speed limits on most of its highways in March 1996. The detailed research study reported herein concentrated on analyzing the before and after Kansas' speed and accident databases. In regard to speed analysis, the t-test was applied to investigate whether significant increases in 85^{th} percentile speeds were noted during the after period on both interstate and 2-lane rural highways. In this case, a 3-mph increase in 85^{th} percentile speeds was noted on interstate highway sections and a 3 to 5 mph increase was noted on the 10-mph speed limit increased 2-lane highways. None was noted on the 5-mph speed limit increase on the 2-lane highways.

The 3-Step Sequential Analysis approach was utilized to analyze the before-and-after Kansas' accident database. By performing the analysis, it was concluded that, as of 1998, no statistically significant increases in crash, fatal crash and fatality rates were noted during the after period on either rural or urban interstate highway networks. On the other hand, statistically significant increases in crash, fatal crash and fatality rates were observed on the 2-lane rural highway network. Subsequent detailed analysis on the 2-lane highway databases filtered out all highway sections that have experienced, during the after period, the most significant increases in crashes (MSICR). Additionally, it is concluded that those MSICR sections (represent about 7% of the entire 2-lane rural highway network sections) have accounted for most of the noted significant increases in crash and fatal crash rates. Fatal crashes on the remaining 93% of the 2-lane rural network were found to be less than those observed during the before period.

17 Key Words Accident, crash, highway, speed, speed limits.		**18 Distribution Statement** No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19 Security Classification (of this report) Unclassified	**20 Security Classification (of this page)** Unclassified	**21 No. of pages** 63	**22 Price**

Form DOT F 1700.7 (8-72)

IMPACT OF NEW SPEED LIMITS ON KANSAS HIGHWAYS

By

Yacoub M. Najjar

Robert W. Stokes

Eugene R. Russell

Hossam E. Ali

Xiaobin "Carol" Zhang

Department of Civil Engineering

Kansas State University

Manhattan, KS 66506-2905

Prepared for

Kansas Department of Transportation

K-TRAN Project Number: KSU-98-3

Linda G. Voss

KDOT Monitor

FINAL REPORT

November 2000

PREFACE

This research project was funded by the Kansas Department of Transportation K-TRAN research program and the Mid-America Transportation Center (MATC). The Kansas Transportation Research and New-Developments (K-TRAN) Research Program is an ongoing, cooperative and comprehensive research program addressing transportation needs of the State of Kansas utilizing academic and research resources from the Kansas Department of Transportation, Kansas State University and the University of Kansas. The projects included in the research program are jointly developed by transportation professionals in KDOT and the universities.

NOTICE

The authors and the State of Kansas do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

This information is available in alternative accessible formats. To obtain an alternative format, contact the Kansas Department of Transportation, Office of Public Information, 7th Floor, Docking State Office Building, Topeka, Kansas, 66612-1568 or phone (785)296-3585 (Voice) (TDD).

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the State of Kansas. This report does not constitute a standard, specification or regulation.

ABSTRACT

On November 28, 1995, the National Highway System (NHS) Designation Act abolished the federal mandate for the NMSL and returned the authority of establishing speed limits to the states. By the end of 1996, 32 states had passed laws to raise speed limits on various highways. Accordingly, Kansas' law increased speed limits on most of its highways in March 1996. The detailed research study reported herein concentrated on analyzing the before an after Kansas' speed and accident databases. In regard to speed analysis, the t-test was applied to investigate whether significant increases in 85th percentile speeds were noted during the after period on both interstate and 2-lane rural highways. In this case, 3-mph increase in 85th percentile speeds was noted on interstate highway sections, and 3 to 5 mph on the 10-mph speed limit increase 2-lane highways. None was noted on the 5-mph speed limit increase 2-lane highways.

The 3-Step Sequential Analysis approach was utilized to analyze the before-and-after Kansas' accident database. By performing the analysis, it was concluded that, as of 1998, no statistically significant increases in crash, fatal crash or fatality rates were noted during the after period on either rural or urban interstate highway networks. On the other hand, statistically significant increases in crash, fatal crash and fatality rates were observed on 2-lane rural highway network. Subsequent detailed analysis on the 2-lane highway database filtered out all highway sections that have experienced, during the after period, the most significant increases in crashes (MSICR). Additionally, it is concluded that those MSICR sections (represent about 7% of the entire 2-lane rural highway network sections) have accounted for most of the noted significant increases in crash and fatal crash rates. On the other hand, fatal crashes on the remaining 93% of the 2-lane rural network were found to be less than those observed during the before period.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1

INTRODUCTION

1.1 RESEARCH OBJECTIVES

Speed limits are the maximum legal travel speeds under favorable situations of good weather, free-flowing traffic and good visibility. Appropriate speed limits are necessary to ensure a reasonable level of safe and efficient travel on highways and streets.

Posting of appropriate speed limits on state and interstate highways is of great importance. Unrealistic posted speed limits generally reduces the drivers' compliance rate. In addition, the number of accidents, related injuries and fatality rates may increase in these situations. Previous research (Florida Department of Transportation, 1980) has shown that finding the optimal speed limit for highway sections reduces the potential for speed-traffic related accidents.

The impact of recent changes of posted speed limits on Kansas highways needs to be assessed in terms of how speed and the traffic-related statistics have changed, if at all. Of great importance are the accident-related statistics and their relation to roadway characteristics and prevailing posted speed limits. The main objective of this research project is to examine whether statistically significant changes have occurred in 85^{th} percentile speeds and/or accident-related indices such as crash and fatal crash rates after posted speed limits on Kansas highways were raised. Carrying out this research study will aid the Kansas Department of Transportation (KDOT) in evaluating the suitability of current posted speed limits.

1.2 SPEED LIMIT CHANGE: HISTORICAL PROSPECTIVE

In 1974, as a result of the Arab oil embargo, the United States Congress adopted a National Maximum Speed Limit (NMSL) of 55 miles per hour (mph). Previously, states had the authority to set speed limits within their states and limits of 65 mph and 70 mph were posted on most of the United States' highways. As a result of the new adopted 55 mph speed limit, traffic slowed on all major highways and the total amount of travel declined. These changes in speed and travel were accompanied by a noticeable decrease in the number of traffic fatalities.

Despite much lower oil prices afterwards, this NMSL remained in effect for 13 years. But in the mid 1980s, average highway travel speeds were increasing. The 55 mph speed limit was increasingly ignored by many drivers and police agencies, and public officials from many western states were urging for higher speed limits to decrease the time of long distance travel. Finally, in 1987 Congress voted to allow speed limits to be increased to 65 mph on rural interstate highways in specified experimental states. The law took effect on April 1, 1987. By the end of 1987, 38 states had raised the posted speed limits on their rural interstate highways to 65 mph.

On November 28, 1995, the National Highway System (NHS) Designation Act was signed into law. The NHS Act eliminated the Federal mandate for the NMSL, thus returning the authority of establishing speed limits to the states. By the end of the calendar year 1996, a total of 32 states had passed laws to raise posted speed limits on various types of roadways. In response to the repeal of NMSL, Kansas' posted limits were raised to: i) 70 mph on most rural separated multilane highways and ii) 65 mph on most urban interstate and 2-lane rural highways.

1.3 LITERATURE REVIEW

From 1987 to present, a large number of research studies have been conducted in order to investigate the safety impact of the increased posted speed limits (Advocates for Highway and Auto Safety, 1995; Chang and Paniati, 1990; McCarthy, 1988; and Retting and Greene, 1996). Some of these studies dealt with the accident data of the whole nation (Garber and Graham, 1990; and National Highway Traffic Safety Administration, 1998) while others focused on the accident data pertaining to individual states (Agent et al., 1998; Binkowski et al., 1998; Barckett and Ball, 1990; and Brown et al., 1990). The time lengths for the data evaluated ranged from one year to several years. The analyzed data included actual traffic speed, traffic volume, numbers of accidents and accident rate per million vehicle miles (pmvm) traveled. Analysis techniques utilized in these studies can generally be divided into two main categories: i) the straightforward comparison analysis of the before-and-after accident-related statistics, and ii) the time-series regression-based accident forecasting models. Brief descriptions of both categories is presented in this section.

1.3.1. Before-And-After Comparison Analysis

Before-and-after comparison is an approach commonly applied by many researchers to analyze databases containing historical accident-related data for 10 years or less (Baum et al, 1998; Barckett et al., 1990; Oklahoma Department of Transportation, 1998; and Retting and Greene, 1996). The period before the speed-limit increase is referred to herein as the "before period" while the period after the speed-limit increase is defined as the "after period". Different comparison techniques are utilized to investigate the existence of a significant difference between the before and the after period data which can be attributed to the increase in posted speed limits. Some of the studies reported in the literature simply compared the before-and-after accident numbers and/or accident rates (Brown et al., 1990; and Sidhu, 1990). Other studies, (Oklahoma Department of Transportation, 1998) plotted the time series accident-related statistics and then used the simple eye-checking technique to detect any abnormal increases in the after period. Statistical approaches such as t- and F-tests are commonly used in this type of analysis (Brackett et al., 1990).

1.3.2. Regression-Based Analysis

One major disadvantage of comparing the after data with the before data is that this comparison ignores obvious long-term trends in the before period database (Sidhu, 1990). Regression-based accident forecasting models, when properly developed, has the advantage of projecting the number or rate of accidents for the after period based on trends obtained from the before period data. As a result, this enables researchers to compare the actual data with the model-based prediction(s), thus accounting for the long-term trends represented in the before period data. Utilizing the developed accident forecasting model, the number or rate of a specific accident-related category (example, fatal, personal injury, or property damage) expected to occur for the after period, assuming no change in speed limit, are projected. The difference between the projected and actual or reported values can then be attributed to the change in the posted speed limit.

Liner regression-based models are the most simple and widely used accident forecasting models. Various research studies have used the linear regression approach to develop accident number and/or accident rate forecasting models as a function of explanatory variables such as vehicle speed, vehicle miles traveled, vehicle volume, road geometric properties, and weather conditions (Garber and Graham, 1990). In addition to linear regression models, various nonlinear regression-based models, even though time-demanding, were successfully developed. Examples of these models are the Times Series Models (McKinght & Klein, 1990) and the Dynamic Linear Models (Raju et. al., 1998).

Even though regression-based analysis is more rational than the before-and-after comparison analysis, the validity of the forecasting models involved (both linear and nonlinear regression-based) is highly questionable when derived from historical databases containing data for 10 years or less (Oklahoma Department of Transportation, 1998). For this obvious reason and realizing that our accident database (discussed in detail in Chapter 3) for the before period is about 3.5 years, a statistical-based version of the before-and-after comparison method, referred to herein as the 3-Step Sequential Analysis technique, is utilized in this research study.

CHAPTER 2

SPEED DATA AND ANALYSIS

2.1 DESCRIPTION OF SPEED DATABASE

The speed limit statutes in Kansas were changed in March 1996. By June 1996, all new speed limit signs were posted on most Kansas highways. Therefore, in our database, the before period refers to the period before March 1, 1996, while the after period (i.e., after the speed limit change) is defined as the period after May 31, 1996.

Our analysis of speed data concentrated on the 85th percentile speed which is regarded by many traffic engineers as a major factor in evaluating operating speed as well as the primary criteria in establishing reasonable speed limits. The speed database analyzed herein included the following sub-databases: i) six rural interstate highways sections whose 85th percentile speed in the after period were evaluated every 3-months for a period covering a full year, ii) 16 2-lane rural highway sections whose 85th percentile speed in the after period were evaluated every 3-months for a period covering a full year, and iii) 51 2-lane rural highway sections whose 85th percentile speed in the after period were evaluated in the 1997 and 1999 calendar years. Evaluation of the 85th percentile speeds for the three sub-databases occurred once in the before period. Details on the before and after posted speed limits, average and standard deviation of the 85th percentile speeds prevailing on these sub-databases are given in Tables 2.1 to 2.3. Note that, sub-base (iii) was further divided into three groups (i.e., a, b and c) based on the mph increase in posted speed limits. Accordingly, group (a) contained 16 sections whose posted speed limit was kept at 55 mph, while group (b) contained six section whose speed limit was raised from 55 mph to 60 mph. The remaining 29 sections represent group (c) whose posted speed limit was increased by 10 mph from 55 mph to 65 mph (the maximum allowed on 2-lane rural highways). Detailed analysis of each sub-base is presented in the next section.

2.2 SPEED DATA ANALYSIS

2.2.1 Methodology

The primary technique adopted in this study was to compare the 85th percentile speeds (of the same sections) for the before and after periods utilizing the statistically based t-test. Based on the before and after 85th percentile speed data, the two-tailed t-test was employed to investigate whether a statistically supported significant difference in 85th percentile speeds (between the before and after data) can be noted with at least a 95% confidence level (i.e., p-value of 0.05 or less). If statistically supported significant difference is noted, then the one-tailed t-test is invoked to assess the overall mph increase (based on a 95% confidence level) in the 85th percentile speed.

2.2.2 Rural Interstate Highways : Database I

Before and after spot speed studies were performed by KDOT on the same six sections representing this database. KDOT evaluated 85th percentile speeds and then provided this information to our research team. As can be noted from Table 2.1, the 1995 spot speed studies are used herein to represent the prevailing 85th percentile speeds for the before period. During the after period, 85th percentile speeds on the same six sections were surveyed for four successive 3-month periods. Due to the 5-mph increase in the posted speed limit, it can be observed that the average 85th percentile speed has increased from 69.5 mph to 74 mph during the July-September 1996 period. After one year from increasing the speed limit, the average 85th percentile speed increased to 76.17 mph and the standard deviation of the 85th percentile speeds decreased from the 3.02 mph in the before period to 1.47 mph for the April–June 1997 after period. This means that the variation in the 85th percentile speeds between those six sections has decreased due to the 5 mph speed limit increase. Utilizing the statistical analysis methodology described in section 2.2.1, it was concluded that the increase in 85th percentile speed is significant. As of June-September 1997 period (last data available for the research team), the statistically supported increase in 85th percentile speed on those sections (with a 95% confidence level) is 3 mph. In other words, increasing the speed limit by 5 mph, has caused the 85th percentile speeds (on those six section) to increase by 3 mph. This finding is statistically supported with a 95% confidence level.

2.2.3 2-Lane Rural Highways: Database II

Spot speed studies similar to those described for database I, were performed on the 16 sections representing this database. Posted speed limits on all 16 sections were increased by 10 mph (i.e., from 55 mph to 65 mph). As can be observed from table 2.2, immediately following the 10 mph speed limit increase, average 85th percentile speed increased from 62.56 mph (in the before period) to 70.06 mph. Contrary to the behavior observed in database I for the after period, constant (about 70 mph) average 85th percentile speed is noted for this database throughout the after period. On the other hand, the 85th percentile speed standard deviation value has decreased to 2.17 mph (as of last survey conducted during April-June 1997). Out of the 10 mph speed limit increase and based on the one-tailed statistical analysis technique described in section 2.2.1, it can be concluded that an overall 5 mph increase in 85th percentile speeds has occurred on those 16 sections.

2.2.4 2-Lane Rural Highways: Database III

As shown in Table 2.3, this database is divided into three groups based on the value of their respected mph speed limit increase. Group (a) contains 16 sections whose speed limit was kept at 55 mph, while group (b) refers to six sections whose speed limit was increased by 5 mph (i.e., increased from 55 mph to 60 mph). Group (c) is represented by 29 sections which had a 10-mph increase in their speed limit. Note that, even though sections contained in both group (c) database and database II fall in the same category and mph speed limit increase value, it was not possible to combine them into one 10 mph increase database because their 85th percentile speeds were obtained at various times. Therefore, the two databases (group (c) and database II) are not compatible in regard to their 85th percentile speeds.

