COMPARISON OF SPEED ZONING PROCEDURES AND THEIR EFFECTIVENESS

FINAL REPORT

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Prepared for

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Traffic and Safety Division
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FOREWORD

This report describes the findings of a study conducted to determine if including factors in addition to the 85th percentile speed could increase the effectiveness of Michigan's speed zoning procedure as measured by improved safety and increased driver compliance.

The study included an examination of speed zoning methods used in other states, including Michigan; an assessment of using selected quantitative methods on Michigan highways; a before and after accident analysis of speed zones implemented on nonlimited access highways in Michigan; and an assessment of how time and location of the speed survey stations affect the 85th percentile speed.

To improve safety and driver compliance, it is recommended that speed limits be posted within 5 mi/h of the 85th percentile speed.

Appreciation is given to the traffic officials who returned the survey and provided background information on their speed zoning procedure.

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16. Abstract

This study was conducted to determine if including factors in addition to the 85th percentile speed could increase the effectiveness of the Michigan speed zoning procedure by improving safety and increasing driver compliance. The scope included a nationwide survey to identify current speed zoning methods, a before and after accident analysis of Michigan speed zones established on nonlimited access highways, and an assessment of the effects of methods used by selected states to set speed limits. In addition, the effects that time of day and location of the speed survey station have on the 85th percentile speed were examined on selected Michigan roadways.

The analysis of accidents at 68 sites on nonlimited access highways revealed that the current Michigan speed zoning method reduced total accidents by 2.2 percent. Accidents were reduced by 3.5 percent at sites posted within 5 mi/h of the 85th percentile speed. Lowering speed limits more than 5 mi/h below the 85th percentile speed did not reduce accidents. An assessment of speed zoning methods revealed that the current Michigan method of setting speed limits within 5 mi/h of the 85th percentile speed was superior to the other methods examined in this study.

Recommendations are offered to minimize time of day effects and data collection errors.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

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EXECUTIVE SUMMARY

Establishment of speed zones on Michigan state highways is primarily based on the 85th percentile speed obtained by measuring a sample of free-flow vehicle speeds traveling under favorable traffic and roadway conditions. While every state uses the 85th percentile speed as a primary factor in setting speed limits, some states use quantitative methods which include factors such as roadside development, pedestrian activity, and accident history.

This study was conducted to determine if including other factors in addition to the 85th percentile speed could improve safety and increase driver compliance. In addition, the effects that time of day and location of the speed survey station have on the 85th percentile speed were examined.

Based on a survey of highway officials in 50 states, the District of Columbia, Guam, and Puerto Rico, background information on speed zoning methods was obtained. Very few evaluations have been conducted of any speed zoning method. An assessment of selected quantitative methods used in other states was conducted at Michigan speed zone sites established on the state trunkline (excluding limited access highways) between 1982 and 1986.

To assess the safety impact of the current Michigan speed zoning method, a before and after design with a comparison group and a check for comparability was employed on speed zones established on state highways during the period 1982 through 1986. To determine if any other quantitative method was superior to the Michigan procedure in improving safety and driver compliance, data needed to calculate the recommended speed were collected for each procedure at each Michigan site. An assessment of selected speed zoning methods was made based on safety, compliance, cost-effectiveness, and other criteria.

The effects of time, location, and other factors were examined by collecting speed data at 80 locations on 28 selected sections of Michigan trunkline which were zoned during the period 1982 through 1986. Speed survey stations within each zone were located based on an analysis of accidents and the geometry in each zone. Automated equipment was used to collect speed data for a 24-hour period at each station.

Finally, data were collected at 13 speed zone locations to validate the recommended procedure.

SUMMARY OF FINDINGS

1. The 85th percentile speed is the primary factor states use in setting speed limits.

2. Engineering judgement is the primary tool used to set speed limits. Frequently, the process is quite subjective which leads to arbitrarily posted limits.

3. The available evidence suggests that posting limits in the region of the 85th percentile speed minimizes accident involvements and provides acceptable driver compliance. There is no information that suggests including other factors in setting speed limits would provide additional safety or compliance benefits.

4. An analysis of accidents at 68 Michigan sites where speed limits were changed and 86 comparison sites revealed that the current speed zoning method practiced in Michigan reduced total accidents by 2.2 percent. The level of confidence of this estimate is 62 percent. The 95 percent confidence interval for this estimate ranges from an accident reduction of 7 percent to an accident increase of 3 percent. The analysis revealed that this effect was not consistent from site to site. Accidents did not increase when speed limits were raised, and accidents did not decrease when speed limits were lowered.

5. The most beneficial safety effect occurred when speed limits were posted within 5 mi/h of the 85th percentile speed. At sites posted near the 85th percentile speed, accidents were reduced by 3.5 percent. The level of confidence of this estimate is 73 percent. At sites where the speed limit was posted more than 5 mi/h below the 85th percentile speed, there was a 0.47 percent increase in accidents, however, this result is not statistically significant.

6. Speed limits posted at approximately 31 percent of the Michigan sites were not within 5 mi/h of the 85th percentile speed.

7. At a typical Michigan site, a 5 mi/h difference in posted speed has a dramatic effect on driver compliance. If limits are set within 5 mi/h of the 85th percentile speed, at a minimum, 67 percent of the motorists would be in voluntary compliance. When limits are set within 7 mi/h, it is possible that only 40 percent compliance would be achieved.

8. An assessment of selected quantitative speed zoning methods used in other states was made based on safety, driver compliance, cost-effectiveness, and other criteria. Based on the assessment, the current Michigan procedure of posting limits within 5 mi/h of the 85th percentile speed was found to be superior to the other speed zoning methods examined.

9. Significant differences in hourly 85th percentile speeds were found at the survey stations on Michigan roadways examined in this study. The average difference for all monitoring stations, between the lowest and highest hourly 85th percentile speed, was 5.7 mi/h. The lowest variation in hourly 85th percentile speeds occurred between the hours of 8:00 a.m. and 5:00 p.m. When data are collected between 8:00 a.m. and 5:00 p.m., the hourly variations due to time of day can produce an error of approximately 1.5 mi/h above or below the 24-hour 85th percentile speed.

10. The method used by the Michigan Department of Transportation to collect speed data appears to have a significant effect on the 85th percentile speed. Based on selected samples, it appears that the Department's estimate of the 85th percentile speed is approximately 3 mi/h lower than the speed recorded by automated equipment.

CONCLUSIONS

1. The current Michigan practice of posting speed limits within 5 mi/h of the 85th percentile speed has a beneficial effect, although small, on reducing total accidents, but has a major beneficial effect on providing improved driver compliance.

2. Posting speed limits more than 5 mi/h below the 85th percentile speed does not reduce accidents and has an adverse effect on driver compliance.

3. The accident analysis revealed that the speed limit changes on Michigan roadways produced a small effect on total accidents, and these effects varied from location to location. Consequently, speed zoning should not be used as the only corrective measure at high-accident locations in lieu of other safety improvements.

4. The quantitative speed zoning methods or other factors used by the other states examined in this study would not improve safety and driver compliance if implemented on Michigan roadways.

5. The 85th percentile speed varies by hour of the day. Speed samples taken for a short period at a survey site can overestimate or underestimate the 24-hour 85th percentile speed by 1.5 mi/h or more.

6. The use of radar to collect speed data in Michigan appears to underestimate the 85th percentile speed by approximately 3 mi/h.

7. Field studies conducted at 13 selected Michigan speed zone sites illustrates the validity of setting speed limits within 5 mi/h of the 85th percentile speed.

8. The speed zoning procedure recommended in this study is not dramatically different from the speed zoning method currently practiced by the Michigan Department of Transportation and the Michigan State Police.

9. The use of automated equipment is strongly recommended to minimize errors associated with time of day effects and current speed data collection methodology.

RECOMMENDATIONS

1. The following speed zoning procedure is recommended for implementation in Michigan.

   - Speed limits should be posted within 5 mi/h of the 85th percentile speed.
   - An accident analysis should be conducted as a routine part of speed zone investigations. The analysis should identify abnormally high accident characteristics and problem locations. A field review should be conducted to identify possible causes and develop recommendations for improvements. Speed zoning, per se, should not be used as a countermeasure to address abnormally high-accident situations.
   - To minimize time of day effects and data collection errors, 85th percentile speeds should be determined by using automated equipment to collect data for a 24-hour period.
   - The location of the survey stations should be based on the geometry in each zone and roadside development. Stations should not be placed within 500 feet of isolated major intersections or horizontal curves.
   - The data should be analyzed in accordance with the guidelines listed below to determine the appropriate speed limit.

2. The following guidelines should be used for setting speed limits.

   - The posted speed limit should be set within 5 mi/h of the 85th percentile speed.
   - The beginning and ending of each speed zone should be at a point obvious to the motorist such as a change in geometry, roadside development, etc. Jurisdictional boundaries such as city or township lines may be an inappropriate location for a speed zone change.
   - The use of short (less than 0.20 mile) speed zones and transition zones is discouraged. The majority of reasonable motorists adjust their speed based on environmental and traffic conditions and not on artificially low or high posted speed limits.
   - Within each zone it is desirable that features such as design, roadside development, etc. be consistent as homogeneous sections tend to encourage similar operating speeds. It is not always practical to subdivide a roadway section into homogeneous zones because this could result in a number of short sections with various speed limits.
   - The speed limit on the entire zone should not be based on one special condition such as an isolated horizontal curve or intersection. When appropriate, advisory speeds should be used at these locations.
   - Combining individual 85th percentile speeds in a zone to arrive at an average or composite figure is discouraged. It is also not necessary to collect speed data for both directions of travel at the same survey station. A more representative sample can be obtained by spreading the stations throughout the zone.

- The 85th percentile speed at each individual survey station should be compared to speeds at other stations in the zone. If the individual 85th percentile speeds vary by more than 5 mi/h, consideration should be given to providing separate zones if this does not result in short section lengths.

- Michigan law and Congressional directives establish a 55 mi/h maximum speed limit on nonlimited access highways. On some rural highways, 85th percentile speeds exceed 55 mi/h. This creates a problem when using the 85th percentile speed to set speed limits in areas that transition from rural to urban conditions. Until realistic zoning is used on all highways, engineering judgement must be employed to set speed limits in transition areas.

3. To improve public understanding of the safety impacts and other benefits of using the 85th percentile speed to set speed limits, a public informational brochure should be developed for distribution.

COMPARISON OF SPEED ZONING PROCEDURES AND THEIR EFFECTIVENESS

INTRODUCTION

Michigan state law delegates authority to set safe and reasonable speed limits on the State Trunkline System to the State Transportation Commission working in conjunction with the Michigan State Police. Safe and reasonable limits are determined upon the basis of an engineering and traffic investigation.

Establishment of speed zones on Michigan state highways is primarily based on measurement of the speed of vehicles traveling under free-flow conditions under normal environmental conditions. Based on the speed samples, the speed limit is generally set within 5 mi/h of the 85th percentile speed.

Speed zoning procedures used in all other states, including Michigan, incorporate consideration of a number of other factors such as roadside development, accident experience, pedestrian activity, etc. to determine an appropriate speed limit.

There is no information available that indicates which speed zoning method results in a speed limit that improves safety and increases driver compliance. Also, there are little data available to indicate what the effects of time of day and location of the speed survey station have on determining the 85th percentile speed.

OBJECTIVES

The specific objectives of this study were to:

1. Determine which states are using speed zoning procedures that include factors in addition to the 85th percentile speed.

2. Determine the rationale used by the states to select the value of the factors used in their speed zoning procedure.

3. Obtain from the states any evaluation that documents the effects of their procedure on accident reduction and driver compliance.

4. Conduct an evaluation of the effectiveness of the Michigan procedure on reducing accidents and increasing driver compliance.

