HE
336
T7.T39
2001

GUIDELINES FOR 4-LANE TO 3-LANE CONVERSIONS

EXECUTIVE SUMMARY

By

William C. Taylor, Ph.D., P.E.
In Kyu Lim
Malik Mahmood

Michigan State University
Department of Civil & Environmental Engineering
3546 Engineering Building
East Lansing, MI 48824-1226

September 2001

EXECUTIVE SUMMARY

INTRODUCTION

Many urban areas in Michigan and throughout the United States are implementing traffic calming measures in an attempt to reduce the speed of vehicles on residential and arterial streets. One of the measures being used for this purpose is the conversion of a four-lane undivided cross section to a three-lane cross section (often with bicycle lanes provided on both sides of the road). Unfortunately there are no published guidelines to assist in determining when this traffic calming measure should be used.

Some of the applications in Michigan have been on local streets, and thus did not require Michigan Department of Transportation (MDOT) approval. However, many of the applications have been on Urban Trunkline Roads (M-43 in East Lansing, M-83 in Frankenmuth, etc.). The objective of this study was to develop guidelines for MDOT to use in reviewing requests from local communities to convert four lane urban trunklines to the three-lane configuration.

This study was designed to analyze the operational and safety impacts of a reduction of four lane streets to three lane operations with one lane in each direction and a center turn lane. These projects are sometimes referred to as "Road Diet" projects. On a four lane street, drivers change lanes to pass slower vehicles, whereas on a two lane street, speeds are limited by the speed of the lead vehicle. Thus, the reduction in laneage is intended to reduce speeds, and consequently to reduce the total number and severity of crashes. The added advantages include convenience to pedestrians, as they have to cross only two through lanes of traffic as compared to four, and will face reduced traffic speeds. Moreover, bicyclists experience an increased comfort level and safety by being separated from motorized traffic when bicycle lanes are provided.

The literature contained a description of case studies from eight different states where road diets were deployed. Table 1 summarizes the results of the literature review related to traffic crashes. Each of the sites reported in the literature experienced a reduction in traffic crashes. The reduction ranging from 5 percent to over 60 percent, with a 25-30 percent reduction being the most common finding.

Table 1 – Reported Crash Experience with 4 lane to 3 lane Conversions

Location		Annual Crashes		Percent Change
State	City	Before	After	
California	Oakland	80	55	-31
California	San Leandro	33	24	-27
Minnesota				-33 (Injury)
Montana	Billings			-62
California	Oakland	46	27	-41
California	Oakland	27	19	-30
California	San Francisco	72	59	-18
California	Sanheadro	47	40	-19
Washington	Seattle	21	19	-10
Washington	Seattle	19	18	-5

Surprisingly, even though many of these projects were initiated as a traffic calming measure, very few measured the change in travel time or the speed of traffic.

In a study by Hummer and Lewis at North Carolina State University the operational characteristics of the four lane and three lane configurations were estimated based on a simulation model. The results generally show that for ADT over 15,000 a four lane cross-section will operate at a higher LOS than a three lane cross-section for all categories except for residential development. For residential areas the level of service (LOS) was equal.

MICHIGAN EXPERIENCE

A total of nine sites were used in the analysis of the Michigan experience of converting a four lane cross-section to a three lane cross-section. Table 2 lists these sites, along with a brief description and the date of the conversion. Six of the nine sites were on urban trunklines, and the other three were on local streets. The conversions occurred between 1989 and 1999, but only one site was converted prior to 1996.

The number of reported crashes on each of the study sections was extracted from the Michigan Department of Transportation Crash files for the year 1988 through 1999. These data are also shown in Table 2, and were used to determine the average reduction in crashes following the conversion.

There were only two sites that had at least three years of data in both the "before" and "after" period, and each of these sites experienced a 27.6% reduction in crash frequency. This is consistent with the results reported in the literature.

Changes in the crash types were only analyzed for the two sites with three years of data (US-31 in the Village of Parkdale, and Burcham Road in East Lansing), and one site with 2 years of data (M-43 in the City of East Lansing).

There were two crash types that were reduced at all three sites. Pedestrian and bicycle related crashes decreased from 12 to 2 on M-43; from 8 to 3 on Burcham Road; and from 1 to 0 on US-31. Intersection crashes decreased from 175 to 82 on M-43; from 43 to 28 on Burcham Road and from 20 to 19 on US-31.

The results for rear-end crashes was mixed with two sites experiencing a reduction, and one site experiencing an increase. At the M-43 site, this type of crash was

TABLE 1 **Traffic Crashes on the Michigan Sites by Year**

Trunk Line/Street Name	Location	Date of Converstion	Total Number of Crashes											
			1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
M-83	City of Frankenmuth	Sep-99	35	36	34	23	27	24	20	24	19	14	16	18
US-31	Village of Parkdale	Oct-96	14	19	10	17	20	20	10	11	11	11	11	12
M-115/M-55	City of Wexford	89	8	14	11	7	4	12	13	19	12	10	12	13
M-43	City of East Lansing	Oct-97	130	123	100	101	87	94	82	101	84	74	40	62
M-53/M-142	City of Bad Axe	Aug-98	29	49	56	37	27	56	41	53	36	45	48	28
M-81	City of Caro	Sep-98	58	48	52	49	27	31	37	39	34	50	21	9
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	67	61	63	54	53	47	55	64	51	65	51	35
Abbott Road	City of East Lansing	Jul-99	54	69	53	37	28		33	49	48	45	42	39
Burcham Road	City of East Lansing	Jun-96	13	16	16	19	11	19	11	16	13	10	10	13

reduced from 85 to 59; on Burcham Road the reduction was from 7 to 2; but on US-31 this type of crash increased from 10 to 17.

Driveway related crashes also showed mixed results. However the numbers are small and the difference may not have practical significance. For this crash type, M-43 experienced an increase from 6 to 7, while Burcham Road (5 to 1) and US-31 (5 to 2) experienced a decrease in driveway related crashes.

Mid-block crashes also showed mixed results, but in this case two of the three sites experienced an increase in the crash frequency. On M-43, the number of crashes doubled from 10 to 20; on Burcham Road the increase was from 3 to 5; but on US-31 this crash type decreased from 21 to 15.

DELAY ANALYSIS

The Abbott Road site located in the City of East Lansing was selected as the test site for the operational analysis. Abbott Road was converted from four lanes to three lanes in the summer of 1999. The project runs for 0.4 miles, from Burcham Road to Saginaw Street. There are traffic signals at each of these two end points, with stop controlled intersections between the ends. The street is basically a commercial street, but with business type commerce rather than consumer based commerce. There are a total of five stop-controlled intersections and seven driveways within the test section.

A series of sensitivity analyses were conducted to provide guidance for establishing the desired guidelines. The variables included in the sensitivity analyses were the minor street access density (access points per mile) and the percentage of vehicles turning left from the major street for different major street volumes.

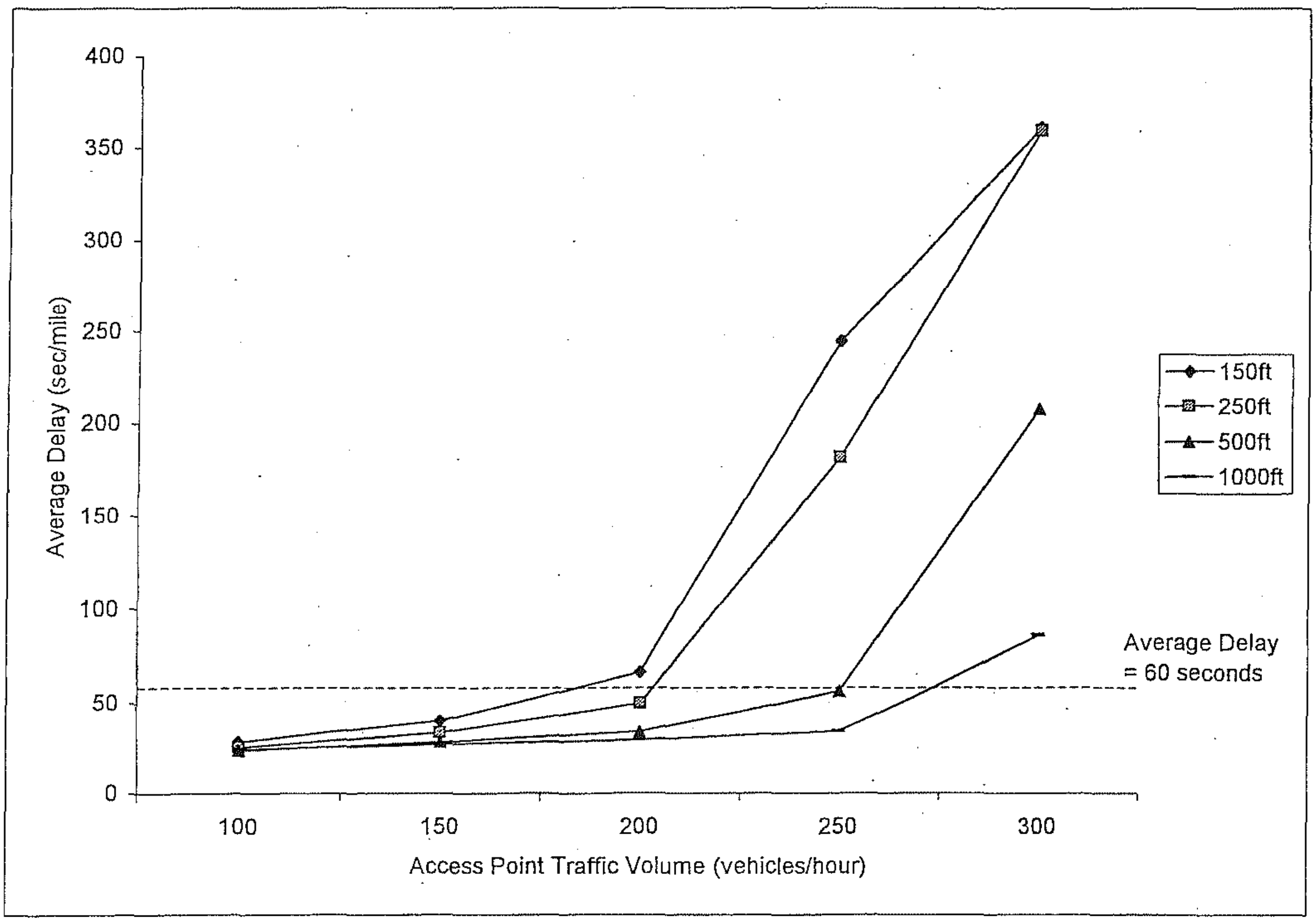
The first analysis was conducted to determine the impact of the minor street volume on the average delay to traffic on the major street. The major street volume for these simulation runs was 1000 to 2000 vehicles per. The results show that the minor street volume does not effect delay on the major street, at least in the volume range of interest to this study. There is very little effect on the average delay for volumes as high as 2000 vph when the left turn percentage is five percent. With ten percent left turns, the average delay increases from about 5 seconds at a volume of 1000 vph to 12 seconds at a volume of 2000 vph.

If the turning percentage reaches twenty percent, the delay increases very rapidly, and the site would become congested, with an average speed of only 22-mph. This would be an unacceptable level of service, even for a residential street. However, it is not likely that any site with a volume of 2000 vph in the peak hour would also have twenty percent of the traffic turning left at each access point.

A set of nomographs were developed to provide guidance in determining whether a four lane to three lane conversion would result in an undesirable level of delay to the main street traffic. The variables included in the graph are the major street volume, the volume on the minor street (or driveway), the access point average spacing and the percent of vehicles turning left from the major street.

Figure 1 is presented to illustrate the relationship among these variables. For a candidate site carrying a volume of 1000 vph (in both directions combined), with 5% of the vehicles turning left from the main street at each access point; IF an average delay of one minute (60 seconds) per mile is selected as an acceptable criterion, THEN a site with an average spacing between access points of 1000 feet with volumes as high as 275 vph

Figure 1 Average Delay per Vehicle for - Major Street Volume of 1000 veh/hour with 5% Left Turns



approaching the major street, the conversion would still be acceptable. With the same assumptions, if the average spacing between access points is only 250 feet, the maximum volume at the access points would be 200 vph before the delay exceeded this criterion.

All residential streets with an ADT of less than 10,000 (and thus a peak hour volume of less than 1000 vph) would be acceptable candidates for the conversion under this definition of acceptable delay.

Similar figures for major street volumes of 1200, 1400, 1600, 1800 and 2000 vph are included in the report. Figures for volumes from 1000 vph to 2000 vph with 10% of the traffic turning left are also included in the report.

CONCLUSIONS

The safety impact of converting four lane roads to three lane roads with a continuous two-way left-turn lane appears to be positive at all volume levels where the conversion has been used. The average reduction in crashes reported in the literature was 25 to 30 percent. The experience in Michigan has been similar, with the two sites with at least three years of crash data available averaging a 27.6 percent reduction.

At the Michigan sites, pedestrians and bicycle crashes showed the most consistent results and experienced the highest reduction, decreasing from 21 to 5 at the three sites where data exists. Intersection crashes also decreased at each of these sites, with the total number of crashes being reduced from 238 to 129.

An analysis of the average delay to vehicles on both the major street and the minor streets (or driveways) was conducted. The minor street delay increases as the major street volume increases because the delay is created by vehicles waiting for an acceptable gap in the traffic stream. There is no significant queuing delay until the minor street approach volume reaches 180 vehicles per hour. At this volume, the traffic signal

The delay to traffic entering the major street would not be significant for volumes associated with residential streets, where the conversion is frequently used as a traffic calming measure. The delay to the major street traffic is also low for the volume levels of most residential streets.

The delay to both the minor street (or driveway) and the major street traffic increases rapidly as the volumes reach levels associated with commercial streets. As the major street volume approaches 2000 vehicles per hour, and the minor street volume approaches 200 vehicles per hour, the delay to both traffic stream becomes large. Nomographs illustrating the increase in delay to the major street traffic are contained in this report.

Proposals to convert 4 lane streets to 3 lane streets should be based on an engineering study that considers the potential crash reduction and the estimated delay from the nomographs included in this report. If traffic signals are located in the corridor, an intersection capacity analysis should be performed at each signalized intersection.

HE
336
T7.T39
2001
c.1

GUIDELINES FOR FOUR-LANE TO THREE-LANE CONVERSIONS

By

William C. Taylor, Ph.D., P.E.
In Kyu Lim
Malik Mahmood

Michigan State University
Department of Civil & Environmental Engineering
3546 Engineering Building
East Lansing, MI 48824-1226

September 2001

MICHIGAN STATE UNIVERSITY
1855

COLLEGE OF ENGINEERING
MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN 48824

MSU IS AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY INSTITUTION

ACKNOWLEDGMENT

The authors wish to acknowledge the support for this research which came from the Michigan Department of Transportation (MDOT). They also wish to express their appreciation to the MDOT professional staff who provided data and other background materials for this project. The assistance of graduate students in the Departments of Civil and Environmental Engineering at Michigan State University who provided assistance in data collection and analysis is also acknowledged.

DISCLAIMER

This document is disseminated under the sponsorship of the Michigan Department of Transportation and the United States Department of Transportation in the interest of information exchange. The sponsors assume no liability for its contents or use thereof.

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the sponsors.

The State of Michigan and the United States Government do not endorse products or manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the objectives of this document.

This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No. Research Report	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Guidelines for 4 Lane to 3 Lane Conversion		5. Report Date September 2001
7. Author(s) William C. Taylor, Ph.D., P.E. In Kyu Lim Malik Mahmood		6. Performing Organization Code
9. Performing Organization Name and Address Michigan State University Department of Civil and Environmental Engineering East Lansing, MI 48824-1226		8. Performing Org Report No.
12. Sponsoring Agency Name and Address Michigan Department of Transportation Construction and Technology Division P.O. Box 30049 Lansing, MI 48909		10. Work Unit No. (TRAIS) 11. Contract/Grant No.
15. Supplementary Notes		13. Type of Report & Period Final Report 14. Sponsoring Agency Code

16. Abstract: Many urban areas in Michigan are implementing traffic calming measures on residential and arterial streets. One of these measures is the conversion of a four-lane to a three-lane cross section. Unfortunately there are no published guidelines to assist in determining when this treatment should be used.

All of the reports found in the literature reported a reduction in the crash frequency or rate for road segments after converting from four-lane to a three-lane cross section. However, the experience varied from small changes that are well within the error rate for the sample size available, to large changes that are statistically significant. None of the articles provided details on the type of crashes that were reduced, or if there were any crash types that showed an increase in frequency after the conversion.

A total of eight sites were identified for use in the analysis of the experience in Michigan. The number of reported crashes on each of the study sections was extracted from the Michigan Department of Transportation Crash files. All of the locations where this conversion was implemented since 1996 experienced a decrease in the average frequency of crashes per year. Thus, there appears to be a safety benefit that accrues from the conversion. The average daily traffic volume (ADT) on these roads ranged from 7500 to 20,000.

