

TE
176
T39
2000
c.2

EFFECT ON CRASHES DUE TO CONSTRUCTION OF DIRECTIONAL
CROSSOVERS TO REPLACE BIDIRECTIONAL CROSSOVERS

By

William C. Taylor

In Kyu Lim

Department of Civil & Environmental Engineering
Michigan State University
February 25, 2000



COLLEGE OF ENGINEERING

MICHIGAN STATE UNIVERSITY

EAST LANSING, MICHIGAN 48824

MSU IS AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY INSTITUTION

**EFFECT ON CRASHES DUE TO CONSTRUCTION OF DIRECTIONAL
CROSSOVERS TO REPLACE BIDIRECTIONAL CROSSOVERS**

By

William C. Taylor

In Kyu Lim

**Department of Civil & Environmental Engineering
Michigan State University
February 25, 2000**

DISCLAIMER

This document is disseminated under the sponsorship of the Michigan Department of Transportation (MDOT) in the interest of information exchange. The MDOT assumes no liability for its contents or use thereof.

The contents of this report reflect the views of the contracting organization, which is responsible for the accuracy of the information presented herein. The contents may not necessarily reflect the views of the MDOT or the U.S. Department of Transportation and do not constitute standards, specifications, or regulations.

Table Of Contents

	DESCRIPTION	PAGE
Executive Summary		i
Introduction		1
Study Section Description		2
Data Sources		6
Results		8
Other Results		28
Conclusions		31
Bibliography		32
Appendix		33

EFFECT ON CRASHES DUE TO CONSTRUCTION OF DIRECTIONAL CROSSOVERS TO REPLACE BIDIRECTIONAL CROSSOVERS

Executive Summary

The objective of the this study was to develop an entry in the Michigan Department of Transportation (MDOT) crash reduction factor table for the safety countermeasure of replacing bidirectional crossovers with directional crossovers. With this data the Department will be in a position to compare the safety benefits of this countermeasure with other possible countermeasures with known crash reduction factors. This will assist the Department in selecting the most cost effective safety treatment for those situations where this treatment is an option.

This study analyzed the change in crash patterns on eight projects in Michigan where directional crossovers were used to replace some or all of the bidirectional crossovers an divided highways. All of these projects were located in the Detroit Metropolitan Area. Five of the projects are on Telegraph Road, two are on Grand River Avenue, and one is on Fort Street. These eight study sections comprised a total of 15.75 miles and included the elimination of 54 bidirectional crossovers and the construction of 67 directional crossovers.

The analysis was conducted in two phases. First, the annual average total crashes occurring in each section for the years before the construction were compared to the annual average total crashes on each section after the construction. This analysis included the crashes that occurred at the signalized intersections where directional crossovers already existed. The second analysis excluded the crashes occurring at those

intersections and determined the crash reduction for only the roadway segments between signalized intersections.

The percent reduction in crashes for each of the study sites for these two analyses are shown in Figures 1 and 2. While there is considerable variation in the effectiveness across the study sections, this safety countermeasure resulted in a reduction in the average annual crashes at each location for both analyses. The average reduction in crashes when considering the entire roadway is 31%. When considering only those crashes in the study section where bidirectional crossovers were replaced with directional crossovers, the reduction averaged 42%.

Figure 1. Percent reduction in total crashes after construction

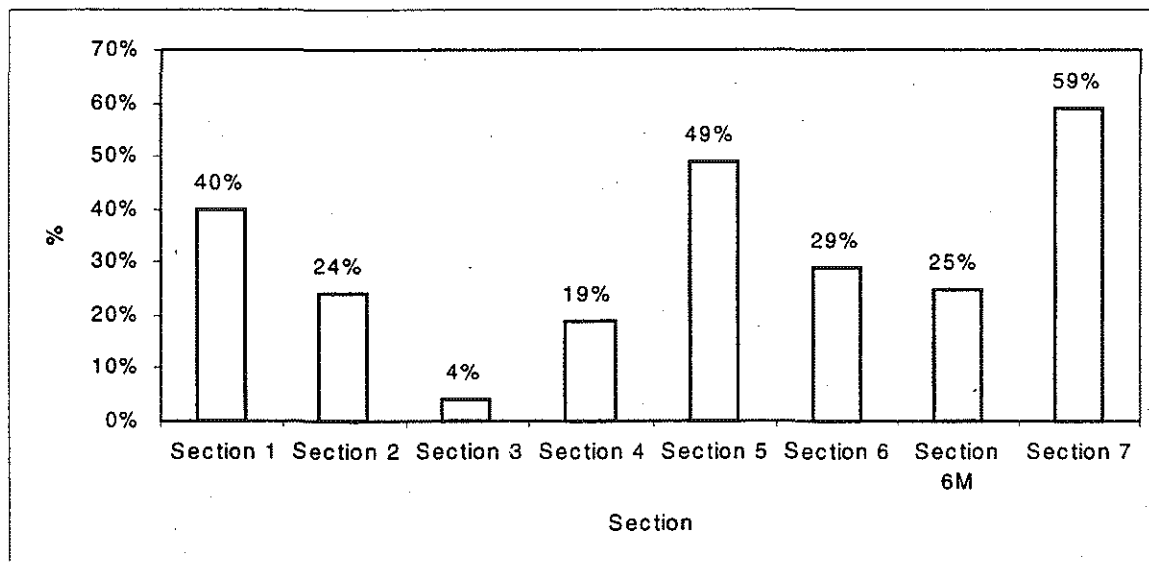
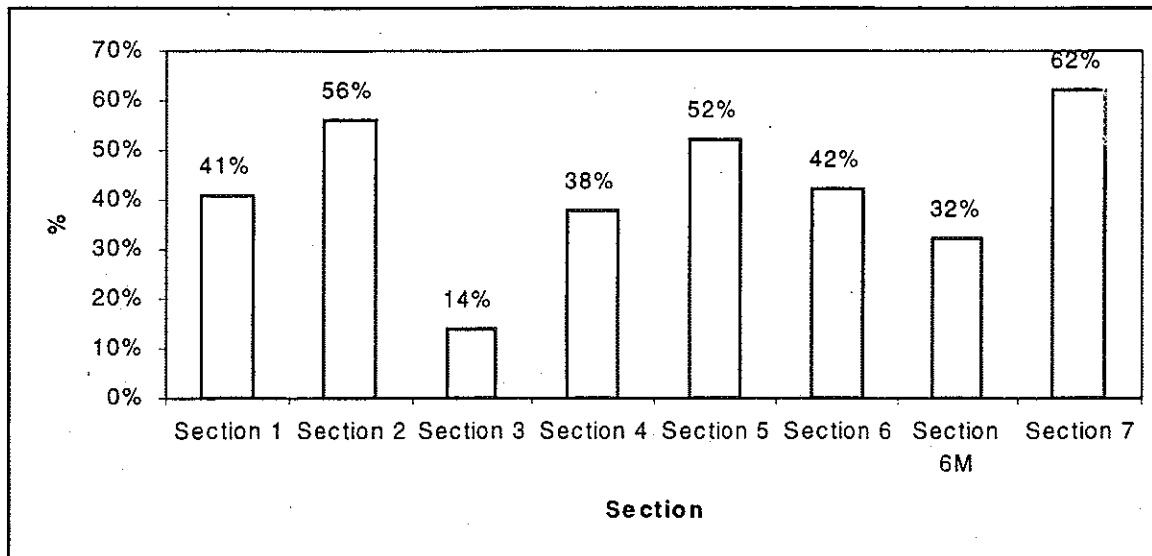


Figure 2. Percent reduction in non-intersection crashes after construction



The conclusion from this study is that the use of directional crossovers to replace bidirectional crossovers on multilane arterials is an effective safety countermeasure. The most common crash type associated with the use of median crossover (rear end collision) can be expected to decrease by an average of 37% based on this study.

The results as they would appear in a crash reduction factor table are shown in Table 1.

Table 1. Effect on crashes after construction

Treatment	Crash types	Reduction		
		Average	High	Low
Convert bidirectional crossovers to directional crossovers	Total	31%	59%	4%
	Injury	32%	70%	3%
	Non-intersection	42%	62%	14%
	Rear-End	37%	66%	-8%

Effect on Crashes due to Construction of Directional Crossovers to Replace Bidirectional Crossovers

Introduction

The objective of this study was to develop an entry in the Michigan Department of Transportation (MDOT) crash reduction factor table for the crash countermeasure of replacing bidirectional crossovers with directional crossovers. This objective was accomplished by analyzing the safety impact of eight projects in Michigan where directional crossovers were used to replace some or all of the bidirectional crossovers on divided highways.

A secondary objective of the study was to identify any outliers in the study sections to determine if there were traffic or geometric features that would explain why the crash reduction experience at these sections was different than the average reduction. The study was also designed to study the phenomenon known as crash migration, to determine whether the crash reduction resulted from displacing crashes rather than reducing them.

A literature search identified only two studies that had addressed the crash reduction potential of this countermeasure and both were MDOT publications (1, 2). However, these studies were limited to only one section of highway, and thus it was not known if the results were generic or site specific. These same sections were included in this study, with the analysis period expanded to include more data. With the limited data available in the literature, it was not possible to isolate geometric or traffic variables that affected the crash reduction potential of this countermeasure. Thus, data on several

geometric and traffic variables were collected on each of the study sections. (These variables are included in Table 1, and discussed later in this report).

Study Section Description

This study used eight roadway segments where bidirectional median crossovers were partially or entirely replaced with directional median crossovers. The location of these study segments are shown in Figure 1, and described below.

- Section 1 is on Telegraph Road between Five Mile Road and Grove Street, a total distance of 0.73 miles. In this segment, 5 bidirectional crossovers were replaced with 6 directional crossovers. This segment had an ADT of 44,500 before construction and 40,500 after construction. This is the highest ADT of any section. Construction was completed in 1991.
- Section 2 is on Telegraph Road between Fordson/Denwood Street and Wilson Street, a total distance of 1.13 miles. In this segment, 4 bidirectional crossovers were eliminated and 7 directional crossovers were constructed. This segment had an ADT of 37,000 before construction and 34,500 after construction. Construction was completed in 1992.
- Section 3 is also on Telegraph Road between McNichols Street and Grand River Avenue, a total distance of 0.82 miles. In this segment, 3 bidirectional crossovers were removed and 3 new directional crossovers were constructed. The ADT on this section changed from 43,400 to 38,000. Construction was completed in 1994.

Table 1. Project site road information before and after

Before

Section	1		2		3		4	5		6	6M	7	
A.D.T.	44500		37000		43400		26200	30880		25600	21200	11157	
# of lanes	NB	SB	NB	SB	NB	SB	6	NB	SB	8	8	4	
	4	3	4	3	4	3		4	3				
Lane width	NB	SB	NB	SB	NB	SB	12	NB	SB	10	10	NB	SB
	10	12	11	12	10	12		10	12			12	11
Surface cond	4.0		4.5		4.0		4.5	4.0		3.5	3.5	4.0	
Inter/mile	0		0.9		2.4		1.5	0		1.6	1.8	1.2	
Dir Cross/mile	1.4		3.5		2.4		2.5	0		2.3	6.2	3	
Bidir/mile	6.8		4.4		3.6		4	9.2		6.5	2.7	1.2	

After

Section	1		2		3		4	5		6	6M	7	
A.D.T.	40500		34500		38000		21000	28250		13375	21000	10838	
# of lanes	NB	SB	NB	SB	NB	SB	4/3	NB	SB	8	8	4	
	4	3	4	3	4	3		4	3				
Lane width	NB	SB	NB	SB	NB	SB	12	NB	SB	10	10	12	
	10	12	11	12	10	12		10	12				
Surface cond	4.0		4.5		4.5		3.5	2.5		4.0	4.0	1.0	
Inter/mile	0		0.9		2.4		1.5	0		1.6	1.8	1.2	
Dir Cross/mile	9.6		10.6		6.1		7.5	7.6		7.4	8.0	4.9	
Bidir/mile	0		0.9		0		0.5	2.3		0	0.9	0.5	

Figure 1. Map of project sites

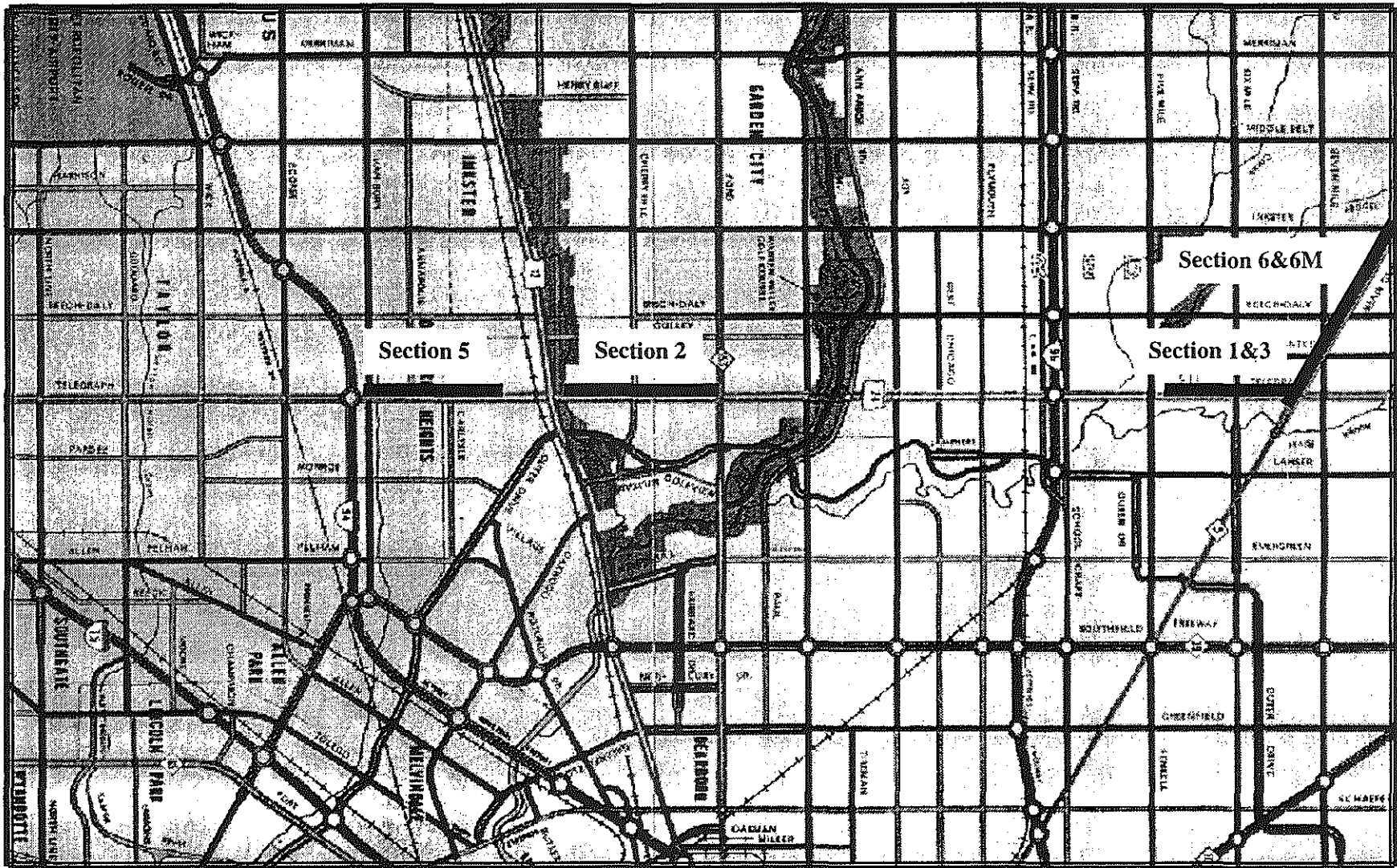
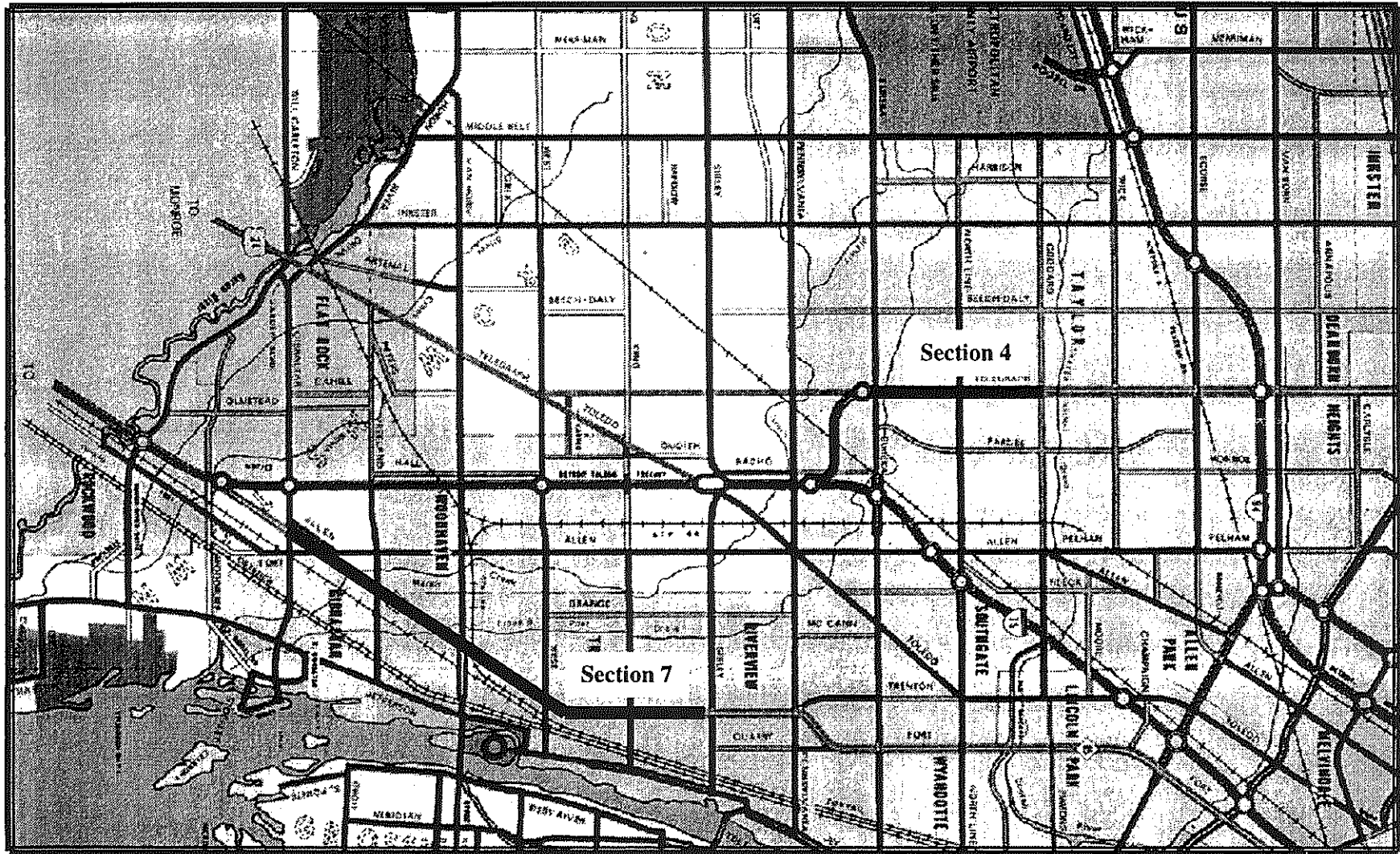