As of 1999, no statistically supported increases in 85th percentile speed were noted for either group (a) or group (b) databases, while a 3-mph increase in 85th percentile speeds for group (c) database is noted. Note that, a 5-mph increase was noted earlier for sections described in database II. Since group (c) database contain more sections than databases II (29 vs. 16) and almost have similar averages and standard deviations, it is logical to assume that findings inferred from group (c) are more reliable than those obtained from database II.

Based on results obtained in this section and further examination of speed data reported in Tables 2.1 to 2.3, the following additional summary conclusions are cited :

1. Statistically supported significant increases in 85th percentile speeds are noted to be less than the actual speed limit increases. In our case, a 3 mph increase was realized on the 5-mph speed limit increased rural interstate highway sections; 3 to 5 mph on the 10-mph speed limit increased 2-lane highways, and none on the 5-mph speed limit increased 2-lane highways.

2. Standard deviation of 85th percentile speeds (i.e., speed variation) for both rural interstate and 2-lane rural highways are generally less in the after period than those noted for the before period.

3. On average, it is noted that 85th percentile speeds on:

   a. rural interstate highway sections are about 5 mph above the posted speed limit for the before and after periods,

   b. 0-mph speed limit increased 2-lane highway sections are about 10 mph above the 55 mph posted speed limit,

   c. 5-mph speed limit increased 2-lane highway sections are about 12 and 9 mph above the posted speed limit for the before and after periods, respectively, and

   d. 10-mph speed limit increased 2-lane highway sections are about 10 and 5 mph above the posted speed limit for the before and after periods, respectively.

4. Based on previously stated findings and the realization that 85th percentile speed is regarded as a major parameter in describing actual travel speed, it can be concluded that there was a significant increase in the actual travel speed in the after period on rural interstate highways and 2-lane rural 65-mph posted speed limit highways.

Table 2.1: Speed Statistics for Rural Interstate Highways (Database I) Before and After the Change in Posted Speed Limits

Posted speed limit (MPH)	65	70	70	70	70
Date of Spot Speed Study	Calendar year 1995	July to September 1996	October to December 1996	January to March 1997	April to June 1997
Number of sites*	6	6	6	6	6
Average 85th percentile speed value (MPH)	69.50	74.00	75.00	75.33	76.17
Standard deviation of 85th percentile speed values (MPH)	3.02	3.85	3.03	2.94	1.47
MPH increase in 85th percentile speed values based on 95% statistically-based level of confidence	------	< 1.0	2	2	3

***Same sites were used for the entire duration of the Spot Speed Studies**

Table 2.2: Speed Statistics for 2-Lane Highways (Database II) Before and After the Change in Posted Speed Limits

Posted speed limit (MPH)	55	65	65	65	65
Date of Spot Speed Study	Calendar year 1995	July to September 1996	October to December 1996	January to March 1997	April to June 1997
Number of sites*	16	16	16	16	16
Average 85th percentile speed value (MPH)	62.56	70.06	69.38	69.88	69.81
Standard deviation of 85th percentile speed values (MPH)	3.08	3.13	2.58	2.09	2.17
MPH increase in 85th percentile speed values based on 95% statistically-based level of confidence	------	5	5	5	5

***Same sites were used for the entire duration of the Spot Speed Studies**

Table 2.3: Speed Statistics for 2-Lane Highways (Database III) Before and After the Change in Posted Speed Limits

Date of Spot Speed Study	1996#	1997	1999
a) 0 MPH Speed Limit Increase Sites			
Posted speed limit (MPH)	55	55	55
Number of sites*	16	16	16
Average 85th percentile speed value (MPH)	64.75	66.50	66.13
Standard deviation of 85th percentile speed values (MPH)	3.53	2.31	2.55
MPH increase in 85th percentile speed values based on 95% statistically-based level of confidence	----	None	None
b) 5 MPH Speed Limit Increase Sites			
Posted speed limit (MPH)	55	60	60
Number of sites*	6	6	6
Average 85th percentile speed value (MPH)	67.67	69.67	69.00
Standard deviation of 85th percentile speed values (MPH)	2.94	1.03	2.45
MPH increase in 85th percentile speed values based on 95% statistically-based level of confidence	----	None	None
c) 10 MPH Speed Limit Increase Sites			
Posted speed limit (MPH)	55	65	65
Number of sites*	29	29	29
Average 85th percentile speed value (MPH)	66.86	70.86	71.38
Standard deviation of 85th percentile speed values (MPH)	2.74	2.34	2.11
MPH increase in 85th percentile speed values based on 95% statistically-based level of confidence	----	2	3

 # Before any change in the posted speed limits
***Same sites were used for the entire duration of the Spot Speed Studies**

CHAPTER 3

ACCIDENT DATA AND ANALYSIS

3.1 DESCRIPTION OF THE ACCIDENT DATABASE

The accident database investigated in this study was obtained from KDOT-Bureau of Transportation Planning. Complete crash data from 1993 to 1998 was obtained for the following three highway networks: i) rural interstate (RI) highways, ii) urban interstate (UI) highways, and iii) 2-lane rural (2LR) highways. For each highway network, three accident-related categories, namely; Crash Rate (CR) per million vehicle miles (pmvm), Fatal Crash Rate (FCR) and Fatality Rate (FR) per 100 million vehicle miles (p100mvm), were chosen as the 3-key indices to investigate the impact of the new speed limits on highway safety. CR is used herein to assess the impact of new speed limits on all crashes, while FCR and FR are used to assess the impact on severity of accidents. Note that, in the accident severity analysis, FCR is considered as the primary factor, while FR is analyzed herein as a supplement to FCR. Generally, FCR is a more stable accident-related parameter than FR. In this research study, the word crash is used to represent an accident involving at least one vehicle, fatal crash represents an accident which has resulted in at least one fatality, while fatality refers to person(s) who died in an accident. Moreover, rates are used in this study instead of actual numbers because it has long been recognized by traffic engineers that the single factor that correlates most closely with accident frequency for a given highway segment is the average daily traffic (ADT) volume. Accordingly, the more vehicles on a given roadway segment the larger the probability of an accident to occur on that segment. Therefore, it is more reasonable and accurate to analyze accident-related statistics such as crashes, fatal crashes and fatalities using rates (pmvm or p100mvm) instead of numbers.

3.2 ACCIDENT DATA ANALYSIS

3.2.1 3-Step Sequential Analysis Methodology

The analysis approach utilized in this study is termed as the 3-Step Sequential Analysis technique. This technique utilizes a pure statistics-based approach along with time-series yearly rate trend plots in order to thoroughly analyze the crash, fatal crash and fatality rate databases. In particular, this technique is composed of following three sequential steps:

Step A: Pure Statistics Approach

In this stage, monthly accident rates from 1993 to 1998 were divided into three periods, namely; i) the before period which contains monthly crash, fatal crash and fatality rates for all 1993, 1994 and 1995 years, ii) the after period represented by the monthly rates for all 1997 and 1998 years, and iii) the intermittent period which is composed of all 1996 monthly rate data. In this study, intermittent 1996 period data were not considered in this analysis stage since speed limits were increased during this year. Accordingly, part of this intermittent data belongs to the before period while the remaining part belongs to the after period. Moreover, omitting this data from the statistical analysis would eliminate any abnormalities that might have occurred in the immediate before and after transition periods. In doing so, stable before and after period monthly rate databases were obtained. The before and after period databases respectively contained 36 and 24 consecutive monthly rate data sets. Consequently, the two-tailed t-test was used to investigate whether a statistically supported significant difference of a specific monthly rate (i.e., CR, FCR or FR) between the before and after period databases can be noted with at least a 95% confidence level (i.e., p-value of 0.05 or less). In other words, the change in monthly rate values between the before and after periods is considered statistically significant (with 95% confidence) only if the resulting p-value is less than or equal to 0.05. On the other hand, if the resulting p-value is greater than 0.05, then any difference in monthly rate values between the before and after periods is considered statistically insignificant.

Step B: Evaluation of Time-Series Yearly Rate Trend Plot

Time-series yearly rates from 1993 to 1998 were plotted and personally examined by the research team to determine whether the change in a specific yearly rate is significant or not. If a noticeable and consistent upward trend in the after period is observed, the increase is considered significant. The change is considered insignificant if any of the following conditions are noted: (i) a slight consistent upward yearly rate trend in the after period, (ii) inconsistent yearly rate trend in the after period (i.e., zigzagging behavior), and (iii) presence of higher yearly rate(s) in the before period.

Step C: Final Conclusion

Conclusive results regarding significant or insignificant increases in CR, FCR or FR are reached if results deduced from Step A and Step B are in full agreement. Otherwise, the results are considered inclusive.

The 3-Step Sequential analysis technique adopted in this study was utilized to analyze the accident-related data for rural interstate (RI), urban interstate (UI) and 2-lane rural (2LR) highway networks. Note that, no 3-Step Sequential analysis was performed on any portions of these networks where the speed limit was unchanged. Detailed analysis and findings for each highway network are presented in the following sections.

3.2.2 Rural Interstate Highway Network

The posted speed limit was increased from 65 mph to 70 mph (by 5 mph) on 97% of this highway network. Therefore, all data termed herein as "Change Section" represent all highway sections whose posted speed limit was increased by 5-mph. Figure 3.1(a) shows a histogram of monthly crash rates for the before (i.e., 36 months) and after (i.e., 24 months) periods. Average and standard deviation of monthly crash rates for the before and after periods are also posted on Figure 3.1(a). Utilizing the two-tailed t-test according to Step A analysis method described in section 3.2.1, a p-value of 0.17 (posted on Figure 3.1(a)) was obtained. Since this resulting p-value is < 0.05, it can be concluded that the noted increase in monthly crash rates from an average of 0.75 pmvm (for the before period) to an average of 0.85 pmvm (for the after period) is statistically insignificant. In other words, the noted numerical increase (i.e., from 0.75 to 0.85) cannot be statistically defined as significant with a 95% confidence level. Therefore, the Step A conclusion is statistically insignificant.

By examining the yearly crash rate plot depicted in Figure 3.1(b) and utilizing the Step B procedure in terms of rules and conditions, it can be concluded that the increase in crash rate is insignificant. Note that, the yearly crash rate for the 1993 year is higher than those reported for 1997 and 1998 years. Since conclusions obtained from Step A and Step B are in full agreement (i.e., insignificant from Step A and insignificant from Step B), the final conclusion is: the noted increase in crash rate during the after periods is “statistically insignificant”.

A histogram of monthly fatal crash rates (p100mvm) for the before and after periods is shown in Figure 3.2(a). In this case, the average monthly rate has decreased from 0.84 p100mvm for the before period to 0.74 p100mvm for the after period. Clearly there was no increase in fatal crash rate during the after period. Therefore, in this case, a t-test is not needed to investigate whether a significant increase in the after period is noted. To investigate whether the noted decrease is statistically supported, the two-tailed t-test was performed and yielded a p-value of 0.58. This p-value indicates that the decrease in fatal crash rate is statistically insignificant. Therefore, the conclusion from Step A analysis: no increase in fatal crash rate is noted.

Referring to Figure 3.2(b) to perform the Step B analysis, it can be noted that a sharp zigzagging behavior is evident in the after period. Accordingly, it can be concluded that there is no evidence of any significant increase in fatal crash rates due to the increase in posted speed limit. The final conclusion on whether a statistically significant increase in fatal crash rate (with 95% confidence level) is evident can be obtained by performing the Step C analysis. In this case, Step A and Step B conclusions are in full agreement that no significant increase is noted during the after period. Therefore, the final conclusion is: difference in fatal crash rate between the before and after periods is “statistically insignificant”.

The same 3-Step Sequential analysis was performed on the fatality rate database represented by Figures 3.3(a) and 3.3(b). Note the similarities between these figures and Figures 3.2(a) and 3.2(b). This similarity is due to the fact that, the majority of fatal crashes in this highway network has resulted in one fatality. In general, FR is always greater or equal to FCR. Based findings of Step A conclusion (p-value = 0.62 which is <0.05) and Step B (sharp zigzagging behavior is evident in the after period), the final conclusion according to step C is: the noted difference in fatality rate is "statistically insignificant".

A summary of all conclusions obtained herein using the 3-Step Sequential analysis procedure for crash, fatal crash and fatality rates is presented in Table 3.1. As explained before, Step C is executed based on the sub-conclusions obtained from pure statistics analysis (Step A) and examination of the yearly rate trend plot (Step B). Since Step A and B agreed on the sub-conclusion that there are no significant increases in the after period, it is summarized in Step C that there are no statistically supported significant increases in crash, fatal crash and fatality rates.

3.2.3 Urban Interstate Highway Network

In this network, posted speed limits were increased by 5, 10 or 15 mph on 97% of its highway sections. Therefore, the database labeled herein as "Change Section" contains highway sections whose posted speed limit was increased by 5, 10 or 15 mph. In this case, data for the 10- and 15-mph increase sections accounted for almost 87% of this "Change Section" database. By referring to the p-values posted on Figures 3.4(a), 3.5(a) and 3.6(a), it can be concluded that noted increases in crash, fatal crash and fatality rates on this network are “statistically insignificant”. The after period zigzagging behavior (Step B) noted in all yearly rate trend plots depicted in Figures 3.4(b), 3.5(b) and 3.6(b), further support conclusions inferred from Step A analysis. Therefore, based on the unanimous sub-conclusions obtained from pure statistics and yearly rate trend plot approaches, the final conclusion (according to Step C) is**:** no statistically supported significant increases in crash, fatal crash or fatality rates are noted in the after period for this highway network. A summary of all conclusions obtained herein from Steps A, B and C for crash, fatal crash and fatality rates is presented in Table 3.1.

3.2.4 2-Lane Rural Highway Network

On the 2-Lane Rural Highway network, the posted speed limits on about 75% of the entire highway sections were increased by 5, 10, 15 or 20 mph. In this study, this portion of the network is designated as the “With Change” section database. The remaining 25% of the highway sections that were kept at their original posted speed limits are termed as the “No Change” section database. The 10-mph speed limit increase sections accounted for almost 87% of the “With Change” database and for about 65% of the entire 2-lane rural highway network.

Based on 0.0, 0.01 and 0.04 p-values posted respectively on crash, fatal crash and fatality rate histograms depicted in Figures 3.7(a), 3.8(a) and 3.9(a), it can be concluded that the noted increases during the after period in crash, fatality crash and fatality rates are “statistically significant”. Close examination of yearly crash, fatal crash and fatality rate trend plots for “With Change” database shown in Figures 3.7(b), 3.8(b) and 3.9(b), yielded similar conclusions to those obtained from Step A analysis. Accordingly, based on the summary conclusions presented in Table 3.3, the step C final conclusion is: “statistically significant” increases in crash, fatal crash and fatality rates are noted in the after period for the "With Change" database network sections.

Further analysis using the one-tailed t-test on crash and fatal crash rate histograms; indicated that, with 95% confidence, the noted statistically significant monthly rate increases are equivalent to yearly increases of about 800 crashes and 10 fatal crashes.

Subsequent examination of “With Change” and “No Change” yearly rate trend plots depicted in Figures 3.7(b), 3.8(b) and 3.9(b), indicated that consistent increases are noted for crash rate on both “With Change” and “No Change” networks during the after period. This indicates that raising the speed limits on 75% of the 2-lane rural network might have affected also the accident-related statistics on the “No Change” network database sections. This clearly indicates that there is an on-going interaction between the “No Change” and "With Change" 2-lane highway sections.

Statistical results related to average and standard deviation values of crash, fatal crash and fatality rates during the before and after periods for all three networks are listed in Table 3.4. Corresponding p-values obtained from the two-tailed t-test are also listed in Table 3.4.

3.3 DETAILED ANALYSIS ON THE 2-LANE HIGHWAY NETWORK

The 3-Step Sequential analysis approach used to analyze the accident database for the 2-lane rural network, indicated that significant increases in crash, fatal crash and fatality rates have taken place in the after period. Therefore, it is necessary to identify those 2-lane highway sections that are currently experiencing the Most Significant Increases in Crash Rate (MSICR).