5. Conduct a comparative analysis on selected sections of Michigan highways to determine if the quantitative speed zoning procedures used in selected states would have improved safety and increased driver compliance.

6. Determine the effects that time of day and location of the speed survey station have on the 85th percentile speed.

7. Conduct a field validation of the recommended speed zoning procedure.

METHOD

The efforts required to accomplish the study objectives were divided into the following major areas.

- **Evaluation of Speed Zoning Methods**

  A survey was conducted of the 50 states, District of Columbia, Guam, and Puerto Rico to obtain background information on their speed zoning procedures. The topics addressed included determining what factors were considered in setting speed limits, how the factors were used, and if evaluations of their speed zoning procedure had been conducted to examine the effects of the procedure on safety and driver compliance.

- **Comparison of Speed Zoning Procedures**

  The effectiveness of the current Michigan speed zoning method on safety was examined through an analysis of accidents reported on nonlimited access state highways where speed zones were established from 1982 through 1986. Quantitative methods used in selected states were also examined by applying the methods to the Michigan speed zone sections. Based on safety, driver compliance, cost and other factors, an assessment of the methods was conducted to identify a recommended speed zoning procedure.

- **Determination of Time of Day and Location Effects**

  Using a sample of speed zones sections established in Michigan from 1982 through 1986, accident, speed, and other data were collected to determine the effects that time of day, day of the week, season, and location of the speed survey station have on the 85th percentile speed.

- **Field Validation of the Recommended Procedure**

  A sample of 13 Michigan highway sections was selected, and speed and other data were collected to validate the recommended speed zoning procedure. Guidelines were developed for analyzing the data and determining the numerical value of the speed limit.

Specific details of the methodology used to accomplish the study objectives, as well as the analysis, and study findings are presented in the following chapters.

EVALUATION OF SPEED ZONING METHODS

INTRODUCTION

Statutory speed laws, set by the legislature, cannot cover every condition found on state highways. It is, therefore, necessary in many cases to modify the speed limits to be applicable to specific roadway characteristics. Speed zoning is the process of determining what adjustment in the statutory limit, if any, is needed to establish a safe and reasonable maximum speed limit on a roadway section.

Most states and localities set safe and reasonable maximum limits based on the results of an engineering and traffic investigation. A review of the literature revealed that there is little consensus among engineers as to what factors should be considered and how they should be objectively evaluated to determine the appropriate speed limit.[1, 2]

National standards provide little guidance on how speed limits should be determined. For example, the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)[3] provides the following statement:

> "In order to determine the proper numerical value for a speed zone on the basis of an engineering and traffic investigation the following factors should be considered:
>
> 1. Road surface characteristics, shoulder condition, grade, alignment, and sight distance.
> 2. The 85-percentile speed and pace speed.
> 3. Roadside development and culture, and roadside friction.
> 4. Safe speed for curves or hazardous locations within the zone.
> 5. Parking practices and pedestrian activity.
> 6. Reported accident experience for a recent 12-month period."

The 1990 American Association of State Highway and Transportation Officials' (AASHTO) A Policy on Geometric Design of Highways and Streets does not provide a specific recommendation, but suggests that the posted maximum speed is about the 85th percentile speed.[4]

The Institute of Transportation Engineers'(ITE) policy on speed zoning advocates "--that the establishment of speed zones be guided by established traffic engineering principles and be based realistically on route and traffic characteristics, and not on artificial criteria, jurisdictional boundaries, or other considerations not related to the safety and efficiency of vehicle operations."[5] The ITE Traffic Engineering Handbook[6] suggests using the 85th percentile speed as a first approximation of the speed zone that might be imposed, subject to consideration of other objective and subjective criteria. These criteria were developed by a technical committee of the Institute and first published in July 1961.

In the absence of national guidelines, states and localities were left to establish their own procedure for setting appropriate speed zone limits. Throughout years of experience, the states have developed a wide variety of methods for establishing maximum speed limits.[7]

In all states and in most localities, the 85th percentile speed is used as a factor in establishing appropriate limits for speed zones. Many other factors are subjectively considered. As subjectivity can lead to nonuniform and unrealistic speed zones, Michigan, as well as some other states, uses the 85th percentile speed as a primary factor in setting speed limits. It is also recognized that objective procedures used in some states could provide speed zones that increase safety and driver compliance with posted limits.

This chapter provides a summary of the speed zoning procedures used in the states and a list of methods that will be used in a comparative evaluation to identify a method(s) that increases safety and driver compliance.

METHOD

The data presented in this chapter was obtained from a mail survey of highway officials in the 50 states, District of Columbia, Guam, and Puerto Rico. The survey was sent to the officials in November 1989. Follow-up letters and telephone conversations with a number of engineers provided additional background information.

The survey form and a brief summary of the results is shown in Appendix A. Of the 53 agencies contacted, 52 (a 98 percent response rate) engineers returned the survey. Only Wyoming, did not provide a response, however, based on the 1984 AASHTO survey,[7] no new quantitative methods are being used in this state.

The survey was designed to obtain information for three major areas:

- Methods used to determine maximum speed limits.
- Evaluation of current speed zoning methods.
- Speed data collection methods.

The results of the first two areas are described in this chapter. The data collection methods will be used as background information in examining the effects that time of day and location have on the 85th percentile speed.

METHODS USED TO ESTABLISH SPEED ZONES

This section summarizes the factors used to set speed limits, the primary methods used to determine the numerical value of the speed limit, and the rationale and basis used to quantify each factor.

Factors Considered

A list of the factors and summary of the current use of each factor by the 52 states and agencies that responded to the survey is shown in Table 1.

Table 1. Summary of factors considered.

Number of Responses Received	Percent of Responses Received	Factors Considered
52	100	85th percentile speed
45	87	Type and amount of roadside development
44	85	Accident experience
34	65	Pace
33	63	Length of zone and posted limits on adjacent zone
31	60	Horizontal and vertical alignment
30	58	Sight distance
27	52	Design speed of the facility
26	50	Pavement and shoulder widths
24	46	Average test run speed
22	42	Pedestrian volumes
21	40	Presence of parking and loading zones
18	35	Traffic volume
18	35	Hazardous locations within zone
16	31	Unexpected conditions
15	29	Number of signalized intersections on roadways
14	27	High percentage of drivers exceeding speed limit
11	21	50th percentile speed
6	12	Percentage of commercial vehicles
2	4	90th percentile speed
2	4	Road surface
1	2	Neighborhood safety
1	2	Presence of schools
1	2	Effectiveness of local enforcement
1	2	Signal Progression
1	2	Lack of sidewalks
1	2	Signalization in high-speed areas
1	2	Pavement and shoulder condition
1	2	Average speed
1	2	Local attitudes and enforcement.
1	2	Environmental - noise and dust
1	2	Public testimony
1	2	Urban or rural cross-section

As shown in Table 1, a wide variety of factors are currently considered in an engineering and traffic investigation. While the range of factors used was quite broad, the number of factors typically considered in a state was between 6 and 7. Not surprisingly, the 85th percentile speed was considered a major factor by all of the respondents. The prevailing speed, defined as the average of the 85th percentile speed, upper limit of the pace, and average test run speed is used by a number of states instead of the 85th percentile. Roadside development, accident experience, length of zone, and posted limits on adjacent zones were the other major factors considered by at least two-thirds of the states.

Summary of Methods Used

While the relative current use of factors is indicated in Table 1, this use does not imply that an objective technique for evaluating each factor is utilized. One primary purpose of the survey was to determine how each factor is evaluated to determine the appropriate speed limit. Less than half (46 percent) of the agencies have a written procedure describing the method used to set maximum speed limits. Of the 24 states with written procedures, 22 enclosed a copy of their method. The survey responses and written procedures were used to develop a description of each speed zoning method. The results, listed in alphabetical order by state, are shown in Appendix B.

As a general rule, all states use the 85th percentile speed as a major factor in determining the numerical value of the speed limit. Typically, other factors such as roadside development, accident experience, etc. are subjectively considered based on the experience and judgment of the engineer. The final decision takes into account the consistency of posted limits on similar roadways and limits on adjacent speed zones.

In most cases the engineering and traffic investigation consists of an accident analysis conducted primarily to identify safety problems which may or may not be related to unsafe speeds. While this is good engineering practice, it may not have a significant effect on the speed limit decision. In other words, a change in speed limit may not be the correct solution to an accident problem. Some states do have a quantitative method for considering accident data in the speed zoning decision and these methods will be discussed later in this chapter.

Typical use of the 85th percentile speed includes:

- Setting the limit within 5 mi/h of the 85th percentile speed.
- Setting the limit within 5 mi/h of the 85th percentile speed or upper limit of the pace.
- Setting the limit not more than 3 mi/h above or not less than 8 mi/h below the 85th percentile speed.
- Setting the limit not more than 3 mi/h below the upper limit of the pace or the 67th percentile speed.
- If there is a high accident rate, lowering the limit from the 85th percentile speed, but within the pace.
- Using the 85th percentile speed, but posting a limit not less than the 50th percentile speed.
- Posting the 85th percentile speed if it does not exceed the design speed.

Eight states reported that they use a quantitative method to consider factors that affect the posted speed limit. These methods are in addition to the states, such as Michigan, that primarily use the 85th percentile speed as an objective measure. A brief summary of the quantitative methods is given on the next page.

Illinois and Missouri collect prevailing speed data and set the limit within 3 mi/h of the prevailing speed unless further adjustments are justified by supplementary investigations. The prevailing speed is defined as the average of the 85th percentile speed, upper limit of the pace, and average test run speed. In a typical investigation, the speed limit may be set 5 percent below the prevailing speed if the accident rate is 50 percent higher than the statewide rate for the same highway classification. A 10 percent reduction is allowed if the rate is more than double the statewide rate. Also, the number and type of driveways and entrances are counted and an access conflict number is computed for the section. The limit may be set below the prevailing speed if the conflict numbers exceed certain values. Additional reductions may be made for pedestrian activity and where onstreet parking is permitted. After applying all the corrections, the speed limit should not be less than 9 mi/h below the prevailing speed. The method is illustrated in the worksheet shown in Figure 1.

Maine and Nevada use the speed zoning methodology (or a modified version thereof) developed by the Traffic Institute at Northwestern University.[8] Iowa uses the ITE procedures listed in the Traffic Engineering Handbook.[6] Both of these methods are similar to the procedures first reported in July 1961 by ITE Technical Committee 3-C.[9] Basically, the method requires collecting the prevailing speed data and when conditions require, adding or subtracting from the prevailing speed based on factors listed in a series of tables. The primary factors considered are roadside development, design speed, roadway geometrics, pedestrian activity, road class, parking zones, and accident rate.

Ohio also uses a procedure similar to the ITE method. The method was developed over 30 years ago and it is difficult to determine whether the Ohio method preceded the ITE procedure or vice versa. The Ohio method, which considers five roadway and five traffic factors, is illustrated in Figure 2.

Oregon uses a unique method to post speed limits on state roads. The safe speed is established as the algebraic summation of the 85th percentile speed and the difference in the accident rate for similar sections and the accident rate for the section being considered. The posted speed limit should not vary by more than 5 mi/h above or below this value.

Pennsylvania basically considers the 85th percentile speed, accident experience, and sight distance in setting speed limits. The speed limit may be reduced up to 10 mi/h below the average 85th percentile speed or safe running speed on the section if there is inadequate stopping sight distance, intersection sight distance is inadequate, or the 3-year accident rate is greater than values set by highway type.

Adjustments and Deviations From the Procedure

Of the 52 agencies responding, 28 indicated that they do not make any further adjustments in the speed limit after their procedure is used to determine the appropriate speed. Of the 17 states which do make adjustments, the majority provide for reductions of 5 mi/h based on geometrics, accidents related to speeding, roadside development, and the limits posted on adjacent zones.