Figure 1 continued



- Section 4 is on Telegraph Road between Eureka Road and Goddard Road, a length of 1.99 miles. In this segment, 7 bidirectional crossovers were replaced with 10 directional crossovers. The ADT changed from 26,200 to 21,000. Construction was completed in 1995.
- Section 5 is on Telegraph Road between Currier Road and Princeton Road, a total distance of 1.31 miles. In this segment 9 bidirectional crossovers were eliminated and 10 directional crossovers were constructed. The ADT changed from 30,880 to 28,250. Construction was completed in 1997.
- Section 6 is on Grand River Avenue (M-5) between Eight Mile Road and Rouge River, a total distance of 3.1 miles. Nineteen bidirectional crossovers were removed and 18 directional crossovers constructed in this section. This section had the highest ADT change, from 25,600 to 13,375. This segment was constructed in 1993.
- Section 6M is also on Grand River Avenue (M-102) between Purdue Street and Eight Mile Road, a total distance of 1.13 miles. In this section, 3 bidirectional crossovers were eliminated and 2 directional crossovers were constructed. The ADT changed from 21,200 to 21,000. Construction was completed in 1993.
- Section 7 is on Fort Street (M-85) between Gibraltar Road and Sibley Road, a distance of 5.57 miles. In this section, 4 bidirectional crossovers were removed and 11 directional crossovers were constructed. The ADT changed from 11,157 to 10,838. Construction was completed in 1997.

Data Sources

Crash data for this project were collected from the Michigan Department of Transportation SPSS System Accident Master File. The data files from this program

include the type of crash, crash location (mile point), hour, month, weather, surface condition and injury severity. Ten years (1989 – 1998) of data for each section were used for the analysis. “Before” and “After” data for total crashes, non-intersection crashes, and 4 types of crashes (Rear-End Straight, Fixed Object, Sideswipe Passing and Straight Angle) were analyzed.

An analysis of the crash reduction in each of the study segments was first conducted using all crashes that occurred between the beginning and ending point of each section. When the results were presented to the MDOT advisory team, there was concern expressed that including crashes that occurred at those intersections where the directional crossovers were already in place before these projects were constructed could “mask” the true crash reduction resulting from the project. Thus, a second analysis for each section was conducted with the crashes at the intersections excluded from the data. This includes all crashes on the minor street approaches and all crashes occurring between the existing directional crossovers on each side of the intersection.

The results of both analyses are included in the report, with the first analysis referred to as “total crashes” and the second referred to as “non-intersection crashes”.

The volume data were taken from the sufficiency rating books.⁽³⁾ Volumes for 1990, 1994 and 1997 were recorded. For sections where the construction occurred between 1990 and 1993, the 1990 volumes are listed as the before data, and 1994 volumes are listed as the after data. For all other sections, the 1994 volume is used as before data, and 1997 volume is listed as after data. It is recognized that this data is not updated on an annual basis, and may not accurately reflect the traffic volume in the years specified. However, these volumes were not used to calculate a crash rate (crashes per

mvm), but simply to show the volume differences between sections and the trend in volume over time for each section. The surface condition data were taken from the same source, and the same caveats apply to the use of these data.

The construction drawings were used to determine the geometric variables, such as lane width, number of lanes, location of the crossovers before and after construction and the number of intersecting roads.

The description of each study section for both the before and after period is listed in Table 1.

Results

The initial analysis compared the average annual frequency of crashes occurring on the study section before and after the crossovers were modified. Figure 2 shows the number of crashes per year on each section for each year between 1989 and 1998. The construction period is also indicated on the graph.

Figure 2. Total crashes in each section per year

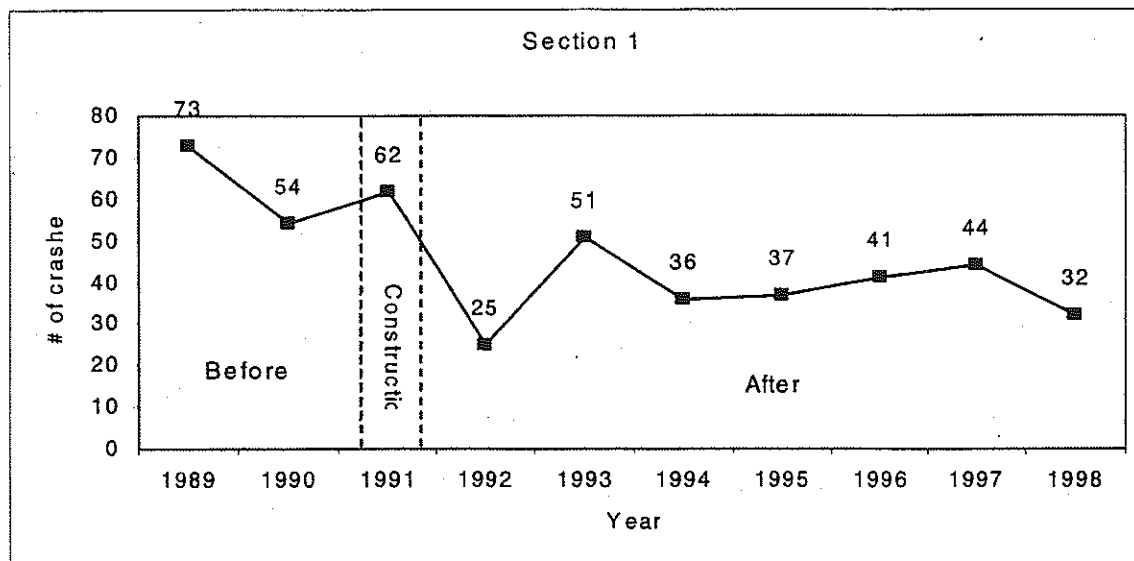


Figure 2 (continued)