Two-lane rural highway network sections were divided into five groups (according to their mph-speed limit increase value) namely; 0-mph (i.e., No Change), 5-mph, 10-mph, 15-mph and 20-mph 2-lane rural section networks. For each section-network, all sections that experienced the MSICR during the after period are identified. In general, MSICR sections are defined as the those which experienced more than 25% increases in crash rate during the after period. Once those sections were identified, further examination of each individual section was performed in order to filter out the final list of sections that have experienced the MSICR during the after period.

On the 0-mph or "No Change" section network, 19 (or about 2.5%) out of 776 sections are identified as those experiencing MSICR during the after period. On those 19 sections (representing about 5% of the total No Change network's length of 2,106 miles), fatal crashes have increased from a yearly average of 0.33 in the before period (i.e., 1993, 1994 and 1995) to six in the after period (i.e., 1997 and 1998). This translates to an increase of over 18 folds. Additionally, crashes were also increased in those 19 sections from 58/year during the before period to 133/year during the after period. Cumulative Annual Average Daily Traffic (AADT), crash, fatal crash and fatality values for the before and after periods for all 19 sections are listed in Table 3.5.

Eight (or about 5%) out of the 158 sections that represent the entire 5-mph network (total length of 765 miles) are identified as those experiencing the MSICR during the after period. Detailed information for each section is given in Table 3.6. Accordingly, yearly averages of crashes on those eight sections (representing 5% of their network's length) were increased from 38 in the before period to 77 in the after period. Moreover, fatal crashes have increased from 0.33/year during the before period to 6.0./year during the after period. These numbers constitute about a 1-fold and 18-fold increase in yearly crashes and fatal crashes, respectively.

Table 3.7 contains details on all 87 10-mph speed limit increases sections which have encountered the MSICR during the after period. Realizing that the 10-mph speed limit increase network accounts for almost 87% of the "With Change" database and for about 65% of the entire 2-lane rural highway network, it is expected that the 10-mph network contains the largest portion of sections experiencing the MSICR. Lengthwise, those 87 sections represent about 12% of the 10-mph network's total length of 5,361 miles. Notably, yearly average crashes and fatal crashes on those 87 sections have respectively increased from 444 and 18 during the before period to 968 and 45 during the after period. Accordingly, these changes indicate respective increases of about 120% and 250% in yearly crashes and fatal crashes.

Close examination of the relatively small 15 and 20-mph speed increase networks (represent total of 19 miles and 24 sections), indicated that both of these networks have performed, during the after period, at the same safety level noted during the before period. No sections in either network were identified to fall in the MSICR category.

Adding length and number of identified MSICR sections on the With Change 2-lane rural highway network, yields a total of 95 sections and 688 miles. These 95 sections represent about 7% of the total number of sections (1307) making up the entire With Change 2-lane rural highway network. Lengthwise, these section account for about 11% of the total length (6,145 miles) of the With Change network. It is to be noted that fatal crashes, during the after period on the remaining part of the network (i.e., 93% of all sections or 89% of total length) are less than those noted during the before period. Additionally, crashes for the before and after period are statically the same.

Appropriate measures taken by KDOT to bring safety levels (i.e., fatal crash and crash rates) on the 95 MSICR sections to those noted during the before period, will substantially decrease yearly crashes and fatal crashes in the With Change 2-lane rural network by about 563 and 44, respectively. Realization of these reductions will more than offset the statistically projected yearly (10 fatal crashes) increases in fatal crashes. Moreover, the 563 decrease in crashes will compensate for about 70% of the 800 statistically projected increases in crashes. Therefore, attainment of the indicated reductions in fatal crashes and crashes will definitely yield an overall safer With Change 2-lane highway network.

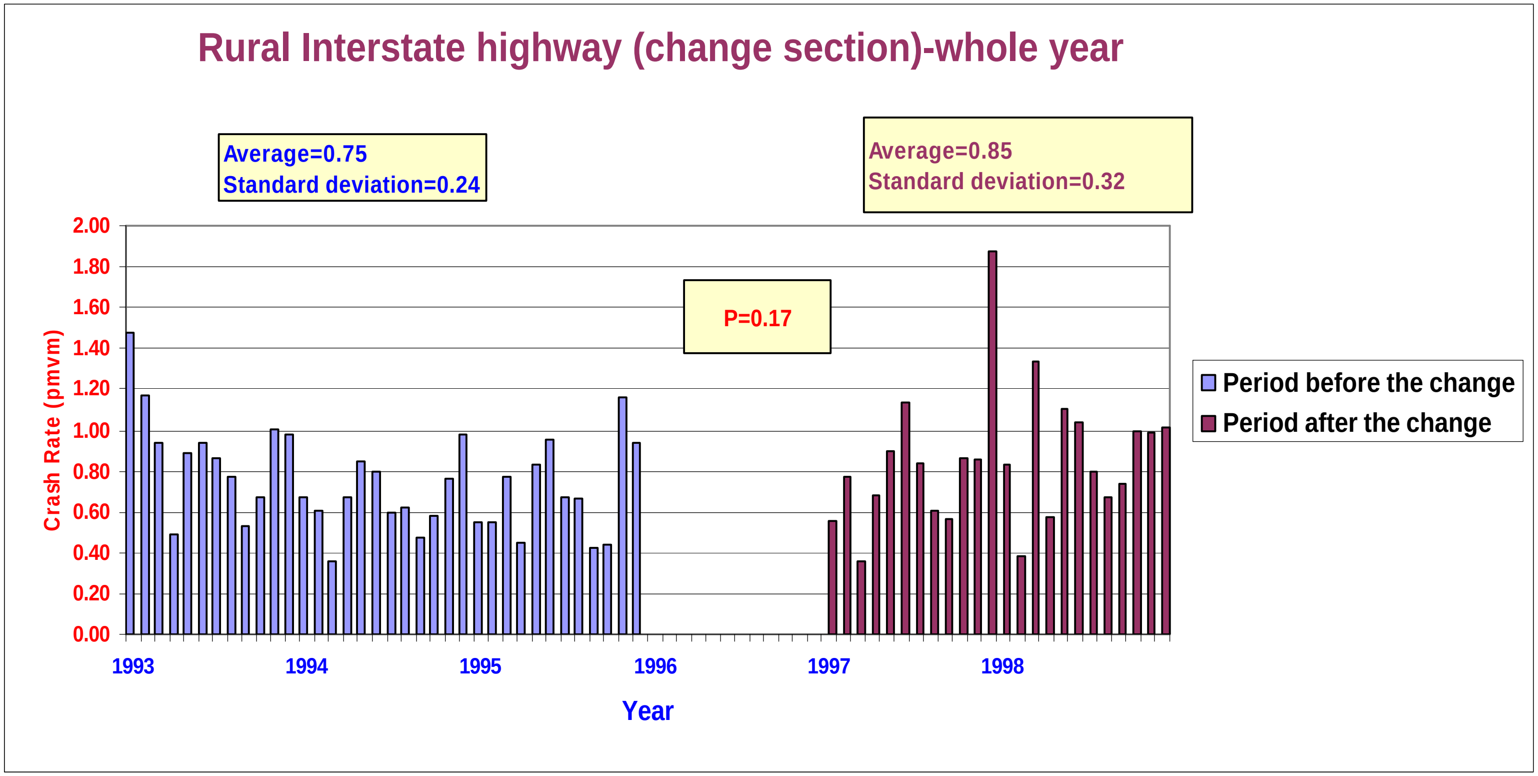

Figure 3.1(a) Crash Rate on Rural Interstate Highway Network (Change Section): Monthly Rate

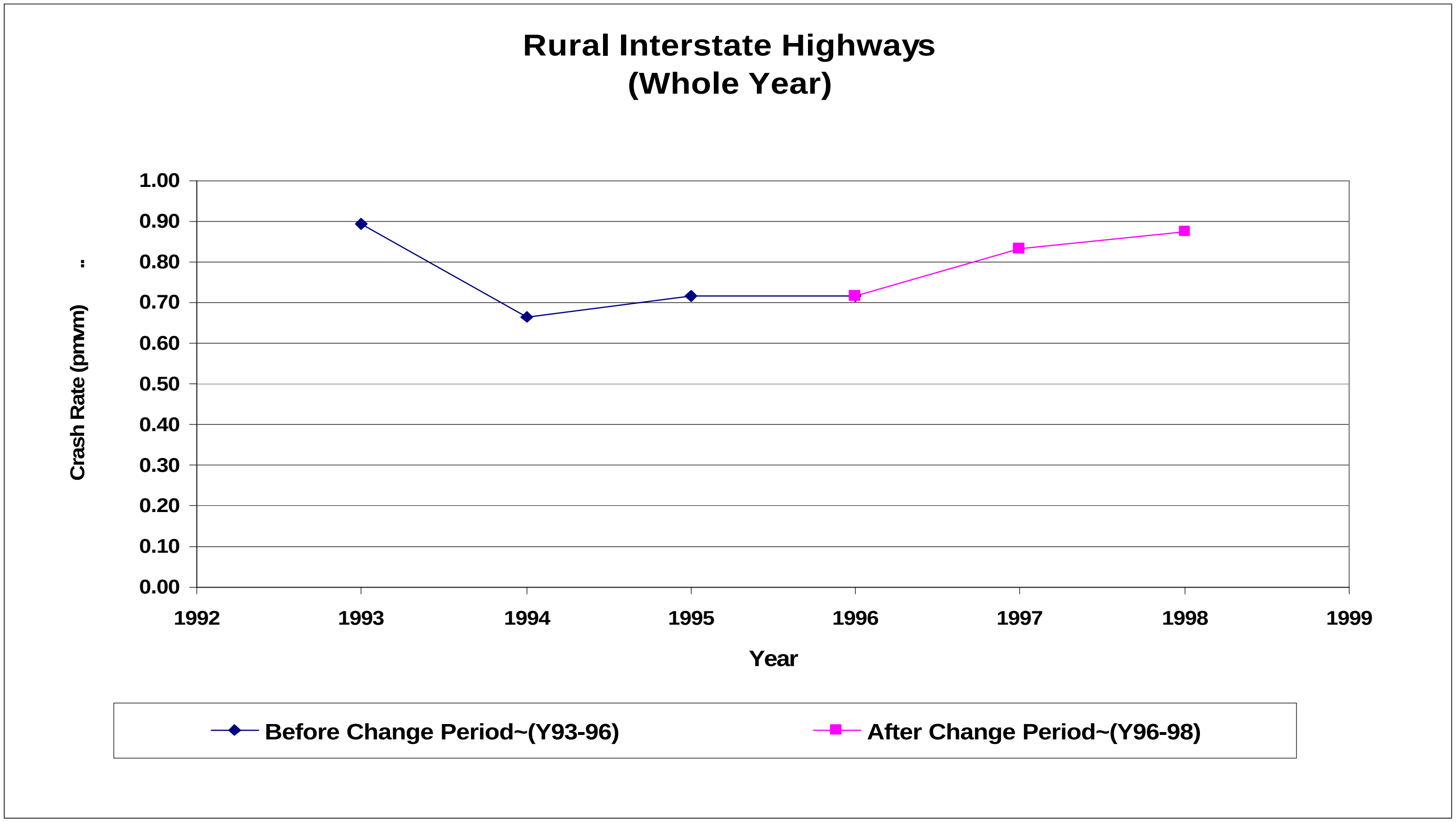

Figure 3.1(b) Crash Rate on Rural Interstate Highway Network (Change Section): Yearly Rate

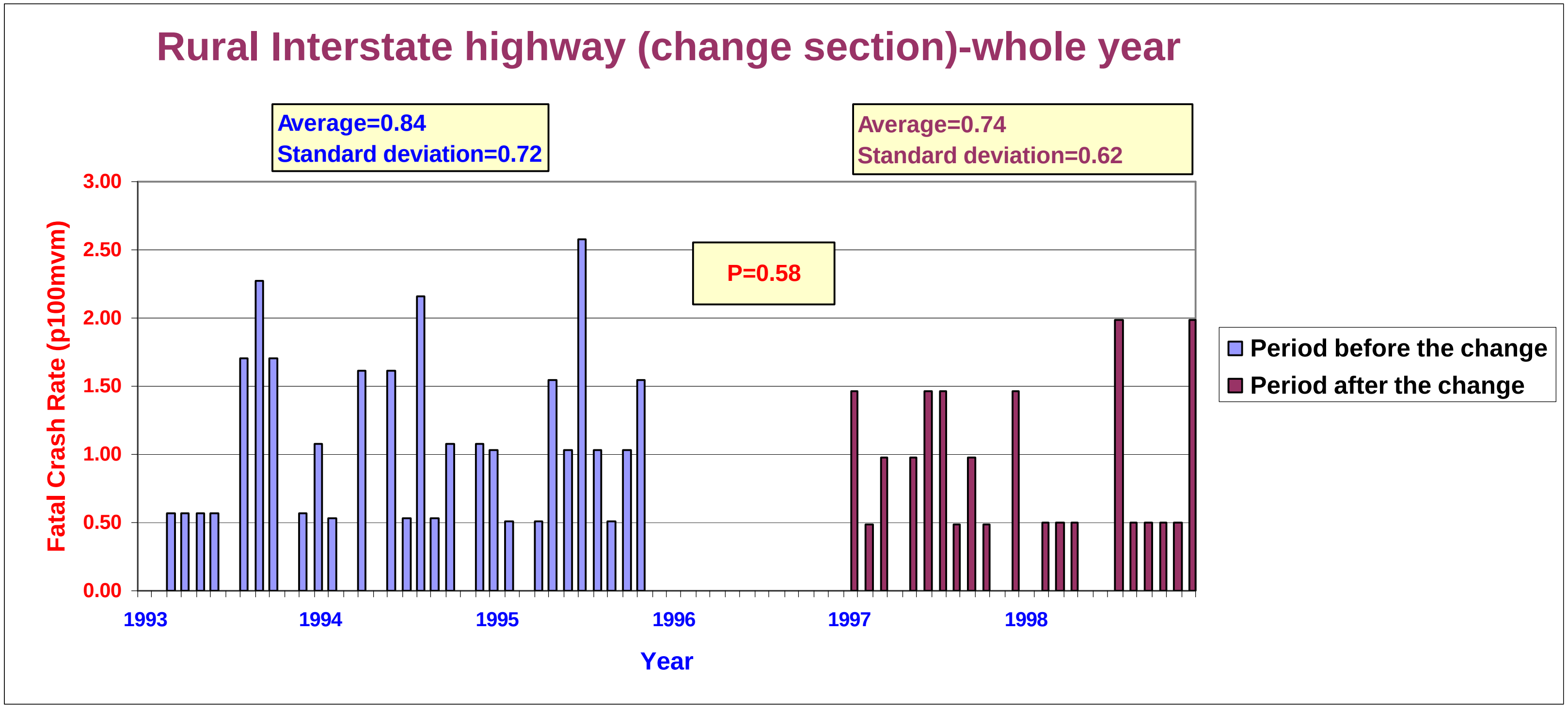

Figure 3.2(a) Fatal Crash Rate on Rural Interstate Highway Network (Change Section): Monthly Rate