A nomograph was developed to provide guidance in determining whether the conversion would result in an undesirable level of delay to the main street traffic at any given location. The variables included in the graph are the major street volume, the volume on the minor street (or driveway), the access point average spacing and the percent of vehicles turning left from the major street. There is no significant queuing delay until the minor street approach volume reaches 180 vehicles per hour.

The delay to traffic entering the major street would not be significant for volumes associated with residential streets, where the conversion is frequently used as a traffic calming measure. The delay to the major street traffic is also low for the volume levels of most residential streets.

17. Key Words: Traffic Calming, Road Diet		18. Distribution Statement Unlimited	
19. Security Classification (report) Unclassified	19. Security Classification (Page) Unclassified	21. No. of	22. Price

GUIDELINES FOR FOUR-LANE TO THREE-LANE CONVERSIONS

By

William C. Taylor, Ph.D., P.E.
In Kyu Lim
Malik Mahmood

Michigan State University
Department of Civil & Environmental Engineering
3546 Engineering Building
East Lansing, MI 48824-1226

September 2001

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Many urban areas in Michigan and throughout the United States are implementing traffic calming measures in an attempt to reduce the speed of vehicles on residential and arterial streets. One of the measures being used for this purpose is the conversion of a four-lane undivided cross section to a three-lane cross section (often with bicycle lanes provided on both sides of the road). Unfortunately there are no published guidelines to assist in determining when this traffic calming measure should be used.

Some of the applications in Michigan have been on local streets, and thus did not require Michigan Department of Transportation (MDOT) approval. However, many of the applications have been on Urban Trunkline Roads (M-43 in East Lansing, M-83 in Frankenmuth, etc.). The objective of this study was to develop guidelines for MDOT to use in reviewing requests from local communities to convert four-lane urban trunklines to the three-lane configuration.

The procedure used to meet this objective involved three steps;

- A review of the literature to document the impact of these conversions on safety and operations. This review was also to be used to define limits on the analytical study in step three.
- An analysis of the safety impact of the conversions made in Michigan. This step was also intended to be used to define the limits for step three. This step was limited to the safety impact, because "before" data on existing conversions was not available, and there were no new conversions planned for the time period encompassed by this study.

- A simulation study to determine the impact of mainstreet volume, left-turn percentages, driveway frequency and minor street volume on delay.

LITERATURE REVIEW

The literature was reviewed to determine the experience of other transportation agencies that had converted four-lane undivided streets to three-lane operations. The objectives of the review were to determine:

- The change in traffic crash frequency and severity
- The change in traffic characteristics, primarily speed and travel time
- Characteristics of road segments that affect either the change in crashes or the change in characteristics.

Through the past decade, many transportation agencies, public groups and individuals became proponents of various measures to reduce the speed of vehicles on urban streets. This concept is generally referred to as Traffic Calming, a terminology used to refer to physical measures that reduce the speed of traffic and improve conditions for non-motorized street users – ITE [1]. The literature offered several examples of traffic calming, including implementation of physical measures (e.g., humps, diverters, traffic circles, chokers, raised intersections, textured pavements) as well as a reduction in the number of traveled lanes. Reduction in roadway laneage is a measure that can be adopted independently or used in conjunction with other Traffic Calming measures.

This study was designed to analyze the operational and safety impacts of a reduction of four-lane streets to three-lane operations with one lane in each direction and a center turn lane. These projects are sometimes referred to as "Road Diet" projects. On a four-lane street, drivers change lanes to pass slower vehicles, whereas on a two-lane street, speeds are limited by the speed of the lead vehicle. Thus, the reduction in laneage is intended to reduce speeds, and consequently to reduce the total number and severity of crashes. The added advantages include convenience to pedestrians, as they have to cross only two through lanes of traffic as compared to four, and will face reduced traffic speeds. Moreover, bicyclists experience an increased comfort level and safety by being separated from motorized traffic when bicycle lanes are provided.

Traffic Crashes

Huang et. al. [2] compiled a description of case studies from eight different states where road diets were deployed. A reduction in the number of crashes was reported in each of the states that reported crash data, with specific numbers reported by California, Pennsylvania and Washington. In California, one street with an average daily traffic volume (ADT) of 22,000-24,000, which is a higher volume than generally considered as a candidate site, was converted from four to three lanes. The number of crashes decreased from an annual average of 81 in the years before the change to 68 in the first year after the conversion, a 16 percent reduction. On a lower volume street, the total number of crashes were reported to have been reduced by 52 percent as a result of a similar laneage reduction. In Washington State, the research team investigated crash data for selected intersections and midblock sections along nine road diet projects. There was a 34.1 percent reduction in total crashes and a 4.7 percent drop in injury crashes in the after period compared to the before period. However, this reduction was not calculated based on the entire length of the projects, but only on selected intersections which were experiencing problems. Minnesota and Montana each analyzed a single street conversion, and reported crash reductions of 33 percent and 62 percent, respectively.

In their study, Huang et. al. [2] evaluated additional road diet projects in different cities in the States of California and Washington. A "before-and-after" study with control sites design was used to determine the effectiveness of the road diet measures in terms of crash frequency, type and severity. The road diets were located in seven different cities, and crash data were obtained for 23 road diet locations and 36 total matching control sites across these seven cities. Data on eight of the locations were included in a paper presented at the 2001 TRB meeting.

The number of crashes per month declined more sharply on each of these eight road diet locations than on their matching control sites. The crash reductions on the road diet streets ranged from 2 to 42 percent. The reduction in crash severity on road diet streets was only marginally significant. Injury and fatal crashes comprised 27.5 percent of all crashes in the before period, compared to 24.8 percent in the after period.

A study by Hummer and Lewis [5] was conducted to develop a model for use by the North Carolina Department of Transportation to estimate the operational capacity and expected collision rates of two-lane, three-lane, and undivided four-lane cross-sections for different levels of roadside development. The model estimates lower collision rates on the road segments between signalized intersections for three-lane as compared to four-lane cross-sections across all development levels for both residential and commercial development. For medium density residential areas, the reported collision rate for three-lane cross-sections was 1.8 collisions per million-vehicle-miles (mvm) as compared to 2.3 collisions per mvm for four-lane cross-sections; for high density residential areas it was 1.9 collisions per mvm as compared to 3.7 collisions per mvm. Similarly, the collision rates for low and high-density commercial areas were 2.1 collisions per mvm versus 2.6 per mvm; and 2.3 per mvm versus 15.0 per mvm, respectively.

Table 1 summarizes the results of the literature review related to traffic crashes. Each of the sites reported in the literature experienced a reduction in traffic crashes. The reductions ranged from 5 percent to over 60 percent, with a 25-30 percent reduction being the most common finding.

Table 1 – Reported Crash Experience with Four-lane to Three-lane Conversions

Location		Annual Crashes		Percent Change
State	City	Before	After	
California	Oakland	80	55	-31
California	San Leandro	33	24	-27
Minnesota				-33 (Injury)
Montana	Billings			-62
California	Oakland	46	27	-41
California	Oakland	27	19	-30
California	San Francisco	72	59	-18
California	Sanheadro	47	40	-19
Washington	Seattle	21	19	-10
Washington	Seattle	19	18	-5

Since many of the other conversions discussed in the literature were implemented as a traffic calming measure, the traffic crash impact was not reported, and, in fact, may not have been studied. A concern is that only sites with a positive safety impact appear in the literature, since many local agencies do not publish negative results. Almost none of the studies controlled for factors such as crash migration or trends. Fortunately, a study currently being conducted by North Carolina State University is addressing these factors. However, it is not known if they will address the potential problem of multiple changes, which is common in traffic calming projects.

Traffic Characteristics

Surprisingly, even though many of these projects were initiated as a traffic calming measure, very few reported on the impacts to the change in travel time or the speed of traffic. Only one study reported quantitative results, and one other study reported there was no change in travel time. The results of these two reports are contained in Table 2.

Table 2 – Reported Operational Experience with Four-lane to Three-lane Conversions

Location		ADT	Measure of Effectiveness
State	City		
Iowa	Sioux Center	N/A	A speed reduction of 1.7m/hr
Pennsylvania	Lewistown	13,000	No change in travel time

In the study by Hummer and Lewis [5] the operational level-of-service (LOS) estimates are categorized by development type and density, the number of driveways on each side per mile, and by ADT. The results generally show that for ADT over 15,000 a three-lane cross-section will operate at a lower LOS than a four-lane undivided cross-section for all categories except for residential development. For residential areas the LOS did not change with ADT as the LOS on commercial streets is influenced by the delay due to turning operations at commercial driveways.

Conclusions of Literature Review

All of the reports found in the literature reported a reduction in the crash frequency or rate for road segments after converting from a four-lane to a three-lane cross-section. However, the experience varied from small changes that are well within the error rate for the sample size available, to large changes that are statistically significant. None of the articles provided details on the type of crashes that were reduced, or if there were any crash types that showed an increase in frequency after the conversion.

There is very little information on the impact of the conversions on traffic operations. The few articles that address this question suggest that there is little or no impact at volumes less than an ADT of 15,000 on commercial streets, to over 20,000 on residential streets.

The issue of safety will be addressed more fully in the next section of this report, and the operational impacts will be addressed in the "OPERATIONS ANALYSIS" section.

MICHIGAN EXPERIENCE

A total of eight sites were identified for use in the analysis of the experience in Michigan of converting a four-lane cross-section to a three-lane cross-section. Table 3 lists these sites, along with a brief description including the location, PR number with mile points and the date of the conversion. Five of the eight sites were on urban trunklines, and the other three were on local streets. The conversions occurred between 1996 and 1999.

The number of reported crashes on each of the study sections was extracted from the Michigan Department of Transportation Crash files for the year 1988 through 1999. These data are shown in Table 4, and were used to determine the average reduction in crashes following the conversion.

Overall, using the average annual number of crashes for the five years prior to the conversion, and the average annual number of crashes for the years following the conversion, the crash reductions ranged from 27.4 percent to 76.4 percent. However, in the case of the 76.4 percent crash reduction, the "after" period contained only one year of crash data.

There were only two sites that had at least three years of data in both the "before" and "after" periods. These sites experienced 27.4 percent and 27.6 percent reductions in crash frequency. This is consistent with the results reported in the literature.

The type and severity of crashes before and after the conversion were analyzed to determine if there was a pattern. The comparison of fatal crashes was not meaningful because only one site (Kalamazoo Street) had any fatalities. There were two fatalities on this segment in 1995, which was before the conversion.

Table 3 Four Lane to Three Lane Conversions in Michigan

County	Trunkline/Street Name	Location	Control Section/ PR No.	Mile Point	Date of Conversion
Saginaw	M-83	City of Frankenmuth	73131	7.30-7.72	Sep-99
Manistee	US-31	Village of Parkdale	51011	6.45-7.23	Oct-96
Ingham	M-43	City of East Lansing	33082	0.11-1.08	Oct-97
Huron	M-53/M-142	City of Bad Axe	32032	0.07-0.50	Aug-98
Tuscola	M-81	City of Caro	79061	15.65-16.24	Sep-98
Ingham	Kalamazoo St-Pennsylvania Ave. to US-127	City of Lansing	335505	2.15-3.52	Fall-98
Ingham	Abbott Road	City of East Lansing	349410	0.17-0.97	Jul-99
Ingham	Burcham Road	City of East Lansing	347804	0.00-1.09	Jun-96

Table 4 Traffic Crashes on the Michigan Sites by Year

Trunkline/ Street Name	Location	Date of Conversion	Total Number of Crashes											
			1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
M-83	City of Frankenmuth	Sep-99	35	36	34	23	27	24	20	24	19	14	16	18
US-31	Village of Parkdale	Oct-96	14	19	10	17	20	20	10	11	11	11	11	12
M-43	City of East Lansing	Oct-97	130	123	100	101	87	94	82	101	84	74	40	62
M-53/M-142	City of Bad Axe	Aug-98	29	49	56	37	27	56	41	53	36	45	48	28
M-81	City of Caro	Sep-98	58	48	52	49	27	31	37	39	34	50	21	9
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	67	61	63	54	53	47	55	64	51	65	51	35
Abbott Road	City of East Lansing	Jul-99	54	69	53	37	28		33	49	48	45	42	39
Burcham Road	City of East Lansing	Jun-96	13	16	16	19	11	19	11	16	13	10	10	13

The number of injury crashes was lower after the conversion at five of the six sites where data exists for both the before and after period. However, once again, many of these comparisons have only one year of data in either the "before" or the "after" period. For those two sites with at least three years of data before and after the conversion, one showed a decrease from an average of 4.0 injury crashes per year to an average of 3.3 injury crashes per year; and the other site showed an increase from 4.3 to 4.6 injury crashes per year. This result is also consistent with the literature review, which reported only small changes in crash severity. The M-43 site in the City of East Lansing, however, experienced a significant change in injury crashes between the two-year period prior to the conversion and the two years after the conversion. There were 67 injury crashes in the before period and only 21 in the after period, a reduction of 69 percent.

Changes in the crash types were only analyzed for the two sites with three years of data (US-31 in the Village of Parkdale, and Burcham Road in East Lansing), and one site with two years of data (M-43 in the City of East Lansing).

There were two crash types that were reduced at all three sites. Pedestrian and bicycle related crashes decreased from 12 to 2 on M-43; from 8 to 3 on Burcham Road; and from 1 to 0 on US-31. Intersection crashes decreased from 175 to 82 on M-43; from 43 to 28 on Burcham Road and from 20 to 19 on US-31.

Rear-end crashes is one of the categories where a change in the frequency was expected. However, there are competing phenomena that may apply. Removing left-turning vehicles from the fast lanes of a four-lane highway by providing a left-turn lane should reduce this type of crash. However, as volumes increase the headway between vehicles flowing in the through lane will decrease, which could lead to an increase in this type of crash.

The results for rear-end crashes were mixed, with two sites experiencing a reduction, and one site experiencing an increase. At the M-43 site, this type of crash was reduced from 85 to 59; on Burcham Road the reduction was from 7 to 2; but on US-31 this type of crash increased from 10 to 17.

Driveway related crashes also showed mixed results. However the numbers are small and the difference may not have practical significance. For this crash type, M-43 experienced an increase from 6 to 7, while Burcham Road (5 to 1) and US-31 (5 to 2) experienced a decrease in driveway related crashes.

Mid-block crashes also showed mixed results, but in this case two of the three sites experienced an increase in the crash frequency. On M-43, the number of crashes doubled from 10 to 20; on Burcham Road the increase was from 3 to 5; but on US-31 this crash type decreased from 21 to 15.

The data for each of the sites studied are included in Tables 5 through 13, and the change in crash frequency for each type discussed above (except pedestrian/bicycle crashes) are illustrated in Figures 1 through 4.

The analysis of the safety benefits of converting four-lane roads to three-lane roads in Michigan is consistent with the results found in the literature.

All of the locations where these conversions have been implemented since 1996 experienced a decrease in the average frequency of crashes per year. Thus, there appears to be a safety benefit that accrues from the conversion. These reductions were experienced on each of the study sections, independent of the volume, as measured by the

ADT. The ADT on the State Trunklines, as reported on the ADT maps from the Michigan Department of Transportation, ranged from 7500 to 20,000.