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

ESTABLISHMENT OF SPEED ZONES ZONE NO.________

ROUTE________________ FROM________________

TO________________ A DISTANCE OF________________MILES

IN____________, ____________ TOWNSHIP,____________COUNTY

I SPOT SPEED STUDIES (ATTACHED)

CHECK NO.	85th %	10 MPH PACE UPPER LIMIT

II TEST RUNS

RUN NO.	AVERAGE SPEED MPH	
	NB or WB	SB or EB
1		
2		
3		
4		
5		

III PREVAILING SPEED

85th PERCENTILE AVG. ____ MPH

PACE UPPER LIMIT AVG. ____ MPH

TEST RUN AVG. ____ MPH

PREVAILING SPEED: ____ MPH

IV EXISTING SPEED LIMITS

ZONE BEING STUDIED ____ MPH

VIOLATION RATE ____ %

ADJACENT ZONES N or W ____ MPH

LENGTH ____ MILES

S or E ____ MPH

LENGTH ____ MILES

V ACCESS CONFLICTS

RESIDENTIAL DRIVES ____ x 1.0 = ____
SMALL BUSINESS DRIVES ____ x 5.0 = ____
LARGE BUSINESS DRIVES ____ x 10.0 = ____
ACCESS CONFLICT NUMBER TOTAL ____

(D.C.N) / MILES = ____ CONFLICT NO./MILE

VI MISCL. FACTORS

PEDESTRIAN VOLUME ________

ACCIDENT RATE RATIO:
STATEWIDE AVG. / ROUTE = ________

PARKING PERMITTED ☐ YES ☐ NO

VII PREVAILING SPEED ADJUSTMENT

DRIVEWAY ADJUSTMENT ____ %
PEDESTRIAN ADJUSTMENT ____ %
ACCIDENT ADJUSTMENT ____ %
PARKING ADJUSTMENT ____ %
TOTAL (MAX 20%) ____ %

____ MPH PREVAILING SPEED x ____ % ADJUSTMENT = ____ (Max. 9 MPH)

ADJUSTED PREVAILING SPEED: ________MPH

VIII REVISED SPEED LIMIT

RECOMMENDED SPEED LIMIT ________MPH

ANTICIPATED VIOLATION RATE ________%

RECOMMENDED BY ________
ORGANIZATION ________
DATE ________

APPROVED BY ________
DATE ________

BT 1003

Figure 1. Illinois method for considering factors.

WARRANTS FOR RURAL SPEED ZONES
(SAMPLE)

Location: Perry Road, Malvern County
From: SR 8 To: SR US 99
Length: 1.3 miles

Road Conditions		Value of Each Factor	40	50	58	67	75	83	92	100	
1. Apparent Design Speed	(MPH)	20	25	30	35	40	45	50	55	60	83
2.* Length of proposed zone	(Miles)						>0.5			<0.5	75
3. Minor public highways & private access points	(No./Mile)			>50	41-50	31-40	21-30	16-20	11-15	0-10	67
4. State routes & thru county or twp. highways	(No./Mile)		>7	7	6	5	4	3	2	0-1	92
5. Roadside businesses	(No./Mile)		50% of front	>15	9-15	8	7	6	5	0-4	92
Traffic Experience											
1. Both limits of pace are between	(MPH)		13-27	18-32	23-37	28-42	33-47	38-52	43-57	48-62	83
2. 85 Percentile is between	(MPH)		23-37	28-32	33-37	38-42	43-47	48-52	53-57	58-62	83
3. Total accidents	(No./Mile)			>12	11-12	9-10	7-8	5-6	3-4	0-2	75
4. Driveway or intersection accidents	(No./Mile)			>6	6	5	4	3	2	0-1	92
5. Test runs average	(MPH)	20	25	30	35	40	45	50	55	60	75
									Total value of factors		817
									Average value of factors		81.7
									Warranted speed		50

* Minimum length of zone is 0.25 of a mile
Business districts may be not less than 300'

Conditions at 60 MPH are considered as standard with a value of 100

\> More than
< Less than

REF. SEC.
5I-4

Figure 2. Ohio method for considering factors.

Problems Experienced in Using Existing Methods

A summary of the major problems experienced by the states in using their current speed zoning method is given below:

- Considering factors subjectively complicates training new engineers and technicians.
- Many local officials and citizens feel speed limits should be lower.
- Convincing officials and the public that unreasonably low speed limits do not slow traffic.
- Political intervention into the speed zoning process.
- Local and law enforcement officials prefer to set lower speed limits so speeding citations greater than 8 to 10 mi/h over the posted speed limits will stand up in court.
- The design speed is sometimes lower than the 85th percentile speed.
- Enforcement problems are encountered when the limit is set below the 85th percentile speed.
- Radar detectors used by motorists identify study sites.

Many of the problems cited by the respondents have been mentioned many times before. The design speed issue is somewhat of a new problem as mentioned by New Mexico, Ohio, and Texas. The AASHTO[4] policy clearly indicates that design speed is the maximum safe speed that can be maintained over a specific section of highway where conditions are so favorable that the design features of the highway govern. Typically, the 85th percentile speed represents the speed of drivers under favorable weather, light, and traffic conditions who are free to choose their own speeds and are not impeded by other vehicles. While all the factors involved in setting the design speed were not examined in this study, it is the opinion of the author that the problem is primarily due to selecting artificially low design speeds. This problem is best resolved by discussion of the issues and consensus between designers and traffic engineers.

RATIONALE AND BASIS FOR QUANTIFYING FACTORS

As previously mentioned, the 85th percentile speed is considered as a major factor in setting speed limits by every state. The scientific basis for using the 85th percentile speed was outlined by Parker[7] and is briefly summarized below.

Studies conducted by Solomon,[10] Cirillo,[11] and Joscelyn, et al.[12] found that the probability of an accident is low for vehicles traveling in the region of the 85th percentile speed. In other words, the 85th percentile speed is the upper limit of the region of lowest accident involvements. A recent study conducted by Harkey, et al.[13] found that accident risk was minimized at the 90th percentile speed. Using a different approach, Munden[14] found that the average speed driver has the lowest accident rate and the rates are higher for people who drive too slow or too fast. Hauer[15] provided an explanation of these phenomena by using an overtaking model. The preponderance of evidence indicates that the 85th percentile speed is a good indicator of the maximum safe speed limit which is largely enforceable. Several states indicated that they felt very strongly that the great majority of reasonable drivers who are attempting to minimize their accident risk should have a major voice in setting a safe and reasonable speed limit. The 85th percentile factor clearly encompasses these qualities.

The MUTCD was mentioned by five states as the basis for considering their factors. The MUTCD procedure, mentioned in the introduction, does indeed list a number of factors, but provides no indication of how those factors should be used to establish speed limits. A background check into the origin of the procedure in the MUTCD indicated that the current method was first introduced in the 1971 manual. Prior to 1971, the MUTCD suggested establishing the speed limit after an appropriate engineering and traffic investigation according to law.

The ITE Transportation and Traffic Engineering Handbook, as well as the speed zoning methodology developed by the Traffic Institute, Northwestern University, were also cited by several respondents as the rationale for using their factors and method.

In addition to the above reference sources, also included in the responses were the following rationale:

- Departmental policy developed over the years.
- Engineering judgment.
- Consistency.
- Consensus of traffic engineers throughout the country.

EVALUATIONS OF SPEED ZONING PROCEDURES

Thirty-seven of the 52 respondents advised that they had not conducted an evaluation of their speed zoning method. Kansas is currently in the process of planning a study to determine the effects of speed limits on speeds and driver compliance. Twelve respondents indicated that they had conducted evaluations, however, most were informal observations. Two research studies specifically mentioned were the study completed by Michigan State University[16] and an ongoing (at the time of the survey) FHWA study by Parker entitled "Effects of Raising and Lowering Speed Limits." In February 1985, Montana asked the Traffic Institute to evaluate the current speed zoning policy, which is based on the 85th percentile. Mr. Robert Seyfried of the Institute conducted the evaluation, however, the results were primarily a reiteration of the speed zoning philosophies and practices. No accident or compliance data were collected.

In 1988, Taylor, et al.[16] collected speed and accident data on 20 speed zone sections located on Michigan state highways. They found that the Michigan procedure (85th percentile) used to establish speed limits resulted in a significant reduction in total accidents. The small sample size prohibited further analysis to determine if any other factors should be incorporated into the current Michigan speed zoning procedure.

In 1986 Dudek and Ullman[17] conducted a study for the Texas Department of Highways and Public Transportation to evaluate the effects of posting speed limits lower than the 85th percentile speed in rapidly developing areas. Their analysis of speed and accident data at the study sites indicated that posting speeds lower than the 85th percentile speed did not have an effect on speeds or accidents. They recommended that Texas continue using the 85th percentile speed to establish speed zones.

Very few studies have been undertaken by the states to examine the effects of their speed zoning method on reducing accidents and increasing driver compliance. The majority of engineers feel that the 85th percentile speed is a good objective measure and cite studies conducted over many years which indicate that posted speed limits alone have little effect on safety and motorists' speeds. Of course, the effects of arbitrary limits on driver compliance are dramatic. Even 5 mi/h reductions below the 85th percentile speed can decrease compliance by 25 percent or more.

A recent study completed by Harkey, et al.[13] and an ongoing effort by Parker provides evidence that the effects of current speed zoning practices are much greater than the engineers indicated in the survey. For example, Harkey found that 85th percentile speeds ranged from 6 to 14 mi/h over the posted speed limits on roadways examined in four states. Generally, 85th percent compliance was achieved at speeds 10 mi/h over the posted limit. Preliminary results from Parker's study indicate a similar finding on roadways examined in 22 states.

In summary, there is a need to evaluate procedures used by the states to identify the method(s) that lead to improved safety and increased driver compliance with posted limits.

ASSESSMENT OF CURRENT PRACTICES

Based on a review of the information collected during this investigation, it is obvious that there is considerable difference in the criteria and methods used to establish posted speed limits. Although all the states reported using the 85th percentile speed as a major factor, the limits appear to vary from the 50th percentile to the 95th percentile speed. While the 85th percentile speed is an objective measure, actual implementation often provides posted limits that greatly deviate from the 85th percentile speed.

As previously mentioned, several states, including Illinois, Ohio, Oregon and Pennsylvania report that they use a numerical process to consider other factors in addition to the 85th percentile speed. These methods were developed many years ago, and their origination could not be determined. Based on a literature review and conversations with traffic engineers, it is the opinion of the author that most of the criteria represent a consensus of practice and experience with speed zoning at that time. Unfortunately, as few effectiveness evaluations have been conducted, there is little scientific evidence to suggest that one method is more effective than another or than in simply using the 85th percentile speed alone. Generally, the qualifying restrictions applied tend to reduce the objectivity of the procedure.

Based on a preliminary analysis of data collected by Parker during an FHWA study conducted in 22 states, it appears that overall, the states deviate from the 85th percentile speed considerably. Posted speed limits in the samples of both experimental sites (where speed limits were altered) and control sites where no speed limit changes were made indicate that the posted speed limits ranged from the 1st to the 99th percentile speeds. Similar to the results reported by Harkey,[13] the typical speed zone appears to be posted near the 50th percentile speed, or average speed of traffic.

Although there are differences in data collection techniques, number of samples taken, sample size, etc., a preliminary analysis was conducted using the procedures in several states to see if there was evidence that the state actually followed their procedure. The samples considered in the analysis were all on non-65 mi/h roadways. Both rural- and urban-type conditions were included. A brief summary of the procedures in selected states is given below.