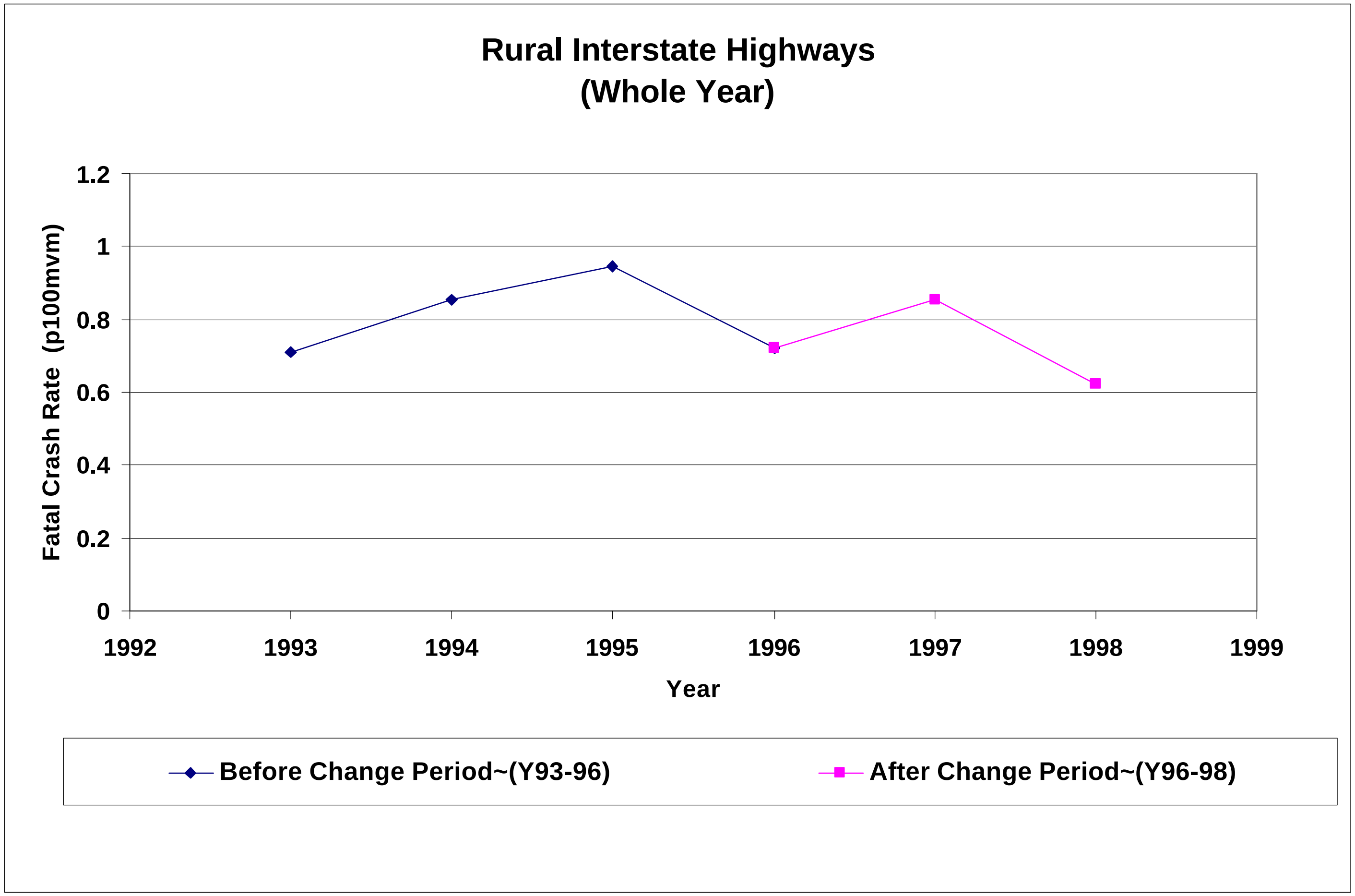

Figure 3.2(b) Fatal Crash Rate on Rural Interstate Highway Network (Change Section): Yearly Rate

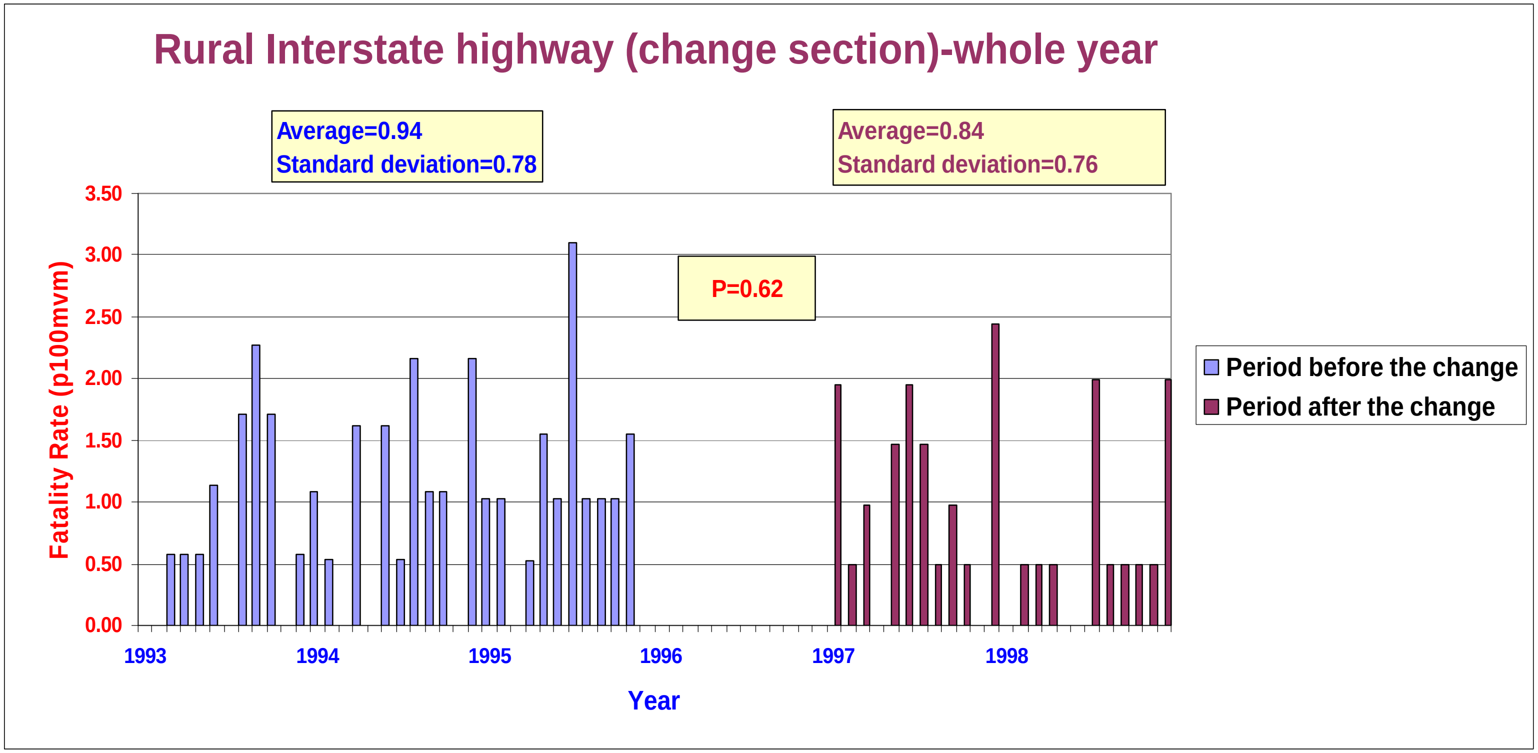

Figure 3.3(a) Fatality Rate on Rural Interstate Highway Network (Change Section): Monthly Rate

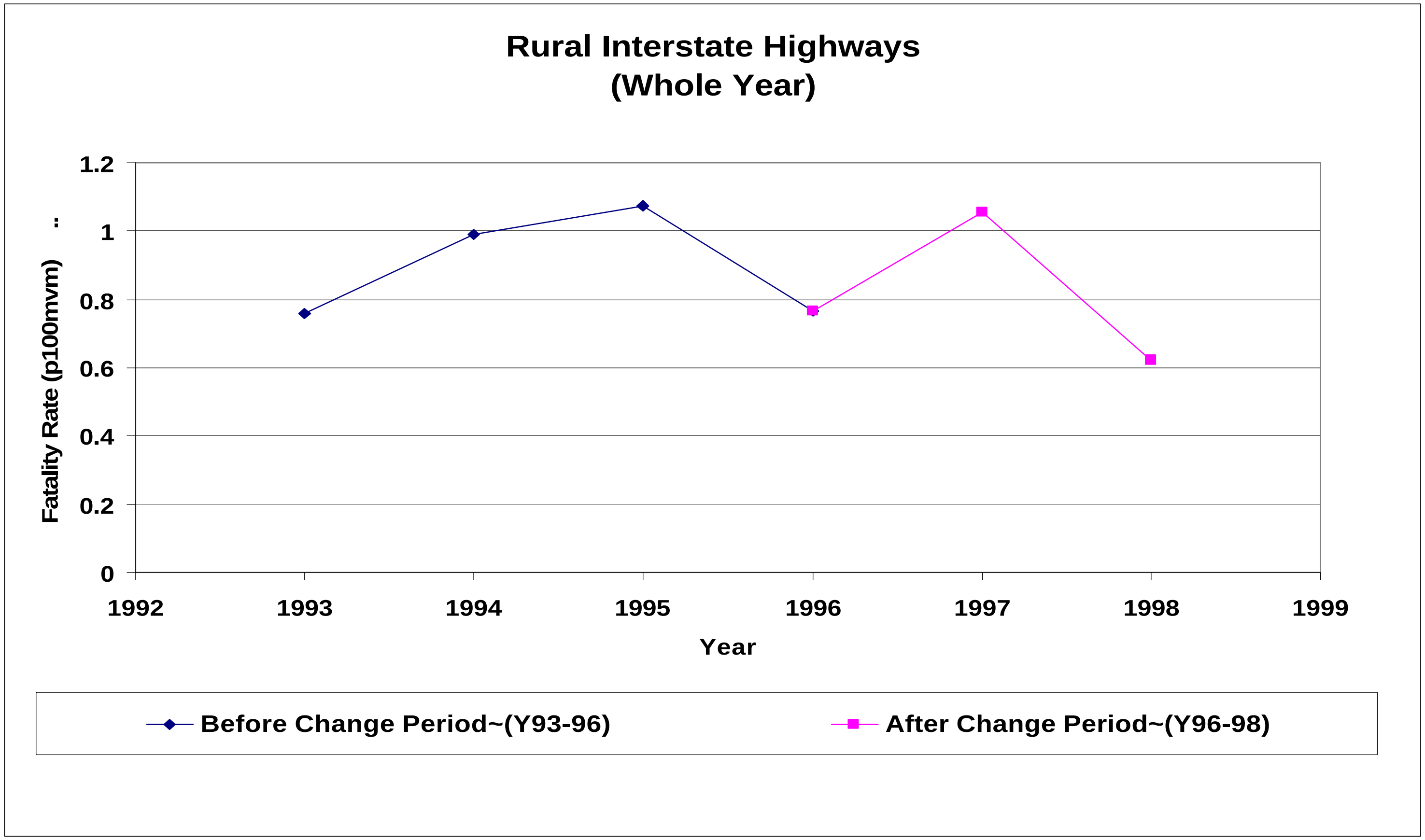

Figure 3.3(b) Fatality Rate on Rural Interstate Highway Network (Change Section): Yearly Rate

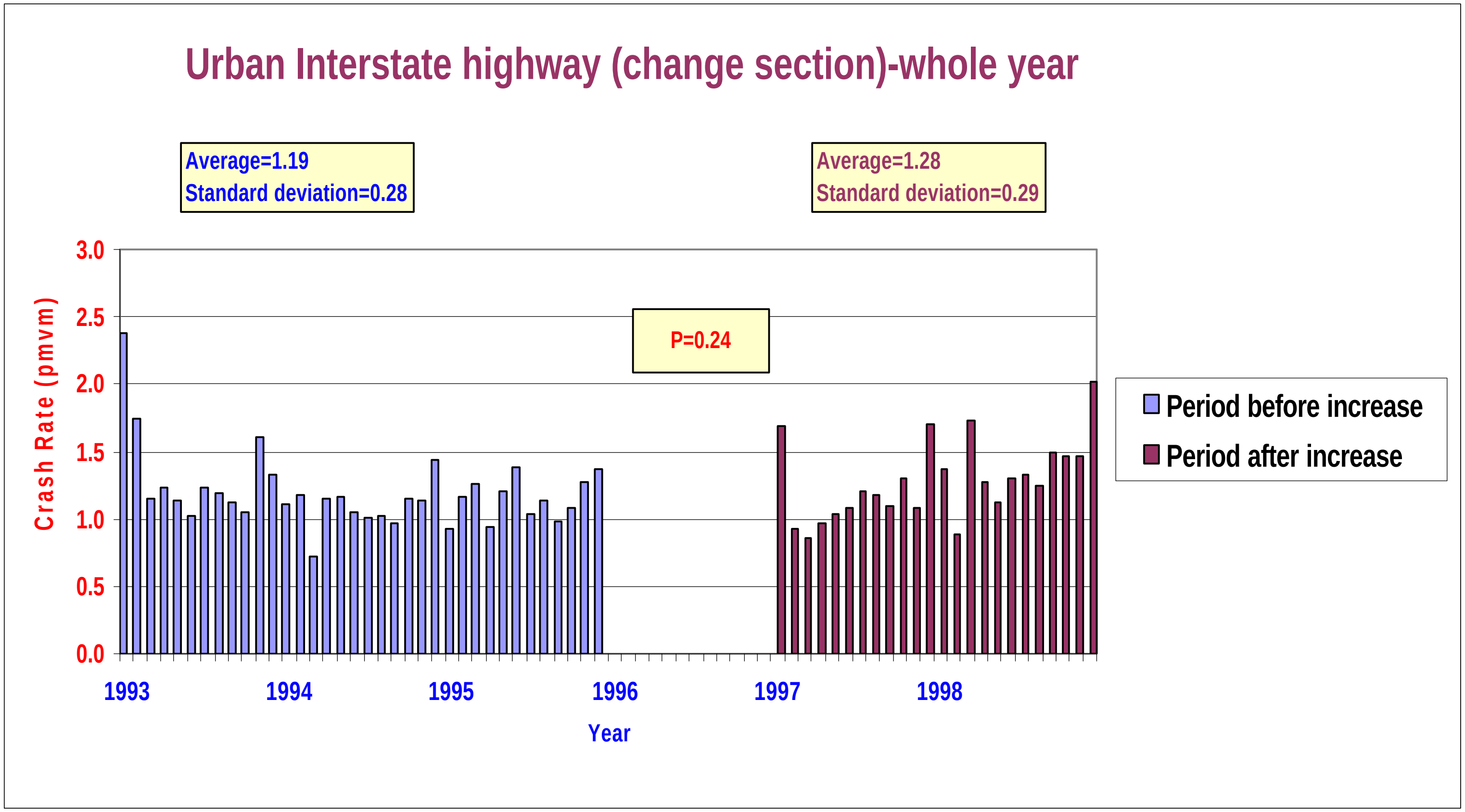

Figure 3.4(a) Crash Rate on Urban Interstate Highway Network (Change Section): Monthly Rate