Figure 1 Intersection and Non-Intersection Crashes on Burcham Road

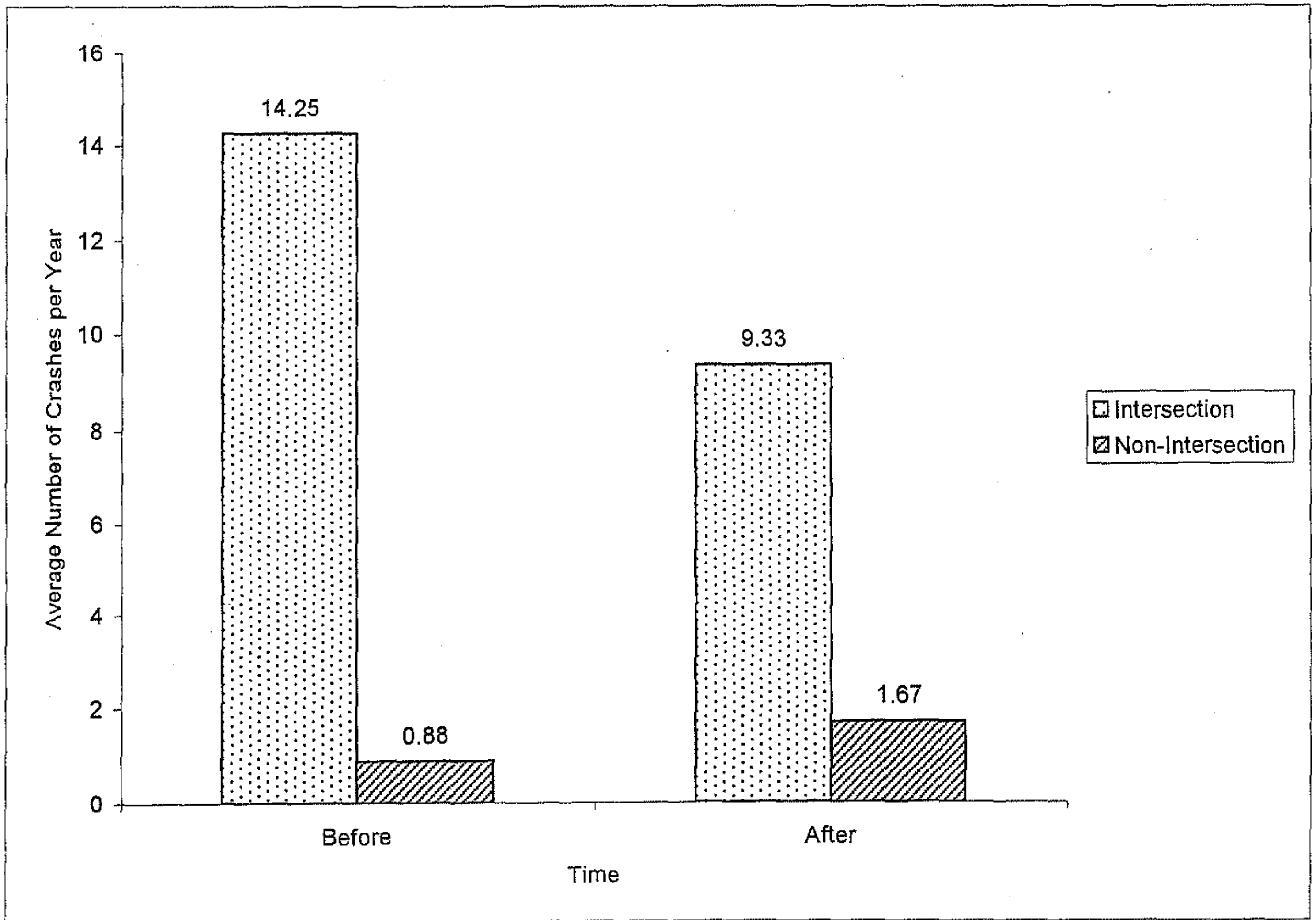


Figure 2 Intersection and Non-Intersection Crashes on US-31

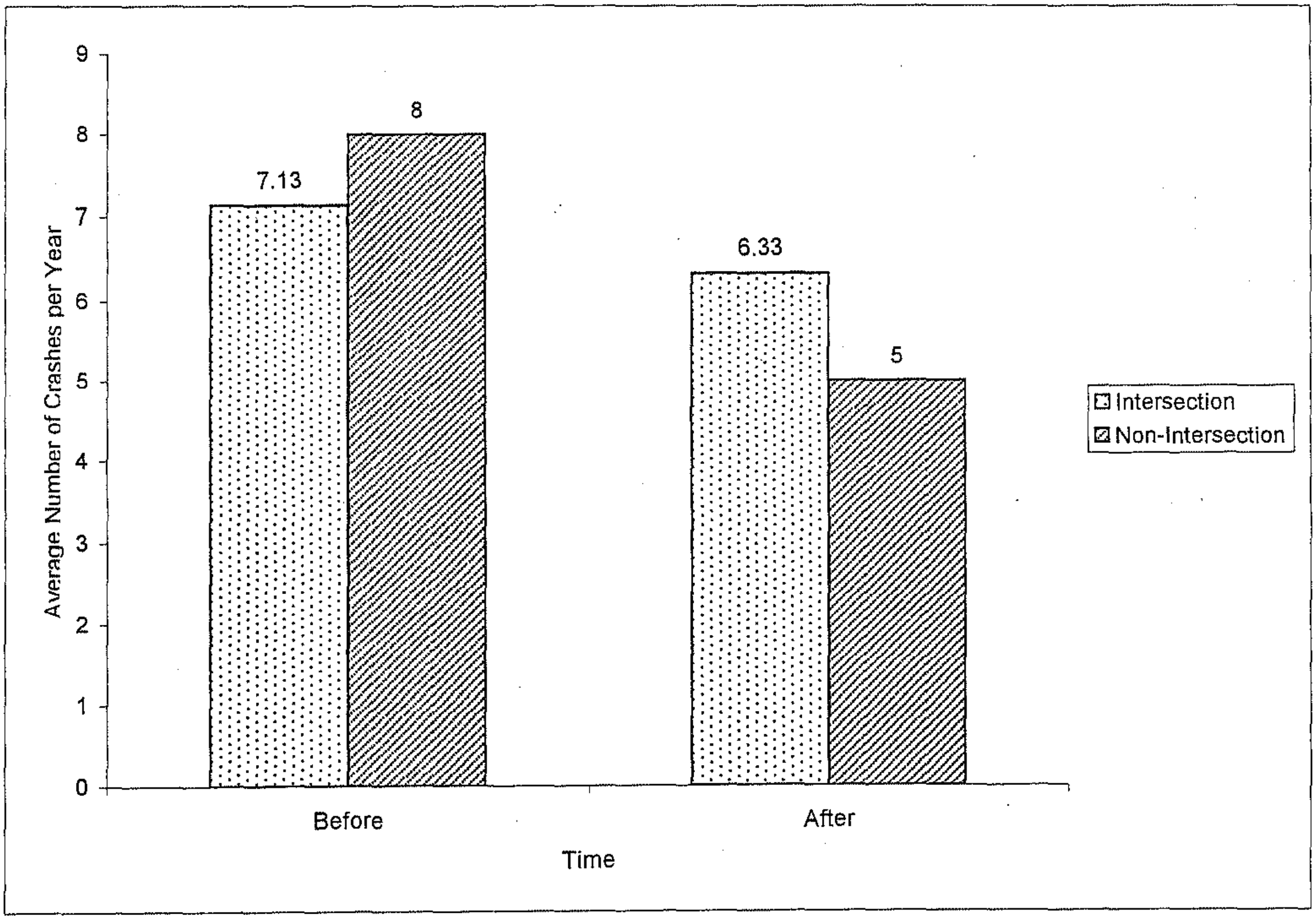


Figure 3   Driveway and Rear-End Crashes on Burcham Road

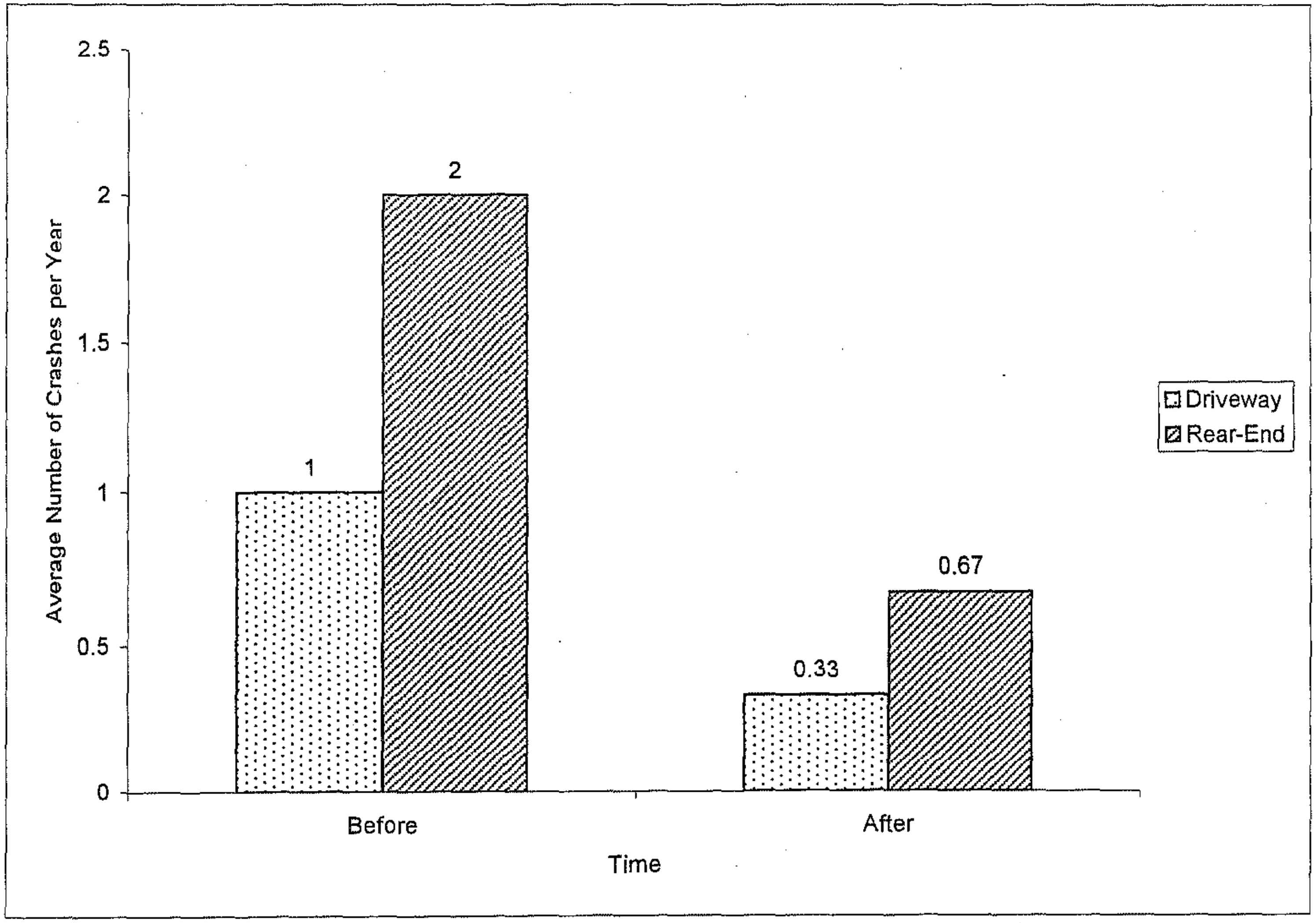


Figure 4 Driveway and Rear-End Crashes on US-31

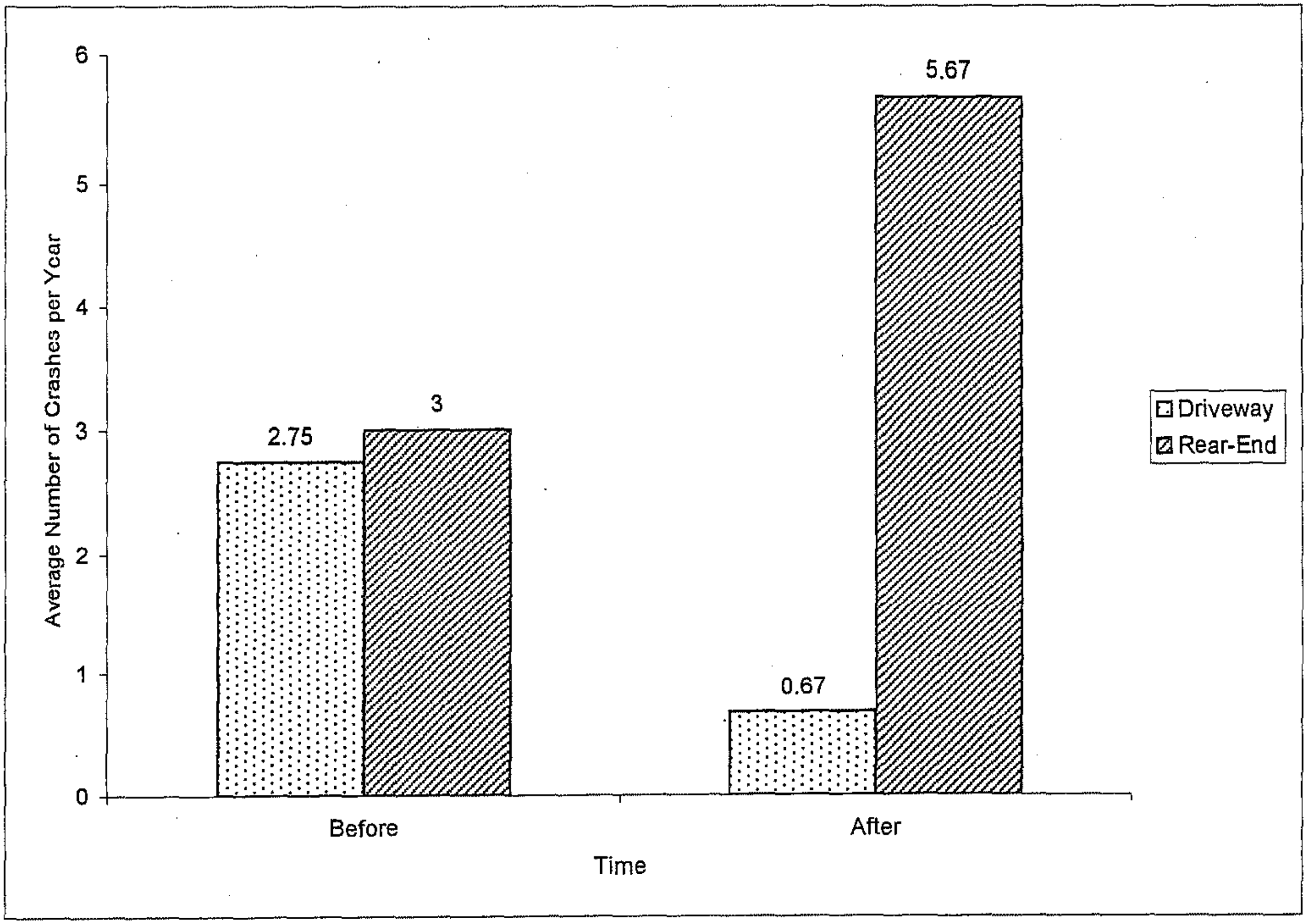


Table 5 Crashes by Type in 1999

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1999	0	0	0	0	11	1	0	4	14	18	0	1	0	2
US-31	Village of Parkdale	Oct-96	1999	0	0	0	0	5	0	0	5	7	12	0	0	1	1
M-43	City of East Lansing	Oct-97	1999	0	2	3	5	32	1	1	47	15	62	0	0	1	9
M-53/M-142	City of Bad Axe	Aug-98	1999	0	0	1	1	14	1	0	9	19	28	0	0	2	4
M-81	City of Caro	Sep-98	1999	0	0	2	2	2	0	0	7	2	9	0	0	0	1
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1999	0	1	2	3	5	2	0	26	9	35	0	1	1	10
Abbott Road	City of East Lansing	Jul-99	1999	0	4	4	8	6	0	0	32	7	39	0	0	0	6
Burcham Road	City of East Lansing	Jun-96	1999	0	0	0	0	1	2	0	11	2	13	0	0	3	1

Table 6 Crashes by Type in 1998

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1998	0	1	0	1	10	2	0	12	4	16	0	0	2	6
US-31	Village of Parkdale	Oct-96	1998	0	0	2	2	7	0	0	7	4	11	0	0	5	4
M-43	City of East Lansing	Oct-97	1998	0	0	2	2	27	1	0	35	5	40	0	0	3	8
M-53/M-142	City of Bad Axe	Aug-98	1998	2	1	1	4	28	0	0	35	13	48	0	3	4	13
M-81	City of Caro	Sep-98	1998	0	1	3	4	7	2	2	16	5	21	0	1	2	5
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1998	1	1	0	2	8	2	0	49	2	51	0	2	4	17
Abbott Road	City of East Lansing	Jul-99	1998	0	2	1	3	14	0	0	40	2	42	0	0	0	4
Burcham Road	City of East Lansing	Jun-96	1998	0	0	1	1	0	0	0	8	2	10	0	0	0	3

Table 7 Crashes by Type in 1997

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1997	0	1	0	1	11	0	0	7	7	14	0	0	0	2
US-31	Village of Parkdale	Oct-96	1997	0	0	0	0	5	0	0	7	4	11	0	0	1	2
M-43	City of East Lansing	Oct-97	1997	0	3	4	7	28	4	1	69	5	74	0	1	3	15
M-53/M-142	City of Bad Axe	Aug-98	1997	0	1	2	3	21	1	0	37	8	45	0	3	1	9
M-81	City of Caro	Sep-98	1997	1	2	5	8	9	1	1	41	9	50	0	0	3	6
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1997	1	1	1	3	5	1	1	60	5	65	0	2	3	15
Abbott Road	City of East Lansing	Jul-99	1997	1	7	3	11	10	4	0	44	1	45	0	0	4	12
Burcham Road	City of East Lansing	Jun-96	1997	0	0	0	0	1	1	0	9	1	10	0	0	2	1

Table 8 Crashes by Type in 1996

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1996	0	0	1	1	6	0	0	14	5	19	0	0	0	2
US-31	Village of Parkdale	Oct-96	1996	0	0	0	0	6	0	0	7	4	11	0	0	1	4
M-43	City of East Lansing	Oct-97	1996	0	1	1	2	38	8	0	79	5	84	0	4	12	14
M-53/M-142	City of Bad Axe	Aug-98	1996	0	2	0	2	15	0	1	30	6	36	0	0	1	11
M-81	City of Caro	Sep-98	1996	2	1	5	8	13	1	0	25	9	34	0	1	1	4
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1996	0	4	1	5	8	1	1	50	1	51	0	1	5	12
Abbott Road	City of East Lansing	Jul-99	1996	1	3	4	8	6	3	0	45	3	48	0	1	2	7
Burcham Road	City of East Lansing	Jun-96	1996	1	0	1	2	1	1	0	10	3	13	0	0	1	3