- A sample of 5 sections was examined in Delaware, a state which posts speeds between the 50th and 85th percentile. Of the test sections examined, only 1 of the 5 locations was posted above the 50th percentile after the limit was changed. On the other hand, data at the control sections indicated that only 1 section was posted below the 50th percentile speed.

- Only 2 sections were available for analysis in Illinois. Using the objective criteria reported by Illinois, the posted speed limits at these sections were within their criteria. The results were the same for both the test and control sections.

- A sample of 3 sections in Maine, which uses a modified version of the ITE procedure, indicated that the posted limits fell within the criteria they reported using.

- A sample of 8 sections in Texas, which uses the 85th percentile speed but permits a maximum 7 mi/h deviation, indicated that the posted speed limit was within the criteria for 7 of the 8 test sections examined. However, at the control sites, the criteria was met at only half of the sites.

PROCEDURES RECOMMENDED FOR FURTHER STUDY

In order to examine the effectiveness of current procedures for establishing speed limits on driver compliance and accidents, the following procedures are recommended for further study:

- The Michigan method of using the 85th percentile speed with a 5 mi/h deviation (base condition).

- The 85th percentile with a 7 mi/h deviation, not lower than the 67th percentile speed.

- The quantitative procedure used in Illinois and Missouri which includes, among other factors, accident experience.

- The Ohio procedure which includes some of the factors used in the Traffic Institute method.

- The Oregon method which also quantitatively includes accident rates.

- The Traffic Institute method used by Nevada and Maine (both minimum and refined study procedures).

In addition, several of the deviations from the 85th percentile speed, as reported by a number of states, will be examined to determine if significant differences exist between the Michigan method and a 7 mi/h deviation. It is also possible that the results of the comparative analysis could indicate that a modification of some existing method would be desirable.

A comparison of these methods was conducted using roadway, speed, and accident data collected for a sample of speed zoned locations on nonlimited access highways in Michigan. The results are presented in the next chapter of this report.

COMPARISON OF SPEED ZONING PROCEDURES

INTRODUCTION

As mentioned in the preceding chapter, a survey was conducted of the 50 states, District of Columbia, Guam, and Puerto Rico to identify quantitative methods used to determine the numerical value of the speed limit on roadways subject to speed zoning. After conducting an assessment of the current procedures, the following quantitative methods were recommended for evaluation.

- The current Michigan method of using the 85th percentile speed with a 5 mi/h deviation.
- The 85th percentile with a 7 mi/h deviation, not lower than the 67th percentile speed.
- The procedure used in Illinois and Missouri which quantitatively includes other factors such as access points, accident experience, pedestrians, and parking.
- The Ohio procedure which includes five roadway and five traffic measures.
- The Oregon method which quantitatively includes accident rates.
- The Traffic Institute (Northwestern University) method used by Nevada and Maine (both minimum and refined study procedures).

The objectives of this effort were to estimate the impacts of the current Michigan method and to conduct a comparison of the speed zoning procedures on selected sections of Michigan roadways to determine which method(s) results in speed limits that improve safety and driver compliance. The primary focus was to determine if including other factors in addition to the 85th percentile speed would increase the effectiveness of the current Michigan procedure as measured by improved safety and compliance.

METHOD

As safety is a primary concern to engineers, road users, and adjacent property owners, a major effort was conducted to determine if the current Michigan speed zoning method results in improved safety. To assess the safety impact, a before and after design with a comparison group and a check for comparability was employed on speed zones established on the state trunkline during the period 1982 through 1986. It should be noted that the sites used in this study do not include interstate or other limited access roadways subject to the national maximum 65 mi/h speed limit.

To determine if any other quantitative method was superior to the Michigan procedure in establishing speed limits which could improve safety and driver compliance, a comparison of each method was conducted at Michigan speed zone sites established on the state trunkline from 1982 through 1986. To conduct the comparison, the speed zone sites were stratified into the following two groups based on a before and after analysis of reported accidents.

- Sites where accidents decreased following a change in the posted speed limit.

- Sites that demonstrated no change or an increase in accidents following a change in the posted speed limit.

Roadway, traffic flow, and other data needed for each speed zoning method were collected at each Michigan site to determine what speed limit would have been posted if each method were used. The intent of the experiment was to determine the number of times each speed zoning procedure generated the actual speed limit posted at each site in each of the two groups. For example, if the Ohio procedure recommended the actual speed limit posted at 80 percent of the sites where accidents were reduced and the Oregon method only recommended the actual limit at 40 percent of the sites, it could be concluded that the factors considered in the Ohio method were superior to the Oregon method.

Driver compliance with posted speed limits is also an important concern. An assessment of the speed zoning methods on driver compliance was conducted using a sample of selected Michigan locations.

Following a safety and compliance comparison of the speed zoning methods, an assessment was made to identify the procedure which best meets the following criteria:

- Minimize accident involvement risk to the majority of drivers.

- Reasonable and fair.

- Repeatability, i.e., different engineers using the method at the same site could be expected to come to the same conclusion.

- Reliability, i.e., the method will produce uniform results when used at locations with similar traffic and roadway conditions.

- Ease of use.

- Acceptability to engineers, administrators and the public.

- Cost-effectiveness.

SITE SELECTION

All speed zones established on the Michigan Trunkline System during the years 1982 through 1986 encompassed the population of sites available for conducting the accident analysis and assessment of speed zoning methods. During this period, the Department issued 129 Traffic Control Orders for speed zones. Each Traffic Control Order contained one or more roadway sections. The speed zones listed in each Traffic Control Order were reviewed and the sections were selected based on the following procedure:

- All sections on the Traffic Control Orders which were less than 0.5 mile in length were eliminated from further consideration. Previous experience indicates that short segments either have very few accidents or the accidents fluctuate widely from year-to-year.

- Sections subjected to construction during the study period, other than routine maintenance and minor safety improvements, were eliminated.

- Sections which were added to or eliminated from the trunkline system were not used because either the before or after accident data were not available.

- Sections with more than one speed zone change during the study period were eliminated because the effects of multiple changes could confound the results.

Each of the remaining sections were reviewed to identify sites where speed limits were either raised or lowered. Sites where speed limits were changed were identified as experimental and the remaining sites where speed limits were not altered were identified as comparison sites. Although the selected sections met the minimum 0.5 mile length criteria, after subdividing the sections into experimental and comparison sites, some of the sites were less than 0.5 mile in length. For purposes of retaining as many sites as possible for analysis, it was necessary to use a minimum site length of 0.3 of a mile.

A field review was conducted to determine if the sites met the selection criteria and to collect data needed to conduct the assessment of methods.

This procedure yielded 68 experimental sites totaling 60.2 miles of roadway where speed limits were changed and 86 comparison sites totaling 97.6 miles where speed limits were not changed. Of the 68 experimental sites, speed limits were raised at 21 sites and lowered at 47 sites. For each experimental site, one or more comparison sites were identified based on similarities in volume, speed, and geometric design. It should be noted that the experimental and comparison sites are not perfectly matched, i.e., there is some variation in volume and posted speed. There simply were not enough sections available on the trunkline system to make identical matches. The number of lanes and median type are similar for each experimental and comparison site.

Speed zone sites were identified in all 9 Michigan transportation districts and in 41 of Michigan's 83 counties. The majority of the sites are located in urban fringe areas where changes in land use and/or travel demand led to an engineering investigation and subsequent change in the posted limit. Speed limits at the sites ranged from 25 to 55 mi/h, however, 45 mi/h was the most frequently used limit (26 of the 68 sites) on the experimental sections. The sections consisted predominantly of two-lane and multilane undivided and divided roadways. Traffic volumes ranged from 1,300 to 47,200 vehicles per day. The average volume for all sites was 12,000 vehicles per day.

ACCIDENT ANALYSIS

The first objective of this effort was to estimate the impact of the current Michigan speed zoning procedure on safety. As previously mentioned, there has been very little, if any, evaluation of the effects of speed zoning methods on safety. Prior to considering a change in the Michigan procedure, it is important to examine the safety effects of the current method. The analysis methodology and findings are presented in the following sections.

Accident Analysis Methodology

After the experimental and comparison sites were identified, data for reported accidents that occurred during the years 1980 through 1990 were obtained for each site on computer diskette from the Michigan Department of Transportation. At most sites, the accident analysis included a three-year before and three-year after period. The year the speed limit was posted was eliminated from the analysis to avoid any possible novelty effects and to prevent fragmented time periods. To provide a proper comparison, the same before and after time period used at the experimental site was used at its corresponding comparison site(s). The accident data were sorted and tabulated using dBASE IV.

Shown in Table 2 are the summaries of total reported accidents for the sites where speed limits were changed in Michigan. The accident data for the comparison sites where speed limits were not changed are shown in Table 3.

The evaluation design selected to estimate the effectiveness of the speed limit changes on accidents is the before-after design with a comparison group, and a check for comparability.[18] With this design, multiple before and after accident counts are taken at both the experimental and comparison locations. The purpose of the multiple measurements is to determine if the control locations are, in fact, suitable comparisons for the experimental sites. The purpose of the comparison group is to account for changes in safety (such as weather conditions, driver characteristics, etc.) between the before and after periods. The primary benefit of this design is that the comparison group controls for extraneous factors, and as multiple measurements are made over time, some relief from regression-to-the-mean bias is obtained.

Due to the strengths and weaknesses of various accident evaluation methods, three different techniques were used to estimate the safety effects of the speed limit changes. The first method, reported by Griffin,[19] uses multiple before and after analysis with paired comparison ratios to estimate the overall safety effects at multiple treatment locations. The second method is the classical cross-product ratio or odds ratio which is also discussed by Griffin.[18]

Because regression-to-the-mean is an important factor which can often lead to erroneous conclusions in accident analyses, the third analysis method employed the use of a new empirical Bayes method, EBEST (Empirical Bayes Estimation of Safety and Transportation), which adjusts for regression-to-the-mean bias and provides a more realistic estimate of the safety effects.[20] The EBEST procedure requires a reference group and measurement of site exposure. The reference group used in the analysis is the comparison sites where speed limits were not changed which represent all available sites studied for speed zoning during the period 1982 to 1986. To satisfy the assumption of exchangeability required by the procedure, the exposure data used for each site included section length, and before and after average daily traffic volume and time period.

The analysis plan included the following steps:

- Conduct a check for comparability.

- Estimate the treatment effects using multiple before and after analysis with paired comparison ratios.

- Estimate the treatment effects using the classical cross-product ratio or odds ratio.

Table 2. Michigan sites where speed limits were changed.