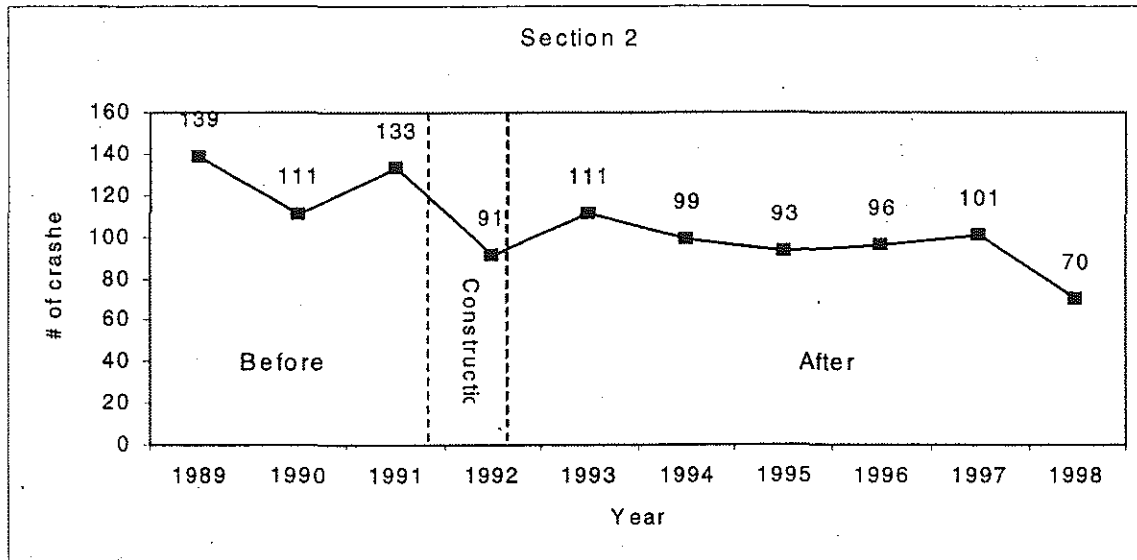


Figure 2 continued

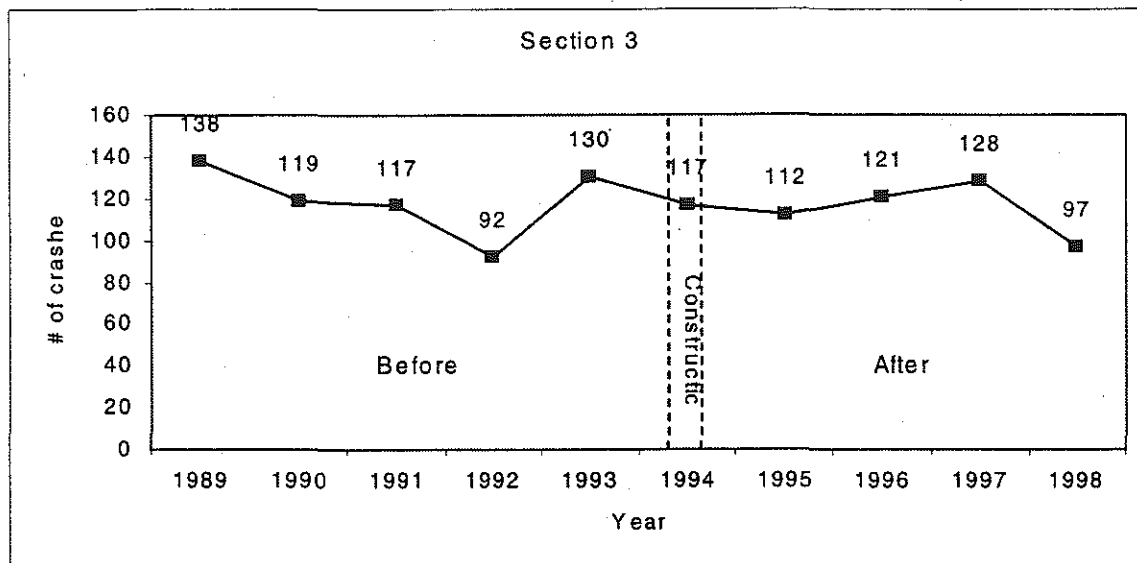


Figure 2 continued

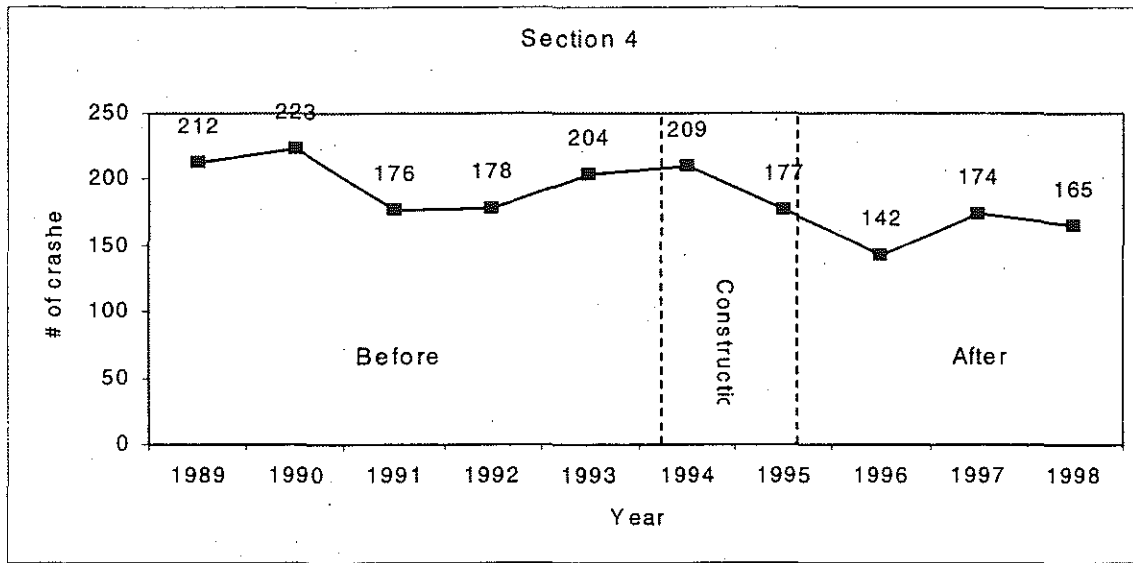


Figure 2 continued

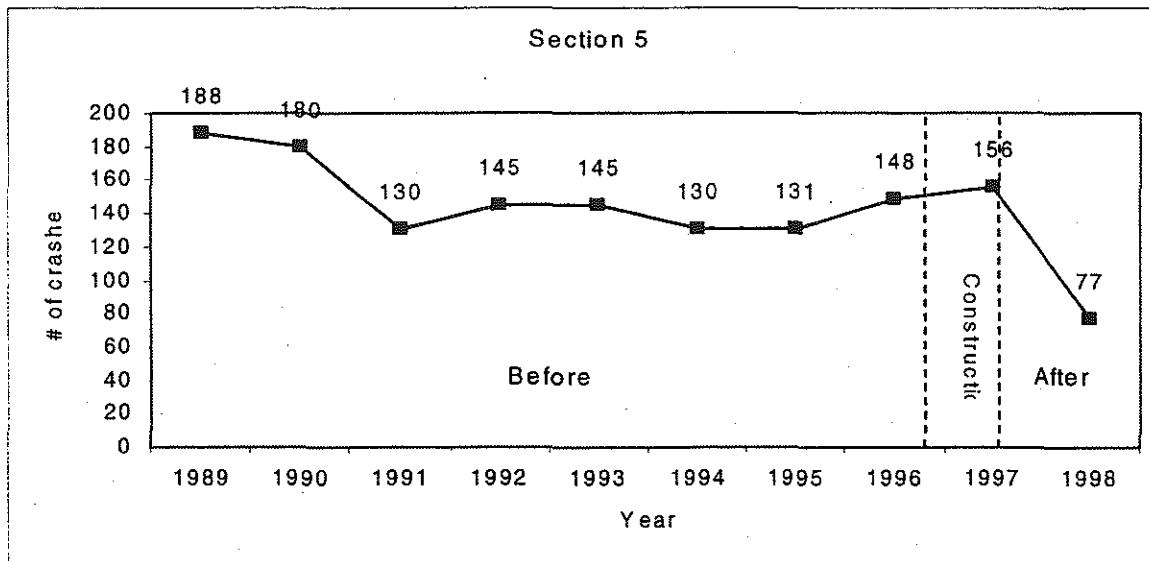


Figure 2 continued

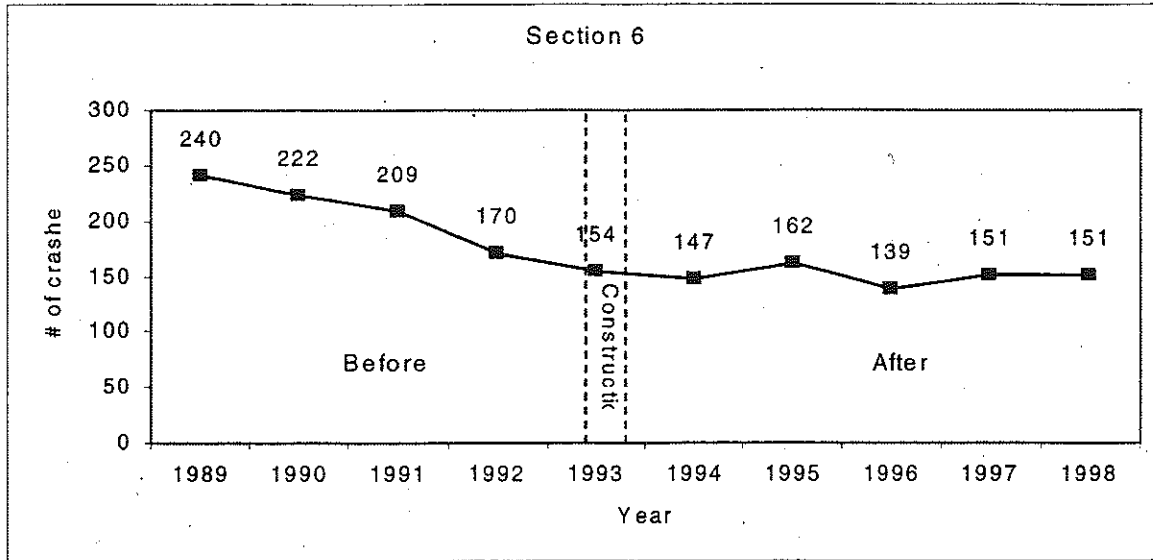


Figure 2 continued

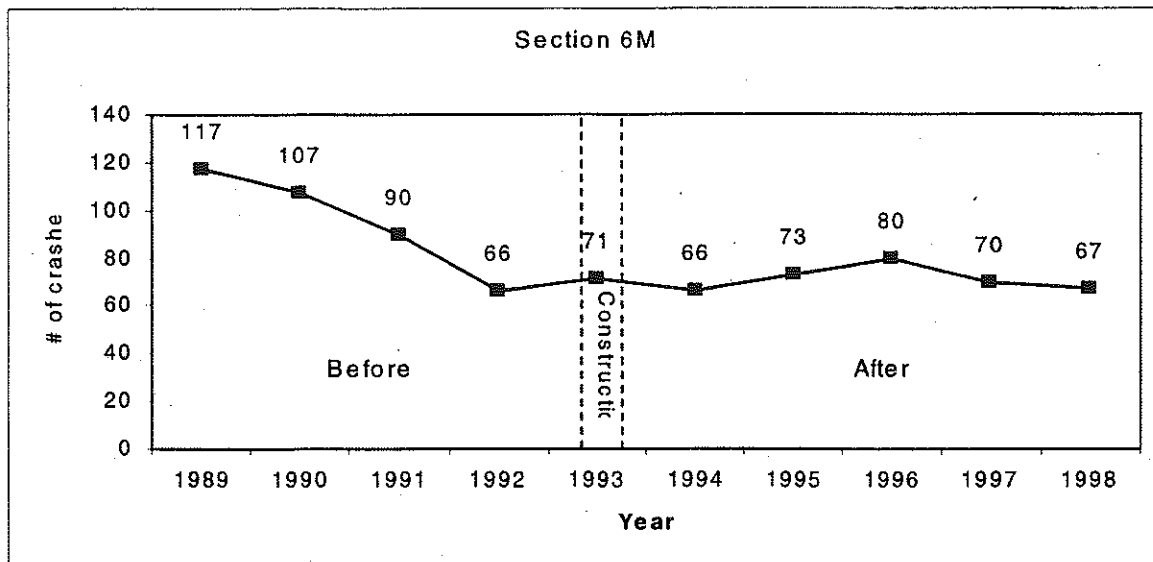


Figure 2 continued

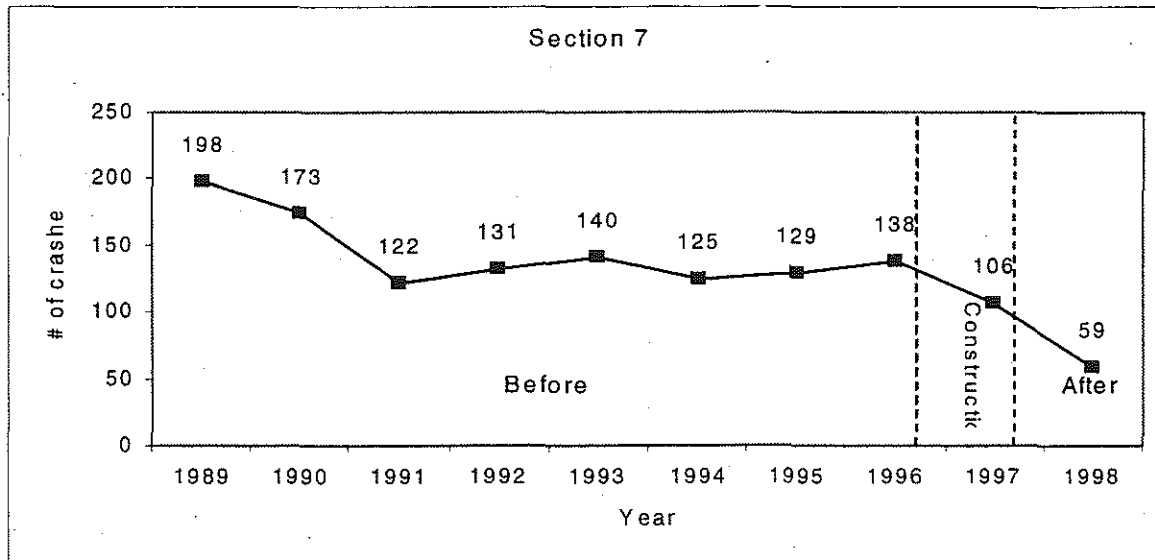


Figure 3 shows the average number of crashes for the before and after period for each study section. This figure shows that all eight study sections experienced a decrease in crash frequency following the change. Figure 4 shows the percent reduction in the annual crash frequency.

Figure 3. Average number of crashes per year before and after

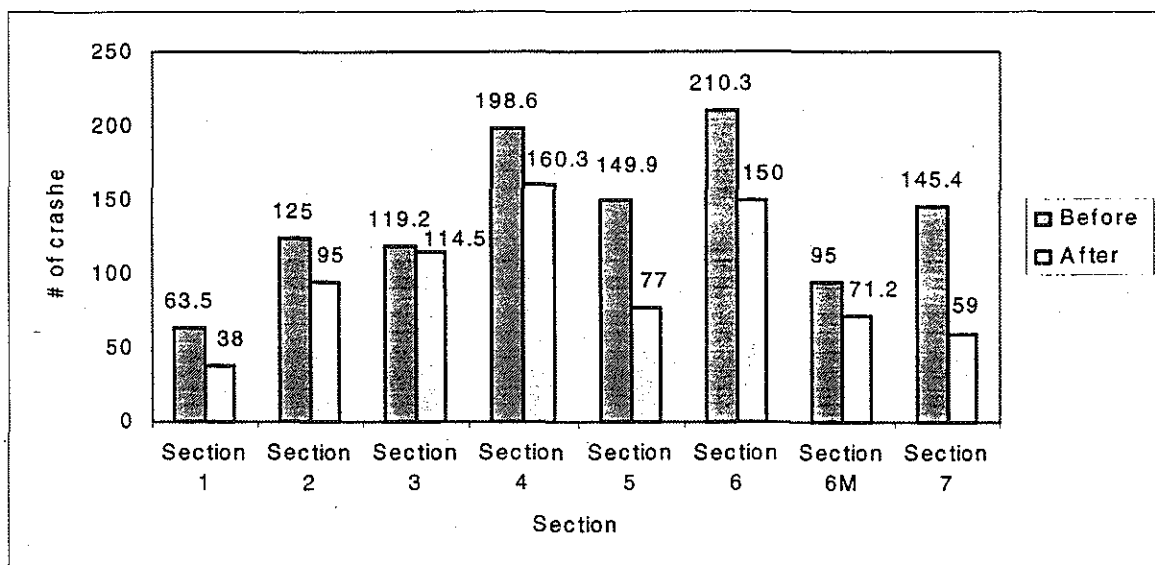


Figure 4. Percent reduction in total crashes after construction

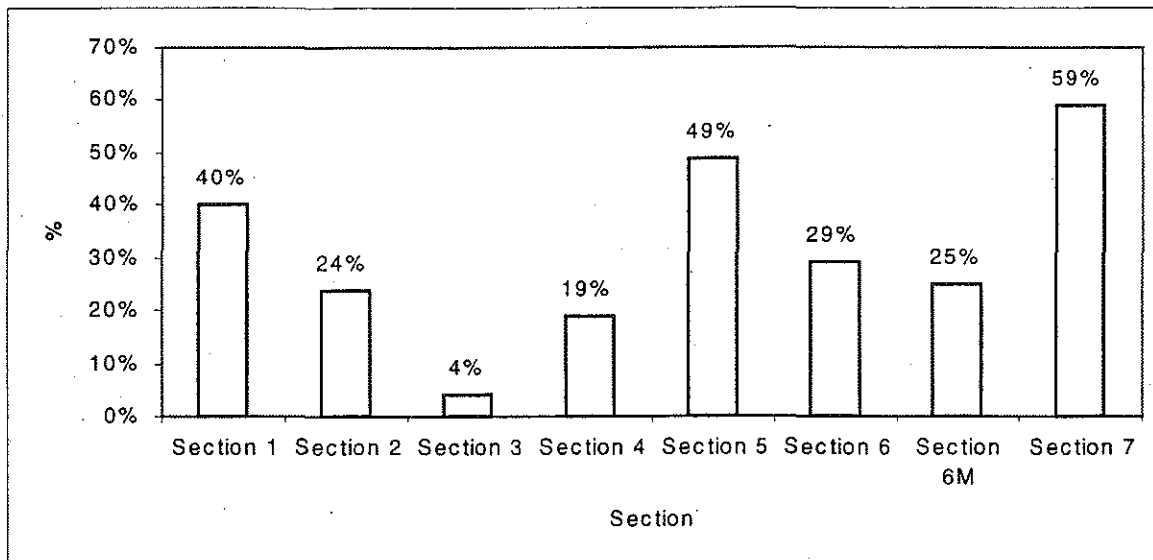


Figure 5 shows these same data ordered from the largest to the smallest percent reduction. It should be noted that study sections 5 and 7, which experienced the largest reduction are based on only one year of after data. The reduction may not be sustained at this level over time.