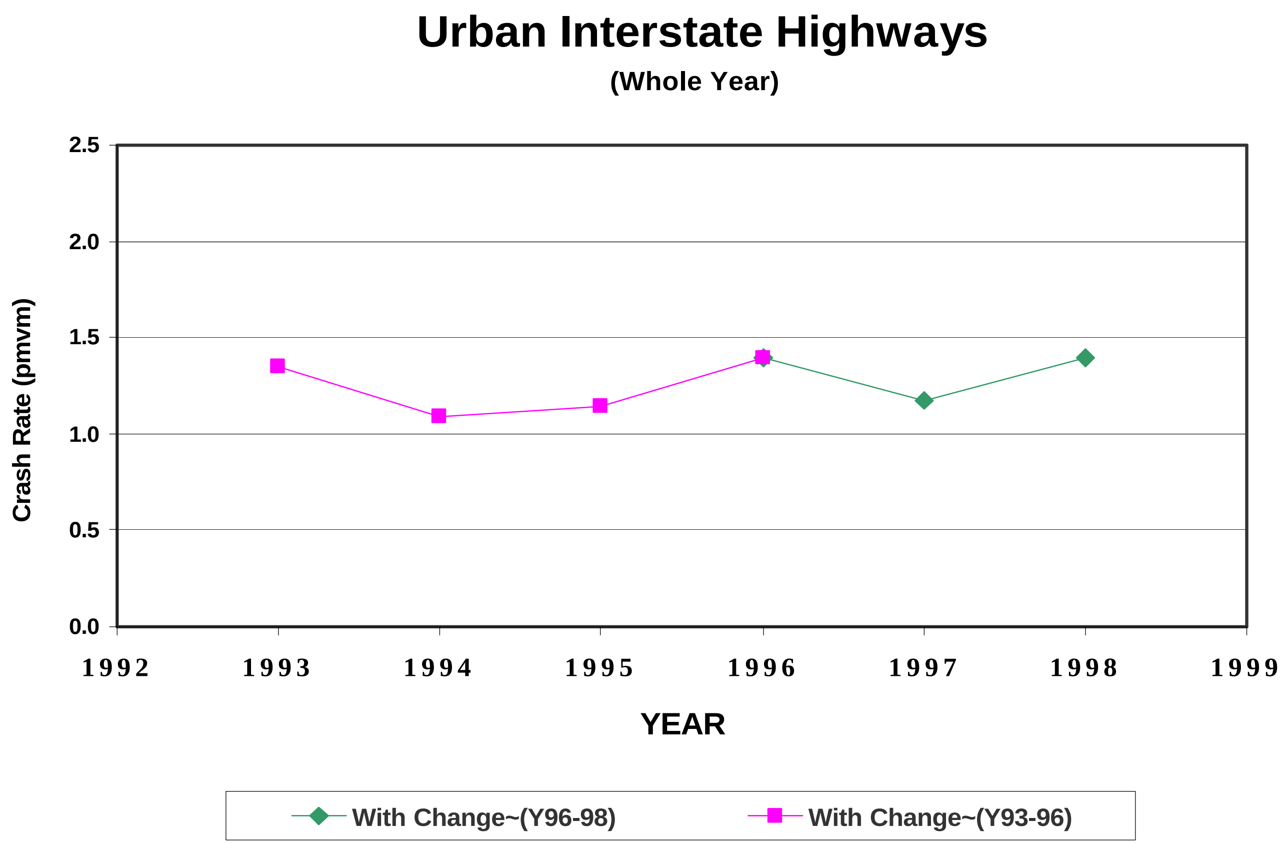

Figure 3.4(b) Crash Rate on Urban Interstate Highway Network (Change Section): Yearly Rate

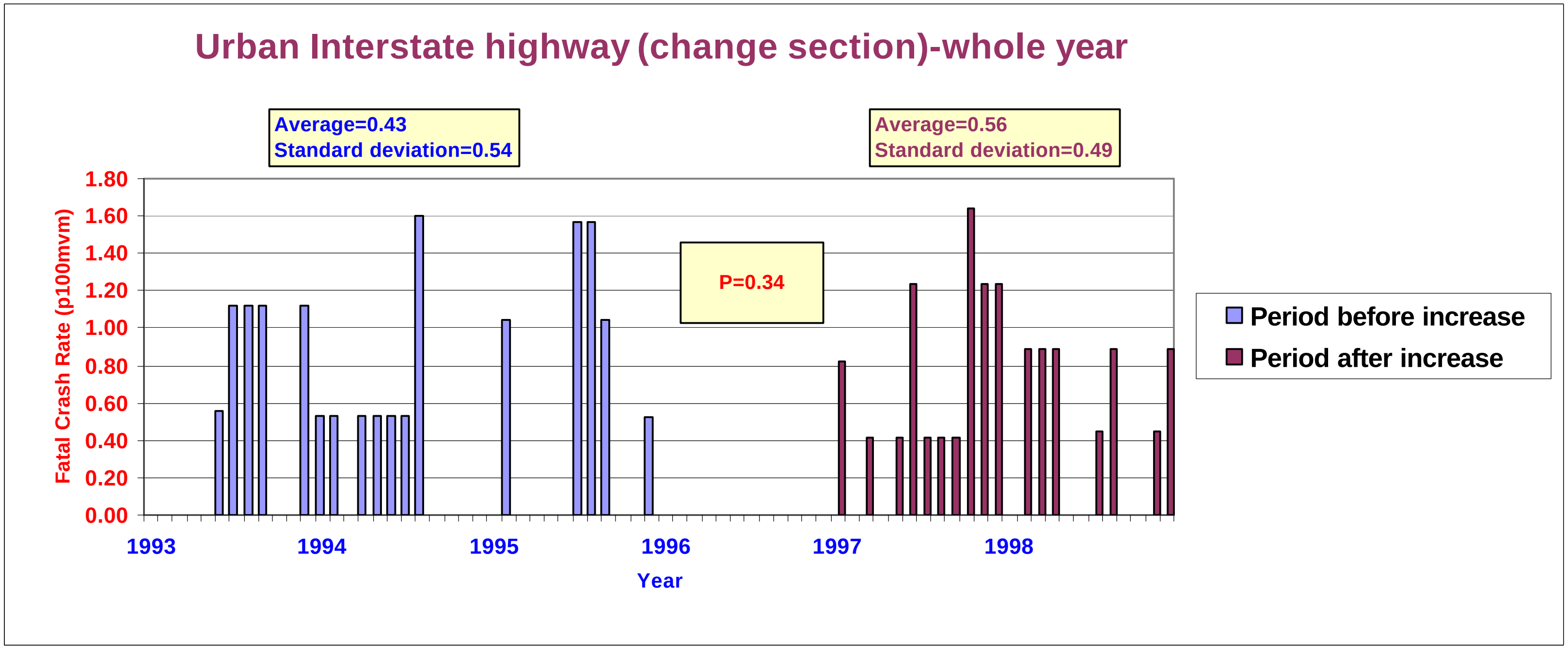

Figure 3.5(a) Fatal Crash Rate on Urban Interstate Highway Network (Change Section): Monthly Rate

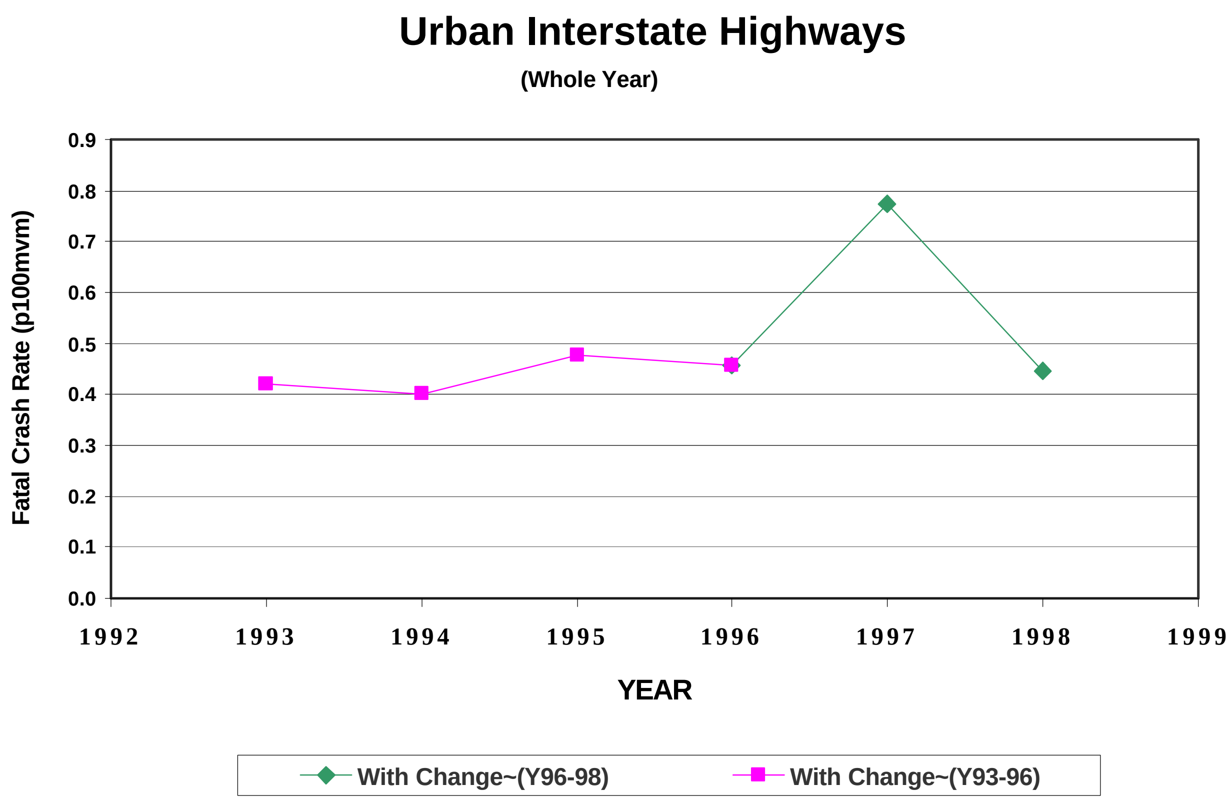

Figure 3.5(b) Fatal Crash Rate on Urban Interstate Highway Network (Change Section): Yearly Rate

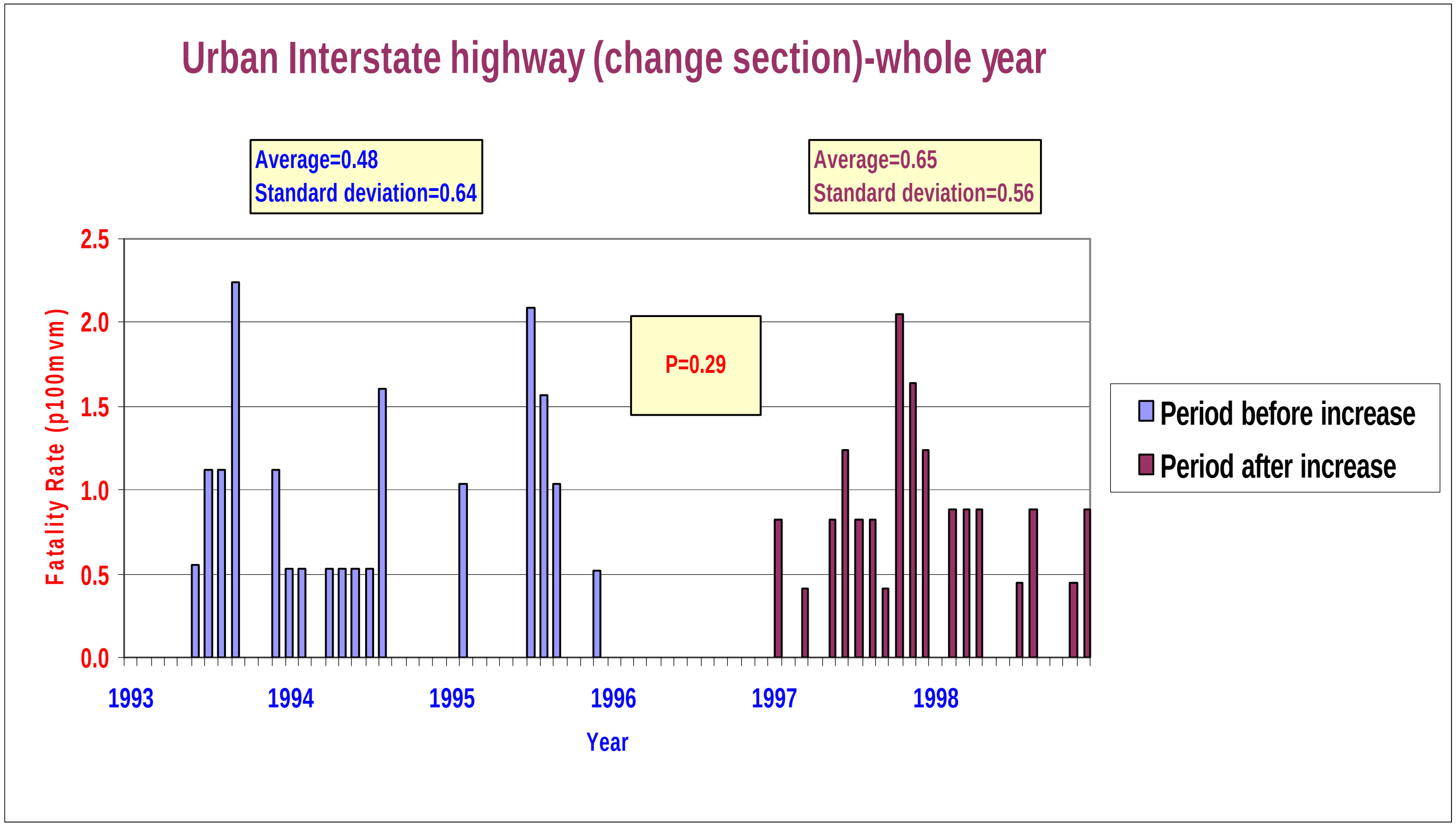

Figure 3.6(a) Fatality Rate on Urban Interstate Highway Network (Change Section): Monthly Rate

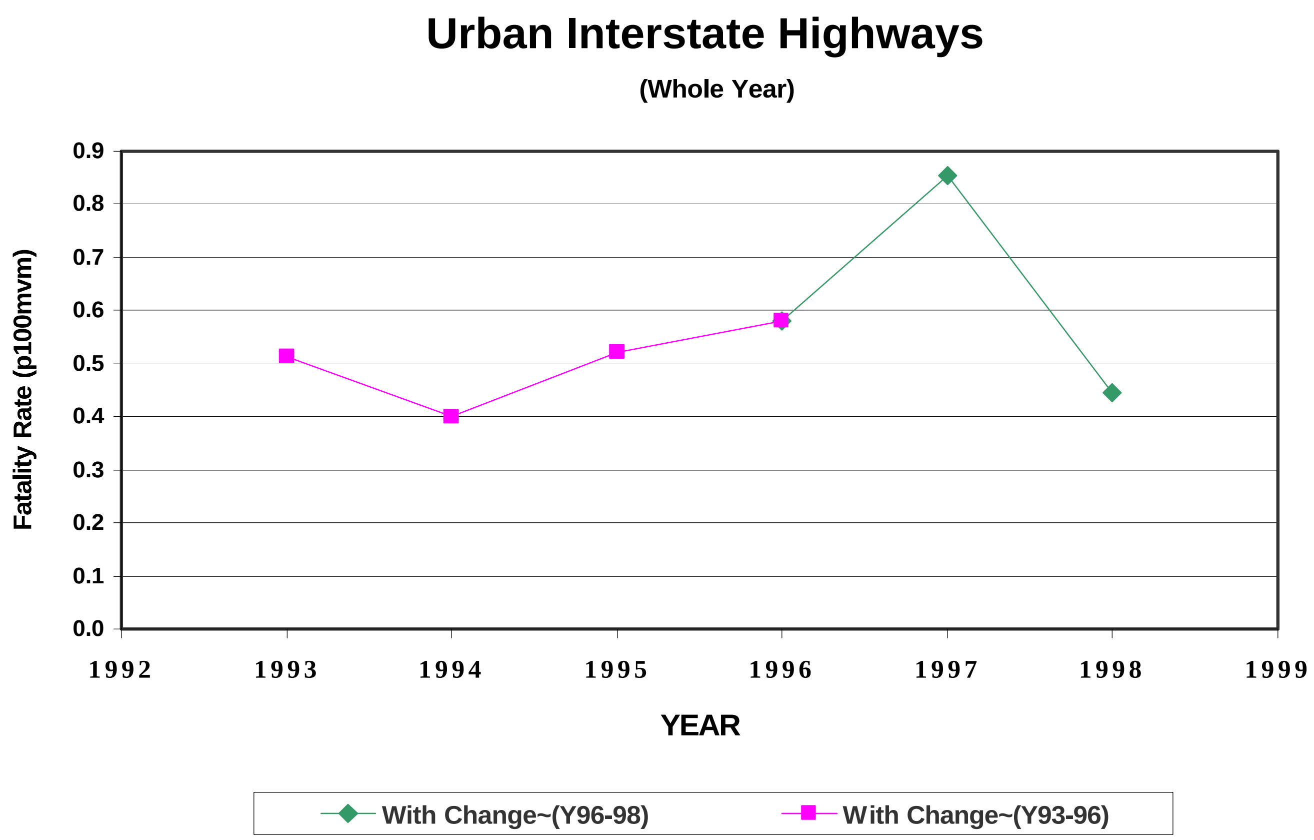

Figure 3.6(b) Fatality Rate on Urban Interstate Highway Network (Change Section): Yearly Rate