Table 9 Crashes by Type in 1995

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1995	0	1	2	3	7	2	1	20	4	24	0	1	1	6
US-31	Village of Parkdale	Oct-96	1995	0	0	2	2	6	0	0	5	6	11	0	0	1	4
M-43	City of East Lansing	Oct-97	1995	0	0	4	4	47	4	1	96	5	101	0	3	9	25
M-53/M-142	City of Bad Axe	Aug-98	1995	3	2	3	8	15	3	0	42	11	53	0	2	4	6
M-81	City of Caro	Sep-98	1995	1	3	1	5	10	0	1	31	8	39	0	0	3	9
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1995	1	1	3	5	5	4	1	60	4	64	2	7	2	9
Abbott Road	City of East Lansing	Jul-99	1995	1	3	1	5	11	2	0	46	3	49	0	1	1	4
Burcham Road	City of East Lansing	Jun-96	1995	0	1	0	1	3	1	0	16	0	16	0	0	1	3

Table 10 Crashes by Type in 1994

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1994	0	2	0	2	10	1	0	15	5	20	0	0	0	6
US-31	Village of Parkdale	Oct-96	1994	0	2	0	2	1	1	1	7	3	10	0	1	1	1
M-43	City of East Lansing	Oct-97	1994	1	1	1	3	38	2	0	80	2	82	0	3	3	18
M-53/M-142	City of Bad Axe	Aug-98	1994	0	1	2	3	12	2	0	35	6	41	0	1	1	7
M-81	City of Caro	Sep-98	1994	2	1	0	3	9	1	0	33	4	37	1	2	4	4
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1994	0	1	1	2	3	4	1	50	5	55	0	6	9	10
Abbott Road	City of East Lansing	Jul-99	1994	1	2	0	3	9	3	0	30	3	33	0	1	4	8
Burcham Road	City of East Lansing	Jun-96	1994	0	1	0	1	2	3	0	10	1	11	0	1	1	2

Table 11 Crashes by Type in 1993

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1993	0	0	0	0	10	0	0	13	11	24	0	0	0	4
US-31	Village of Parkdale	Oct-96	1993	0	1	0	1	3	0	2	8	12	20	0	1	3	2
M-43	City of East Lansing	Oct-97	1993	1	3	2	6	45	10	0	76	18	94	0	3	10	22
M-53/M-142	City of Bad Axe	Aug-98	1993	2	0	3	5	23	1	0	32	24	56	0	0	1	6
M-81	City of Caro	Sep-98	1993	0	1	0	1	10	0	0	22	9	31	0	1	2	4
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1993	0	0	4	4	7	2	2	41	6	47	0	5	7	14
Abbott Road	City of East Lansing	Jul-99	1993											0			
Burcham Road	City of East Lansing	Jun-96	1993	1	0	2	3	2	4	0	17	2	19	0	0	2	5

Table 12 Crashes by Type in 1992

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1992	0	0	1	1	10	0	1	17	10	27	0	1	1	4
US-31	Village of Parkdale	Oct-96	1992	0	0	0	0	2	0	0	7	13	20	0	1	0	2
M-43	City of East Lansing	Oct-97	1992	0	2	0	2	46	0	2	83	4	87	0	1	11	22
M-53/M-142	City of Bad Axe	Aug-98	1992	0	0	0	0	10	1	0	26	1	27	0	0	1	5
M-81	City of Caro	Sep-98	1992	0	1	3	4	9	0	0	23	4	27	0	1	2	8
Kalamazoo St- Pennsylvania Ave to US-127	City of Lansing	Fall-98	1992	0	2	0	2	7	1	1	51	2	53	0	3	3	17
Abbott Road	City of East Lansing	Jul-99	1992	0	2	0	2	7	0	0	25	3	28	0	0	1	3
Burcham Road	City of East Lansing	Jun-96	1992	0	0	0	0	2	0	1	10	1	11	0	0	1	1

Table 13 Crashes by Type in 1991

Trunk line/ Street Name	Location	Date of Conversion	Year	Number of Crashes by Type							Number of Crashes		Total Crashes	Severity			
				Driveway				Rear-End	Bicycle/ Ped	Head On	Intersection	Non Intersection		Fatal	Type A	Type B	Type C
				Other Drive	Angle Drive	Rear-End Drive	Total Driveway										
M-83	City of Frankenmuth	Sep-99	1991	1	1	2	4	11	1	0	16	7	23	0	0	0	2
US-31	Village of Parkdale	Oct-96	1991	0	0	3	3	3	0	2	8	9	17	0	1	1	5
M-43	City of East Lansing	Oct-97	1991	1	1	5	7	69	5	3	101	0	101	0	6	9	24
M-53/M-142	City of Bad Axe	Aug-98	1991	2	2	2	6	20	2	0	30	7	37	0	1	2	5
M-81	City of Caro	Sep-98	1991	0	1	2	3	15	2	1	44	5	49	0	3	3	8
Kalamazoo St-Pennsylvania Ave to US-127	City of Lansing	Fall-98	1991	0	1	4	5	15	1	0	54	0	54	0	1	4	14
Abbott Road	City of East Lansing	Jul-99	1991	2	0	2	4	12	6	0	35	2	37	0	1	5	9
Burcham Road	City of East Lansing	Jun-96	1991	0	1	0	1	3	3	0	17	2	19	0	1	2	4

OPERATIONS ANALYSIS

The literature review provided very little information on the impact of four-lane to three-lane conversions on vehicle delay. The limited information available suggested that the level-of-service (LOS) is not affected at volumes below 15,000 ADT on commercial streets and any measurable impact on residential streets would occur at an even higher volume. However, any given LOS (A, B, C, etc) encompasses a range of average delays, and thus this measure may not be sensitive enough to evaluate the change from four-lanes to three-lanes at lower volumes. For this reason, and to be able to test various combinations of main street volume, access volume, turning volume and driveway density on delay, a simulation approach was adopted.

The NETSIM model developed by the Federal Highway Administration (FHWA) was used for this part of the study. The procedure used was to:

a) Select one of the sites in Michigan where the conversion had been implemented for the simulation study

b) Collect data at the selected site for use in calibrating the NETSIM model

c) Vary the model parameters to determine the relationship between parameter values and average delay.

d) Identify limits on the parameter values where the delay increases rapidly with an increase in the parameter value.

The Abbott Road site located in the City of East Lansing was selected as the test site. Abbott Road was converted from four-lanes to three-lanes in the summer of 1999. The project runs for 0.4 miles, from Burcham Road to Saginaw Street. There are traffic signals at each of these two end points, with stop-controlled intersections between the ends. The street is basically a commercial street, but with business type commerce rather than consumer based commerce. There are a total of five stop-controlled intersections and seven driveways within the test section.

Model Calibration

Data were collected at the test site and the NETSIM model was calibrated with these data. The calibration parameter used was the delay to vehicles entering Abbott Road from the access points (intersections and driveways) since delay is the parameter of interest in the analysis.

Data were collected in both the peak hours and in the off-peak period to represent a range of volumes on the major street. The arrival and departure times of vehicles on the sidestreets were recorded to obtain the delay. The analysis unit was 10 minutes, and the 10-minute volumes on both the major street and minor street were converted to an equivalent hourly volume for the simulation. The average delay for vehicles arriving on the minor street was calculated and compared to the average delay predicted by the NETSIM model when existing values of the major and minor street volume were used as input.

The results of the calibration are shown in Figure 5. The equivalent hourly volume on Abbott Road measured in the field ranged from 500 to 2000. Since delay analysis are generally conducted in the peak hour, and the peak hour represents about ten percent of the daily traffic, the model calibration would be valid for streets with an ADT range of 5000 to 20,000.

There are two variables that will have an impact on the delay to vehicles entering from the minor street; the headway distribution on the major street, and the minor street volume (and thus queuing time). Each of these variables was tested to determine their effect on delay.

Figure 5 Calibration of the NETSIM Model

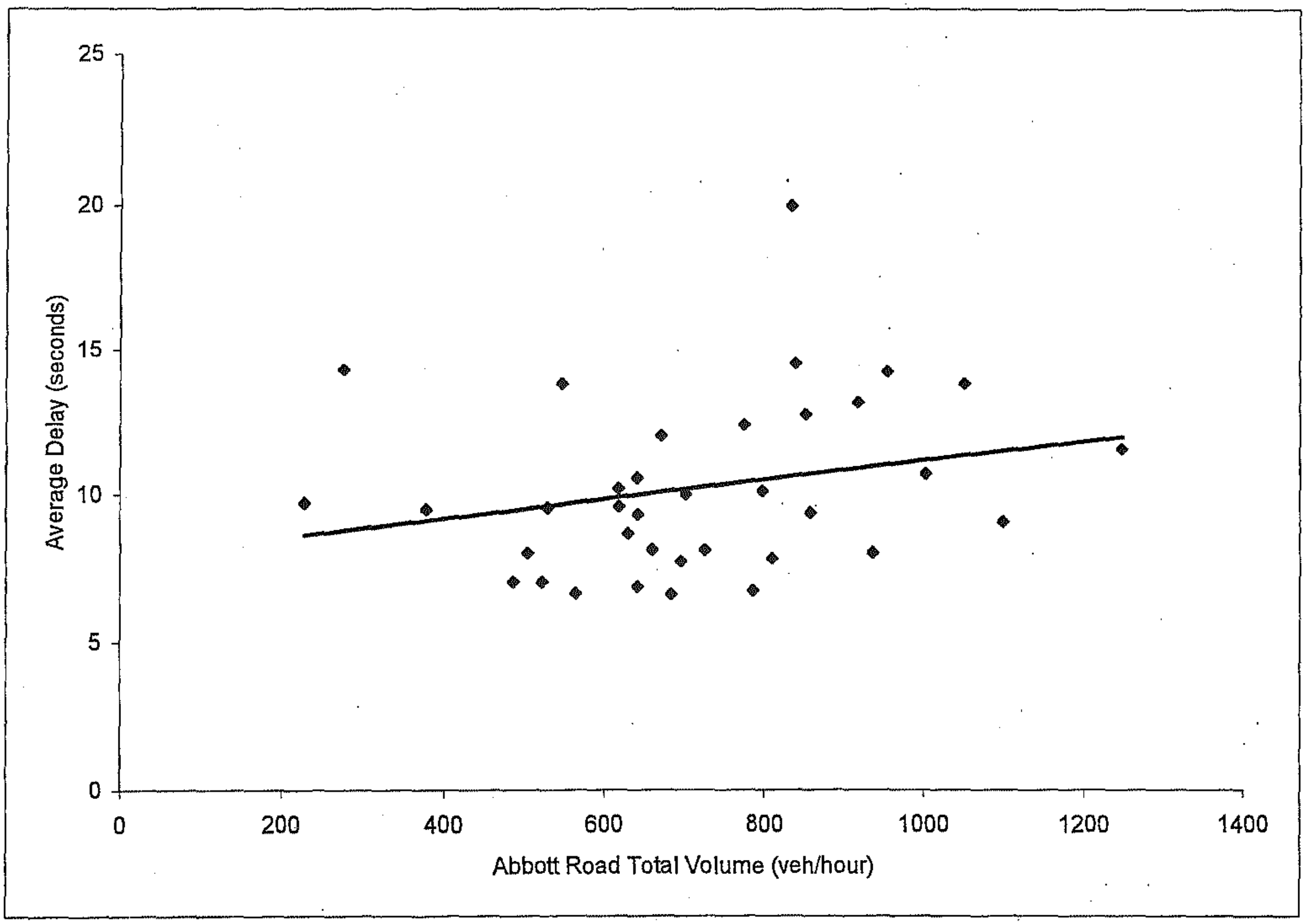


Figure 6 illustrates that at least in the volume range encountered on Abbott Road, the headway distribution has little effect on the minor street delay. The Uniform, Normal and Erlang distributions all produce about the same estimated delay for any specific volume on the major street. The Normal distribution was thus used for all subsequent analysies including the sensitivity analyses.

Figure 7 illustrates similar results for the range of minor street volumes observed in the field studies. The total delay is comprised of the queue time plus the time waiting for an acceptable gap once the driver reaches the front of the queue. For the volume range observed in the field (up to 120 vph), the queue time as a percentage of the total time appears to be constant, with a queue time of one to two seconds greater at a volume of 120 vph compared to a volume of 60 vph. If the side street volume were to reach 180 vph, the queue time can be greater than the gap acceptance time for higher volume flows on the major street, based on the simulation results shown in Figure 7. These graphs are based on 50 percent of the vehicles turning right from the minor street, and the other 50 percent crossing or turning left, which requires an acceptable gap in both directions on the major street.

This simulation was conducted at the higher volume (180 vph) to determine if there is an upper limit on the minor street (or driveway) volume that could be used as a criterion for determining the suitability of a site for this conversion. However, the results indicate that traffic signal warrants would be met at a combination of major and minor street volumes that are lower than the volumes at which the minor street delay becomes unacceptable.

Figure 6 Average Minor Street Delay vs Traffic Volume on the Major Street

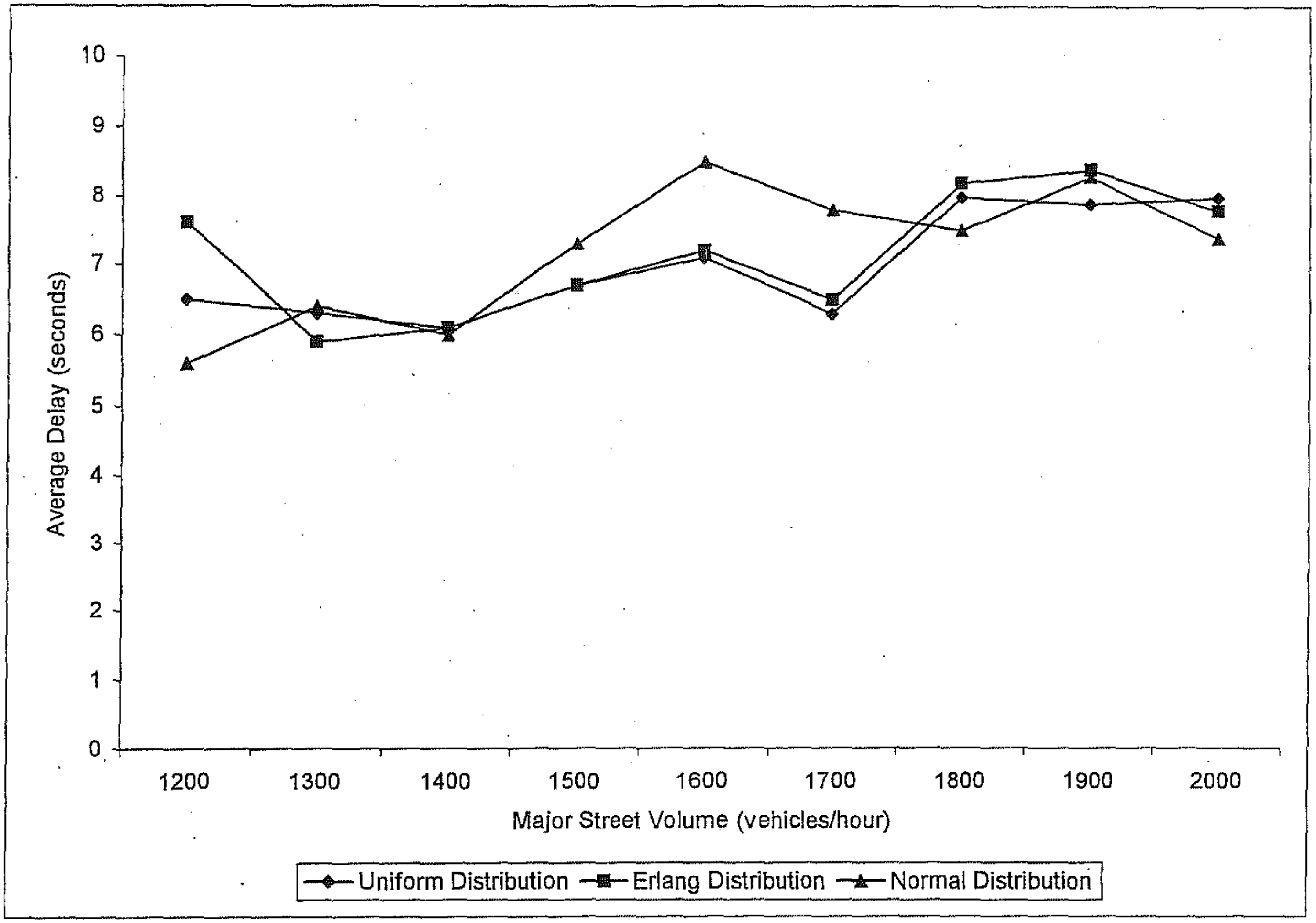
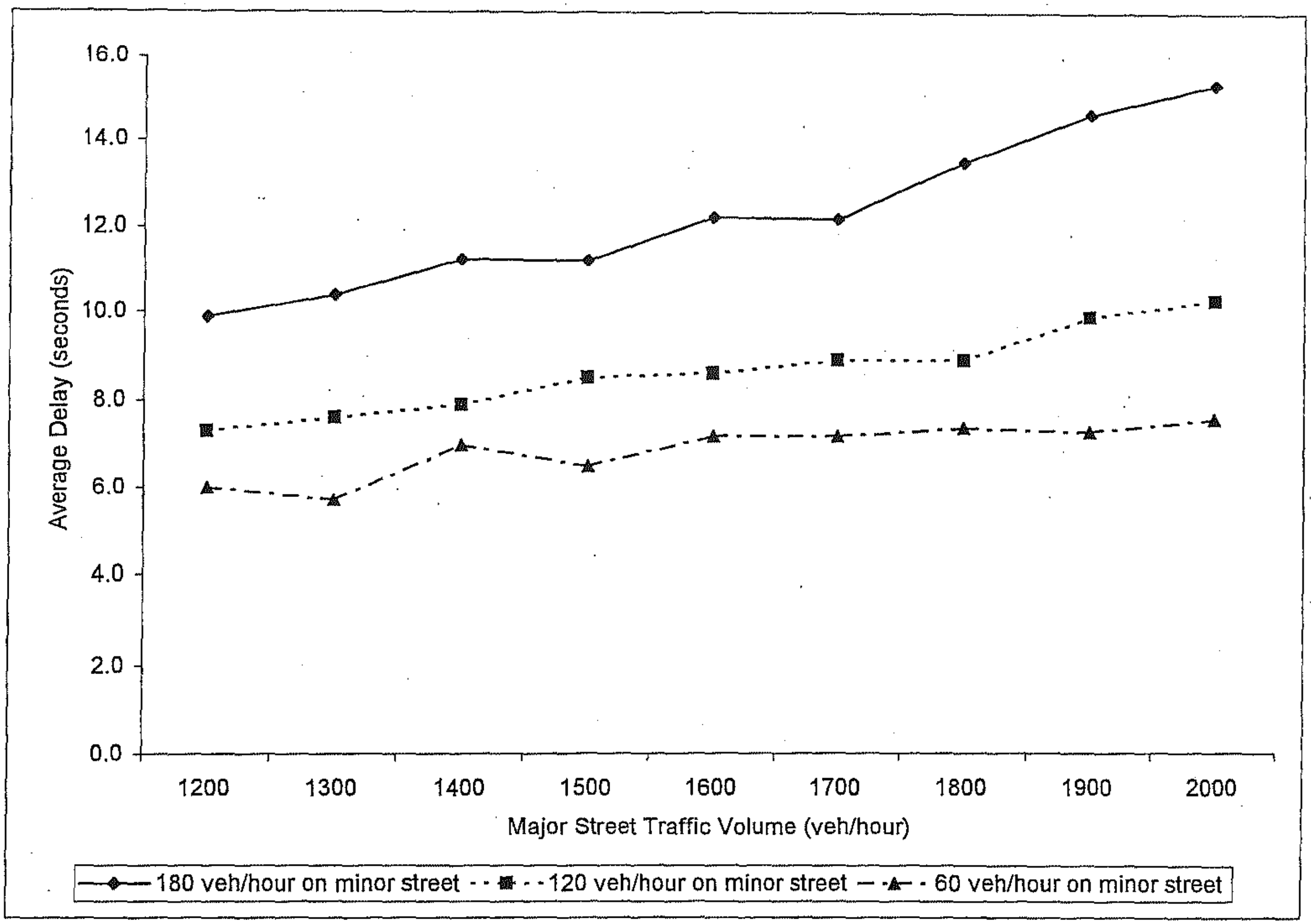