Figure 5. Sections ranked by percent reduction in total crashes

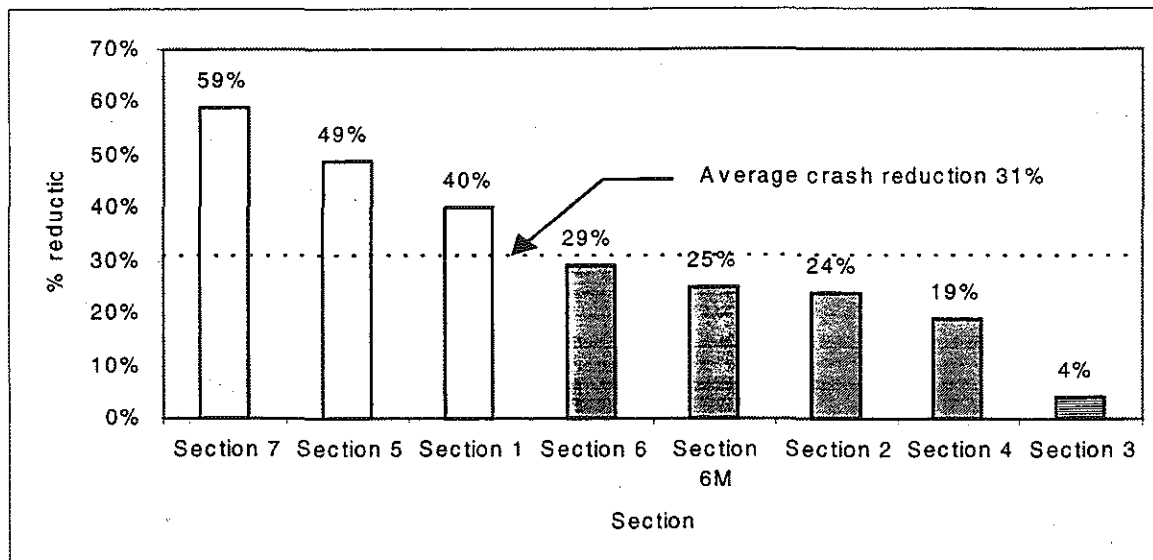


Figure 6 shows the average number of injury crashes for each of the sections for

Figure 6. Total injury crashes in each section per year

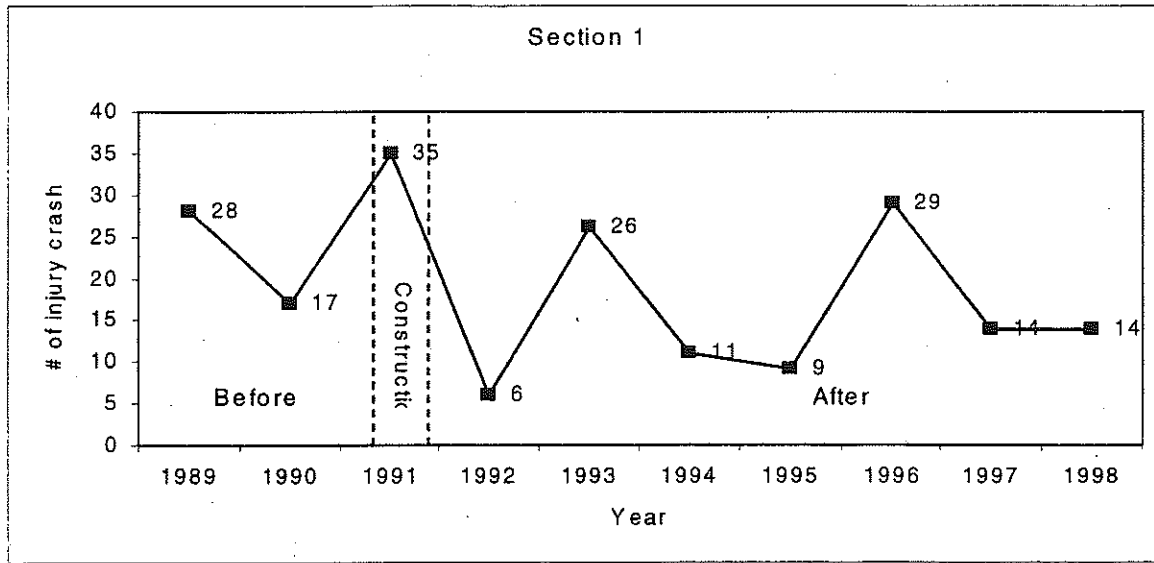


Figure 6 continued

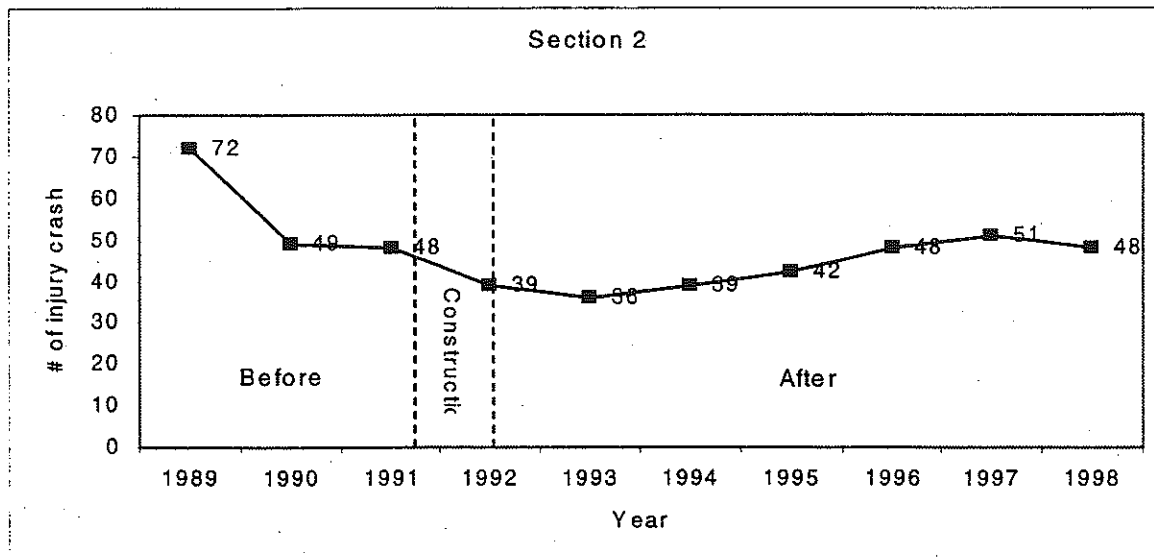


Figure 6 continued

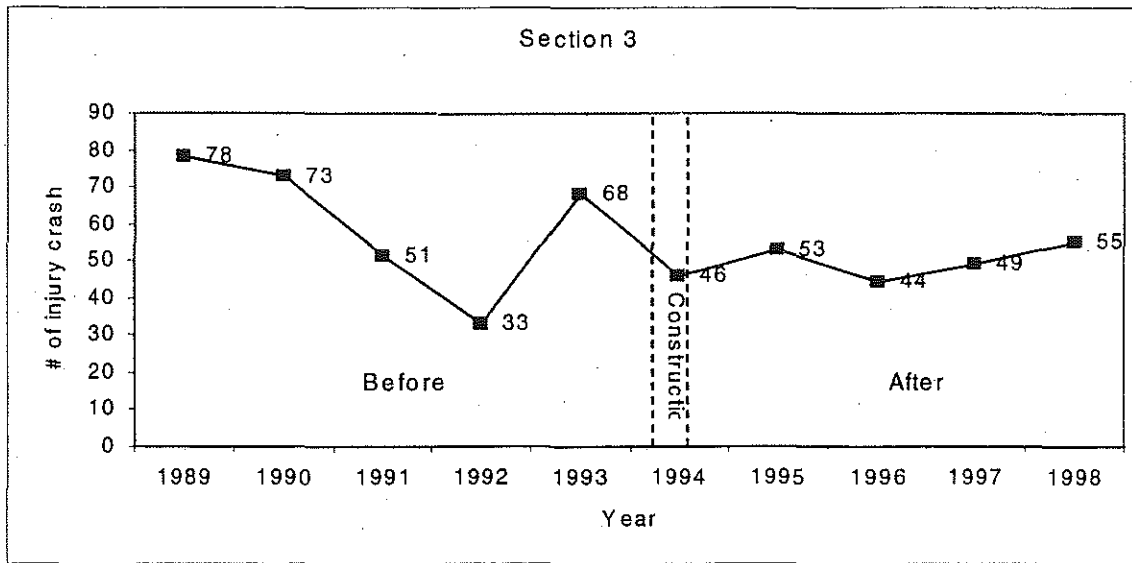


Figure 6 continued

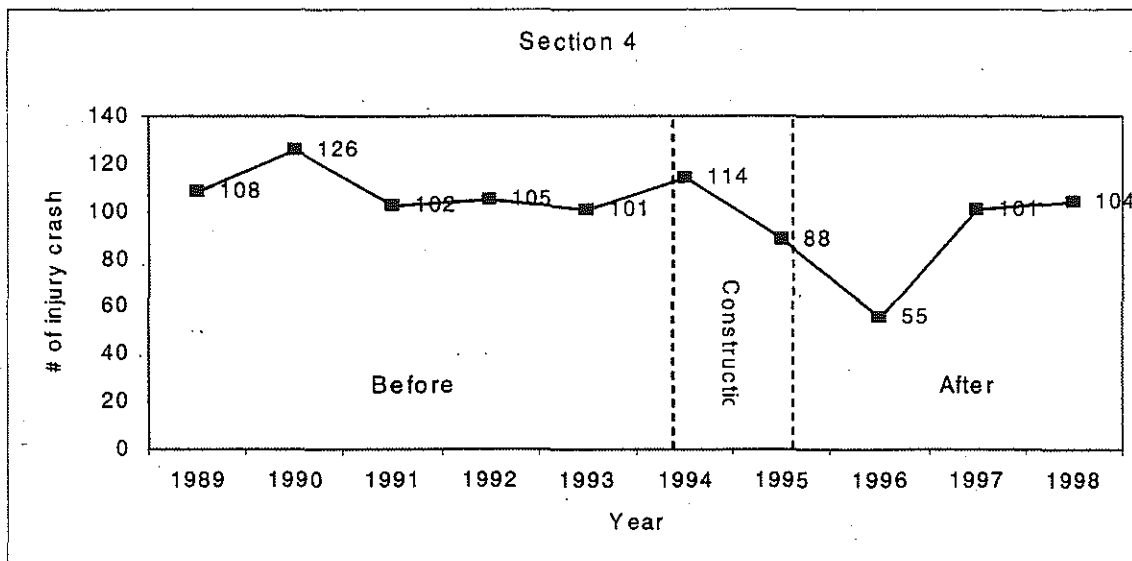


Figure 6 continued

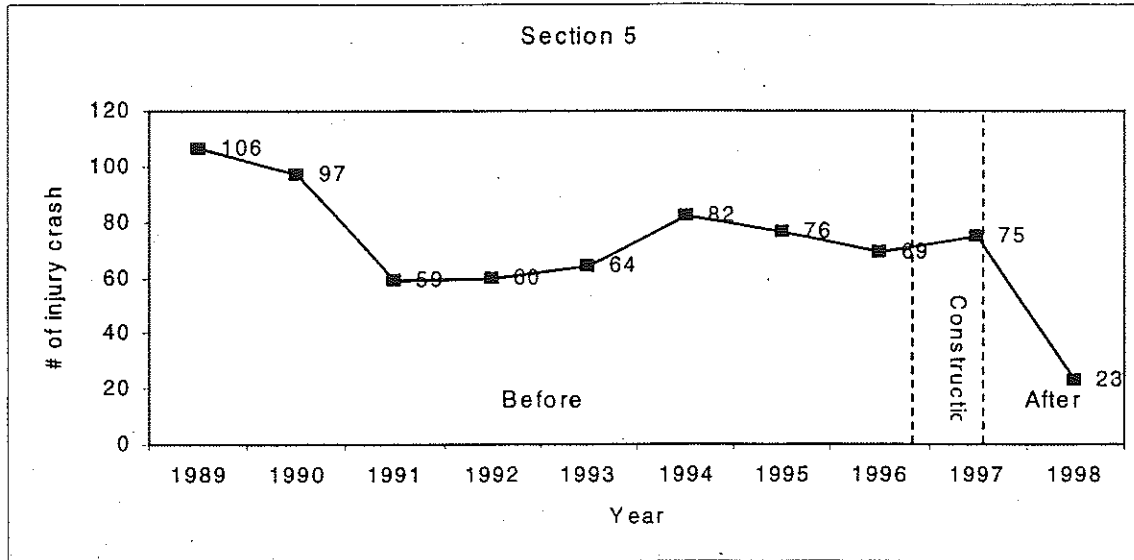


Figure 6 continued

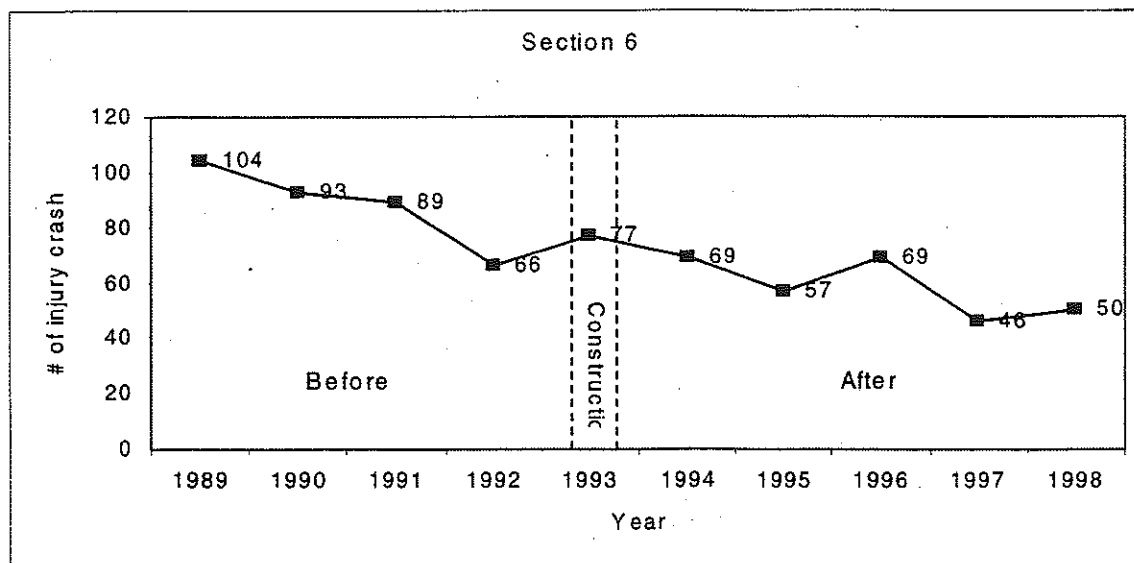


Figure 6 continued

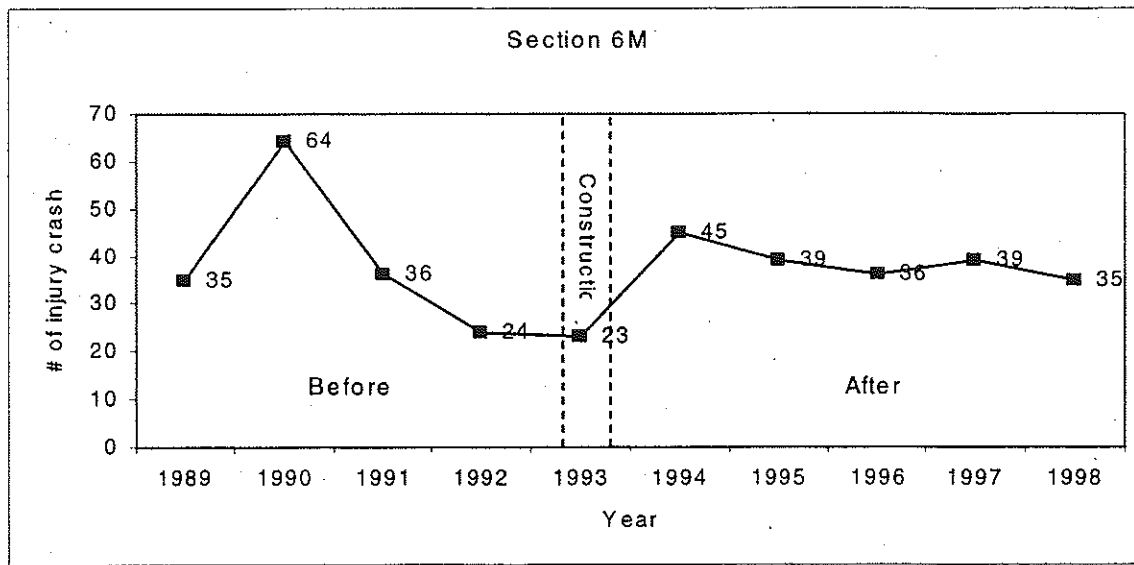
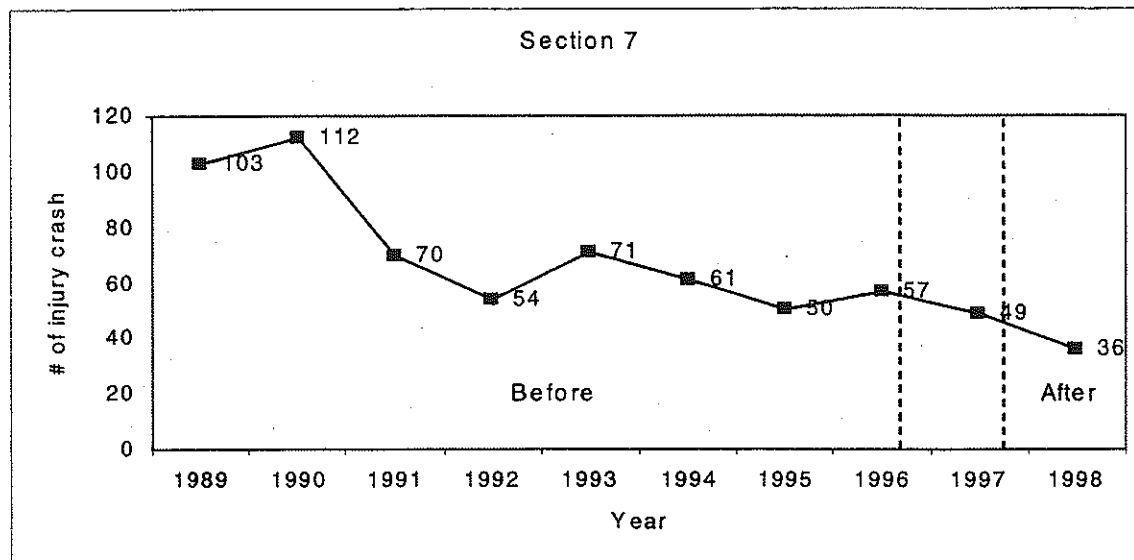


Figure 6 continued



each year. As shown in Figure 7, sections 5 and 7 experience the largest reduction in injury crashes, just as they had experienced the largest reduction in total crashes. Once again, all sections showed a decrease in the average annual frequency of crashes following the construction as shown on Figures 8 and 9. The average reduction was 32%, compared to an average reduction of 31% for all crashes.