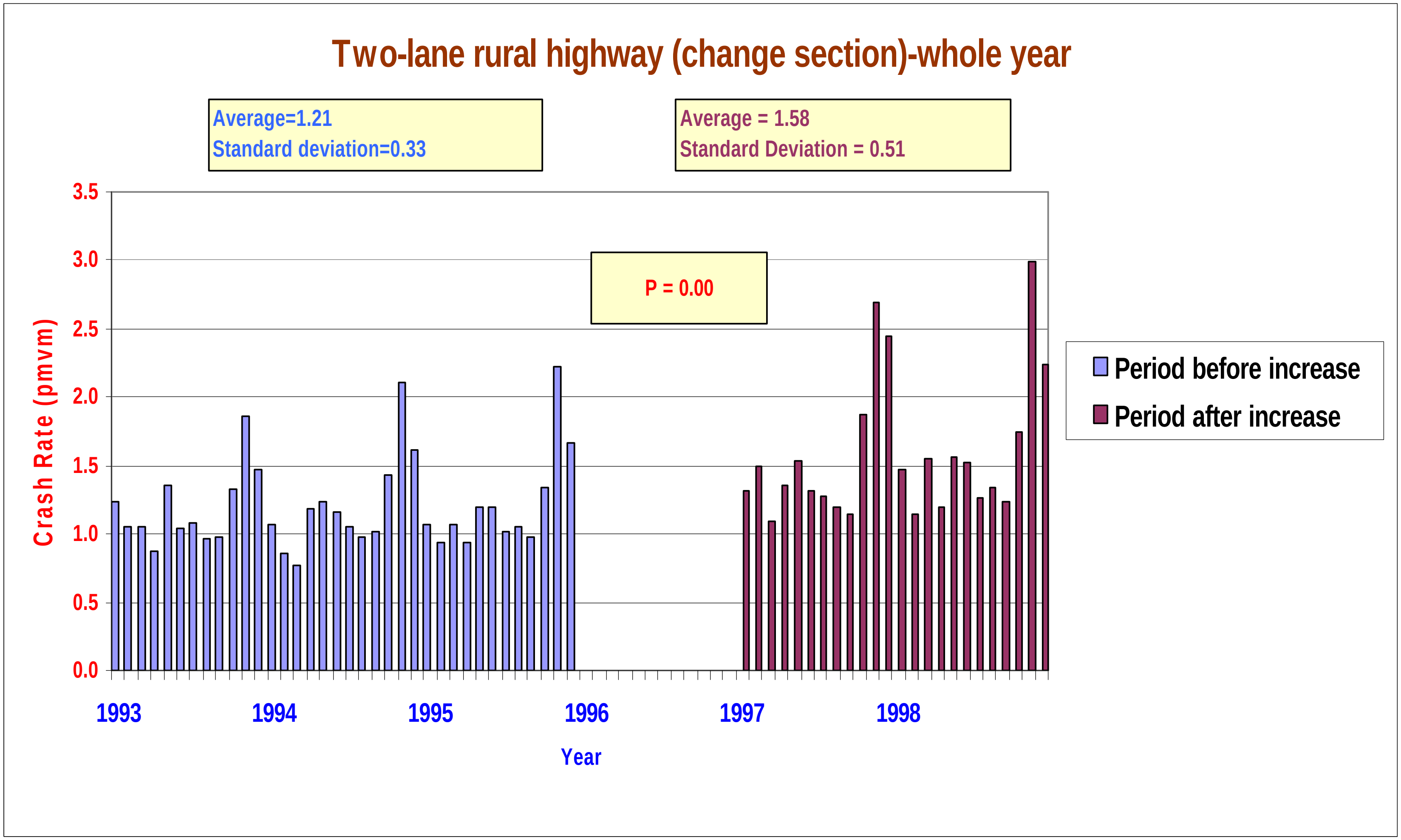

Figure 3.7(a) Crash Rate on 2-Lane Rural Highway Network: Monthly Rate (Change Section)

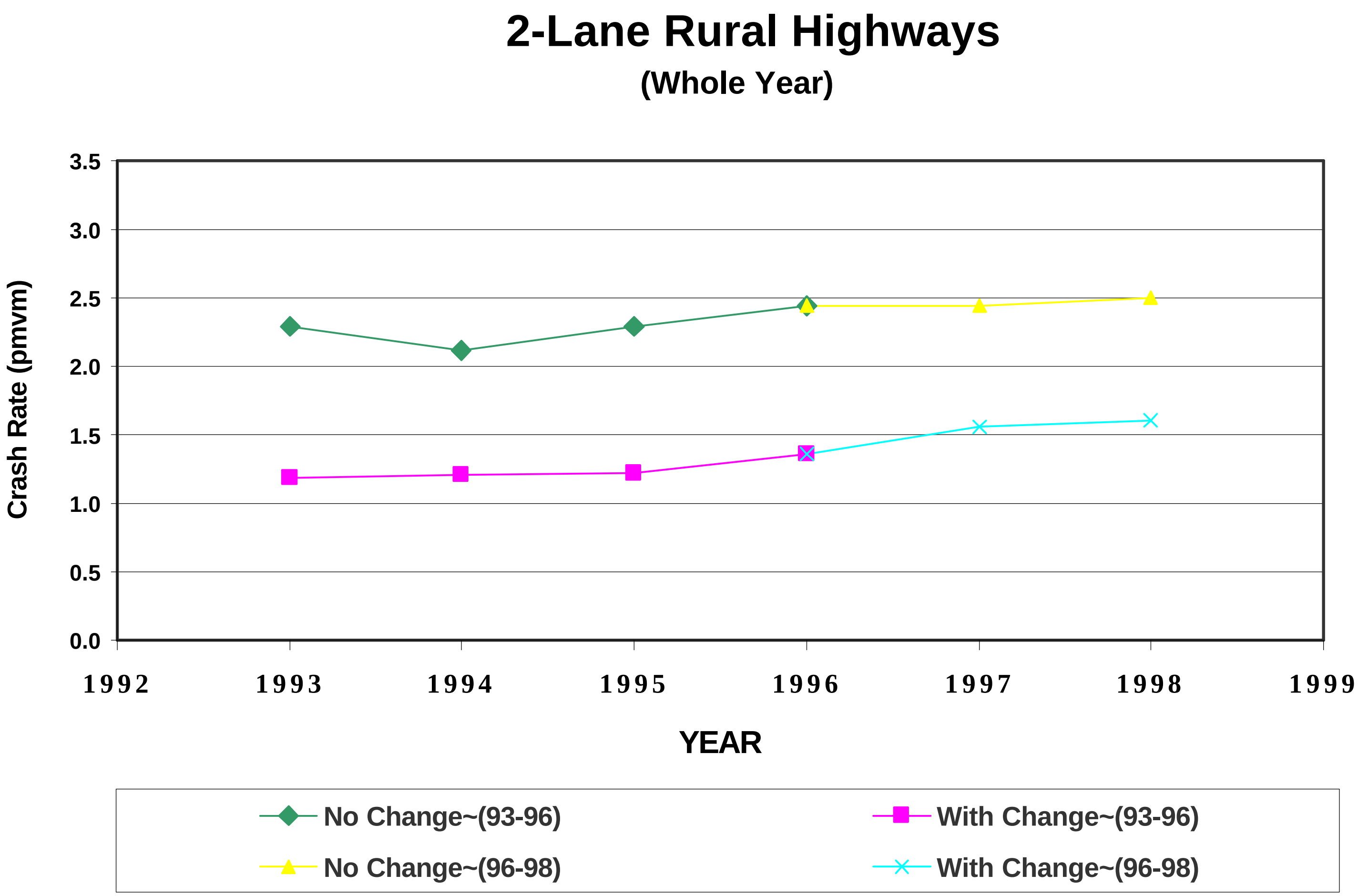

Figure 3.7(b) Crash Rate on 2-Lane Rural Highway Network: Yearly Rate (No Change & With Change Sections)

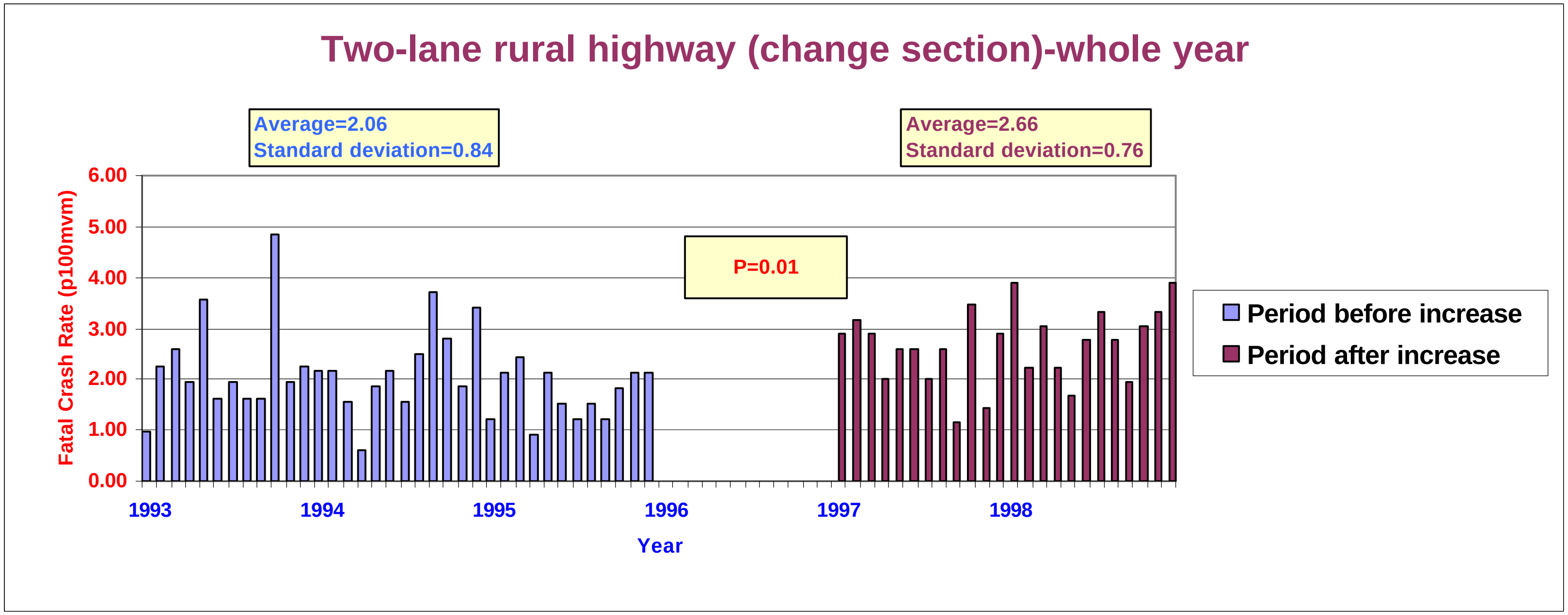

Figure 3.8(a) Fatal Crash Rate on 2-Lane Rural Highway Network: Monthly Rate (Change Section)

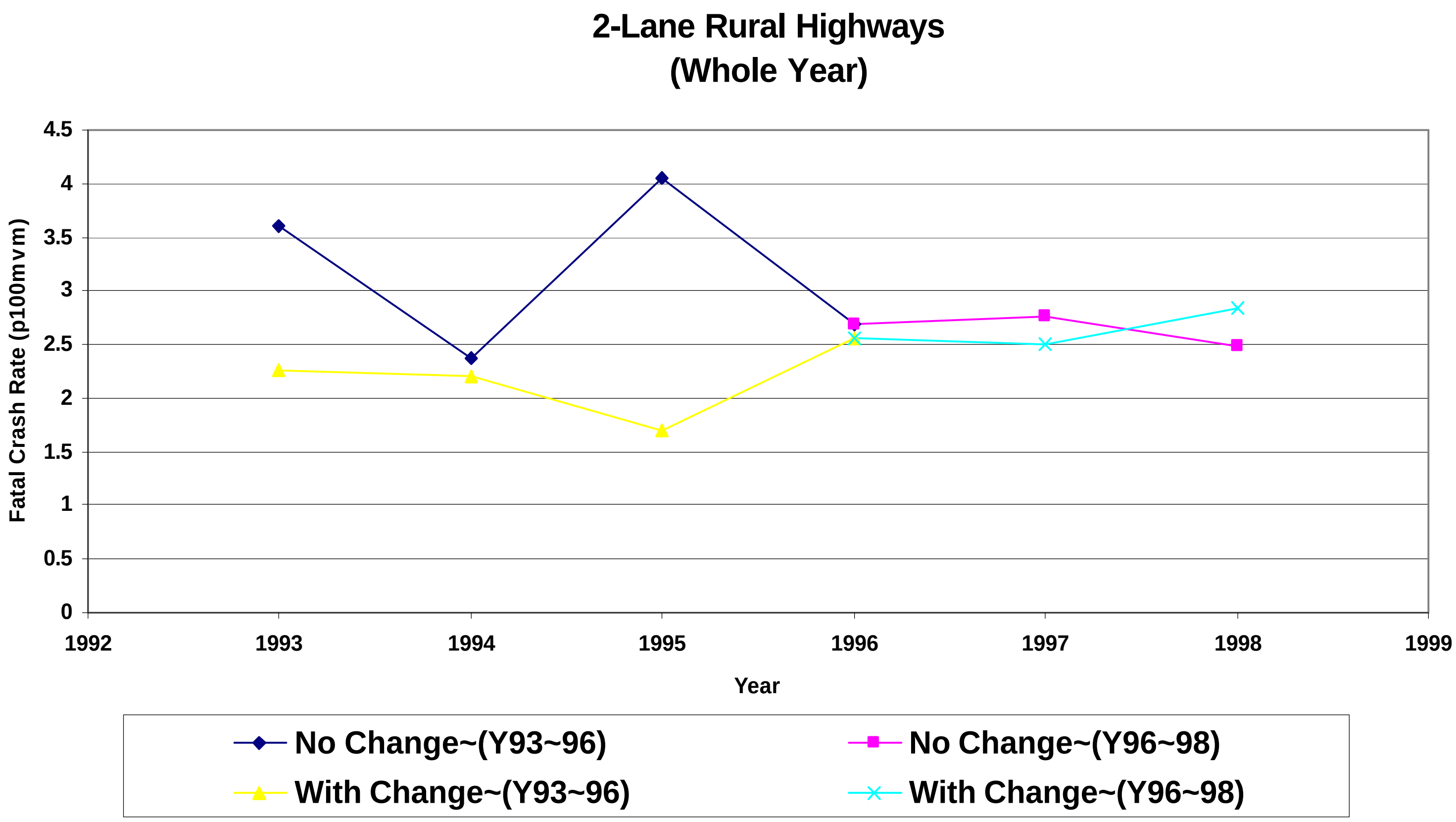

Figure 3.8(b) Fatal Crash Rate on 2-Lane Rural Highway Network: Yearly Rate (No Change & With Change Sections)