Figure 7 Average Minor Street Delay for Different Volumes



Sensitivity Analysis

Having determined that the NETSIM model produces results that match the field observation, and that respond appropriately to both the major and minor street volume changes, a series of sensitivity analyses were conducted to provide guidance for establishing the desired guidelines. The variables included in the sensitivity analyses were the minor street access density (access points per mile) and the percentage of vehicles turning left from the major street for different major street volumes.

The first analysis was conducted to determine the impact of the minor street volume on the average delay to traffic on the major street. Delay is defined by NETSIM as the difference between the travel time through the study segment (0.4 miles) under the simulated condition minus the travel time through the study segment when the minor street volume is set to zero. The major street volume for these simulation runs was 1600 vehicles per hour with 10 percent of the traffic turning left onto the minor streets. As shown in Figure 8, the minor street volume does not effect delay on the major street, at least in the volume range of interest to this study. There is considerable variance in the average delay, because each simulation was run for only 10 minutes. However, there is no apparent trend as illustrated by the graph or as depicted by the equation of the regression line.

Figures 9, 10, 11 illustrate the relationship between the average delay and the percent of vehicles turning left from the major street. There is very little effect on the average delay for volumes as high as 2000 vph when the left turn percentage is 5 percent. With 10 percent left turns, the average delay increases from about 5 seconds at a volume of 1000 vph to 12 seconds at a volume of 2000 vph. This means the average

Figure 8 Major Street Delay as a Function of the Minor Street Volume

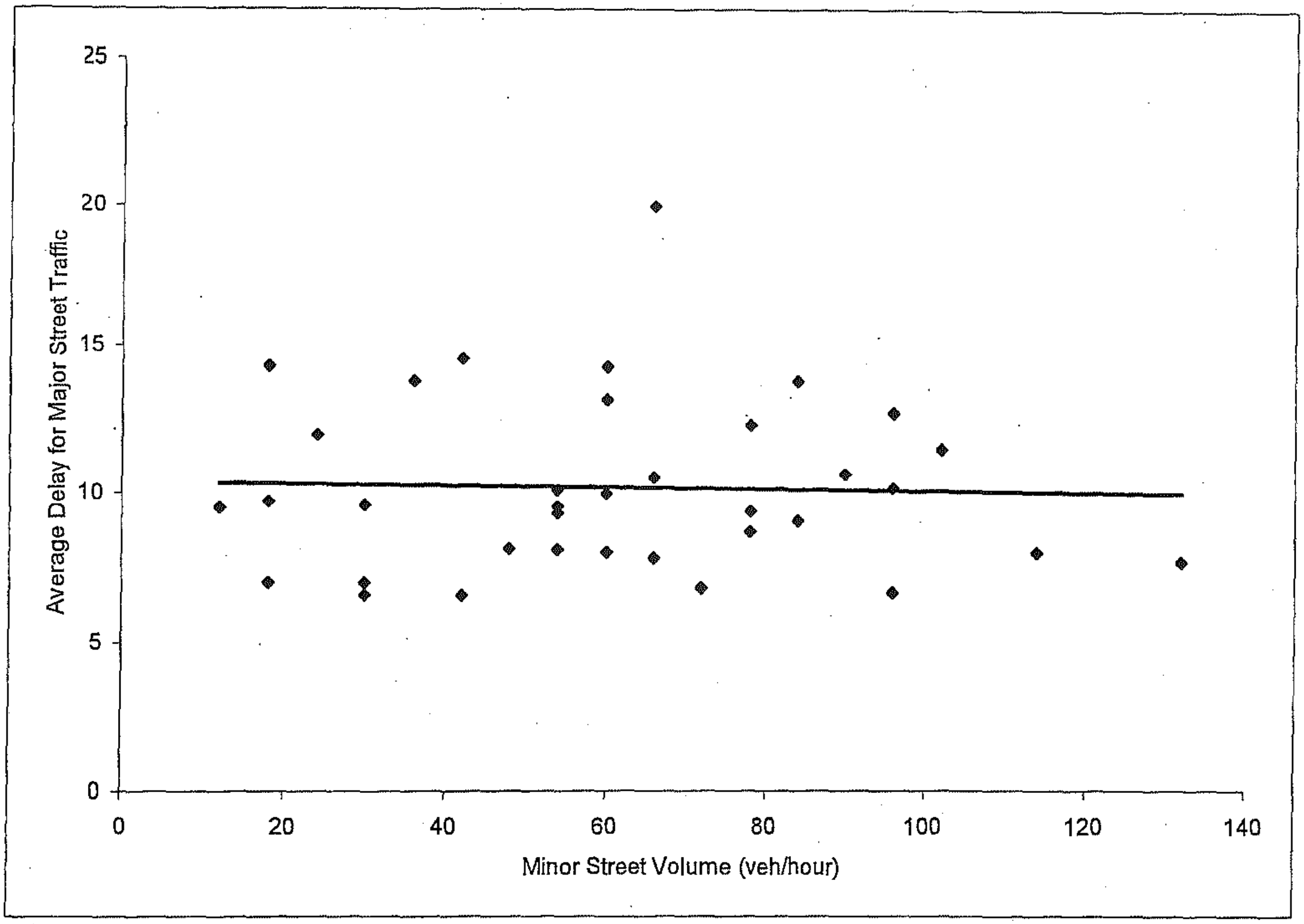


Figure 9 Average Delay as a Function of Major Street Volume with 5% Left Turns

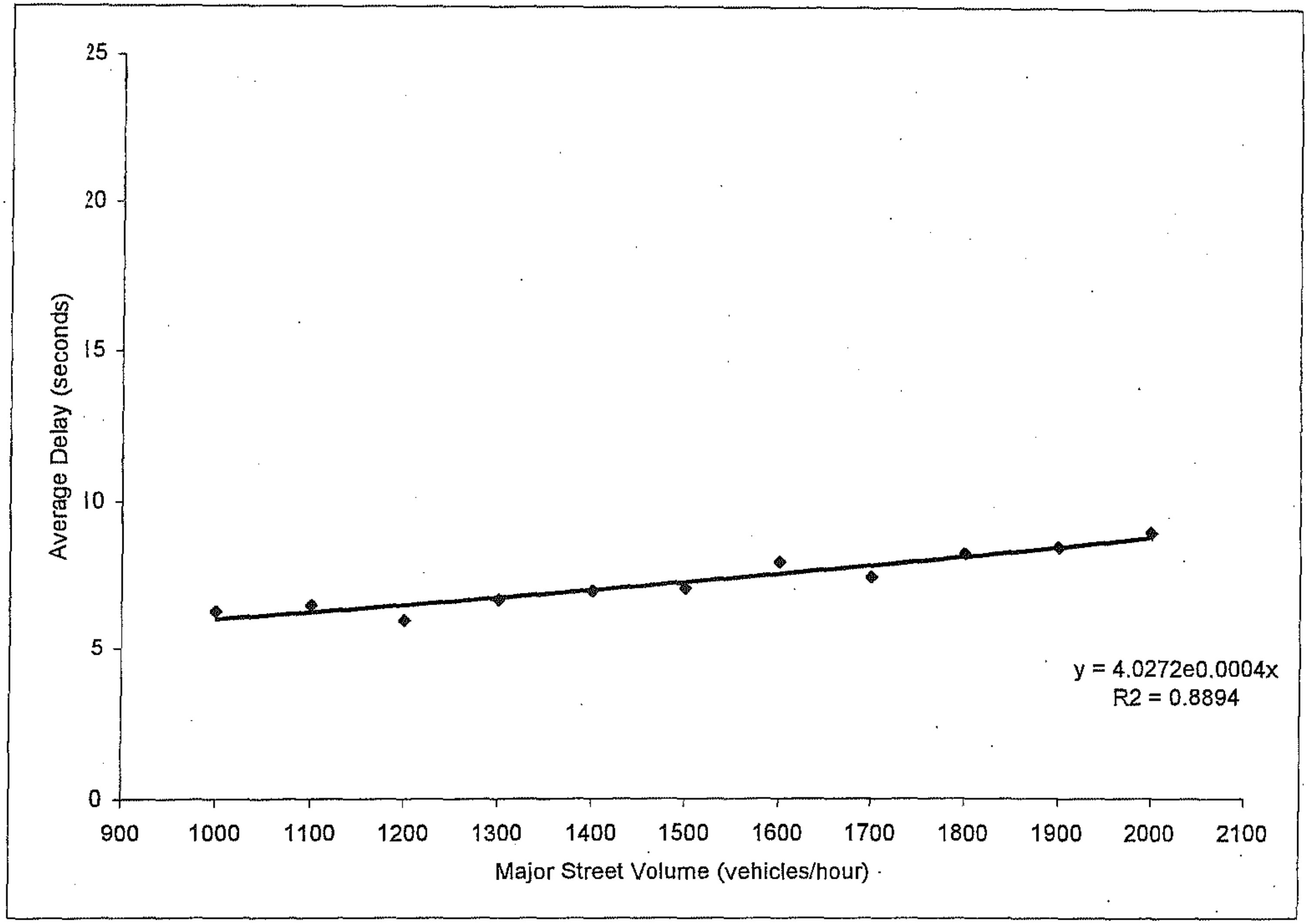


Figure 10 Average Delay as a Function of Major Street Volume with 10% Left Turns

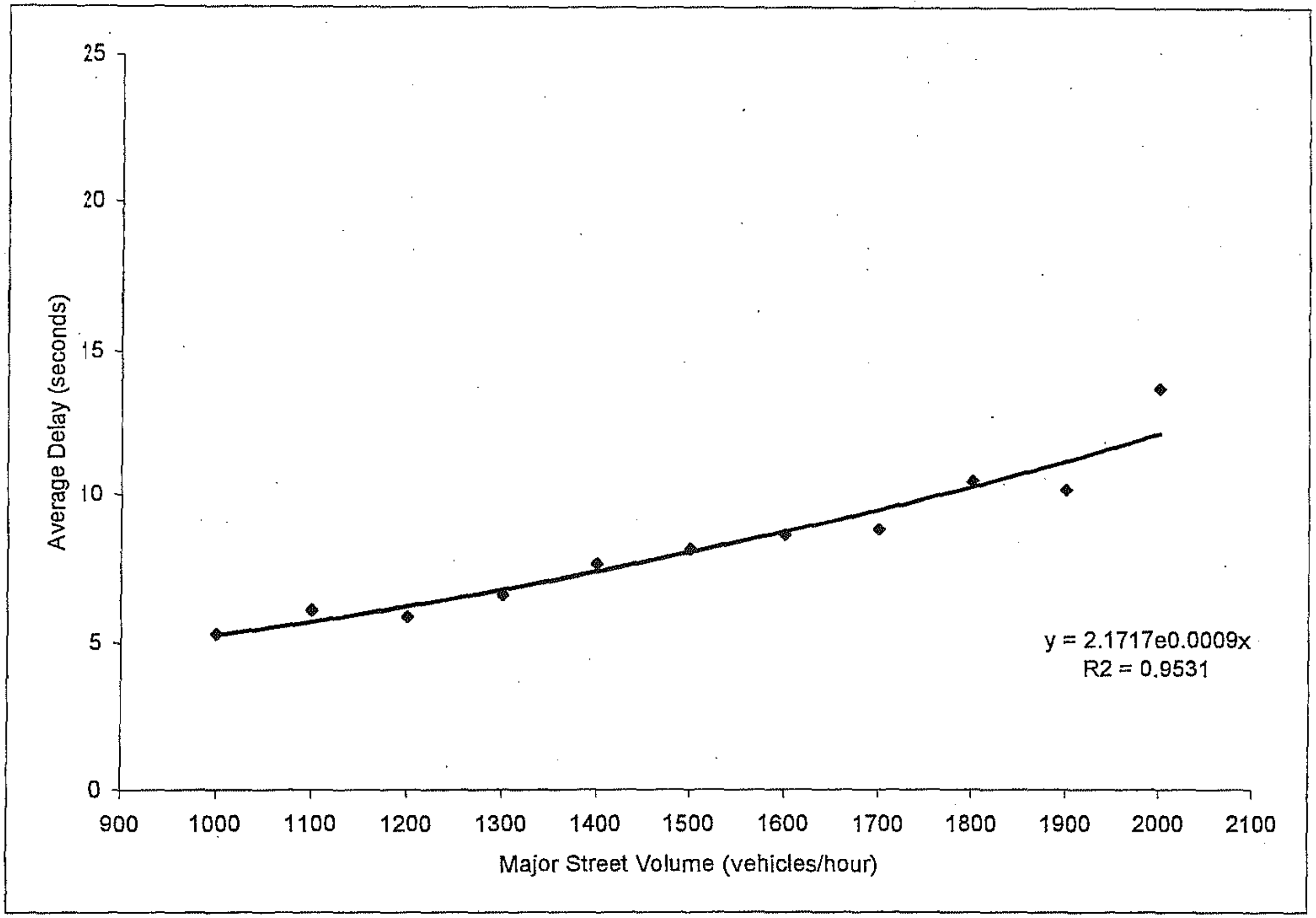
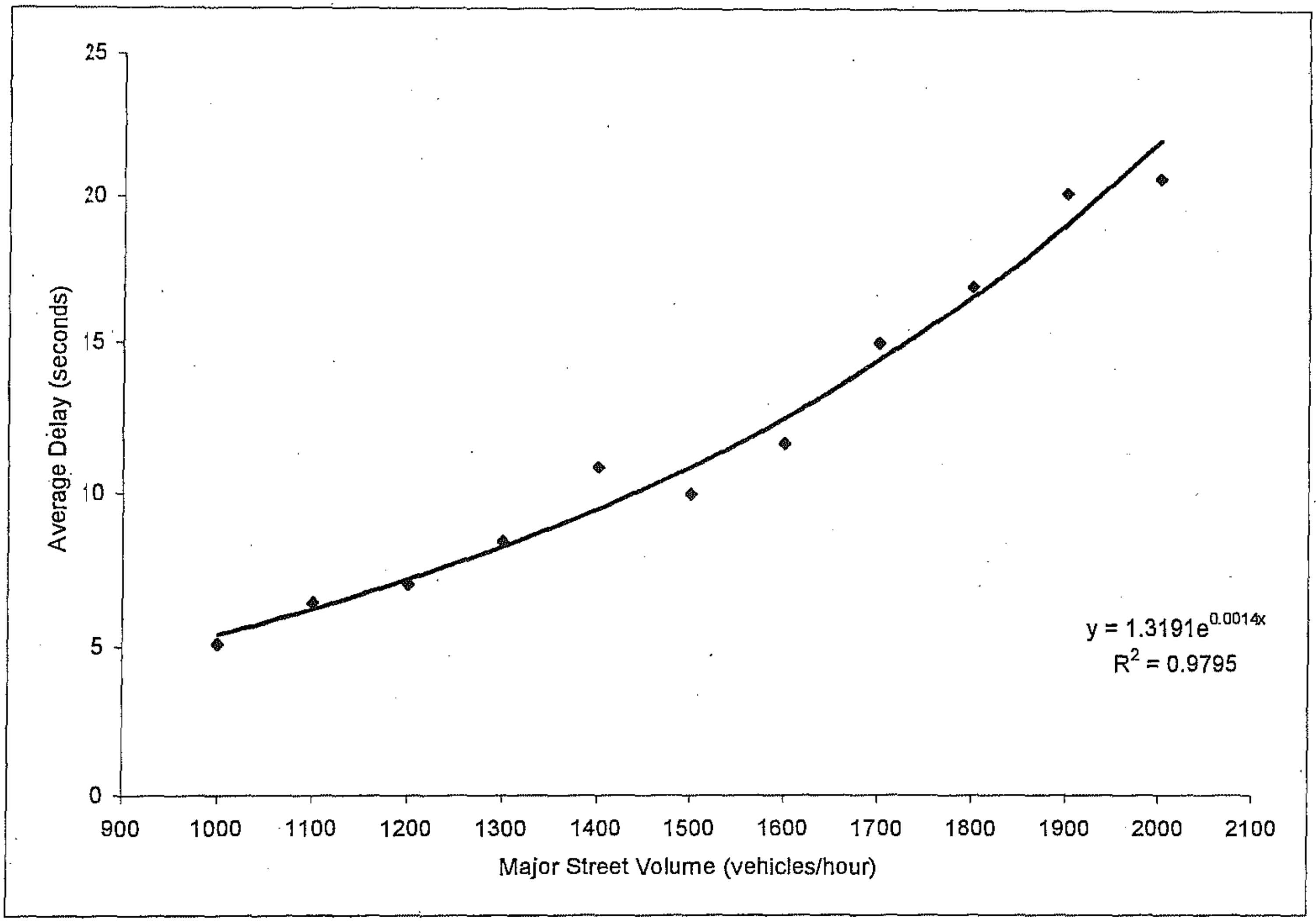