Figure 7. Average number of total injury crashes per year before and after

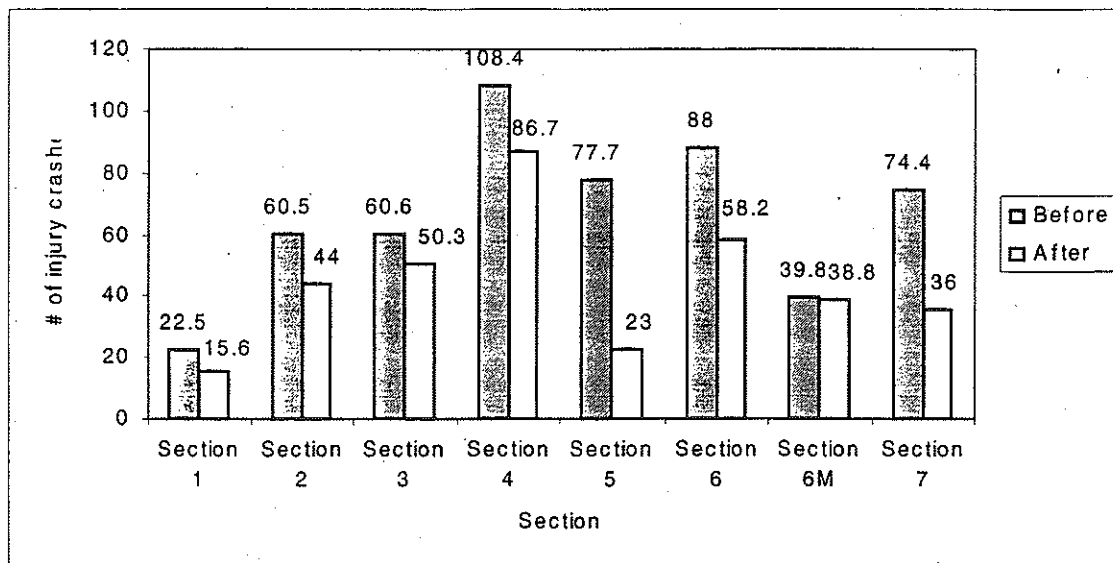


Figure 8. Percent reduction in total injury crashes after construction

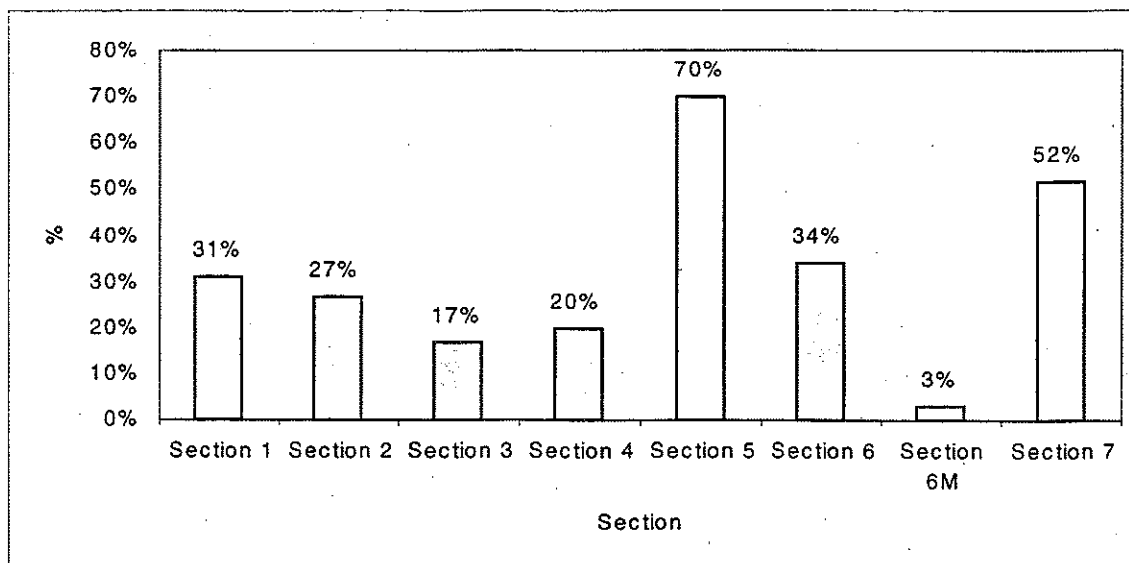


Figure 9. Sections ranked by percent reduction in total injury crashes

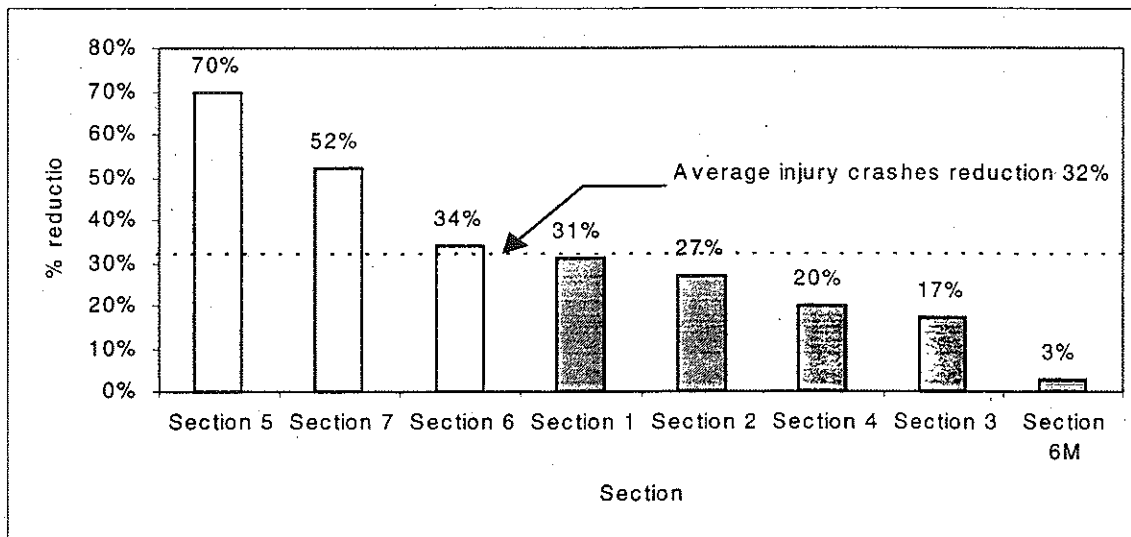


Figure 10 shows the frequency of each of the four most common crash types on each of the study sections. Rear-end accidents are clearly the most frequent crash type in