Site No.	Length Miles	1987 ADT	Speed Limit Bef	Speed Limit Aft	Year Limit Posted	BEFORE B3 Yr	B3 Acc	B2 Yr	B2 Acc	B1 Yr	B1 Acc	Tot Acc	Acc Per Yr	AFTER A1 Yr	A1 Acc	A2 Yr	A2 Acc	A3 Yr	A3 Acc	Tot Acc	Acc Per Yr	Difference Speed Limit	Difference Acc Per Yr
1151	0.607	2,400	45	55	84	81	0	82	3	83	2	5	1.67	85	0	86	2	87	3	5	1.67	10	0.00
1152	0.653	4,000	35	40	84	81	3	82	3	83	2	8	2.67	85	3	86	8	87	11	22	7.33	5	4.67
1153	0.725	25,400	35	40	86	83	28	84	35	85	31	94	31.33	87	46	88	45	89	29	120	40.00	5	8.67
1154	0.755	25,400	45	50	86	83	21	84	20	85	15	56	18.67	87	31	88	33	89	50	114	38.00	5	19.33
1251	0.380	3,500	45	50	86	83	0	84	1	85	0	1	0.33	87	3	88	1	89	2	6	2.00	5	1.67
1252	0.370	2,200	25	50	85	82	0	83	0	84	2	2	0.67	86	4	87	1	88	1	6	2.00	25	1.33
1351	0.320	3,600	40	45	83	80	1	81	0	82	3	4	1.33	84	1	85	1	86	1	3	1.00	5	-0.33
1451	0.460	2,800	25	45	89	86	1	87	0	88	0	1	0.33	90	0					0	0.00	20	-0.33
1452	0.670	2,800	25	35	89	86	5	87	5	88	4	14	4.67	90	4					4	4.00	10	-0.67
1453	0.500	2,800	25	45	89	86	2	87	0	88	1	3	1.00	90	2					2	2.00	20	1.00
1454	1.044	12,500	35	40	87	84	24	85	16	86	24	64	21.33	88	25	89	19	90	14	58	19.33	5	-2.00
1551	0.805	14,900	25	35	86	83	48	84	42	85	50	140	46.67	87	36	88	32	89	56	124	41.33	10	-5.33
1751	0.535	7,900	35	40	85	82	13	83	17	84	23	53	17.67	86	18	87	15	88	20	53	17.67	5	0.00
1752	0.800	9,400	45	50	85	82	6	83	5	84	14	25	8.33	86	21	87	16	88	16	53	17.67	5	9.33
1753	0.720	9,400	35	40	85	82	10	83	18	84	20	48	16.00	86	19	87	21	88	21	61	20.33	5	4.33
1754	0.492	4,100	45	50	85	82	2	83	2	84	8	12	4.00	86	4	87	1	88	3	8	2.67	5	-1.33
1755	1.359	16,700	45	50	86	83	10	84	19	85	18	47	15.67	87	14	88	16	89	14	44	14.67	5	-1.00
1756	0.571	15,700	35	40	86	83	18	84	21	85	25	64	21.33	87	20	88	22	89	24	66	22.00	5	0.67
1757	0.719	12,400	30	35	86	83	22	84	39	85	29	90	30.00	87	44	88	40	89	59	143	47.67	5	17.67
1758	0.540	12,400	30	40	86	83	32	84	34	85	43	109	36.33	87	35	88	49	89	35	119	39.67	10	3.33
1951	2.347	44,100	35	40	86	83	321	84	327	85	352	1000	333.33	87	380	88	365	89	344	1089	363.00	5	29.67
2101	0.486	2,400	45	40	84	81	1	82	3	83	3	7	2.33	85	2	86	1	87	3	6	2.00	-5	-0.33
2102	0.568	5,100	40	35	84	81	10	82	8	83	9	27	9.00	85	8	86	8	87	7	23	7.67	-5	-1.33
2103	0.353	3,500	35	25	83	80	14	81	9	82	11	34	11.33	84	11	85	15	86	14	40	13.33	-10	2.00
2104	0.730	1,600	55	45	83	80	3	81	4	82	3	10	3.33	84	3	85	4	86	3	10	3.33	-10	0.00
2201	0.343	5,000	55	45	86	83	6	84	2	85	5	13	4.33	87	9	88	8	89	8	25	8.33	-10	4.00
2202	0.329	5,800	55	45	84	81	0	82	3	83	0	3	1.00	85	1	86	1	87	2	4	1.33	-10	0.33
2203	0.639	2,200	55	50	85	82	0	83	2	84	1	3	1.00	86	6	87	1	88	2	9	3.00	-5	2.00
2301	1.500	2,400	55	45	83	80	9	81	9	82	15	33	11.00	84	8	85	11	86	15	34	11.33	-10	0.33
2302	0.314	3,600	55	45	83	80	1	81	2	82	2	5	1.67	84	3	85	1	86	2	6	2.00	-10	0.33
2303	1.129	23,700	55	45	82			80	9	81	8	17	8.50	83	6	84	15	85	15	36	12.00	-10	3.50
2304	1.223	14,000	55	45	83	80	19	81	22	82	15	56	18.67	84	14	85	16	86	19	49	16.33	-10	-2.33
2401	3.186	9,500	55	45	82			80	46	81	38	84	42.00	83	40	84	37	85	52	129	43.00	-10	1.00
2402	1.935	6,200	55	50	82			80	9	81	12	21	10.50	83	11	84	16	85	17	44	14.67	-5	4.17
2403	1.579	12,500	45	40	87	84	15	85	21	86	32	68	22.67	88	37	89	27	90	33	97	32.33	-5	9.67
2501	0.309	13,200	55	45	83	80	1	81	1	82	1	3	1.00	84	0	85	3	86	0	3	1.00	-10	0.00
2502	1.656	16,400	50	45	85	82	22	83	27	84	29	78	26.00	86	46	87	51	88	54	151	50.33	-5	24.33
2503	2.371	36,700	50	45	83	80	140	81	128	82	143	411	137.00	84	171	85	157	86	229	557	185.67	-5	48.67

Table 2. Michigan sites where speed limits were changed (continued).

Site No.	Length Miles	1987 ADT	Speed Limit Bef	Speed Limit Aft	Year Limit Posted	BEFORE B3 Yr	B3 Acc	B2 Yr	B2 Acc	B1 Yr	B1 Acc	Tot Acc	Acc Per Yr	AFTER A1 Yr	A1 Acc	A2 Yr	A2 Acc	A3 Yr	A3 Acc	Tot Acc	Acc Per Yr	Difference Speed Limit	Difference Acc Per Yr
2504	1.123	6,000	55	35	83	80	7	81	3	82	0	10	3.33	84	3	85	1	86	4	8	2.67	-20	-0.67
2505	0.573	6,000	40	35	83	80	4	81	3	82	5	12	4.00	84	0	85	4	86	5	9	3.00	-5	-1.00
2506	0.670	6,000	30	25	83	80	7	81	7	82	20	34	11.33	84	14	85	10	86	11	35	11.67	-5	0.33
2507	0.368	6,000	40	35	83	80	0	81	1	82	1	2	0.67	84	0	85	0	86	1	1	0.33	-5	-0.33
2601	2.210	7,200	45	40	85	82	24	83	36	84	47	107	35.67	86	37	87	45	88	31	113	37.67	-5	2.00
2602	0.955	12,000	55	45	82			80	24	81	33	57	28.50	83	15	84	28	85	23	66	22.00	-10	-6.50
2603	0.950	4,800	55	50	83	80	7	81	1	82	2	10	3.33	84	10	85	7	86	10	27	9.00	-5	5.67
2604	0.642	2,700	35	30	85	82	4	83	18	84	11	33	11.00	86	22	87	14	88	26	62	20.67	-5	9.67
2605	0.331	8,000	45	35	85	82	1	83	7	84	7	15	5.00	86	12	87	13	88	10	35	11.67	-10	6.67
2606	0.336	12,000	40	30	83	80	23	81	22	82	33	78	26.00	84	39	85	46	86	51	136	45.33	-10	19.33
2607	0.374	12,000	50	40	83	80	10	81	19	82	15	44	14.67	84	15	85	20	86	22	57	19.00	-10	4.33
2608	0.500	18,000	55	50	86	83	3	84	9	85	12	24	8.00	87	14	88	10	89	9	33	11.00	-5	3.00
2609	0.520	8,400	55	50	83	80	9	81	7	82	8	24	8.00	84	9	85	19	86	16	44	14.67	-5	6.67
2802	0.568	1,300	50	45	86	83	1	84	2	85	1	4	1.33	87	2	88	0	89	0	2	0.67	-5	-0.67
2803	0.680	47,200	40	35	84	81	70	82	55	83	52	177	59.00	85	42	86	77	87	68	187	62.33	-5	3.33
2804	0.750	43,600	45	35	84	81	29	82	30	83	39	98	32.67	85	26	86	23	87	27	76	25.33	-10	-7.33
2805	0.665	32,800	50	45	84	81	28	82	22	83	30	80	26.67	85	18	86	25	87	20	63	21.00	-5	-5.67
2806	1.005	10,000	55	45	82			80	6	81	4	10	5.00	83	9	84	2	85	13	24	8.00	-10	3.00
2807	0.582	20,000	55	45	82			80	23	81	22	45	22.50	83	17	84	16	85	18	51	17.00	-10	-5.50
2808	0.566	8,200	45	35	83	80	27	81	25	82	16	68	22.67	84	15	85	14	86	27	56	18.67	-10	-4.00
2809	1.314	5,300	55	45	82			80	10	81	5	15	7.50	83	10	84	9	85	14	33	11.00	-10	3.50
2810	1.195	5,300	55	45	85	82	5	83	9	84	15	29	9.67	86	18	87	18	88	15	51	17.00	-10	7.33
2811	0.980	12,900	50	45	83	80	30	81	20	82	16	66	22.00	84	17	85	30	86	25	72	24.00	-5	2.00
2812	0.387	20,000	45	35	86	83	31	84	33	85	27	91	30.33	87	57	88	32	89	37	126	42.00	-10	11.67
2813	2.342	25,200	45	40	85	82	278	83	256	84	328	862	287.33	86	359	87	388	88	397	1144	381.33	-5	94.00
2814	0.400	16,000	55	45	85	82	8	83	9	84	8	25	8.33	86	10	87	21	88	16	47	15.67	-10	7.33
2901	0.600	11,000	55	45	84	81	8	82	5	83	3	16	5.33	85	7	86	10	87	8	25	8.33	-10	3.00
2902	0.660	23,600	50	45	85	82	24	83	25	84	35	84	28.00	86	33	87	43	88	42	118	39.33	-5	11.33
2903	1.343	11,900	50	45	85	82	18	83	33	84	30	81	27.00	86	24	87	28	88	32	84	28.00	-5	1.00
2904	2.626	10,500	55	50	84	81	21	82	18	83	7	46	15.33	85	18	86	17	87	17	52	17.33	-5	2.00
Totals 68 Sites	60.237 Miles						1485		1650		1825	4960			1958		2029		2173	6160			362.50

Table 3. Michigan comparison sites where speed limits were not changed.