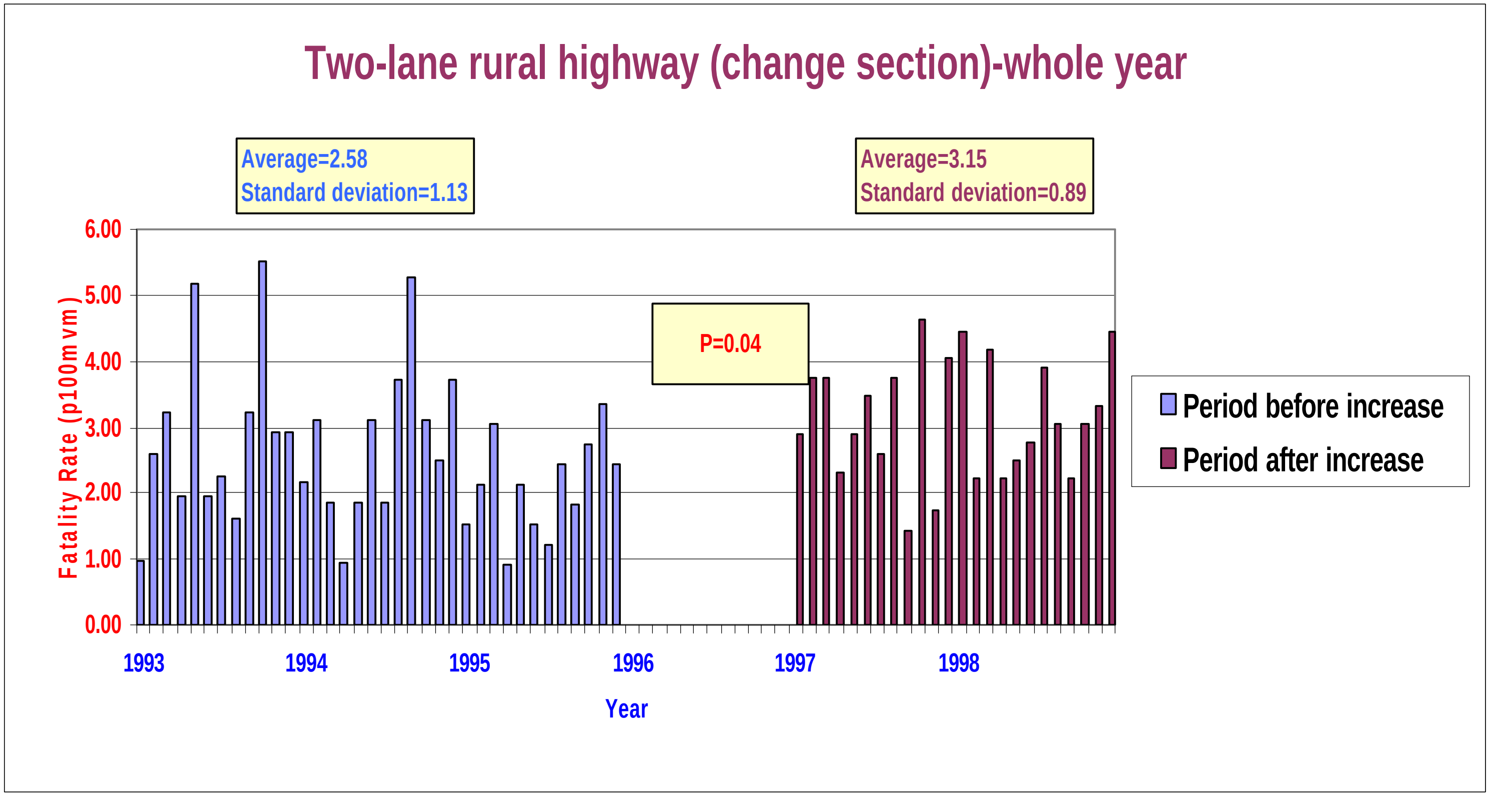

Figure 3.9(a) Fatality Rate on 2-Lane Rural Highway Network: Monthly Rate (Change Section)

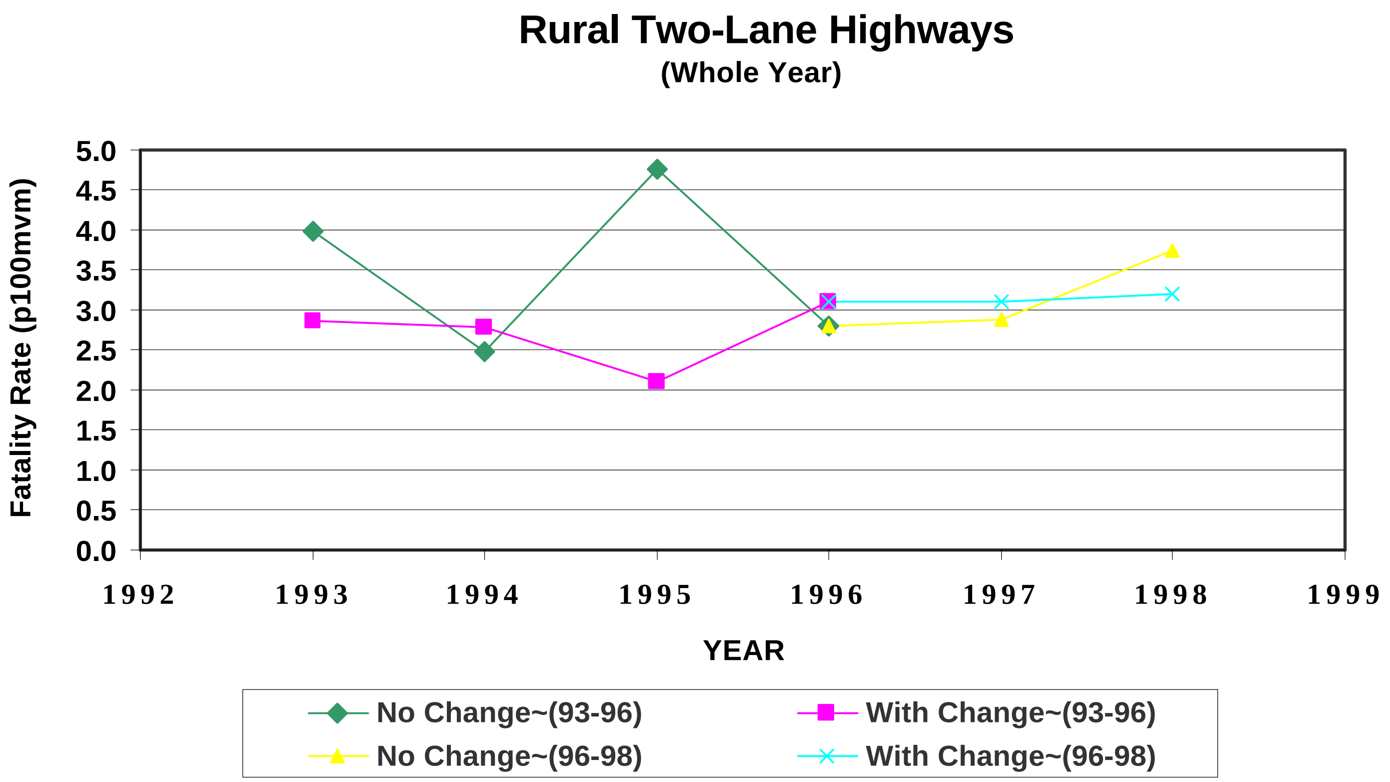

Figure 3.9(b) Fatality Rate on 2-Lane Rural Highway Network: Yearly Rate (No Change & With Change Sections)

Table 3.1 Results Obtained Using the 3-Step Sequential Analysis Method on Change Sections of Rural Interstate Highway Network

Category	Step A: Is there Significant Increase?		Step B: Is There Significant Increase?		Step C Final Conclusion: Is There Significant Increase?		
	YES	NO	YES	NO	YES	NO	INCONCLUSIVE
Crash Rate		X		X		X	
Fatal Crash Rate		X		X		X	
Fatality Rate		X		X		X	

Table 3.2 Results Obtained Using the 3-Step Sequential Analysis Method on Change Sections of Urban Interstate Highway Network

Category	Step A: Is there Significant Increase?		Step B: Is There Significant Increase?		Step C Final Conclusion: Is There Significant Increase?		
	YES	NO	YES	NO	YES	NO	INCONCLUSIVE
Crash Rate		X		X		X	
Fatal Crash Rate		X		X		X	
Fatality Rate		X		X		X	

Table 3.3 Results Obtained Using the 3-Step Sequential Analysis Method on Change Sections of 2-Lane Rural Highway Network

Category	Step A: Is there Significant Increase?		Step B: Is There Significant Increase?		Step C Final Conclusion: Is There Significant Increase?		
	YES	NO	YES	NO	YES	NO	INCONCLUSIVE
Crash Rate	X		X		X		
Fatal Crash Rate	X		X		X		
Fatality Rate	X		X		X		

Table 3.4 Statistical Results from the Two-Tailed t-Test on Change Sections of Rural Interstate, Urban Interstate and 2-Lane Rural Highway Networks

Highway Network	Accident-Related Type	p-value	Before Period		After Period	
			Average	Standard Deviation	Average	Standard Deviation
Rural Interstate	Crash Rate (pmvm)	0.17	0.75	0.24	0.85	0.32
	Fatal Crash Rate (p100mvm)	0.58	0.84	0.72	0.74	0.62
	Fatality Rate (p100mvm)	0.62	0.94	0.78	0.84	0.76
Urban Interstate	Crash Rate (pmvm)	0.24	1.19	0.28	1.28	0.29
	Fatal Crash Rate (p100mvm)	0.34	0.43	0.54	0.56	0.49
	Fatality Rate (p100mvm)	0.29	0.48	0.64	0.65	0.56
2-Lane Rural	Crash Rate (pmvm)	0.00	1.21	0.33	1.58	0.51
	Fatal Crash Rate (p100mvm)	0.01	2.06	0.84	2.66	0.76
	Fatality Rate (p100mvm)	0.04	2.58	1.13	3.15	0.89

Table 3.5 2-Lane Rural Highway Network Sections Experiencing the Most Significant Increases in Crashes During the After Period. (No Change in Speed Limit)

COUNTY	Section Number	ROAD	LENGTH	Old Speed Limit	New Speed Limit	Difference	Total AADT (93+94+95)	Total AADT (97+98)	Total Crashes (93+94+95)	Total Fatal crashes (93+94+95)	Total Fatalities (93+94+95)	Total Crashes (97+98)	Total Fatal Crashes (97+98)	Total Fatalities (97+98)
6	45	K31	1.006	55	55	0	2740	1305	**2**	**0**	**0**	**2**	**0**	**0**
7	1	K20	10.356	55	55	0	3530	4000	**26**	**0**	**0**	**47**	**2**	**8**
7	3	K20	4.569	55	55	0	875	635	**5**	**0**	**0**	**10**	**1**	**1**
16	3	K57	5.514	55	55	0	2955	2170	**5**	**0**	**0**	**13**	**1**	**1**
17	6	K1	10.787	55	55	0	1370	1055	**5**	**0**	**0**	**8**	**0**	**0**
21	2	K4	8.361	55	55	0	1525	1030	**16**	**0**	**0**	**20**	**1**	**3**
21	3	K4	5.736	55	55	0	2890	1750	**14**	**0**	**0**	**18**	**1**	**1**
22	7	K7	6.083	55	55	0	3520	2275	**27**	**0**	**0**	**35**	**0**	**0**
25	8	K99	3.929	55	55	0	2205	2300	**6**	**0**	**0**	**8**	**1**	**1**
44	15	K16	5.6	55	55	0	6585	4830	**18**	**1**	**1**	**17**	**1**	**1**
53	6	K14	11.222	55	55	0	2300	1240	**9**	**0**	**0**	**11**	**0**	**0**
57	13	K150	7.764	55	55	0	3800	2305	**6**	**0**	**0**	**8**	**0**	**0**
57	163	U50	0.371	45	45	0	8600	7940	**0**	**0**	**0**	**4**	**1**	**1**
62	11	K14	15.533	55	55	0	2085	1590	**6**	**0**	**0**	**17**	**0**	**0**
64	4	K4	4.958	55	55	0	965	590	**3**	**0**	**0**	**4**	**0**	**0**
69	155	U36	0.328	45	45	0	8845	6375	**2**	**0**	**0**	**4**	**1**	**1**
78	18	K96	3.43	55	55	0	4075	3100	**9**	**0**	**0**	**17**	**1**	**1**
99	9	K99	5.247	55	55	0	2325	1400	**10**	**0**	**0**	**14**	**0**	**0**
104	10	K105	2.346	55	55	0	2160	1575	**4**	**0**	**0**	**8**	**1**	**1**

Table 3.6 2-Lane Rural Highway Network Sections Experiencing the Most Significant Increases in Crashes During the After Period. (5-mph Change in Speed Limit)

COUNTY	Section Number	ROAD	LENGTH	Old Speed Limit	New Speed Limit	Difference	Total AADT (93+94+95)	Total AADT (97+98)	Total Crashes (93+94+95)	Total Fatal Crashes (93+94+95)	Total Fatalities (93+94+95)	Total Crashes (97+98)	Total Fatal Crashes (97+98)	Total Fatalities (97+98)
18	8	U160	9.854	55	60	5	8010	6070	**49**	**0**	**0**	**52**	**1**	**2**
27	8	K14	1.083	50	55	5	3580	2430	**4**	**0**	**0**	**5**	**2**	**2**
62	14	K14	7.766	55	60	5	3225	2460	**2**	**0**	**0**	**8**	**1**	**1**
87	1	K42	1.973	55	60	5	8160	6410	**3**	**0**	**0**	**6**	**2**	**2**
87	2	K42	7.1	55	60	5	10805	8300	**26**	**0**	**0**	**31**	**2**	**2**
89	6	U24	4.917	55	60	5	13085	8290	**8**	**0**	**0**	**19**	**2**	**2**
96	16	K49	5.476	55	60	5	5595	4325	**5**	**0**	**0**	**8**	**1**	**1**
96	44	U81	2.639	55	60	5	9765	7380	**16**	**1**	**1**	**25**	**1**	**1**

Table 3.7 2-Lane Rural Highway Network Sections Experiencing the Most Significant Increases in Crashes During the After Period. (10-mph Change in Speed Limit)