Figure 10. Frequency of four major crash types by year

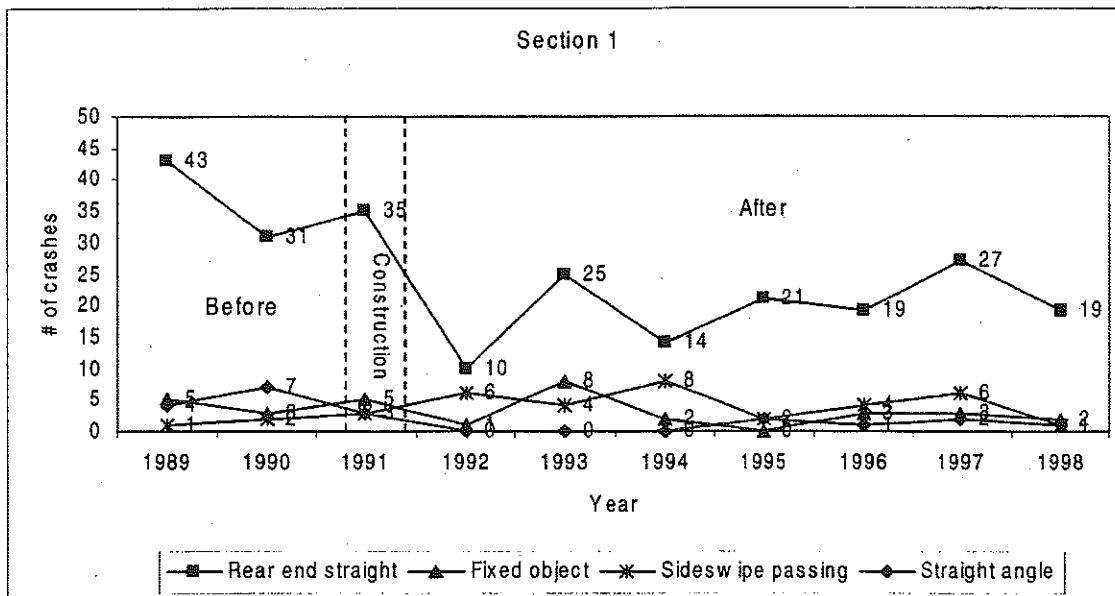


Figure 10 continued

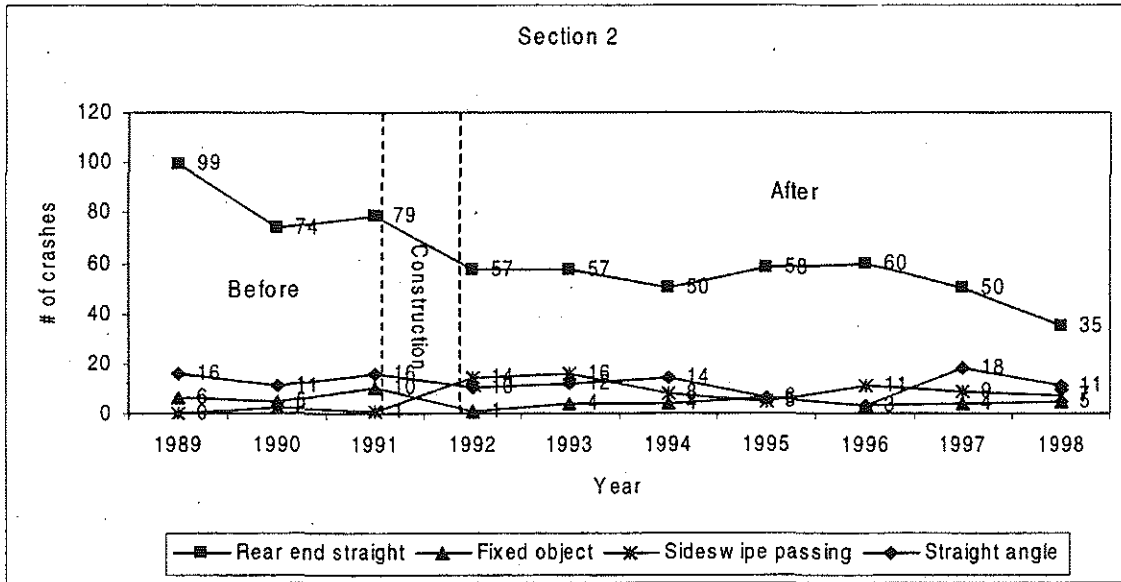


Figure 10 continued

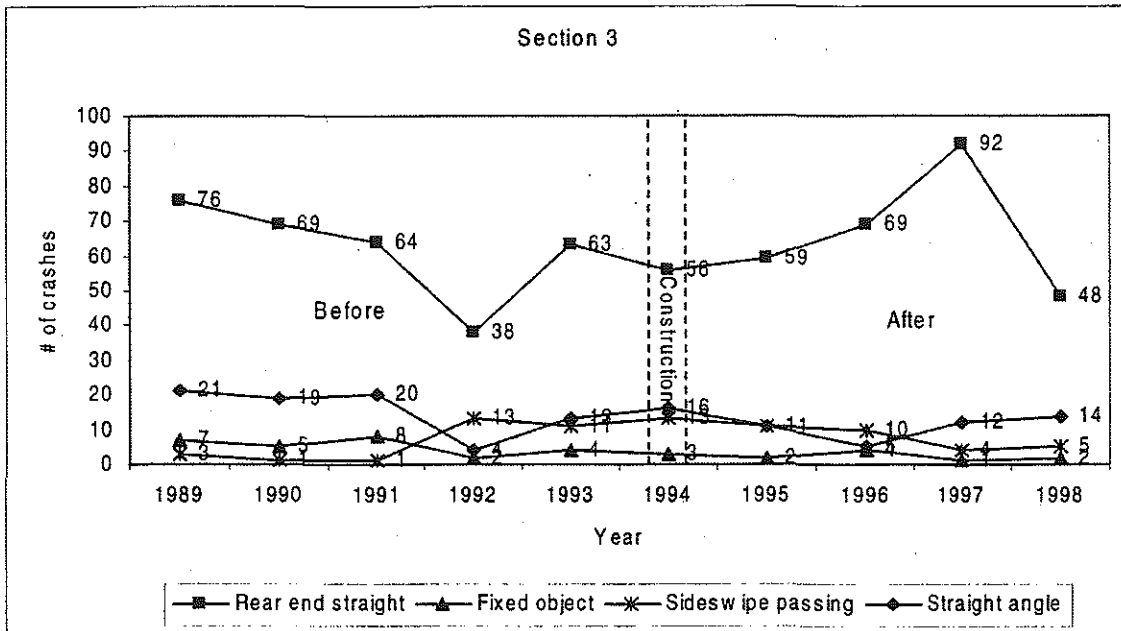


Figure 10 continued

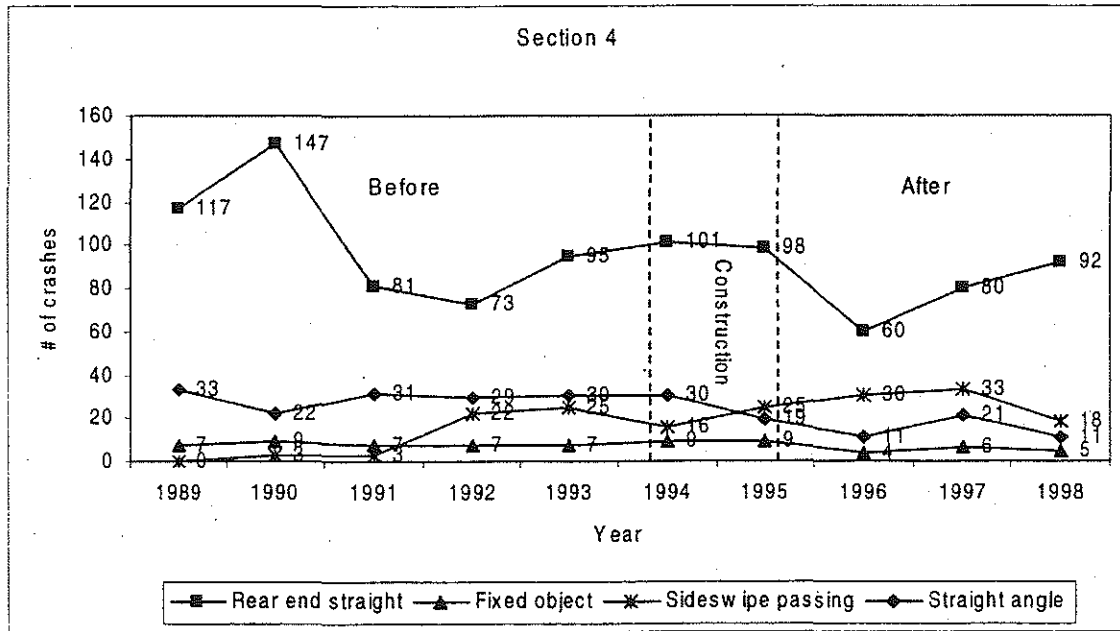


Figure 10 continued

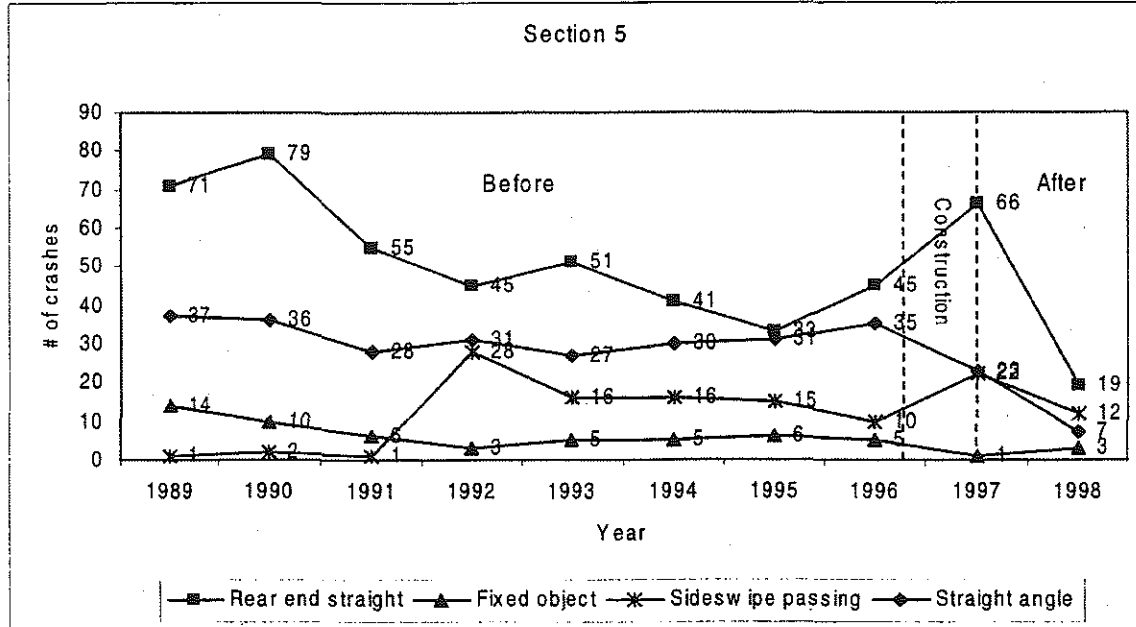


Figure 10 continued

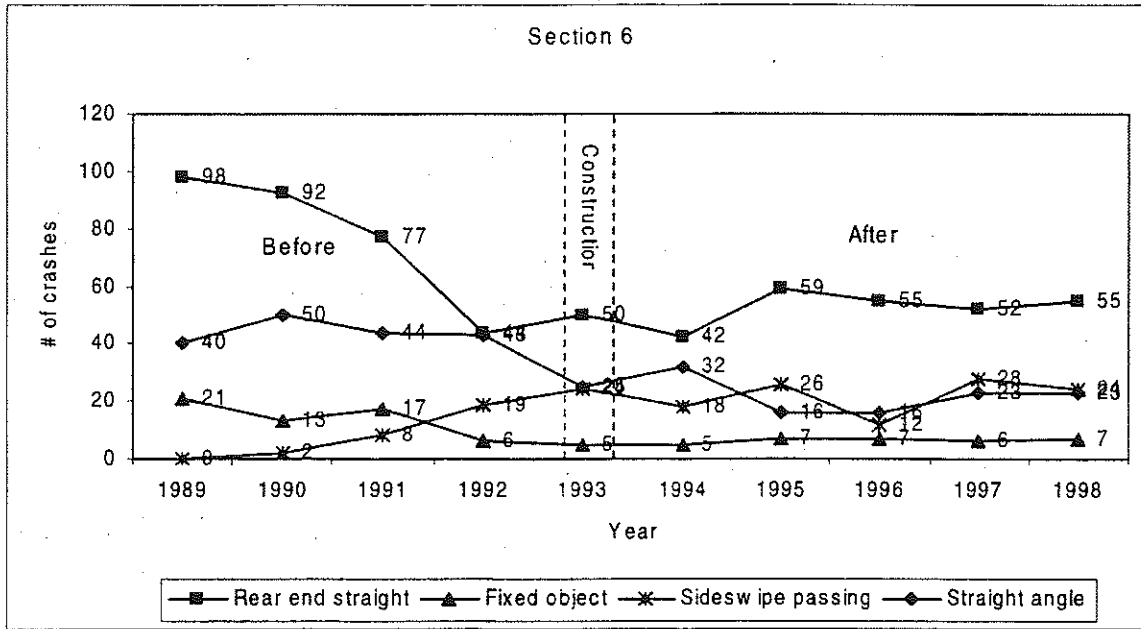


Figure 10 continued

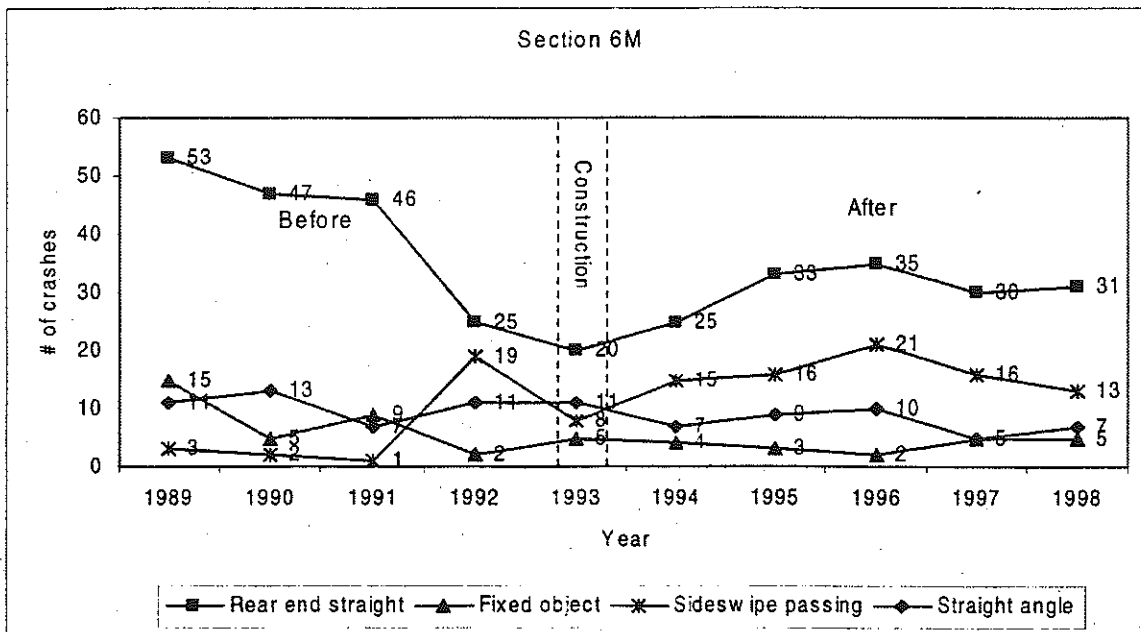
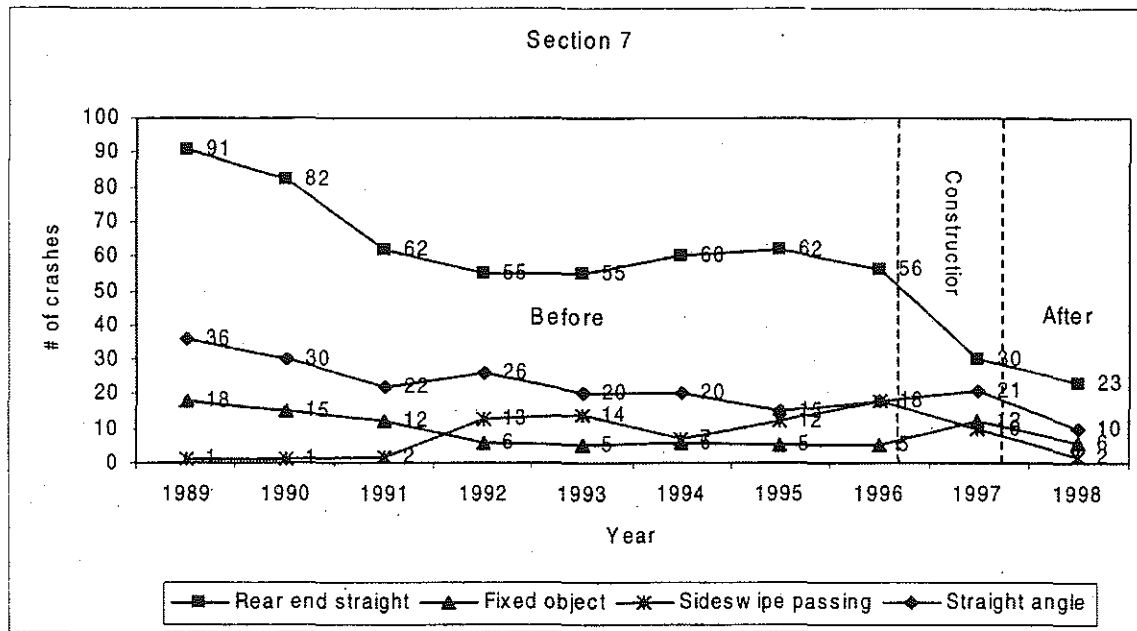


Figure 10 continued



each section, and generally showed a reduction in frequency after the construction. The one exception was section 3, where this type of crash increased after the construction of directional crossovers.

The number of sideswipe passing crashes increased after the conversion to directional crossovers. However, there was a change in the accident type coding in 1992, which resulted in some crashes that were coded as rear end before 1992 being coded as sideswipe same after 1992. The frequency of this crash type is quite small, so the percentage increase appears to be large, but the change in frequency is much less than the reduction in the frequency of other crash types.

The final analysis was conducted with the crashes that occurred at the signalized intersections that already had directional crossovers excluded, as discussed in the data source section of this report. Figure 11 shows the crash frequency for each of the sections over the study period. The results are similar to the trends for all crashes, but the

concern that some of the true impact by this countermeasure might be "masked" by these intersection crashes appears to be valid.