Site No.	Length Miles	1987 ADT	Speed Limit	Year Test Posted	BEFORE B3 Yr	B3 Acc	B2 Yr	B2 Acc	B1 Yr	B1 Acc	Tot Acc	Acc Per Yr	AFTER A1 Yr	A1 Acc	A2 Yr	A2 Acc	A3 Yr	A3 Acc	Tot Acc	Acc Per Yr	Change Acc Per Yr
151	0.430	2,400	45	84	81	1	82	3	83	0	4	1.33	85	0	86	0	87	1	1	0.33	-1.00
152	0.450	6,500	30	84	81	3	82	5	83	5	13	4.33	85	3	86	7	87	2	12	4.00	-0.33
153	0.787	23,800	45	86	83	42	84	59	85	48	149	49.67	87	59	88	62	89	58	179	59.67	10.00
1153	0.860	34,500	35	86	83	52	84	58	85	59	169	56.33	87	67	88	54	89	45	166	55.33	-1.00
154	0.869	17,800	50	86	83	21	84	18	85	19	58	19.33	87	26	88	24	89	20	70	23.33	4.00
1154	2.140	19,900	45	86	83	55	84	63	85	72	190	63.33	87	90	88	99	89	85	274	91.33	28.00
251	0.400	7,000	45	86	83	0	84	3	85	3	6	2.00	87	2	88	3	89	2	7	2.33	0.33
252	0.466	3,500	35	85	82	4	83	2	84	3	9	3.00	86	4	87	2	88	2	8	2.67	-0.33
351	0.795	4,100	45	83	80	4	81	4	82	2	10	3.33	84	10	85	4	86	4	18	6.00	2.67
451	0.750	3,500	45	89	86	2	87	0	88	6	8	2.67	90	2					2	2.00	-0.67
452	0.720	4,100	35	89	86	1	87	9	88	4	14	4.67	90	5					5	5.00	0.33
453	0.559	13,000	35	89	86	8	87	7	88	2	17	5.67	90	3					3	3.00	-2.67
454	0.570	13,400	35	87	84	10	85	11	86	19	40	13.33	88	29	89	19	90	25	73	24.33	11.00
551	1.167	14,900	25	86	83	71	84	94	85	80	245	81.67	87	99	88	94	89	107	300	100.00	18.33
751	0.390	7,000	35	85	82	2	83	4	84	6	12	4.00	86	11	87	18	88	15	44	14.67	10.67
1751	1.300	7,000	25	85	82	43	83	28	84	47	118	39.33	86	39	87	35	88	27	101	33.67	-5.67
752	2.314	20,500	45	85	82	101	83	105	84	132	338	112.67	86	142	87	136	88	141	419	139.67	27.00
753	0.691	7,000	30	85	82	24	83	18	84	18	60	20.00	86	38	87	32	88	45	115	38.33	18.33
1753	1.315	6,500	25	85	82	29	83	31	84	29	89	29.67	86	44	87	26	88	47	117	39.00	9.33
2753	3.952	52,400	40	85	82	692	83	721	84	841	2254	751.33	86	862	87	912	88	903	2677	892.33	141.00
754	0.850	4,100	40	85	82	37	83	32	84	44	113	37.67	86	52	87	59	88	44	155	51.67	14.00
755	1.241	16,700	45	86	83	30	84	27	85	31	88	29.33	87	39	88	44	89	32	115	38.33	9.00
1755	1.509	13,000	50	86	83	10	84	7	85	17	34	11.33	87	16	88	7	89	12	35	11.67	0.33
756	0.737	20,000	35	86	83	37	84	53	85	50	140	46.67	87	76	88	51	89	36	163	54.33	7.67
757	0.687	19,300	30	86	83	65	84	74	85	94	233	77.67	87	81	88	80	89	74	235	78.33	0.67
1757	0.500	3,600	30	86	83	13	84	11	85	11	35	11.67	87	13	88	12	89	14	39	13.00	1.33
758	0.709	18,500	40	86	83	39	84	41	85	46	126	42.00	87	56	88	74	89	91	221	73.67	31.67
951	2.577	38,000	45	86	83	166	84	177	85	223	566	188.67	87	224	88	223	89	211	658	219.33	30.67
1951	1.967	22,200	50	86	83	55	84	86	85	57	198	66.00	87	63	88	78	89	91	232	77.33	11.33
101	0.700	4,700	40	84	81	5	82	4	83	4	13	4.33	85	2	86	1	87	4	7	2.33	-2.00
102	1.161	4,700	30	84	81	19	82	13	83	21	53	17.67	85	20	86	18	87	15	53	17.67	0.00
103	0.708	3,500	35	83	80	6	81	3	82	10	19	6.33	84	6	85	7	86	3	16	5.33	-1.00
104	0.890	1,600	45	83	80	1	81	1	82	0	2	0.67	84	1	85	2	86	2	5	1.67	1.00
201	0.380	5,000	45	86	83	1	84	4	85	7	12	4.00	87	7	88	4	89	2	13	4.33	0.33
202	1.400	7,000	45	84	81	3	82	5	83	2	10	3.33	85	4	86	8	87	3	15	5.00	1.67
203	0.769	2,000	40	85	82	5	83	1	84	4	10	3.33	86	3	87	6	88	2	11	3.67	0.33
301	0.976	2,600	50	83	80	5	81	3	82	7	15	5.00	84	7	85	6	86	4	17	5.67	0.67
302	3.200	19,700	35	83	80	236	81	218	82	189	643	214.33	84	206	85	263	86	289	758	252.67	38.33
303	2.691	26,700	45	82			80	94	81	118	212	106.00	83	80	84	81	85	127	288	96.00	-10.00
304	1.290	23,700	35	83	80	25	81	17	82	30	72	24.00	84	36	85	26	86	26	88	29.33	5.33
401	0.650	3,100	35	82			80	7	81	2	9	4.50	83	4	84	3	85	6	13	4.33	-0.17
402	0.744	6,200	50	82			80	2	81	4	6	3.00	83	3	84	6	85	6	15	5.00	2.00
403	0.829	12,500	35	87	84	21	85	22	86	31	74	24.67	88	35	89	34	90	28	97	32.33	7.67

Table 3. Michigan comparison sites where speed limits were not changed (continued).

Site No.	Length Miles	1987 ADT	Speed Limit	Year Test Posted	BEFORE B3 Yr	B3 Acc	B2 Yr	B2 Acc	B1 Yr	B1 Acc	Tot Acc	Acc Per Yr	AFTER A1 Yr	A1 Acc	A2 Yr	A2 Acc	A3 Yr	A3 Acc	Tot Acc	Acc Per Yr	Change Acc Per Yr
2403	0.425	7,200	40	87	84	3	85	11	86	6	20	6.67	88	9	89	4	90	14	27	9.00	2.33
3403	2.739	12,500	40	87	84	54	85	80	86	76	210	70.00	88	53	89	65	90	66	184	61.33	-8.67
501	1.101	13,200	40	83	80	16	81	14	82	20	50	16.67	84	33	85	26	86	21	80	26.67	10.00
502	1.450	18,900	45	85	82	32	83	30	84	40	102	34.00	86	38	87	45	88	37	120	40.00	6.00
503	3.241	44,400	45	83	80	394	81	392	82	414	1200	400.00	84	481	85	555	86	573	1609	536.33	136.33
504	2.010	12,900	55	83	80	11	81	13	82	19	43	14.33	84	17	85	20	86	16	53	17.67	3.33
505	0.341	7,000	40	83	80	2	81	2	82	5	9	3.00	84	4	85	5	86	5	14	4.67	1.67
506	2.324	7,200	45	83	80	19	81	26	82	20	65	21.67	84	25	85	37	86	22	84	28.00	6.33
507	0.683	9,900	45	83	80	1	81	2	82	1	4	1.33	84	1	85	0	86	3	4	1.33	0.00
601	0.813	7,000	35	85	82	11	83	10	84	9	30	10.00	86	6	87	7	88	8	21	7.00	-3.00
602	0.619	19,700	40	82			80	16	81	18	34	17.00	83	18	84	19	85	27	64	21.33	4.33
603	0.390	5,800	40	83	80	6	81	6	82	4	16	5.33	84	3	85	3	86	2	8	2.67	-2.67
604	0.478	2,700	45	85	82	1	83	5	84	5	11	3.67	86	4	87	8	88	4	16	5.33	1.67
605	1.000	8,000	35	85	82	7	83	5	84	12	24	8.00	86	11	87	7	88	3	21	7.00	-1.00
2605	0.849	18,400	45	85	82	30	83	24	84	37	91	30.33	86	48	87	55	88	51	154	51.33	21.00
3605	3.081	12,500	55	85	82	17	83	18	84	27	62	20.67	86	30	87	33	88	47	110	36.67	16.00
606	0.610	12,000	50	83	80	11	81	10	82	13	34	11.33	84	11	85	25	86	12	48	16.00	4.67
607	0.700	18,000	40	83	80	32	81	20	82	23	75	25.00	84	43	85	51	86	60	154	51.33	26.33
608	1.750	18,000	50	86	83	31	84	42	85	51	124	41.33	87	53	88	56	89	72	181	60.33	19.00
609	1.479	15,500	45	83	80	17	81	11	82	12	40	13.33	84	13	85	29	86	28	70	23.33	10.00
802	1.500	20,300	50	86	83	22	84	29	85	21	72	24.00	87	36	88	31	89	31	98	32.67	8.67
803	0.550	47,200	35	84	81	43	82	59	83	24	126	42.00	85	29	86	55	87	28	112	37.33	-4.67
2803	0.635	18,500	25	84	81	95	82	81	83	92	268	89.33	85	94	86	93	87	117	304	101.33	12.00
804	1.510	23,800	45	84	81	78	82	54	83	61	193	64.33	85	109	86	118	87	96	323	107.67	43.33
2804	0.900	18,400	45	84	81	10	82	19	83	26	55	18.33	85	11	86	12	87	15	38	12.67	-5.67
805	2.692	32,800	50	84	81	48	82	52	83	49	149	49.67	85	45	86	79	87	88	212	70.67	21.00
806	0.502	13,400	45	82			80	0	81	0	0	0.00	83	0	84	1	85	0	1	0.33	0.33
2806	0.459	16,000	45	82			80	4	81	4	8	4.00	83	2	84	5	85	9	16	5.33	1.33
807	0.700	19,700	30	82			80	54	81	54	108	54.00	83	48	84	55	85	53	156	52.00	-2.00
808	0.790	8,200	35	83	80	43	81	23	82	26	92	30.67	84	28	85	34	86	24	86	28.67	-2.00
809	0.653	10,300	40	82			80	16	81	9	25	12.50	83	15	84	15	85	9	39	13.00	0.50
810	1.340	2,500	45	85	82	17	83	18	84	17	52	17.33	86	24	87	26	88	46	96	32.00	14.67
811	0.720	12,200	45	83	80	35	81	32	82	26	93	31.00	84	50	85	42	86	57	149	49.67	18.67
812	0.963	20,000	45	86	83	26	84	30	85	34	90	30.00	87	36	88	36	89	17	89	29.67	-0.33
813	0.823	43,300	45	85	82	66	83	63	84	73	202	67.33	86	92	87	91	88	100	283	94.33	27.00
2813	1.740	32,100	40	85	82	194	83	180	84	189	563	187.67	86	245	87	196	88	199	640	213.33	25.67
3813	0.529	43,300	40	85	82	67	83	70	84	105	242	80.67	86	133	87	142	88	122	397	132.33	51.67
814	1.520	22,200	50	85	82	24	83	14	84	46	84	28.00	86	55	87	58	88	60	173	57.67	29.67
901	0.700	11,000	35	84	81	7	82	14	83	17	38	12.67	85	17	86	21	87	19	57	19.00	6.33
902	2.082	23,100	45	85	82	110	83	99	84	145	354	118.00	86	152	87	150	88	105	407	135.67	17.67
2902	0.620	22,200	35	85	82	33	83	31	84	76	140	46.67	86	67	87	65	88	36	168	56.00	9.33
903	0.943	10,800	45	85	82	23	83	14	84	34	71	23.67	86	29	87	36	88	29	94	31.33	7.67
904	0.530	7,000	40	84	81	5	82	3	83	12	20	6.67	85	10	86	15	87	17	42	14.00	7.33
Totals 86 Sites	97.574 Miles					3585		3841		4349	11775			4797		5046		4999	14842		962.00

- Use the empirical Bayes method to adjust for regression-to-the-mean bias.

- Estimate the treatment effects using the EBEST procedure.

The accident analysis methods mentioned above can be used to estimate the effects of a treatment on accidents at a single site or for a group of sites. In this study, the methods were used to estimate safety effects for groups of sites. The design was not used to estimate the effect of speed limit changes on accidents at each individual experimental site because the small sample sizes at the majority of the sites revealed the results were not statistically significant. In other words, the individual samples were too small to determine if a real effect existed.

Estimates of the effects of speed limit changes on accidents were made for the following experimental and comparison groups:

- All (68) experimental and all (86) comparison sites.

- The 21 experimental sites where the speed limits were raised and the 29 corresponding comparison sites.

- The 47 experimental sites where the speed limits were lowered and the 57 corresponding comparison sites.

- Sites with low (less than 10,000), medium (10,000-20,000), and high (greater than 20,000) average daily traffic.

- Sites where speed limits were posted within 5 mi/h of the 85th percentile speed and sites where the speed limit was posted more than 5 mi/h below the 85th percentile speed.

Although it is possible to subdivide the sites into other groups, this was not done due to the small number of locations studied.