Figure 11 Average Delay as a Function of Major Street Volume with 20% Left Turns



speed of vehicles would be reduced from 30 mph to 26 mph when the volume increases to 2000 vph. For short sections of road like the Abbott Road site, this probably has no practical significance. However, if a proposed site is several miles long, this additional delay would be noticeable to a motorist.

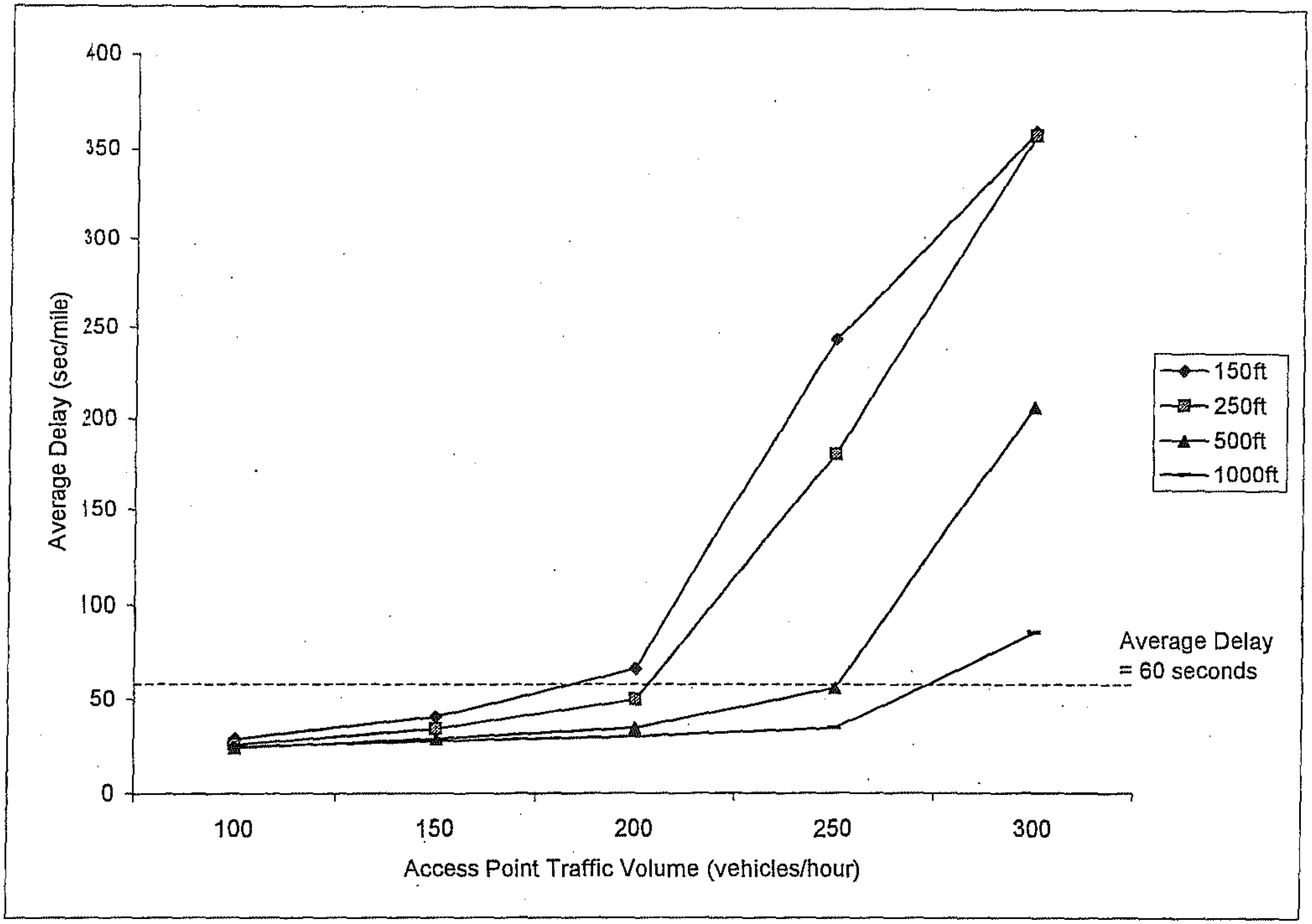
If the turning percentage reaches 20 percent, the delay increases very rapidly, and the site would become congested, with an average speed of only 22 mph. This would be an unacceptable level-of-service, even for a residential street. However, it is not likely that any site with a volume of 2000 vph in the peak hour would also have 20 percent of the traffic turning left at each access point. While this may not be a realistic scenario, these three curves illustrate the impact of the combination of increasing major street volume and increasing turning movements off the major street on the average delay to motorists.

The preceding analyses were all specific to Abbott Road (or a road with similar characteristics) where the average spacing between access points (minor streets and driveways) is 350 feet.

The final set of figures in this report were developed to provide guidance in determining whether a four-lane to three-lane conversion would result in an undesirable level of delay to the main street traffic at any given location. The variables included in the graph are the major street volume, the volume on the minor street (or driveway), the access point average spacing and the percent of vehicles turning left from the major street.

Figure 12 is presented to illustrate the relationship among these variables. For a candidate site carrying a volume of 1000 vph (in both directions combined), with 5

Figure 12 Average Delay per Vehicle for - Major Street Volume of 1000 veh/hour with 5% Left Turns



percent of the vehicles turning left from the main street at each access point; IF an average delay of one minute (60 seconds) per mile is selected as acceptable criterion, THEN a site with an average spacing between access points of 1000 feet with volumes as high as 275 vph approaching the major street, the conversion would still be acceptable. With the same assumptions, if the average spacing between access points is only 250 feet, the maximum volume at the access points would be 200 vph.

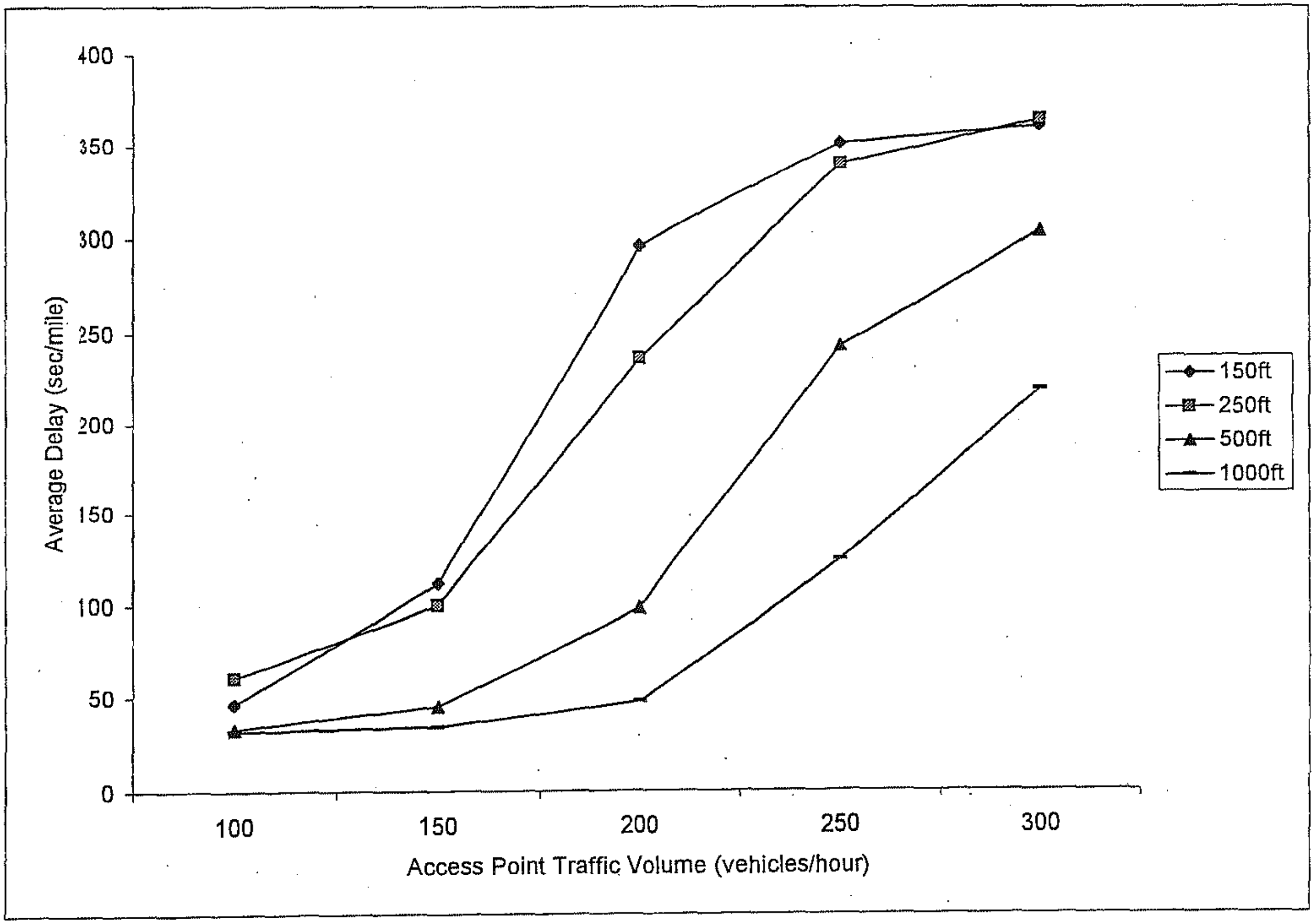
All residential streets with an ADT of less than 10,000 (and thus a peak hour volume of less than 1000 vph) would be acceptable candidates for the four-lane to three-lane conversion under this definition of acceptable delay.

Figure 13 illustrates the relationship between the access point spacing and volume when the major street volume reaches 2000 vph. At this volume, (if the definition of acceptable delay remains the same) the maximum minor street volume for an access spacing of 1000 feet is just over 200 vph, and if the access points are spaced every 250 feet, the maximum volume would be 100 vph.

Even at this higher volume, residential streets would still be acceptable candidates for conversion because a residential driveway would not generate 100 trips in an hour. However, a commercial street, particularly one with high turnover activities like fast food restaurants and service stations, would likely exceed the maximum access point volumes.

Similar figures for major street volumes of 1200, 1400, 1600 and 1800 vph are included in the appendix. Figures for volumes from 1000 vph to 2000 vph with 10 percent of the traffic turning left are also included in the Appendix.

Figure 13 Average Delay per Vehicle for - Major Street Volume of 2000 veh/hour with 5% Left Turns



CONCLUSIONS

The safety impact of converting four-lane roads to three-lane roads with a continuous two-way left-turn lane appears to be positive at all volume levels where the conversion has been used. The average reduction in crashes reported in the literature was 25 to 30 percent. The experience in Michigan has been similar, with the two sites with at least three years of crash data available averaging a 27.5 percent reduction.

At the Michigan sites, pedestrian and bicycle crashes showed the most consistent results and experienced the highest reduction, decreasing from 21 to 5 at the three sites where data exists. Intersection crashes also decreased at each of these sites, with the total number of crashes being reduced from 238 to 129.

An analysis of the average delay to vehicles on both the major street and the minor streets (or driveways) was conducted. The minor street delay increases as the major street volume increases because the delay is created by vehicles waiting for an acceptable gap in the traffic stream. There is no significant queuing delay until the minor street approach volume reaches 180 vehicles per hour.

The delay to traffic entering the major street would not be significant for volumes associated with residential streets, where the conversion is frequently used as a traffic calming measure. The delay to the major street traffic is also low for the volume levels of most residential streets.

The delay to both the minor street (or driveway) and the major street traffic increases rapidly as the volumes reach levels associated with commercial streets. As the major street volume approaches 2000 vehicles per hour, and the minor street volume approaches 200 vehicles per hour, the delay to both traffic streams becomes large.

Nomographs illustrating the increase in delay to the major street traffic are contained in this report. The critical variables are the major and minor street volumes, the percentage of left turning vehicles from the major street and the average spacing between driveways and streets along the major street.

Proposals to convert four-lane streets to three-lane streets should be based on an engineering study that considers the potential crash reduction and the estimated delay from the nomographs included in this report. If traffic signals are located in the corridor, an intersection capacity analysis should be performed at each signalized intersection.

BIBLIOGRAPHY

1. Traffic Calming; State of the Practice. Publication of the Institute of Transportation Engineers, 1999.

2. Huang, H. F., Zageer, C. V. and Stewart, R. J., Evaluation of Lane Reduction "Road Diet" Measures on Crashes and Injuries", TRB Journal, 2001.