Figure 11. Crashes per year excluding signaled intersections

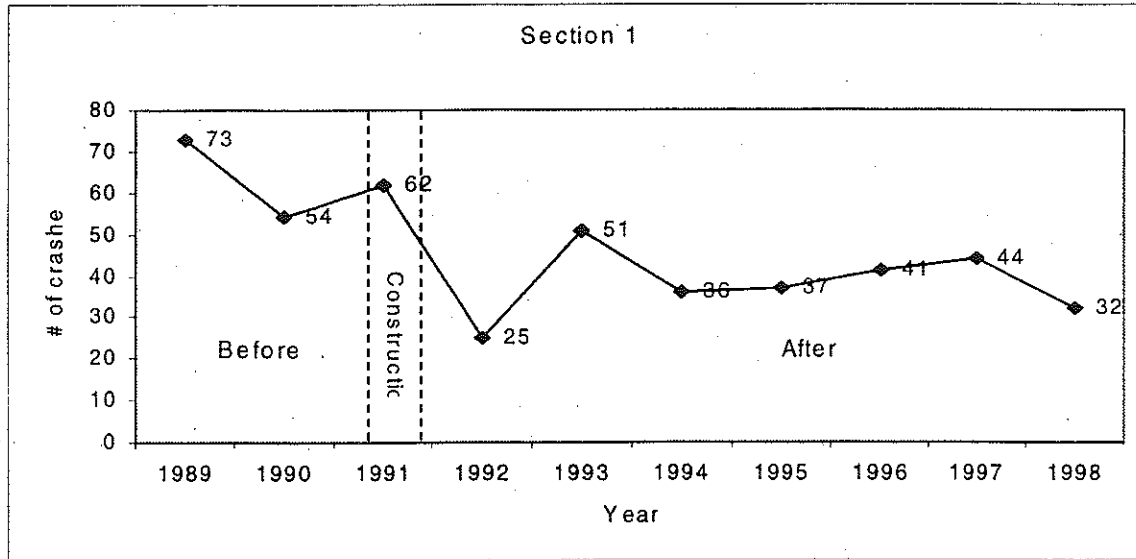


Figure 11 continued

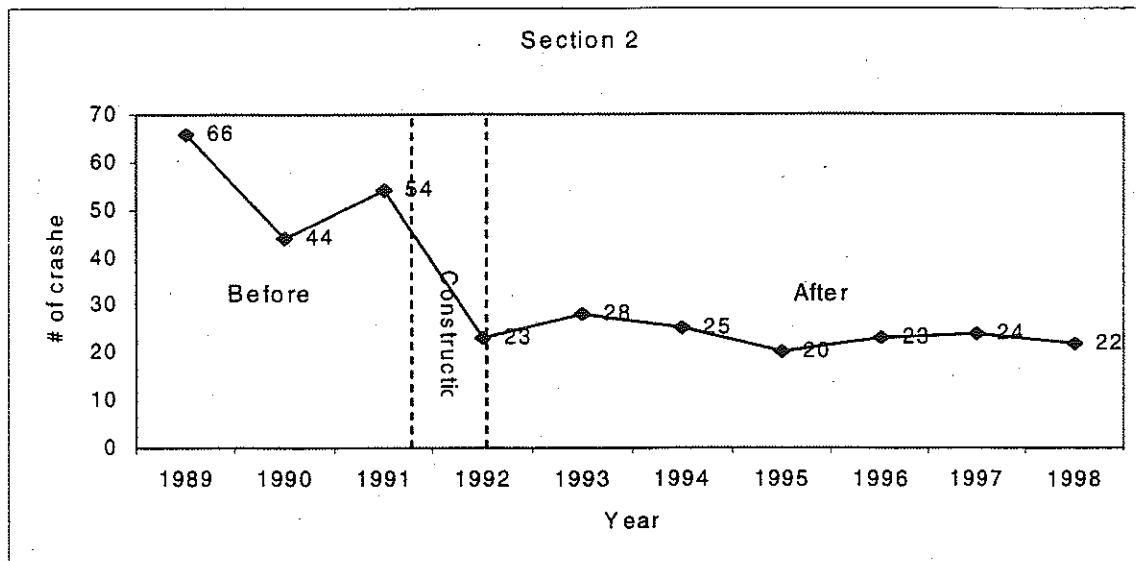


Figure 11 continued

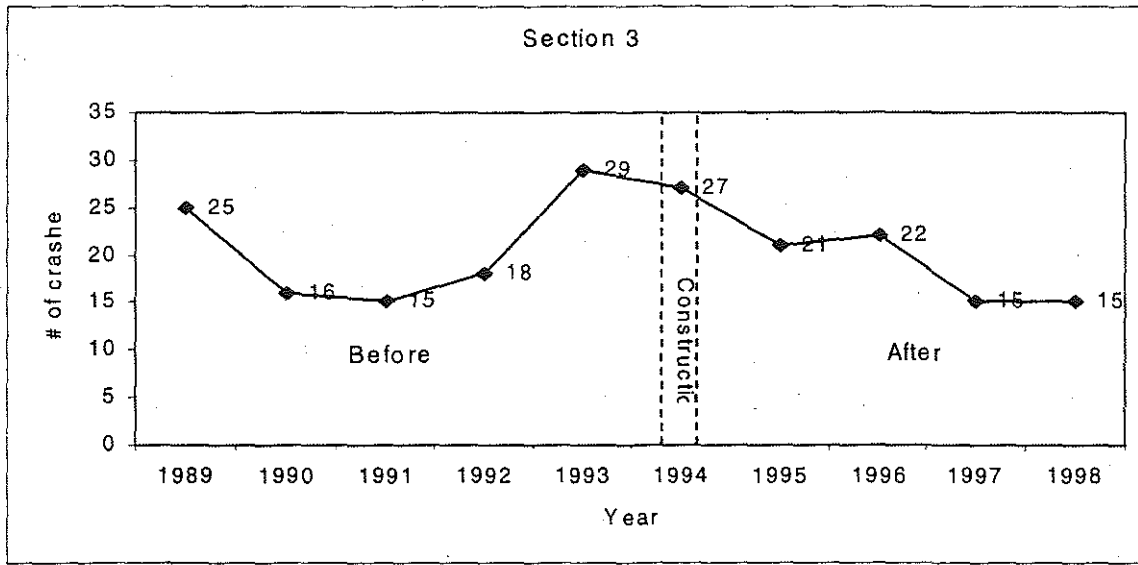


Figure 11 continued

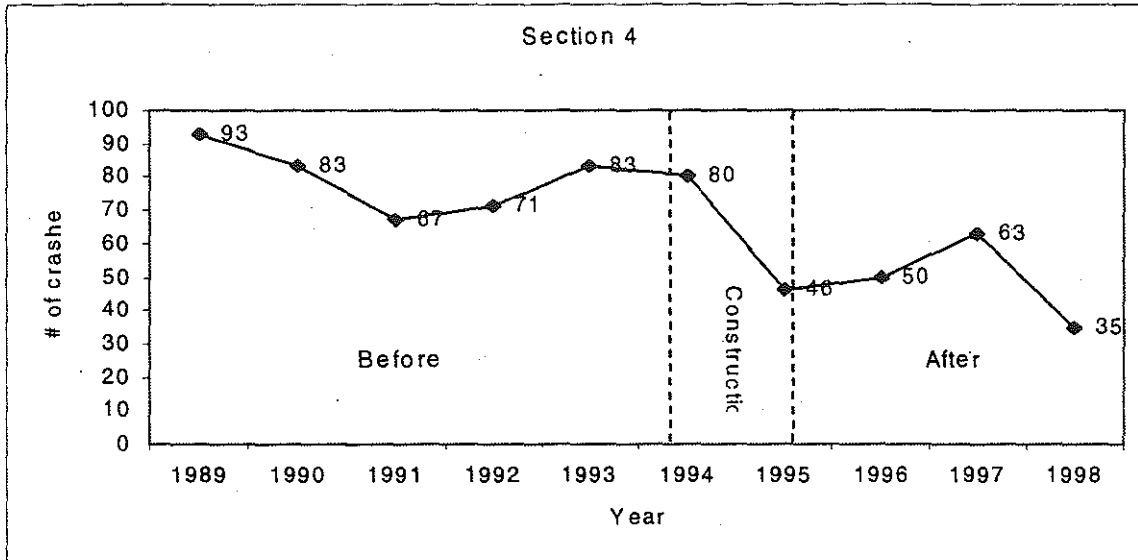


Figure 11 continued

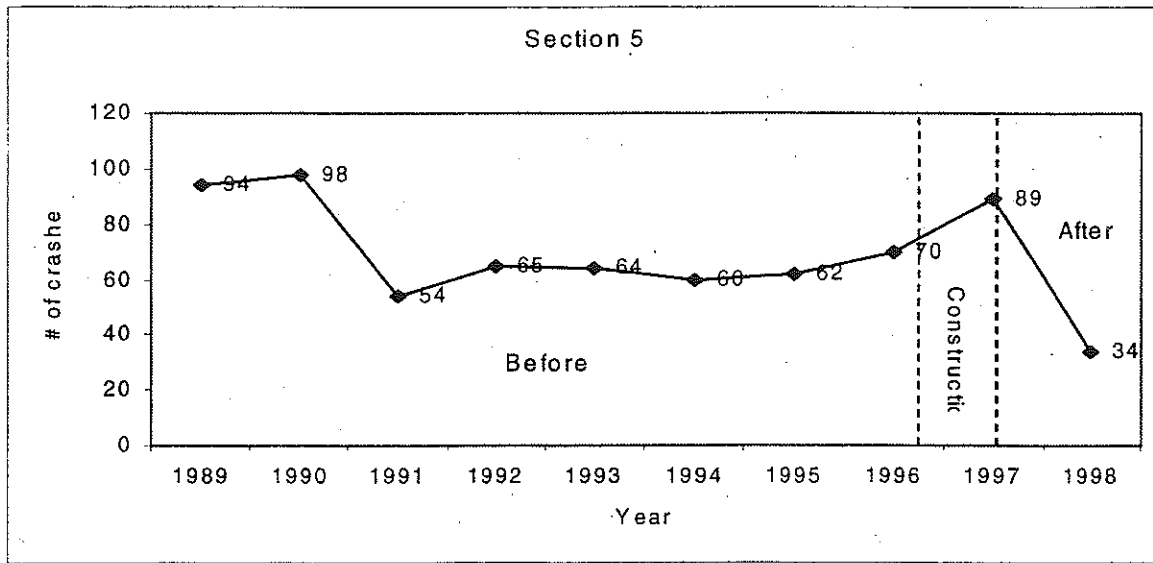


Figure 11 continued

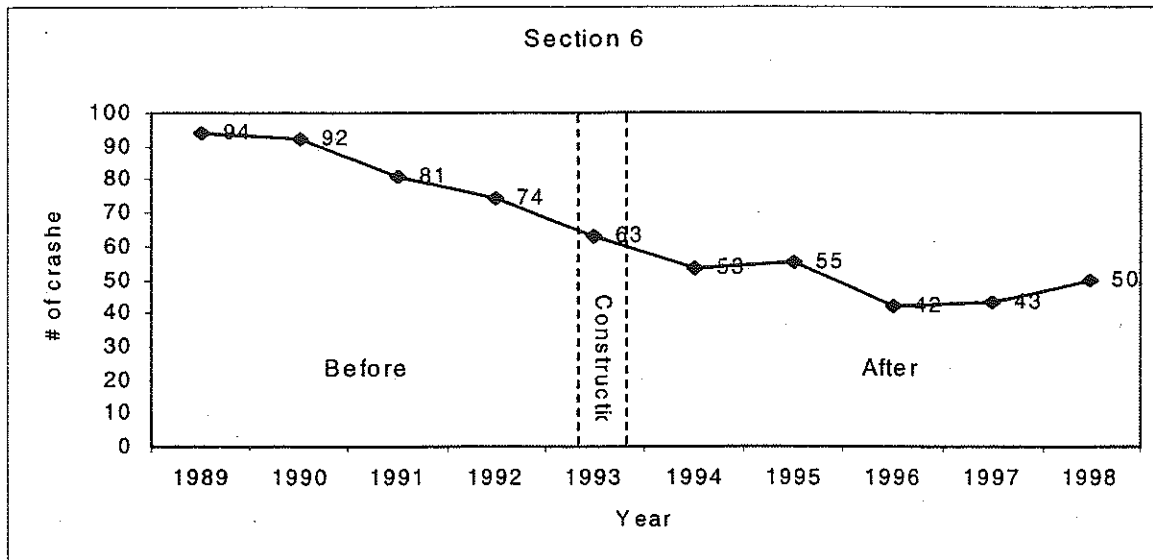


Figure 11 continued

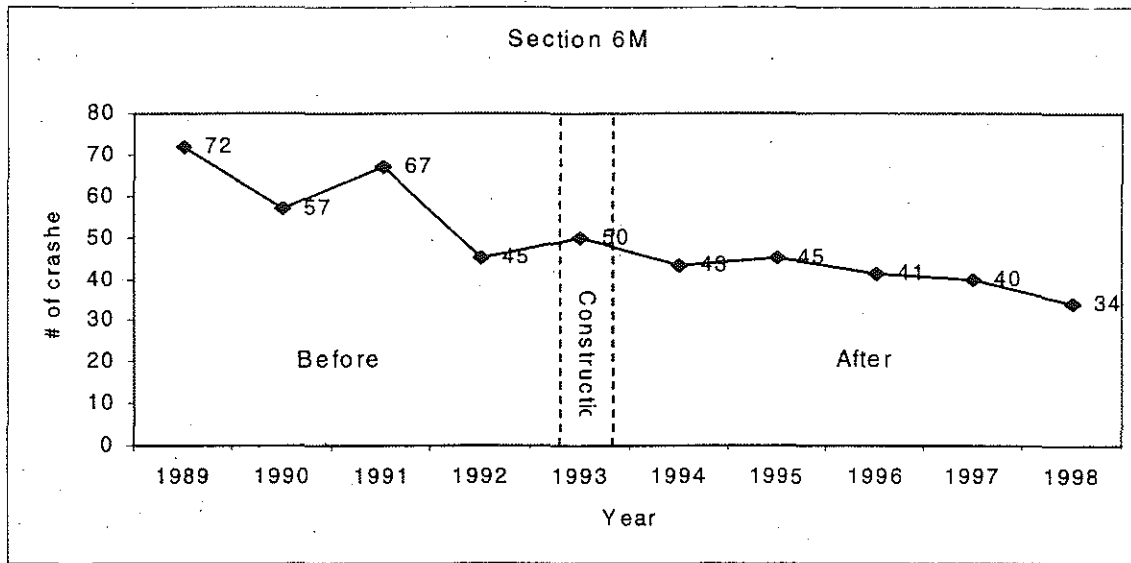
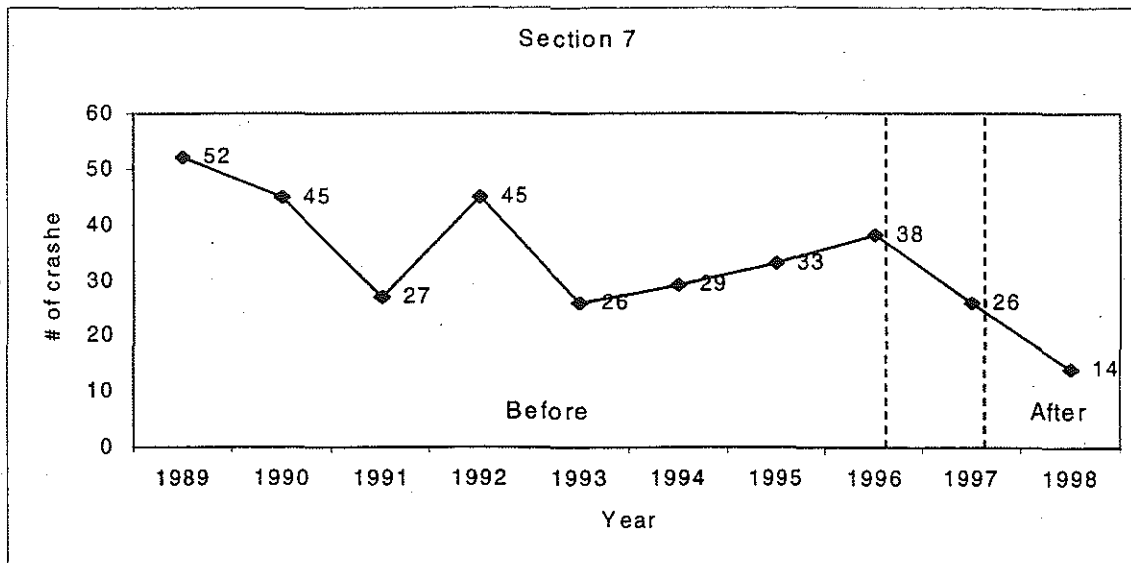
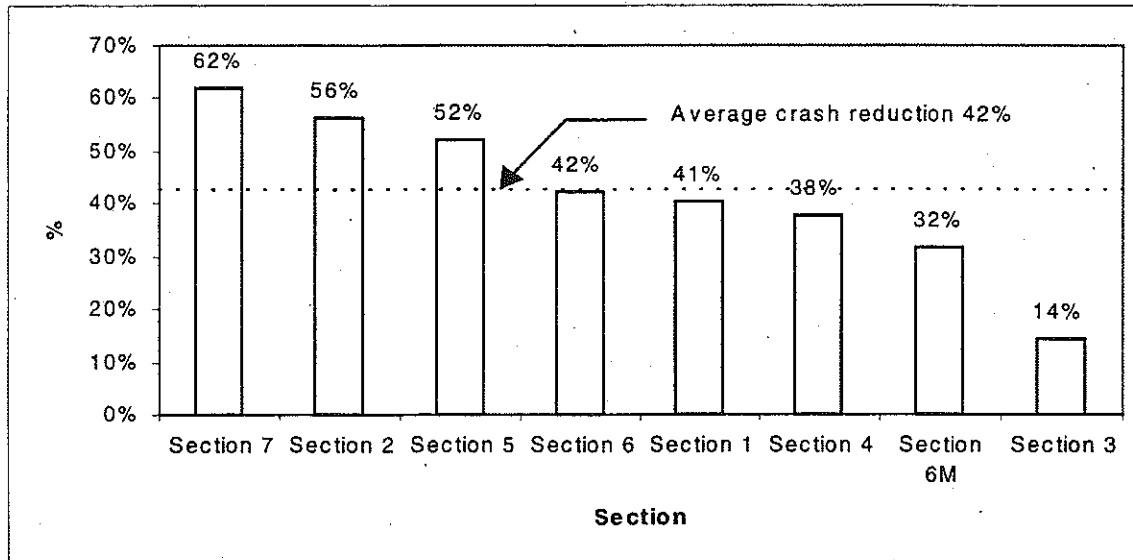


Figure 11 continued



Using all crashes in the analysis, the average reduction was 32%. However, when the intersection crashes were excluded, the average reduction was 42%, as shown in Figure 12.

Figure 12. Sections ranked by percent reduction in crashes, excluding signaled intersection crashes



Other Results

Crash migration could occur if some drivers that formerly used the bidirectional crossovers chose not to use the directional crossovers after they were constructed, but chose an alternative bidirectional crossover instead. However, since some projects eliminated all the bidirectional crossovers, and in the rest of the projects the majority of the bidirectional crossovers were eliminated, the probability of this phenomenon occurring is considered insignificant. Since there are no parallel corridors that would likely entice a driver to leave the study corridor as a result of the changes made, it is unlikely that migration from the corridor took place.

To determine if there was a traffic shift to the intersection related crossovers that were built prior to these projects, a study was conducted to see if these crossovers experienced an increase in traffic crashes. The results are shown in Figure 13 and 14. It can be seen that only section 2 showed an increase in crashes at the intersections, and the increase was too small to be interpreted as indicating a shift of traffic to the intersection. On average, there was an eighteen percent decrease in crashes at these intersections, but much of that decrease was attributed to sections 5 and 7, where there was only one year of data available after construction.