Accident Analysis Procedure

Prior to discussing the results, an example of the analysis procedure is provided in this section to assist the reader in understanding how the analysis was conducted. For purposes of illustration, the analysis described below estimates the safety effects of speed limit changes at the experimental sites shown in Table 2 utilizing the comparison site data shown in Table 3.

The first step in the analysis is to determine if the accident history for the comparison group is comparable to the accident history for the experimental group during the before and after periods. As an excellent discussion of the comparability procedure is provided by Griffin,[18] only a brief summary is included in this section.

To address the comparability question, the goodness of fit test is applied using the likelihood ratio chi-square (G) test as shown below:

$$G = -2 \sum_i \sum_j x_{ij} \ln \frac{\hat{m}_{ij}}{x_{ij}}$$

where:

x_{ij} = observed accident frequency in cell ij, row (i) and column (j)

$$\hat{m}_{ij} = \frac{x_{i+}x_{+j}}{x_{++}}$$

Shown in Figure 3 are total accidents plotted by year for the before and after periods for the experimental and comparison sites. Applying the above formula to the three before periods and to the three after periods produces the following results:

$$G_{Before} = 0.76$$

$$G_{After} = \underline{5.06}$$

$$G_{Comparability} = 5.82$$

Using four degrees of freedom and assuming a level of significance of 0.05, the critical chi-square value is 9.49. As the calculated chi-square of 5.82 is less than 9.49, there is no reason to doubt the comparability of the comparison group. In other words, during the before and after periods, accidents at the comparison and experimental sites changed at a similar rate.

Note, however, in Figure 3 that the rate of change in accidents from B1 (the year before the speed limit change) to A1 (the year after the change) is less for the experimental sites than it is for the comparison sites. This suggests that accidents at the experimental sites may have been reduced following implementation of the speed limit changes.

As accident histories during the before and after periods at the experimental and comparison sites were comparable, the next step in the analysis was to estimate the change in accidents following implementation of the speed limits. The paired comparison ratio method described by Griffin, the classical cross-product ratio, and the EBEST method were used to estimate safety effects.

The paired comparison ratio method estimates the overall effect of the speed limit changes on accidents using a weighted average log odds ratio based upon the individual log odds ratios of the accident counts at each treatment location. In addition, a chi-square test of homogeneity is used to determine if the treatment effects are consistent among the locations studied. A table illustrating application of the method for the sites where speed limits were raised is shown in Appendix C.

Excellent summaries of the paired comparison ratio method with examples are given by Griffin.[19, 21] Both Pendleton[20] and Griffin[18] provide good examples of the cross-product ratio. The EBEST methodology is not presented in this report as an excellent discussion is provided by Pendleton.[20]

The results of the paired comparison ratio analyses indicated that total accidents were reduced by 2.21 percent after speed limits were changed at the 68 experimental sites. The cross-product or odds ratio method suggested that accidents were reduced by 1.47 percent, while the EBEST estimate reveals a reduction of 1.58 percent.

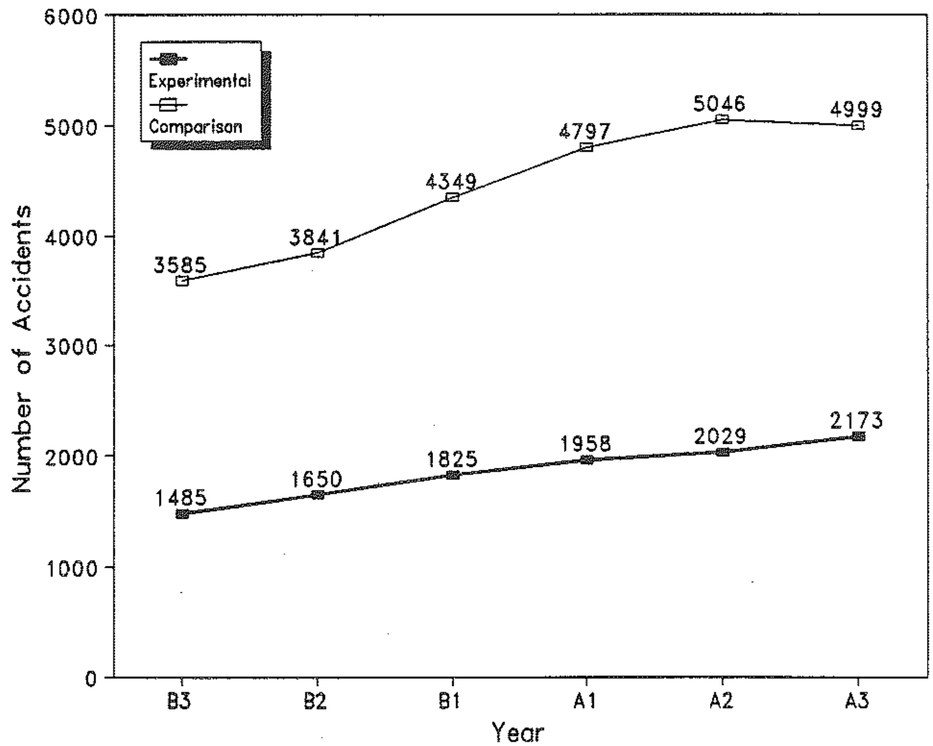

Figure 3. Total accidents by before and after period for all experimental and comparison sites.

Associated with each safety estimate are Z and p values (probability) and confidence limits which reflect the statistical significance of the results. The p values listed in this report reflect the level of significance of the Z values. For example, the Z value for the 2.21 percent reduction in accidents estimated by the paired comparison ratio method was -0.88. The p value associated with a Z of 0.88 is 0.38. Traditional interpretation suggests that the results are not statistically significant unless the p value is less than 0.10 or, in some cases, less than 0.05. The 95 percent confidence limits for the 2.21 percent accident reduction estimate ranges from a reduction of 6.89 percent to an increase of 2.80 percent.

For the accident data set, the EBEST method indicated the average shrinkage was 0.08 which suggests little regression-to-the-mean bias. Average shrinkage factors range from 0 (no regression-to-the-mean bias) to 1.0 indicating substantial bias. A factor of 0.08 suggests that speed zoning in Michigan during the period 1982 through 1986 was not conducted primarily at high-accident locations. Accordingly, the EBEST method and the cross-product ratio would be expected to produce similar results.

Accident Analysis Results

As shown in Table 4, in the three-year period prior to changing speed limits, 4,960 accidents were reported at the 68 experimental sites. In the three-year after period, 6,160 accidents occurred at these sites which represents an increase in accidents by a factor of 1.24. Clearly, total accidents increased at this group of sites after the speed limits were changed.

It is well known that safety is affected by other factors such as weather conditions, driver characteristics, increases in travel demand, etc. To account for the effects of these changes a comparison group was used. Accidents at the comparison sites increased from 11,775 in the before period to 14,842 in the after period, an increase by a factor of 1.26. Without conducting any statistical tests and assuming that the accident history at the comparison sites would have occurred at the experimental sites, the ratio (1.24/1.26) yields a 1.59 percent decrease in total accidents. These data suggest that speed zoning as currently practiced in Michigan may result in a small decrease in total accidents.

Table 4. Before and after accident summary.

Group	Number of Sites	Length, Miles	Total Accidents Before	Total Accidents After
Experimental	68	60.2	4,960	6,160
Comparison	86	97.6	11,775	14,842

As previously mentioned, the statistical analyses were conducted for all sites; sites where speed limits were raised; sites where speed limits were lowered; sites subdivided by traffic volume groups; and sites where the speed limits were posted within 5 mi/h of the 85th percentile speed and sites where the speed limits were posted less than 5 mi/h below the 85th percentile speed. A summary of the results is provided in Table 5. Except for one traffic volume group, the comparability tests indicated that the comparison site data can be used to estimate the accident effects at the experimental sites.

As shown in Table 5, results of the paired comparison ratio method indicates that the current method of setting speed limits in Michigan resulted in an overall decrease in accidents of approximately 2.2 percent. This result is not statistically significant by traditional interpretation as the level of confidence is 62 percent. In other words, in 62 times out of 100, chance alone would not have caused this difference. The cross-product method and EBEST estimate provides similar results.

The chi-square test of homogeneity in this case is large (131.38), which suggests that the speed limit effects were heterogeneous (inconsistence from site to site). In other words, changing the speed limit produced accident reductions at some sites and accident increases at other sites. This analysis indicates that there is no assurance that changing the posted speed limit will produce a 2.2 percent accident reduction at a given site. Because before and after speed data were not collected, it is not possible to determine which driver behavior factors lead to decreases in accidents at some sites and increases in accidents at other sites.

Table 5. Accident evaluation results.

Group	Number of Accidents Before	Number of Accidents After	Comparability G Value	Comparability Sign. p>0.05	Analysis Method	Percent Change In Accidents	Z Value	Significant At p Level	95 Percent Confidence Limits Lower	95 Percent Confidence Limits Upper	X^2 Homogeneity	Degrees of Freedom	Significant At p Level
All Sites													
68 Experimental	4,960	6,160	5.82	No	Paired Comp.	-2.21	-0.88	.38	-6.98	2.80	131.38	67	>0.001
86 Comparison	11,775	14,842			Odds Ratio	-1.47	-0.65	.52	-5.76	3.02			
					EBEST	-1.58	-0.84	.40					
Raise Speed Limit Sites													
21 Experimental	1,840	2,100	0.68	No	Paired Comp.	-3.05	-0.72	.47	-10.86	5.44	52.18	20	>0.001
29 Comparison	5,336	6,444			Odds Ratio	-5.49	-1.53	.13	-12.09	1.60			
					EBEST	-5.86	-1.90	.06					
Lower Speed Limit Sites													
47 Experimental	3,120	4,060	6.92	No	Paired Comp.	-1.75	-0.56	.58	-7.68	4.56	79.14	46	>0.001
57 Comparison	6,439	8,398			Odds Ratio	-0.23	-0.08	>.90	-5.74	5.61			
					EBEST	-0.15	-0.07	>.90					
<10,000 ADT Sites													
36 Experimental	779	1,029	26.48	Yes	Paired Comp.	9.98	1.37	.17	Results not reliable as accident changes at the experimental and comparison sites were not comparable.				
41 Comparison	4,493	5,481			Odds Ratio	8.28	1.54	.13					
10,000-20,000 ADT Sites													
22 Experimental	1,302	1,627	4.61	No	Paired Comp.	-8.87	-1.89	.06	-17.22	0.32	55.90	21	>0.001
27 Comparison	2,248	3,001			Odds Ratio	-6.39	-1.42	.16	-14.54	2.54			
>20,000 ADT Sites													
10 Experimental	2,879	3,504	6.88	No	Paired Comp.	-1.70	-0.52	.60	-7.87	4.89	31.76	9	>0.001
18 Comparison	5,034	6,380			Odds Ratio	-3.67	-1.19	.24	-9.42	2.46			
Posted Limit Within 5 Mi/h of 85th Percentile Sites													
45 Experimental	3,515	4,343	6.62	No	Paired Comp.	-3.45	-1.11	.27	-9.26	2.73	77.80	44	>0.001
57 Comparison	7,102	9,042			Odds Ratio	-2.95	-1.08	.28	-8.08	2.46			
Posted Limit More Than 5 Mi/H Below 85th Percentile Sites													
20 Experimental	1,006	1,227	0.53	No	Paired Comp.	0.47	0.09	>.90	-9.47	11.51	50.76	19	>0.001
26 Comparison	3,322	3,979			Odds Ratio	1.83	0.37	.71	-7.42	12.00			

As can be observed by examining Tables 2 and 3, several sites have a high number of accidents compared to the majority of sites. As the results of an weighted analysis of this type can be influenced by a few sites with a high number of accidents, a reexamination of the data was conducted. Accordingly, all sites which had more than 300 accidents in either the before or after period were eliminated. The paired comparison ratio method revealed a 2.98 percent reduction in accidents at the remaining sites (Z value = -0.88). In other words, the weights given to sites with a high number of accidents did not influence the results.