COUNTY	Section Number	ROAD	LENGTH	Old Speed Limit	New Speed Limit	Difference	Total AADT (93+94+95)	Total AADT (97+98)	Total Crashes (93+94+95)	Total Fatal Crashes (93+94+95)	Total Fatalities (93+94+95)	Total Crashes (97+98)	Total Fatal Crashes (97+98)	Total Fatalities (97+98)
1	17	U59	6.886	55	65	10	3950	3825	14	0	0	17	1	1
2	13	U169	7.916	55	65	10	6365	5125	26	1	1	31	1	1
5	17	U281	7.587	55	65	10	15110	10975	54	0	0	59	1	2
7	9	U75	12.013	55	65	10	7250	6025	25	0	0	60	2	4
7	25	U36	9.994	55	65	10	6980	5895	19	0	0	34	0	0
8	15	K196	9.246	55	65	10	7340	4740	14	0	0	25	1	1
9	24	U50	2.946	55	65	10	10100	6695	4	0	0	9	1	1
11	14	U160	3.392	55	65	10	8955	6485	11	0	0	19	0	0
11	18	U69	2.234	55	65	10	8160	5300	9	0	0	14	0	0
11	22	U69	9.118	55	65	10	12140	9555	31	1	1	43	1	1
11	31	U69	1.967	55	65	10	16865	13260	11	0	0	15	1	1
12	8	K27	21.106	55	65	10	1390	895	4	0	0	8	1	1
14	5	K82	5.753	55	65	10	2115	1630	2	0	0	7	0	0
14	13	K15	3.928	55	65	10	4645	3750	7	0	0	12	1	3
16	7	U75	3.022	55	65	10	5480	4165	2	0	0	3	2	2
16	31	U75	0.989	55	65	10	14635	9685	5	0	0	9	0	0
18	34	U77	9.69	55	65	10	11725	9035	60	0	0	78	2	2
21	9	K15	8.003	55	65	10	3195	2145	14	0	0	12	1	1
21	24	U77	1.979	55	65	10	6475	3930	3	0	0	7	0	0
22	44	U36	3.332	55	65	10	6215	5130	0	0	0	6	1	1
22	46	U36	8.246	55	65	10	6310	5420	13	0	0	18	1	1
22	47	U36	1.542	55	65	10	7925	6040	7	0	0	19	0	0
24	1	U50	0.274	55	65	10	8765	6700	0	0	0	2	2	2
24	12	U50	6.12	55	65	10	4835	3535	2	0	0	7	1	1
26	10	U183	16.204	55	65	10	8395	6310	65	3	3	73	3	5
28	12	K156	6.975	55	65	10	2630	1730	11	0	0	20	0	0
28	13	U83	7.905	55	65	10	9025	7220	18	0	0	20	1	3
28	19	K23	14.092	55	65	10	1750	1035	5	0	0	7	1	1
29	3	U56	9.123	55	65	10	7300	4970	15	1	1	17	1	1
30	2	K68	8.505	55	65	10	9530	8140	56	0	0	62	3	4
31	69	U77	1.14	55	65	10	8680	6475	2	0	0	5	1	1
36	4	K27	15.861	55	65	10	2150	1865	7	0	0	13	0	0
38	3	U50	11.317	55	65	10	6410	4530	21	0	0	32	1	1
38	4	K27	16.235	55	65	10	2580	2525	6	0	0	10	1	1
39	5	U160	6.718	55	65	10	3280	2235	11	0	0	22	0	0
41	6	K190	3.8	55	65	10	1940	1395	2	0	0	3	1	1
41	8	K144	11.984	55	65	10	1855	1620	5	0	0	8	1	1
41	10	U83	6.019	55	65	10	8700	6320	7	0	0	15	1	1
42	3	K156	9.694	55	65	10	2840	2015	11	0	0	16	0	0
44	19	K4	1.902	55	65	10	21650	16275	29	0	0	29	1	1

Table 3.7 (Continued) 2-Lane Rural Highway Network Sections Experiencing the Most Significant Increases in Crashes During the After Period. (10-mph Change in Speed Limit)

44	21	K4	3.475	55	65	10	14865	10290	**31**	**0**	**0**	**28**	**1**	**2**
48	12	U54	3.34	55	65	10	13760	9785	**18**	**0**	**0**	**17**	**1**	**2**
49	3	U54	0.997	55	65	10	16375	11055	**2**	**0**	**0**	**9**	**1**	**1**
49	15	U54	3.128	55	65	10	13725	9625	**6**	**0**	**0**	**14**	**0**	**0**
50	32	U166	6.127	55	65	10	5925	4780	**8**	**0**	**0**	**15**	**0**	**0**
52	3	U24	9.334	55	65	10	11900	9225	**81**	**0**	**0**	**98**	**1**	**2**
53	1	K18	13.46	55	65	10	2490	1870	**14**	**1**	**2**	**18**	**1**	**2**
54	23	U69	1.416	55	65	10	12125	8660	**5**	**1**	**1**	**12**	**0**	**0**
55	4	U40	7.201	55	65	10	3530	1785	**3**	**0**	**0**	**9**	**0**	**0**
55	21	U40	0.09	55	65	10	5645	3285	**0**	**0**	**0**	**2**	**1**	**1**
58	12	U36	3.973	55	65	10	16010	7340	**6**	**0**	**0**	**8**	**0**	**0**
58	34	U36	5.381	55	65	10	8850	5965	**2**	**0**	**0**	**13**	**1**	**1**
60	17	U54	5.469	55	65	10	6845	5640	**7**	**0**	**0**	**15**	**0**	**0**
61	20	U169	1.277	55	65	10	19105	12970	**5**	**0**	**0**	**20**	**1**	**2**
61	23	U169	6.435	55	65	10	22020	17305	**53**	**2**	**3**	**56**	**3**	**5**
61	29	U169	0.829	55	65	10	17865	9385	**10**	**0**	**0**	**20**	**0**	**0**
62	6	U24	6.996	55	65	10	5535	4075	**7**	**1**	**1**	**16**	**0**	**0**
73	9	U183	12.255	55	65	10	1395	1245	**4**	**0**	**0**	**13**	**1**	**2**
73	10	U183	11.18	55	65	10	2210	1880	**15**	**0**	**0**	**21**	**1**	**1**
74	7	U36	13.307	55	65	10	5610	4050	**42**	**1**	**1**	**51**	**1**	**1**
74	10	U183	7.862	55	65	10	4455	2420	**13**	**0**	**0**	**19**	**1**	**1**
78	40	U50	10.526	55	65	10	13725	10970	**41**	**1**	**1**	**61**	**1**	**1**
79	15	U81	11.363	55	65	10	8570	4875	**29**	**1**	**1**	**35**	**0**	**0**
80	11	K14	9.55	55	65	10	4005	2935	**14**	**0**	**0**	**19**	**1**	**1**
81	13	U24	8.616	55	65	10	12420	9590	**68**	**0**	**0**	**78**	**1**	**1**
83	10	U183	7.895	55	65	10	6955	5170	**17**	**0**	**0**	**16**	**1**	**1**
86	5	U83	7.659	55	65	10	8390	6335	**8**	**0**	**0**	**13**	**2**	**3**
86	7	U83	7.316	55	65	10	7850	5750	**13**	**1**	**1**	**15**	**1**	**1**
86	10	K95	6.591	45	55	10	660	670	**2**	**0**	**0**	**6**	**1**	**1**
88	1	U54	3.59	55	65	10	19345	11060	**11**	**0**	**0**	**19**	**0**	**0**
88	8	U160	12.878	55	65	10	1325	960	**8**	**1**	**1**	**12**	**1**	**1**
88	18	U83	7.023	55	65	10	6485	5085	**8**	**0**	**0**	**12**	**2**	**3**
90	2	U24	6.897	55	65	10	2625	1870	**4**	**1**	**1**	**11**	**0**	**0**
92	8	U281	7.874	55	65	10	2510	2150	**9**	**0**	**0**	**14**	**1**	**1**
95	2	U56	7.313	55	65	10	4305	3815	**9**	**0**	**0**	**11**	**3**	**3**
95	13	K51	8	55	65	10	4125	3145	**3**	**0**	**0**	**11**	**1**	**1**
96	3	U166	4.944	55	65	10	4915	3370	**3**	**0**	**0**	**10**	**1**	**1**
98	13	K147	20.97	55	65	10	630	705	**10**	**0**	**0**	**14**	**1**	**1**
101	2	K9	7.574	55	65	10	4540	2840	**7**	**0**	**0**	**20**	**1**	**1**
101	11	U36	9.176	55	65	10	5125	3900	**18**	**0**	**0**	**54**	**1**	**1**
101	19	K15	10.741	55	65	10	1895	1440	**12**	**0**	**0**	**22**	**1**	**1**
102	1	K96	10.854	55	65	10	3455	2380	**10**	**0**	**0**	**11**	**2**	**4**
103	10	K39	10.976	55	65	10	3295	2605	**22**	**0**	**0**	**35**	**1**	**3**
103	17	U75	4.805	55	65	10	4450	3550	**7**	**0**	**0**	**13**	**1**	**1**
103	18	U75	5.817	55	65	10	4600	3495	**8**	**0**	**0**	**11**	**1**	**2**
104	3	U54	8.994	55	65	10	7760	5270	**21**	**0**	**0**	**34**	**0**	**0**
104	7	U75	10.535	55	65	10	6480	4635	**29**	**1**	**1**	**39**	**2**	**2**

CHAPTER 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY

Speed limits are the maximum legal travel speed under favorable situations of good weather, free-flowing traffic and good visibility. In 1974, the U. S. Congress adopted a National Maximum Speed Limit (NMSL) of 55 mph as a result of the Arab oil embargo. This NMSL remained in effect for 13 years until on April 1, 1987, the law was enacted to allow the speed limit to be raised to 65 mph on rural interstate highways and some other highways in specified experimental states. On November 28, 1995, National Highway System (NHS) Designation Act abolished the federal mandate for the NMSL and returned the authority of establishing speed limits to the states. Kansas raised speed limits on repeal of NMSL in March 1996. The research study reported herein concentrated on analyzing the before and after Kansas' speed and accident databases. In regard to speed analysis, the t-test was applied to investigate whether significant increases in 85th percentile speeds were noted during the after period on rural interstate highways and 2-lane rural highways. In this case, a 3-mph increase in 85th percentile speeds was noted on rural interstate highway sections and 3 to 5 mph on the 10-mph speed limit increased 2-lane highways. None was n-oted on the 5-mph speed limit increased 2-lane rural highways.

The 3-Step Sequential Analysis approach was utilized to analyze the before-and-after Kansas' accident database. Crash, fatal crash and fatality rates were the three key accident-related indices analyzed in this studied. By performing the analysis, it was concluded that, as of 1998, no statistically significant increases in crash, fatal crash and fatality rates were noted during the after period on either rural or urban interstate highway networks. On the other hand, statistically significant increases in crash, fatal crash and fatality rates were observed on the 2-lane rural highway network. In order to identify the 2-lane highway sections that have experienced the most significant increases in crashes (MSICR) during the after period, a detailed analysis was carried out to filter out those sections. Accordingly, it was found that MSICR sections (representing about 7% of the entire 2-lane rural highway network sections) have accounted for most of the noted significant increases in crash and fatal crash rates. Fatal crashes on the remaining 93% of the 2-lane rural network were found to be less than those observed during the before period.

4.2 CONCLUSIONS

Based on the analysis of Kansas' speed and accident databases, the following speed and accident related conclusions are summarized in this section.

4.2.1 Conclusions Regarding Speed Data

1. A 3-mph statistically supported significant increase in 85th percentile speeds was noted on rural interstate highway sections and 3 to 5 mph on the 10-mph speed limit increased 2-lane highways. None was noted on the 5-mph speed limit increased 2-lane highways.
2. Increases in 85th percentile speeds are noted to be less than the actual speed limit increases. In our case, a 3 mph increase was realized on the 5-mph speed limit increased rural interstate highway sections; 3 to 5 mph on the 10-mph speed limit increased 2-lane highways, and none on the 5-mph speed limit increased 2-lane highways.

3. Standard deviation of 85th percentile speeds (i.e., speed variation) for both rural interstate and 2-lane rural highways are generally less in the after period than those noted in the before period.
4. Based on previously stated findings and the realization that 85^{th} percentile speed is regarded as a major parameter in describing actual travel speed, it can be concluded that there is a significant increase in the actual travel speed during the after period on rural interstate highways and 2-lane rural 65-mph posted speed limit highways.

4.2.2 Conclusions Regarding Accident Data

1 As of 1998, no statistically significant increases are noted during the after period on either rural or urban interstate highway networks in crash, fatal crash and fatality rates.

2 In general, statistically significant increases during the after period are observed on With Change 2-lane rural highway network (i.e., 2-lane rural highway sections whose posted speed limit was increased) in crash, fatal crash and fatality rates. In particular, the following issues are noted for this network:

- During the after period, about 93% of the network have experienced notable decreases in fatal crashes and statistically insignificant increase in crashes.
- The remaining 7% of the entire network represent the 95 sections that have experienced the most significant increases in crashes.
- Accident-related statistics for those 95 sections account for:
    a. Significant portion (i.e., 563 crashes or 70%) of the overall 800 statistically projected yearly increase in crashes;

b. More than 4-times (44 fatal crashes) the overall statistically projected yearly increase in fatal crashes (i.e., 10).

4.3 RECOMMENDATIONS

1. KDOT need to closely monitor and analyze the identified sections which have experienced the most significant increases in crashes in order to employ the best possible solution scenarios that can substantially decrease the accident-related statistics on those highway sections.
2. Reducing crash and fatal crash rates on the identified sections to 1993-1995 levels will yield an overall safer 2-lane rural highway network.
3. The increase in posted speed limits cannot be solely responsible for the observed increase in crash and fatal crash rates on the 2-lane rural highway network since the 15-mph and 20-mph speed limit increase networks have not observed any increase in their accident-related statistics. Furthermore, significant increases in crash and fatal crash rates were observed on 19 2-lane rural highway sections whose speed limits were unchanged.

REFERENCES

Advocates for Highway and Auto Safety. (1995) States at Risks: Repealing the National Maximum Speed Limit Means More Deaths, Injuries and Costs to Society.

Agent K. R., J. G. Pigman, and J. M. Weber. (1998) Evaluation of Speed Limits in Kentucky. *Transportation Research Record* 1640, pp. 57-64**.**

Baum, H. M., A. K. Lund, and J. K. Wells. (1988) The Mortality Consequences of Raising the Speed Limit to 65mph on Rural Interstates. *Insurance Inst. For Highway Safety*, Arlington, VA, Nov.

Binkowski, S. E., T. L. Maleck, W. C. Taylor, and T. S. Czewski. (1998) Evaluation of Michigan 70-mph Speed Limit, *Transportation Research Record* 1640, pp. 37-45.

Brackett, R. Q. and K. Ball. (1990) The safety impact of the 65mph speed limit in Texas: a thirty-six-month evaluation. *Human Factors Division, Texas Transportation Institute*, Texas A & M University.

Brown, D. B., S. Maghsoodloo, and M. E. McArdle. (1990) The safety impact of the 65mph speed limit: A case study using Alabama accident records. *Journal of Safety Research*, Vol. 21, pp.125-139.

Chang, G. L., and J. F. Paniati. (1990) Effects of 65mph speed limit on traffic safety. *Journal of Transportation Engineering*, Vol. 116, No. 2, pp. 213-225.

Florida Department of Transportation. (1980) Speed zoning for highways, roads and streets in Florida. Final Report, Tallahassee, Florida.

Garber, S., and J. D. Graham. (1990) The effects of the new 65mph speed limit on rural highway fatalities: A state-by-state analysis. *Accident Analysis & Prevention*, Vol. 22, No. 2, pp. 137-149.

McCarthy, P. S. (1988) Highway safety and the 65mph maximum speed limit: An empirical study. *AAA Foundation for Traffic Safety*, Washington, D.C., 1988.

McKnight, A. J., and T. M. Klein. (1990) Relationship of 65mph limit to speeds and fatal accidents. *Transportation Research Record* 1281, pp. 71-77.

National Highway Traffic Safety Administration, U. S. Department of Transportation. (1998) Report to Congress-The Effect of Increased Speed Limits in the Post-NMSL Era.

Oklahoma Department of Transportation, Traffic Engineering Division–Safety Branch. (1998) Effects of Higher Speed Limits on Travel Speeds and Crash Frequencies in Oklahoma.

Raju, S., R. Souleyrette, R., and T. H. Maze. (1998) Impact of the 65mph speed limit on Iowa's rural interstate highways: An integrated Bayesian forecasting and dynamic modeling approach. *Transportation Research Record* 1640, pp. 47-56.

Retting, R. A., and M. A. Greene. (1996) Traffic Speeds Following Repeal of the National Maximum Speed Limit: Preliminary Results. *Insurance Institute for Highway Safety*.

Sidhu, C. S. (1990) Preliminary assessment of the increased speed limit on rural Interstate highways in Illinois. *Transportation Research Record* 1281, pp. 78-83.