Figure 13. Average number of signalized intersection crashes per year before and after

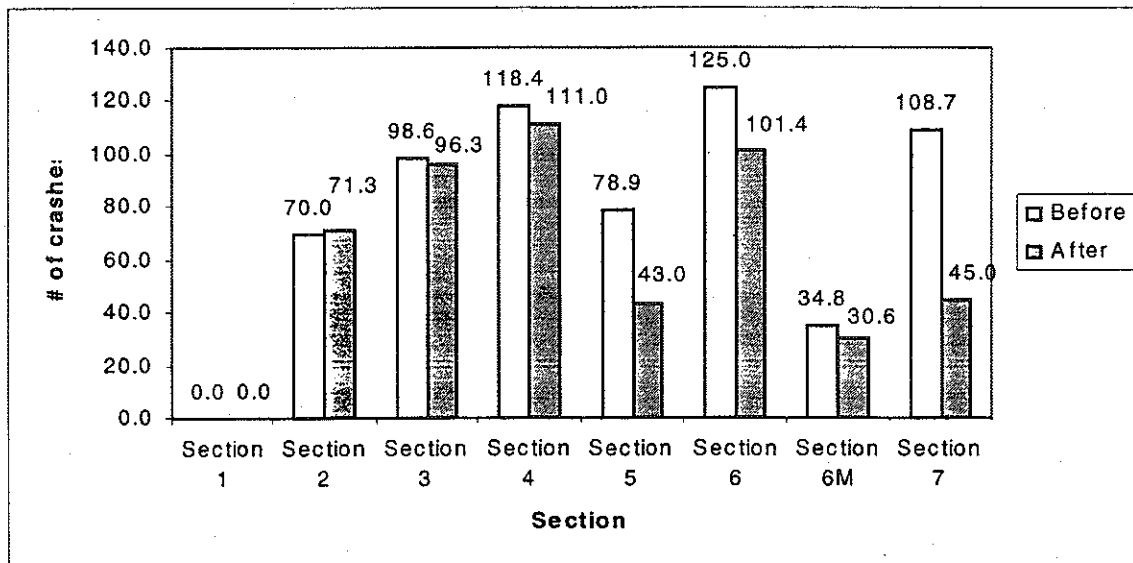
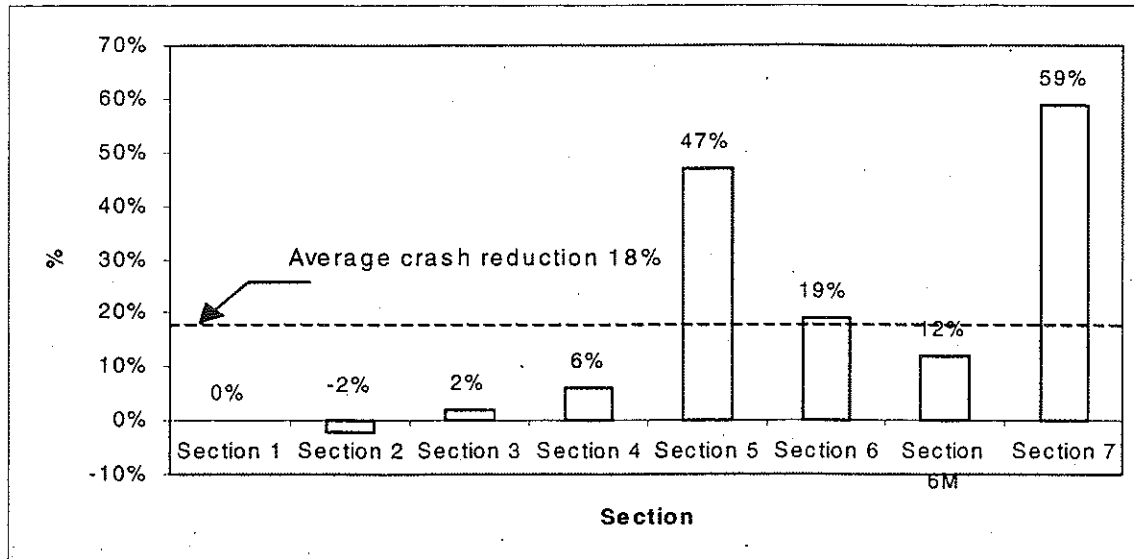


Figure 14: Percent reduction in signalized intersection crashes after construction



Thus, there is no evidence that crash migration contributed to the observed reduction in crashes attributed to this countermeasure.

The only section that could be considered an “outlier” is section 3, where the crash reduction was only fourteen percent compared to the average of forty-two percent. None of the variables investigated in this study explain this result. There were only three bidirectional crossovers eliminated, but the density of these crossovers was not particularly low, as shown in Table 1. Both sections 6M and 7 had a lower density of bidirectional crossovers in the before period.

This smaller than average reduction was due to a large increase in rear-end crashes recorded in 1997, as shown in Figure 9. This type of crash increased from 69 in 1996 to 92 in 1997, but then dropped to 48 in 1998. This appears to be a statistical anomaly rather than a result of any attribute of this study section.

Conclusions

The use of directional crossovers to replace bidirectional crossover is an effective crash countermeasure. In this study, all eight road segments where this countermeasure was applied experienced a reduction in the crash frequency. The percent reduction ranged from 4% to 59% when considering all crashes, and from 14% to 62% when crashes at these intersections on the study segment that already had directional crossovers were excluded.

These results as they might appear in a crash reduction table are shown on Table 2.

Table 2. Effect on crashes after construction

Treatment	Crash types	Reduction		
		Average	High	Low
Convert bidirectional crossovers to directional crossovers	Total	31%	59%	4%
	Injury	32%	70%	3%
	Non-intersection	42%	62%	14%
	Rear-End	37%	66%	-8%

BIBLIOGRAPHY

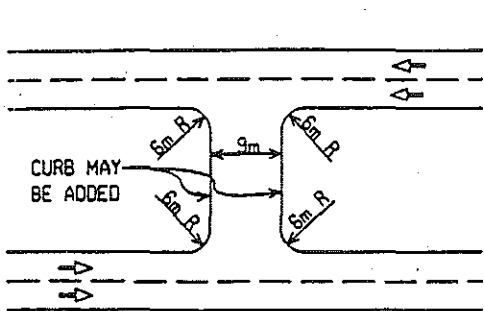
1. Michael Scheuer and Kurt L. Kunde. *Safety Aspects of Directional vs. Bidirectional Crossovers*. Traffic and Safety Division, Michigan Department of Transportation, February 1, 1996.
2. Brett Kach. *Directional Crossovers: Michigan's Preferred Left Turn Strategy*. Traffic & Safety Division, Michigan Department of Transportation, December 27, 1995.
3. Sufficiency Rating for Michigan State Trunkline Highways, Bureau of Transportation Planning, Michigan Department of Transportation, Published Annually.

APPENDIX

BI-DIRECTIONALS

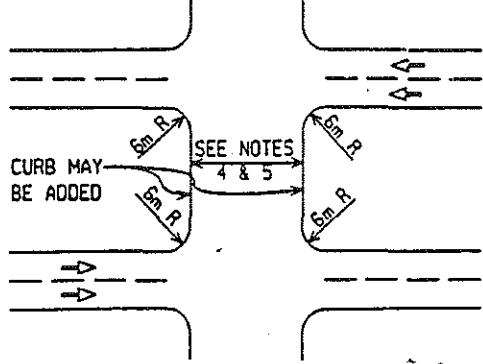
FREE-ACCESS

DIMENSIONS MAY VARY DEPENDING ON DESIGN VEHICLE AND TURNING MOVEMENTS. CONSULT DISTRICT TRAFFIC AND SAFETY ENGINEER FOR USE OF DECELERATION LANES. SEE DESIGN GUIDE G-650 SERIES FOR DETAILS.



RADII SHALL FORM A SEMICIRCLE FOR MEDIAN WIDTHS OF 12m OR LESS. ALSO, SEE NOTES.

8-1



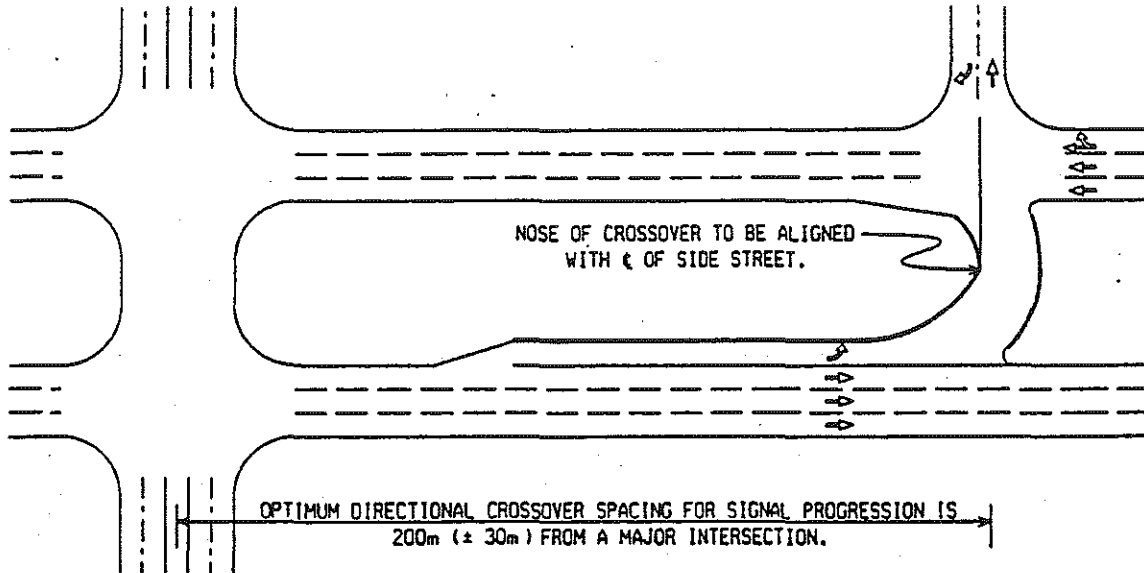
RADII SHALL FORM A SEMICIRCLE FOR MEDIAN WIDTHS OF 12m OR LESS. ALSO, SEE NOTES.

8-2

SPECIAL
SPECIAL SITUATIONS, I.E., WIDE STREETS, ONE-WAY STREETS, OR HEAVY LEFT-TURN MOVEMENTS MAY MAKE OTHER CROSSOVER WIDTHS DESIRABLE. THEIR DETAILS SHOULD BE DETERMINED BY THE GEOMETRIC DESIGN UNIT OF THE TRAFFIC AND SAFETY DIVISION. ALSO, SEE NOTES.

8-0

GENERAL PLACEMENT OF DIRECTIONAL CROSSOVERS



THE NUMBER OF CROSSOVERS PER MILE IS DETERMINED BY NEED. GENERALLY, 200m SPACING IS USED IN URBAN AREAS AND 400m SPACING IS USED IN RURAL AREAS.



PREPARED BY TRAFFIC & SAFETY

DRAWN BY: LPS
CHECKED BY: TEM

Robert E. Melick
ENGINEER OF CONSTRUCTION
James J. Culp
ENGINEER OF MAINTENANCE
Robert E. Melick
ENGINEER OF MATERIALS AND TECHNOLOGY
Robert E. Melick
ENGINEER OF TRAFFIC AND SAFETY

ENGINEER OF DESIGN
DEPARTMENT DIRECTOR
PATRICK M. NOWAK
BY: *Robert A. White*
DEPUTY DIRECTOR - HIGHWAYS

MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS DESIGN GUIDE FOR

CROSSOVERS

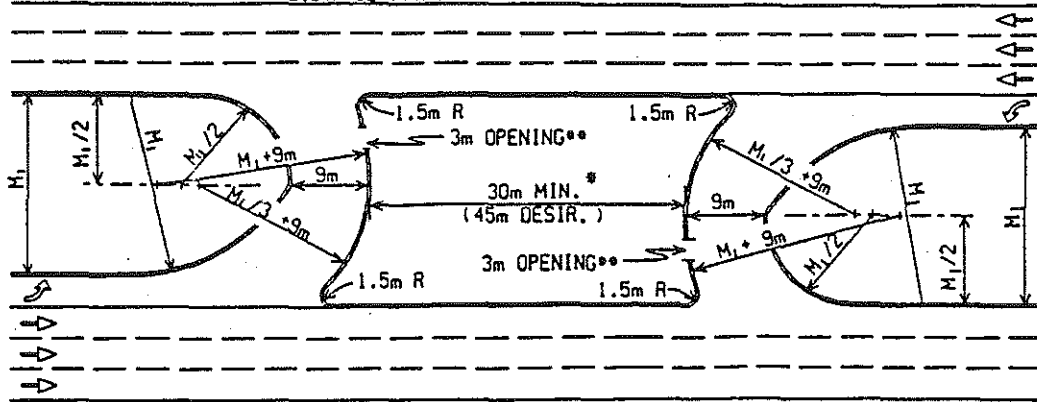
10-15-93
PLAN DATE

METRIC
G-670

SHEET
1 OF 4

CURBED SECTION

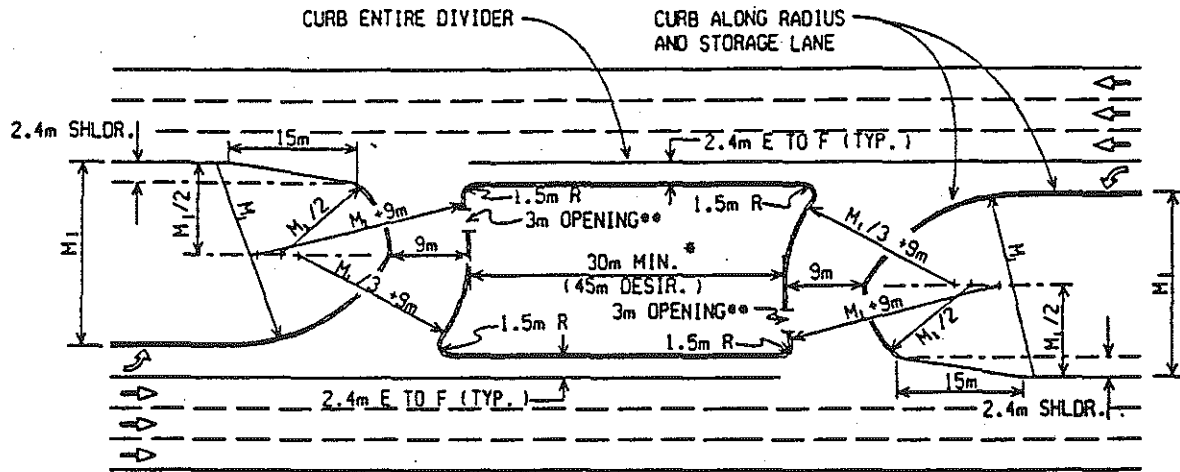
CREST OF MOUND, FOR DRAINAGE AND AESTHETICS,
SHOULD NOT EXCEED .3m ABOVE TOP OF CURB. IF NOT
PAVED, VEGETATION MUST NOT OBSTRUCT DRIVER SIGHT
DISTANCE (TYP.)



*WHERE CONDITIONS REQUIRE MODIFICATION, CONSULT THE GEOMETRIC DESIGN UNIT OF THE TRAFFIC AND SAFETY DIVISION.
**SEE DETAIL *L* ON STANDARD PLAN R-29 SERIES.

D-2

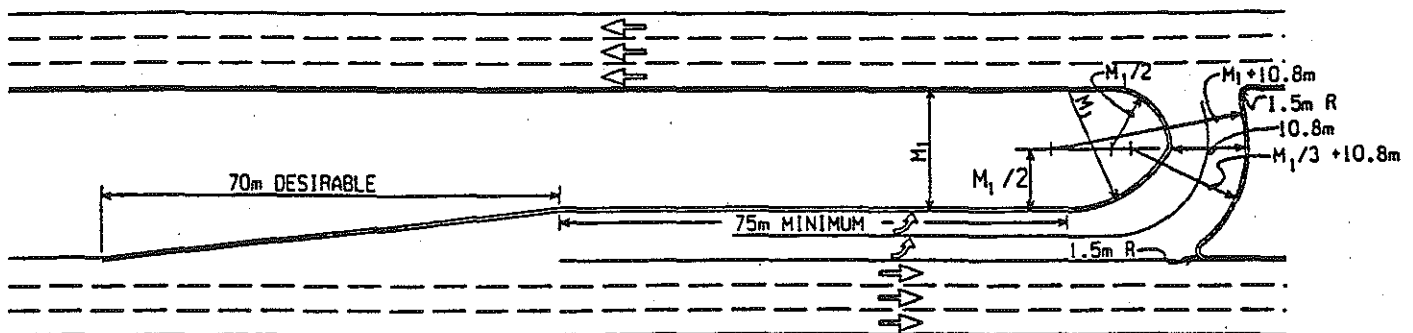
UNCURBED SECTION



*WHERE CONDITIONS REQUIRE MODIFICATION, CONSULT THE GEOMETRIC DESIGN UNIT OF THE TRAFFIC AND SAFETY DIVISION.
**SEE DETAIL *L* ON STANDARD PLAN R-29 SERIES.

D-3

DUAL TURNS



D-4

10-15-93
PLAN DATE

G-670

SHEET
3 OF 4