APPENDIX

NOMOGRAPHS FOR VARIOUS COMBINATIONS OF VOLUME AND TURNING PERCENTAGE

Figure A1 Average Delay per Vehicle for - Major Street Volume of 1200 veh/hour with 5% Left Turns

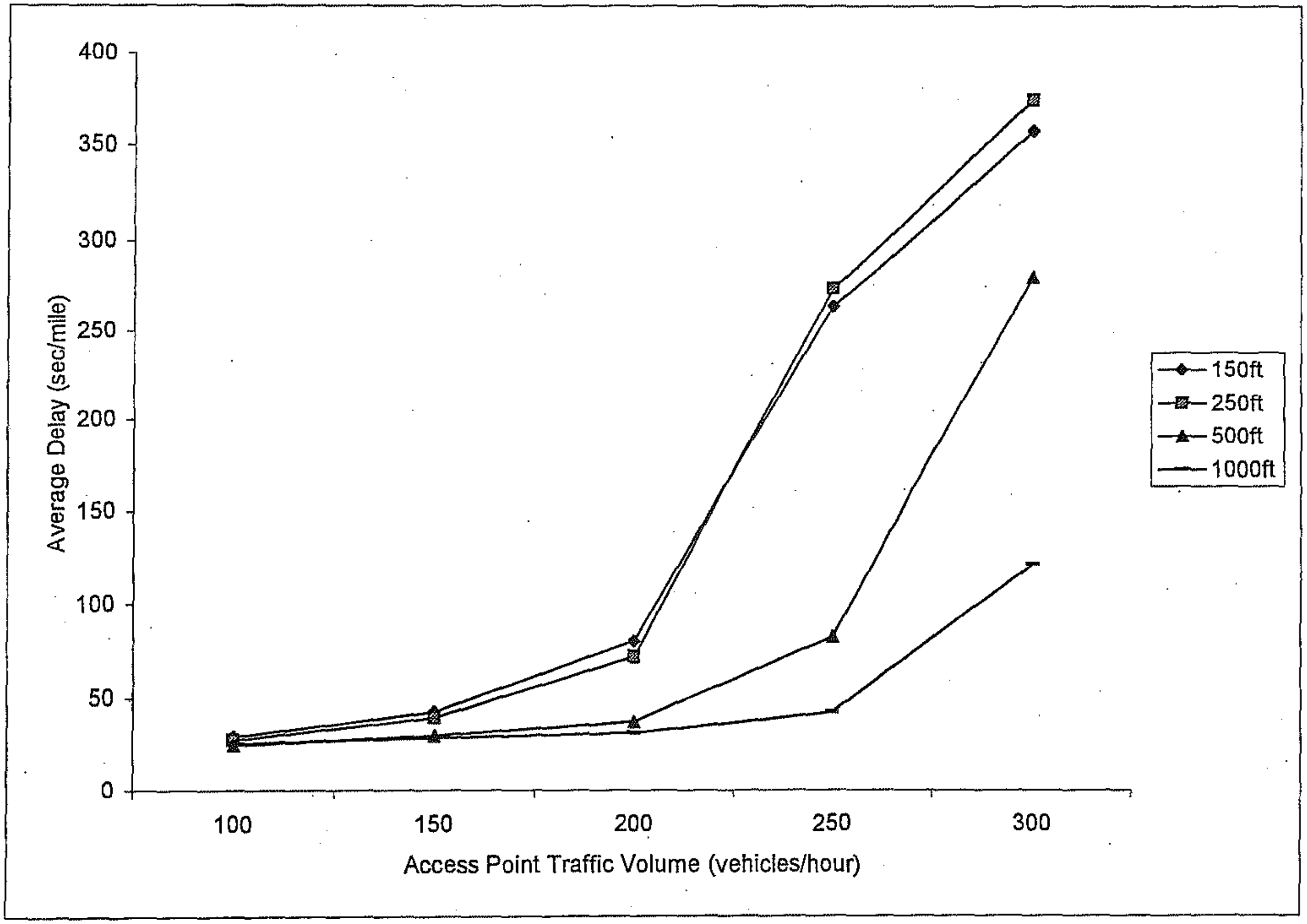


Figure A2 Average Delay per Vehicle for - Major Street Volume of 1400 veh/hour with 5% Left Turns

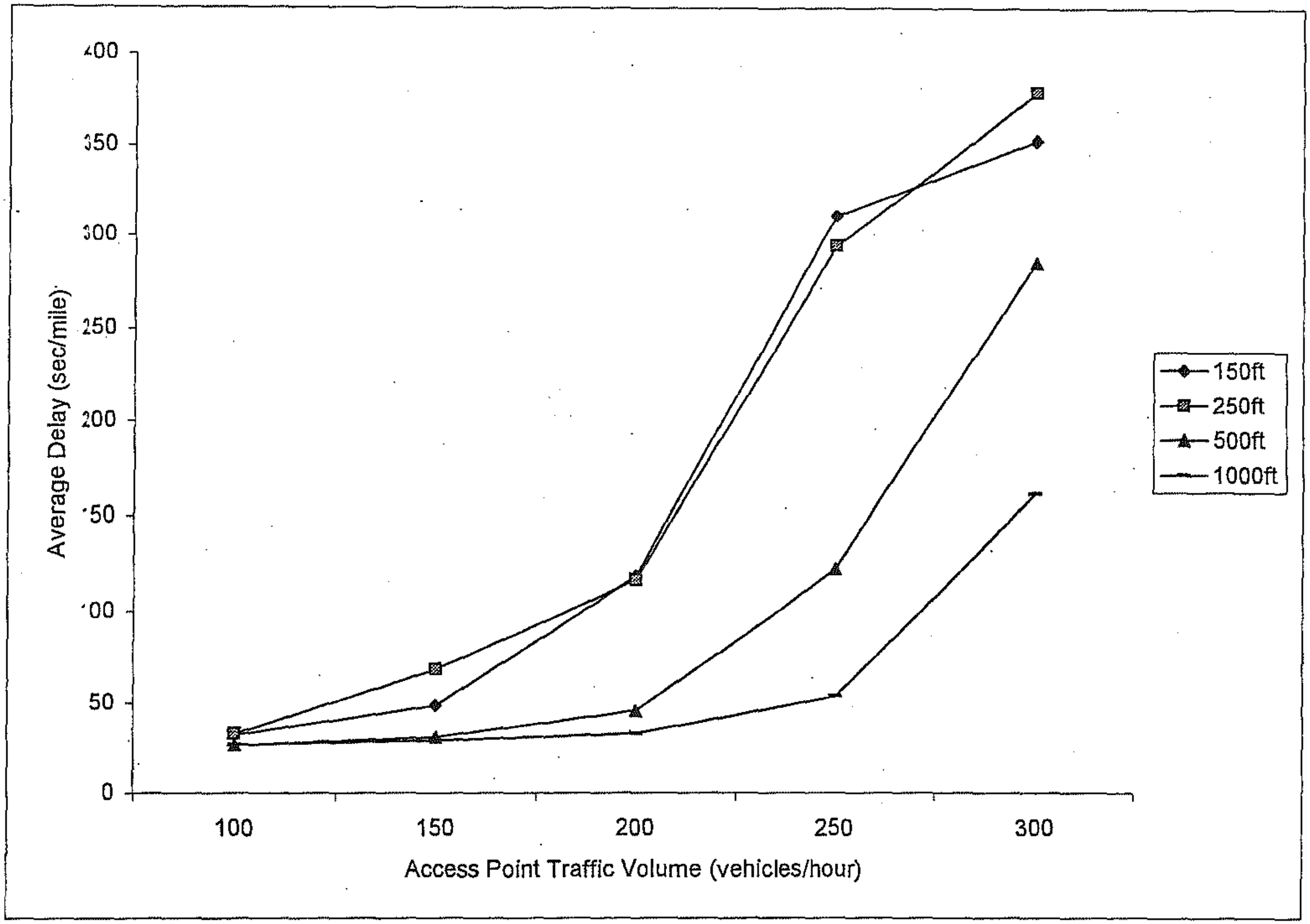


Figure A3 Average Delay per Vehicle for - Major Street Volume of 1600 veh/hour with 5% Left Turns

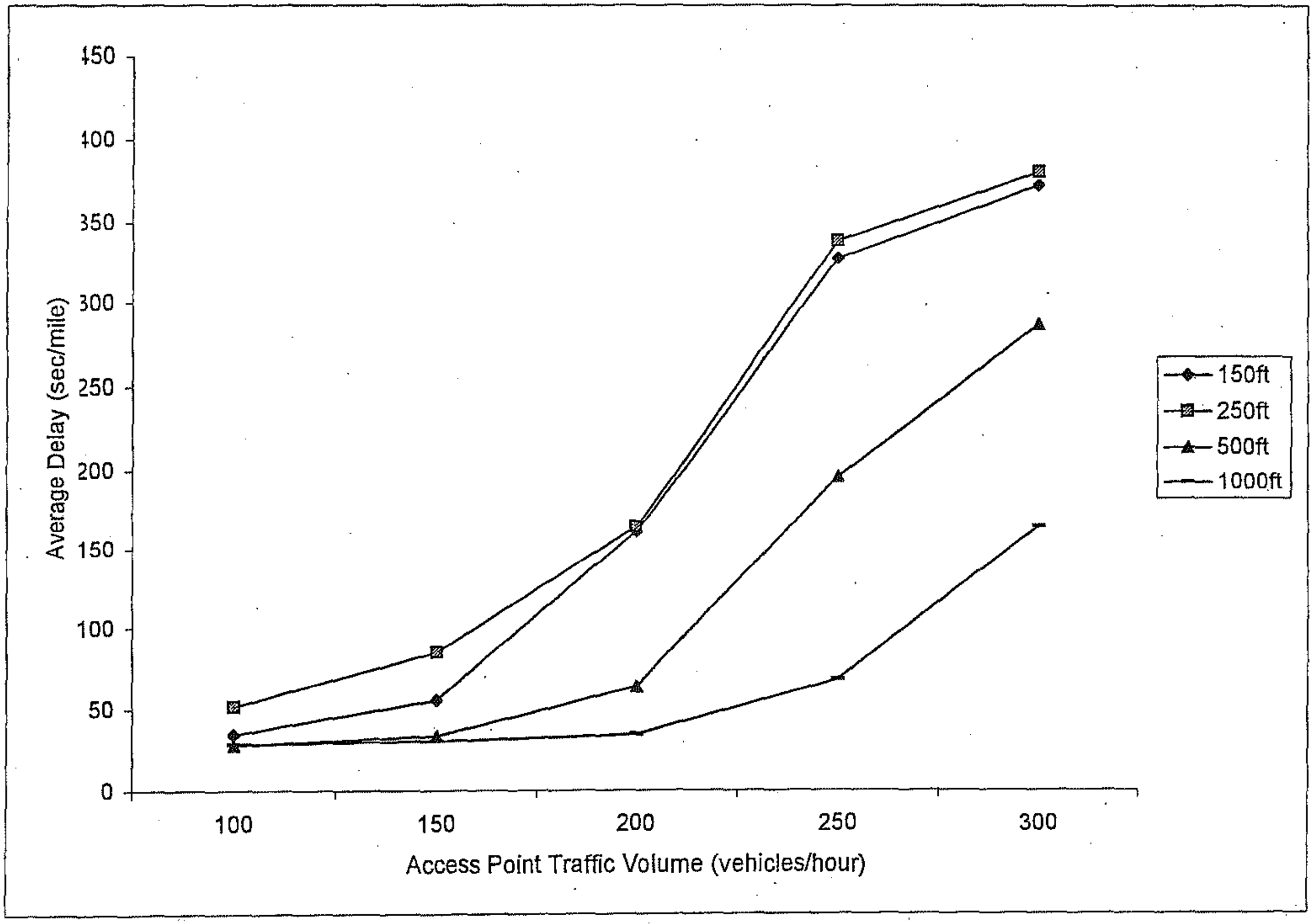


Figure A4 Average Delay per Vehicle for - Major Street Volume of 1800 veh/hour with 5% Left Turns

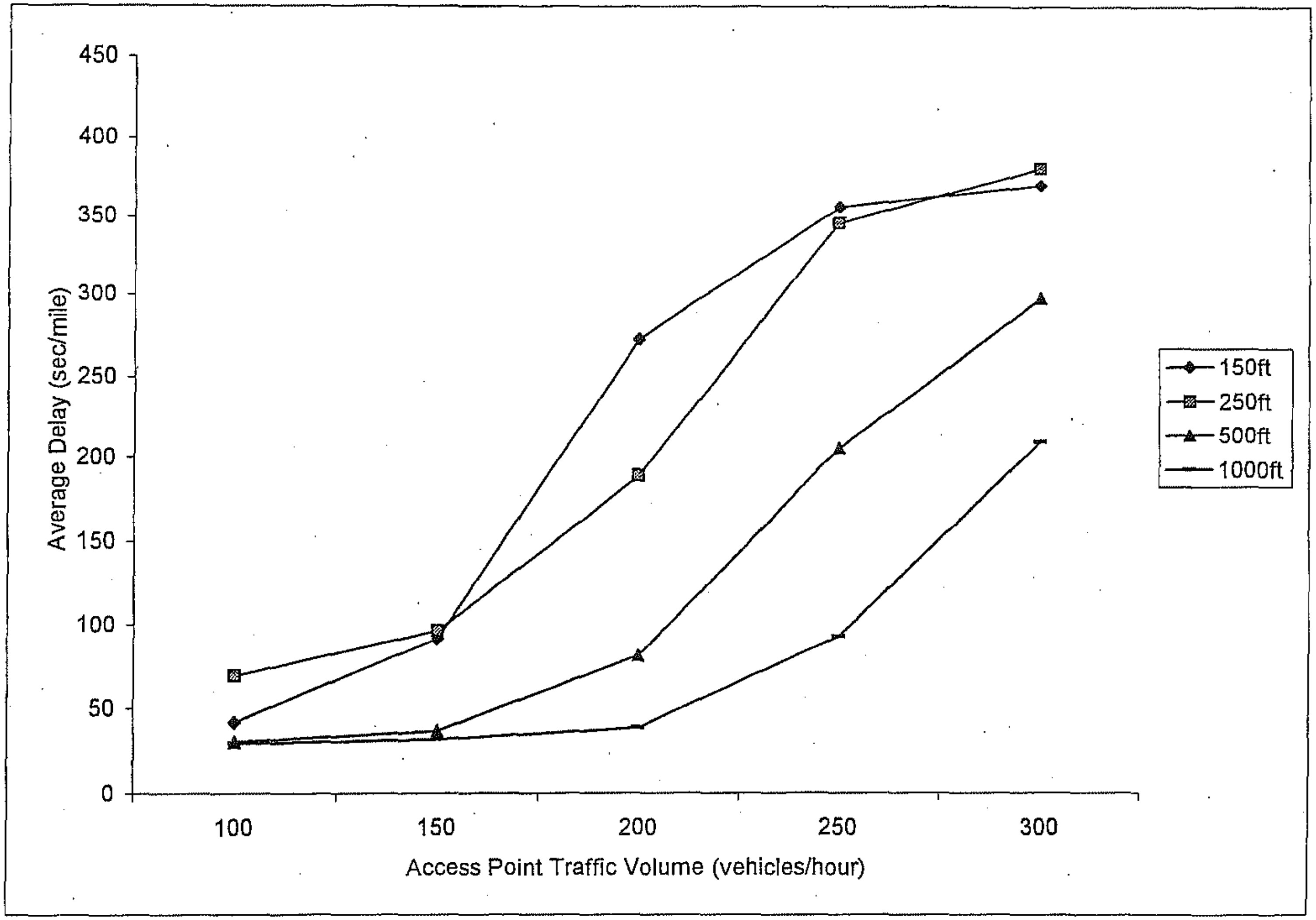


Figure A5 Average Delay per Vehicle for - Major Street Volume of 1000 veh/hour with 10% Left Turns

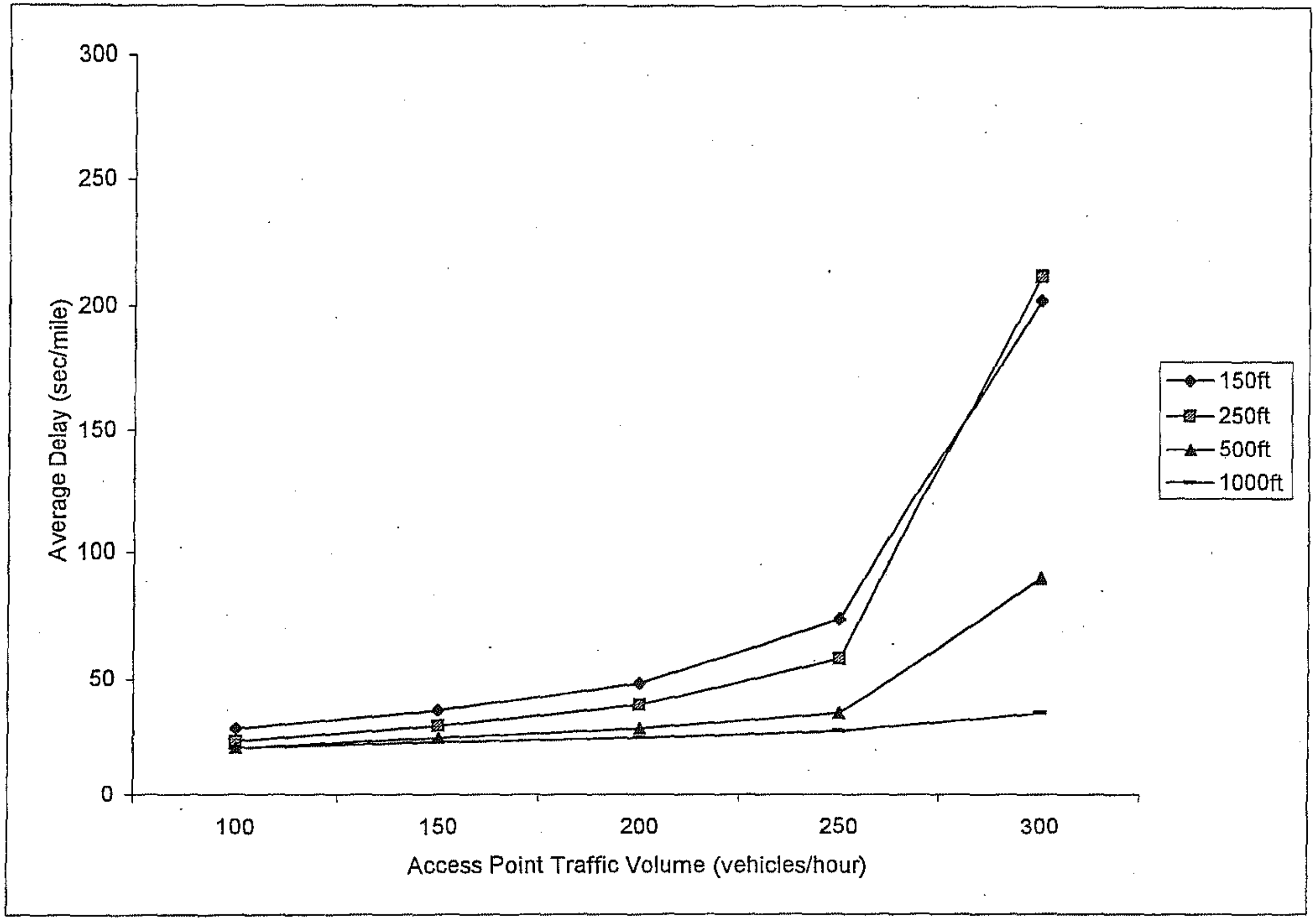


Figure A6 Average Delay per Vehicle for - Major Street Volume of 1200 veh/hour with 10% Left Turns

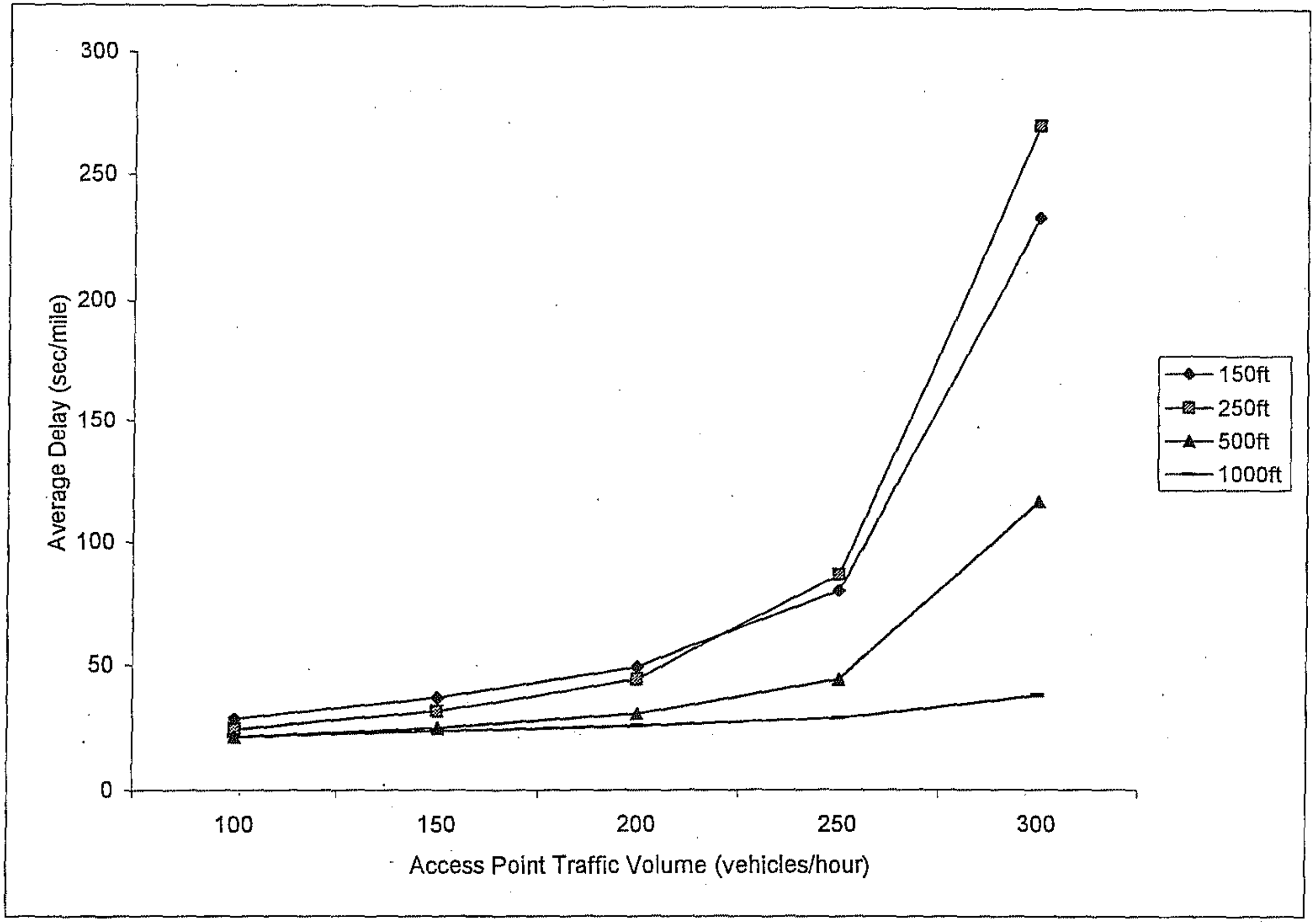


Figure A7 Average Delay per Vehicle for - Major Street Volume of 1400 veh/hour with 10% Left Turns

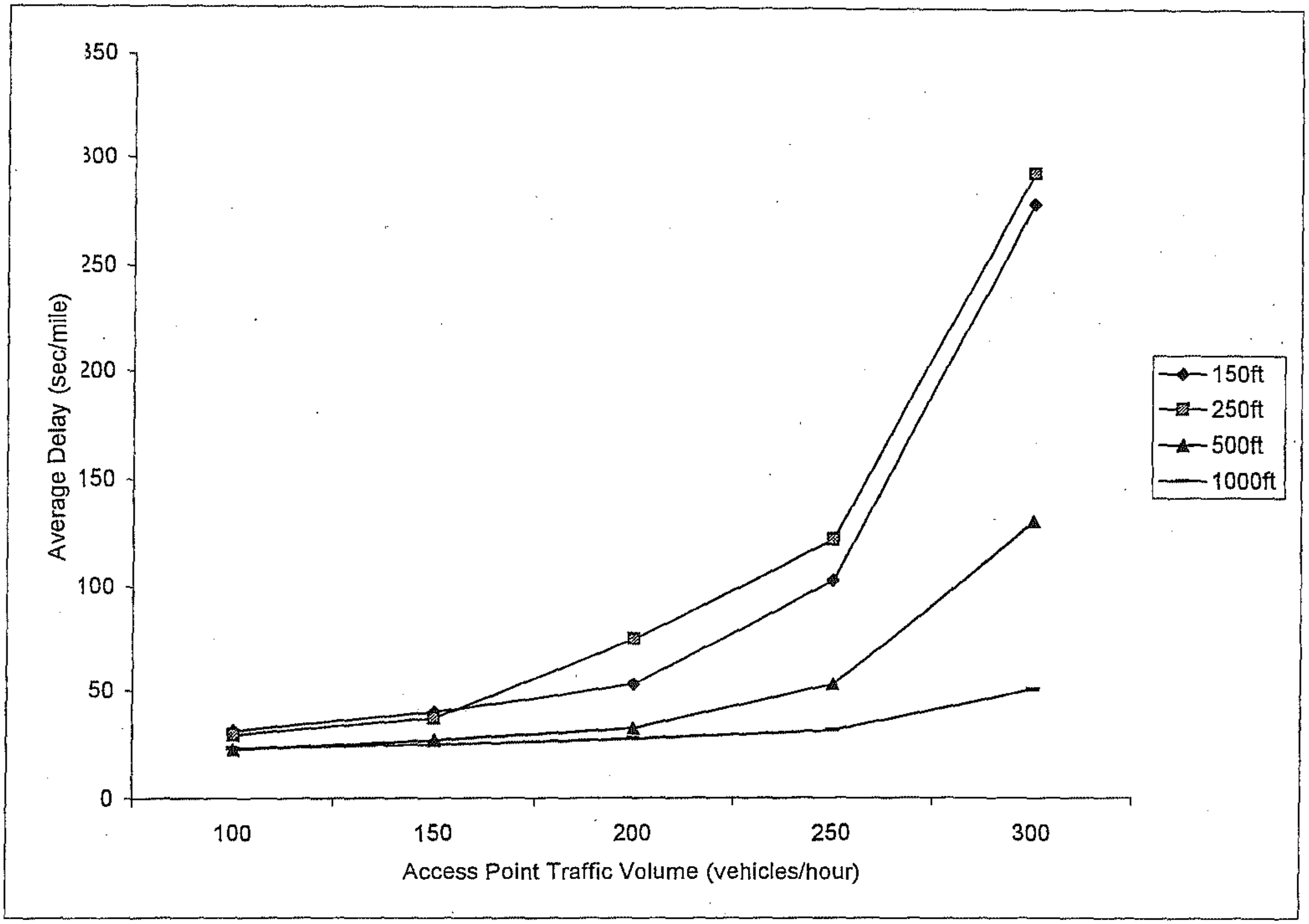


Figure A8 Average Delay per Vehicle for - Major Street Volume of 1600 veh/hour with 10% Left Turns

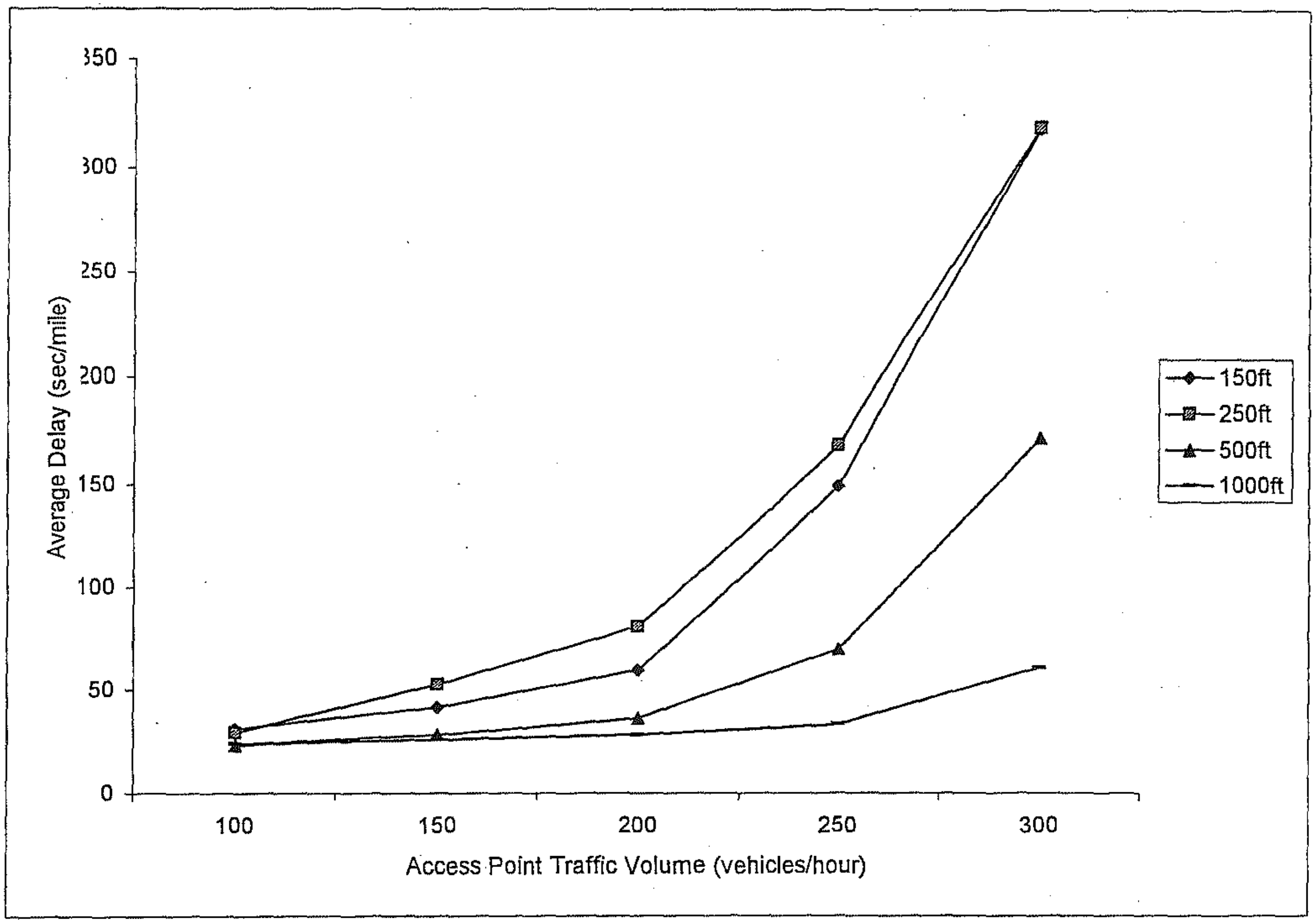


Figure A9 Average Delay per Vehicle for - Major Street Volume of 1800 veh/hour with 10% Left Turns

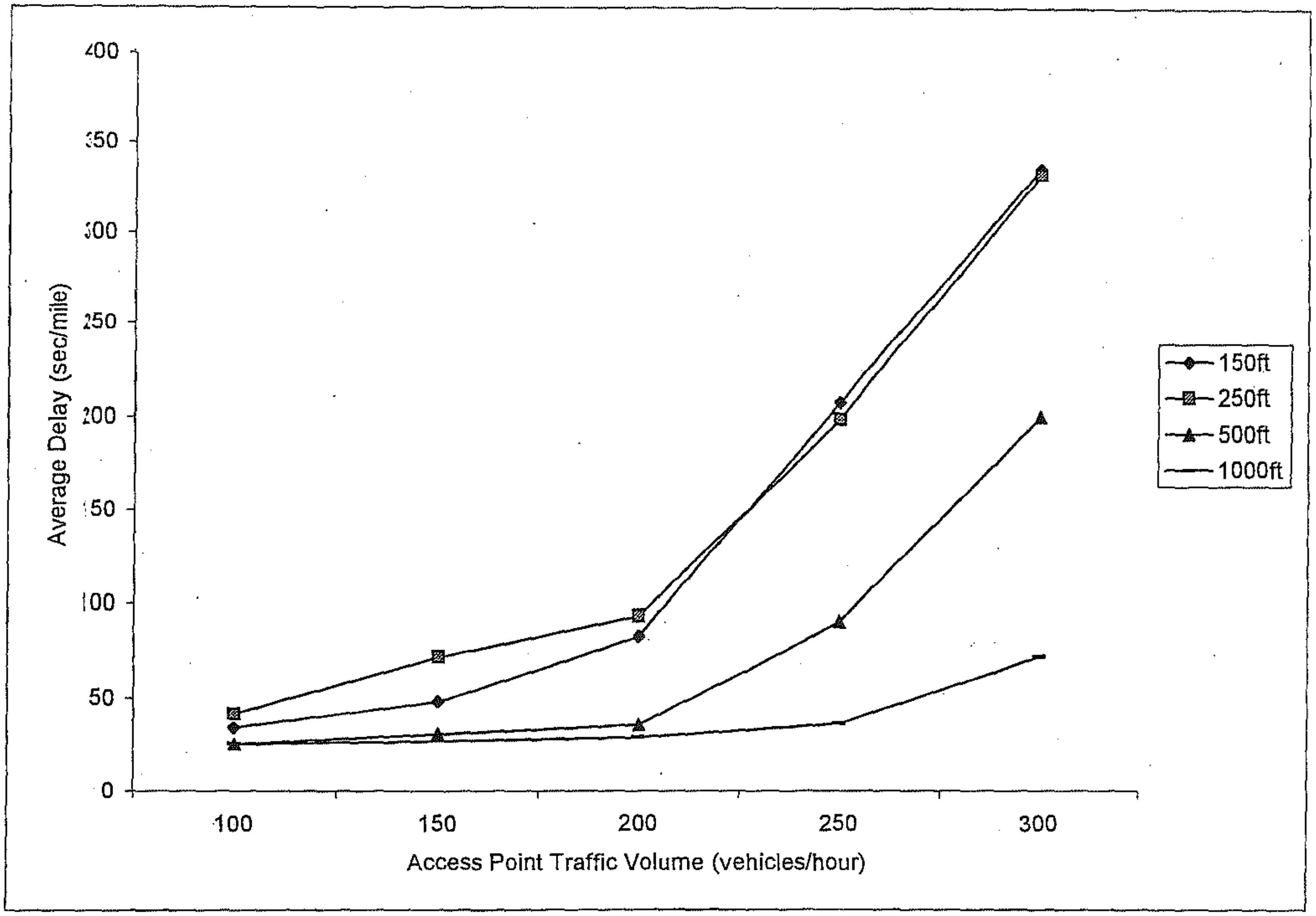


Figure A10 Average Delay per Vehicle for Major Street Volume of 2000 veh/hour with 10% Left Turns