Although the number of sites is small, further analysis indicates that a small (3.05 percent) reduction in accidents occurred at sites where speed limits were raised. Perhaps surprising to those who feel that lower speed limits reduce accidents, the accident reduction at sites where speed limits were lowered appears to be quite small (1.75 percent) and statistically insignificant (42 percent level of confidence). Consequently, the accident reduction appears to be similar whether the speed limits were raised or lowered.

As speed zoning may affect accident experience on low-volume roads differently than it does on high-volume roads, the sites were subdivided by the traffic volume groups shown in Table 5. Due to sample size limitations, a further breakdown by speed limit category, i.e., raised or lowered, was not conducted. When the sites were subdivided by traffic volume group, the comparability tests indicated that the accident history at the comparison sites should not be used to estimate the speed limit effects at the experimental sites with less than 10,000 vehicles per day. Examination of the data revealed that the accident fluctuations at sites where speed limits were lowered were primarily responsible for the comparability problem. As the comparison sites were not comparable, the estimated accident effects for this volume group should be disregarded.

Although the number of sites is small, the accident analysis indicates that the speed limit changes at sites with 10,000 to 20,000 vehicles per day resulted in a statistically significant accident reduction of 8.87 percent. The 1.70 percent reduction in accidents at the 10 sites with more than 20,000 vehicles per day was not statistically significant. Again, the homogeneity tests suggests these results were not consistent from location to location.

Finally, the effect of posting speed limits within 5 mi/h of the 85th percentile speed on accidents was addressed. In this analysis, 85th percentile speeds taken from speed surveys conducted prior to each speed zoning change were obtained from Department records. The average 85th percentile speed in each zone was calculated and used in the analysis.

While the guideline used by the Michigan Department of Transportation suggests posting limits within 5 mi/h of the 85th percentile speed, due to political and community pressures and other nonquantitative considerations, this guideline is sometimes waived. In fact, based on the available data, speed limits posted at nearly 31 percent of the experimental sites and 23 percent of the comparison sites were not within the 5 mi/h guideline. In nearly all cases the limits were posted less than the 85th percentile speed.

As shown in Table 5, the accident analysis of all sites that were posted within the 5 mi/h guideline indicates that a 3.45 percent reduction in accidents occurred. This reduction was larger than experienced when all of the sites were included in the analysis.

Also, as shown in Table 5, lowering the speed limit more than 5 mi/h below the 85th percentile speed did not reduce accidents. The 0.47 percent increase in accidents at these sites was not statistically significant (p >0.90). It should be noted that the number of sites (20) available for this analysis was small.

Based on the results of this analysis, posting speed limits near the 85th percentile speed appears to provide a small beneficial reduction in accidents. Lowering speed limits well below the 85th percentile speed does not appear to reduce accidents. These results are illustrated in Figure 4.

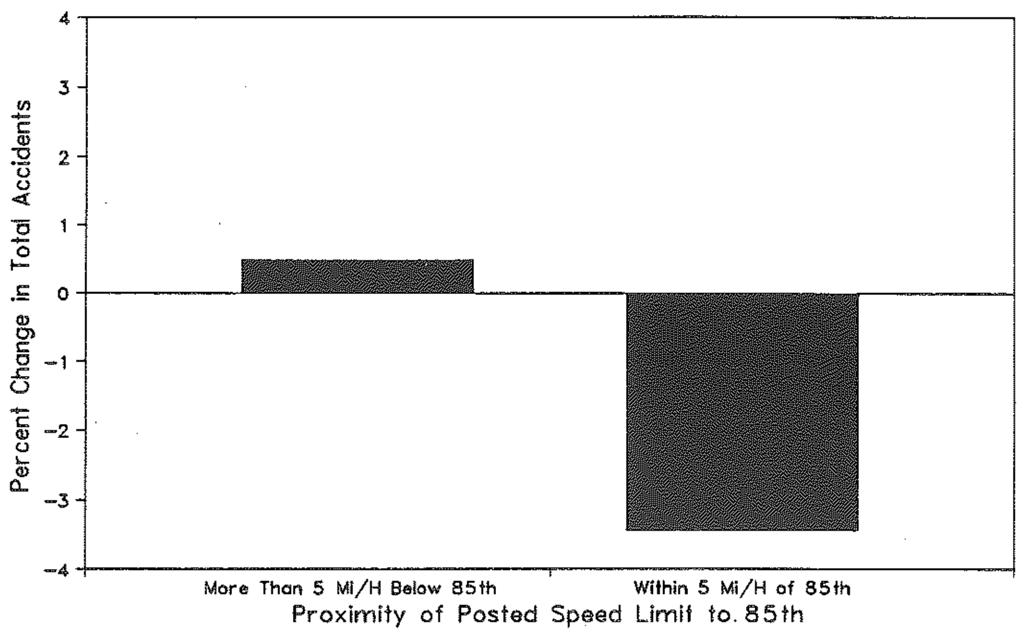

Figure 4. Effect on accidents of setting speed limits near and below the 85th percentile speed.

Discussion of Accident Findings

The results of the 3-year before and 3-year after accident analyses using paired comparison ratios indicate that the current speed zoning method practiced in Michigan reduced total accidents by 2.2 percent. The level of confidence of this estimate is 62 percent. Most statisticians would suggest that the result is not statistically significant unless the level of confidence was much higher such as 95 or 99 percent. Others may feel that the level is acceptable given the large number of accidents reported at the sites and the difficulties and deficiencies associated with using reported accident data to estimate the effectiveness of highway treatments.

It is important to note that none of the analyses indicated that the current Michigan speed zoning method led to a significant increase in accidents.

Regardless of statistical significance, there is a question of practical significance. Some safety managers would conclude that such a small reduction is insignificant compared to the effectiveness of other accident countermeasures. Others, including the author, are persuaded by the data to conclude that speed zoning in Michigan appears to have a small, beneficial effect on safety. This conclusion is reinforced by the results of other related work described below.

Although many transportation engineers and the public consider speed limits to be associated with improved highway safety, there have been very few studies of the effect of changing speed limits on accidents on nonlimited access highways. Kessler[22] found that when speed limits were raised at 30 locations in Illinois, the 85th percentile speeds were not changed, however, accidents decreased from 62 to 40. Wenger[23] examined accident experience at 25 locations in St. Paul, Minnesota and found that raising speed limits from 30 to 35 or 40 mi/h adversely affected accidents. Dudek and Ullman[17] recently examined the impacts of posting speed limits below the 85th percentile speed at 6 locations in Texas and found no conclusive effect on either travel speeds or accidents.

One problem with the previous research is the small sample sizes used to estimate the safety effects. The number of sites and the number of accidents was too small to determine if speed zoning had an effect on accidents, consequently the findings were generally described as not statistically significant.

The study with the largest number of sites conducted to date was recently completed by Parker.[24] The study included experimental sites where speed limits were changed and corresponding comparison sites. Before and after accident and speed data were collected for 99 nonlimited access highway sections in 22 states.

The analysis revealed that accidents on the 41 experimental sections where speed limits were raised were reduced by 6.7 percent after implementation of the speed limit changes. However, this reduction was not statistically significant ($Z = -0.82$). The chi-square test of homogeneity revealed that the accident reduction was consistent from site to site. At the 58 sites where speed limits were lowered, a 5.4 percent increase in accidents was found. The increase was not statistically significant ($Z = 0.59$). Further analysis of the data also revealed that setting speed limits much lower than the 85th percentile speed did not reduce accidents. In fact, accidents increased by 10.8 percent ($Z = 0.95$) at the 34 sites included in this analysis. These results are similar to the findings presented in this report.

In the nationwide study, the volume and number of accidents at the study sites were much lower than the volume and accident experience recorded at the Michigan sites. Also, the states and jurisdictions included in the study used a wide range of methods to set speed limits. Consequently, it is not possible to use the results of this FHWA study to estimate the effects of any particular speed zoning practice on accidents.

It is important to note that before and after speed data were not collected at the Michigan experimental and comparison sites. Consequently, the effects of the posted speeds on driver behavior at the Michigan sites are not known. The recent nationwide study by Parker[24] found little change in the speed distribution as a result of raising or lowering speed limits on urban and rural nonlimited access highways. Unless posted speed limits can be shown to have a large effect on driver behavior, it is unreasonable to expect that altering speed limits would have a large effect on accidents.

In summary, the results of this study indicate that the current speed zoning procedure in Michigan appears to have a small beneficial safety effect. The overall reduction in accidents at the 68 sites where speed limits were changed was 2.21 percent. The 95 percent confidence interval around this estimate ranges from a 7 percent reduction to a 3 percent increase in accidents. This result appears to be similar irrespective of the analysis method or how the data were categorized. The safety effects of speed limit changes were not consistent from site to site indicating that speed limit changes alone do not always reduce accidents.

Contrary to widespread popular belief, the results indicate that raising speed limits to the 85th percentile does not increase accidents. Also, arbitrarily lowering speed limits more than 5 mi/h below the 85th percentile speed does not reduce accidents. In fact, as shown in Figure 4, the most beneficial safety effect occurs when speed limits are posted within 5 mi/h of the 85th percentile speed.

COMPARISON OF SPEED ZONING METHODS

The accident analysis provided evidence that the current Michigan speed zoning procedure produced a small beneficial safety effect. To determine if any other quantitative speed zoning method was better than the Michigan method in establishing speed limits which could improve safety, a comparison of each selected method was conducted at the experimental sites listed in Table 2. To conduct the comparison, the sites were stratified into two groups based on a simple before and after accident analysis. The first group included all sites where accidents decreased, and the second group included sites where accidents did not change or increased.

To conduct a comparison of methods, data were collected using the criteria for each method. For example, the Ohio method requires determining the apparent design speed, length of the speed zone, the number of minor public highways and private access points, roadside businesses, and speed and accident data. The Oregon method required the 85th percentile speed, the statewide accident rate for similar facilities, and the accident rate at the site.

Following data collection, the recommended speed for each method was determined by applying each quantitative procedure. It should be noted that the data were collected and the speed recommendation was made for each method at each study site independent of other nonquantifiable effects such as public and political concerns that can influence the speed limit decision. Attempts were made to follow each method verbatim, using as little engineering judgment as possible. In determining the recommended speed, values were rounded to the nearest 5 mi/h increment, i.e., 42 mi/h was rounded to 40 mi/h. On occasion, some methods recommended speed limits less than 25 mi/h or greater than 55 mi/h. When this occurred, the limits were rounded to a minimum speed of 25 mi/h and a maximum speed of 55 mi/h. Some methods, such as Illinois, require use of the prevailing speed of free-flowing traffic which is defined as the average of the 85th percentile speed, upper limit of the pace, and average test run speed. The 85th percentile speed at the site was used in lieu of the prevailing speed because average test run speed data were not available for the Michigan sites.

Based on the results of each quantitative procedure, shown in Table 6 are the recommended speeds at sites where accidents decreased. The recommended speeds for sites where accidents did not change or increased are given in Table 7. Before data were not available for three sites.

Recommended Speed Limit Results

The data shown in Tables 6 and 7 are summarized in Table 8. At sites where accidents decreased, the other quantitative procedures recommended the speed limit posted at the site in less than one-third of the 18 sites in this group. Application of the Traffic Institute refined method produced the same limit as the Michigan procedure at only 4 sites (22 percent of the sites). The Traffic Institute minimum study recommended the same limit as the Michigan procedure at 8 sites (45 percent of the sites). At sites where accidents did not change or increased, the other methods again were poor at recommending the speed limit posted at each site. The Traffic Institute refined method produced the least replications (26 percent) of the Michigan limit, while the Ohic procedure produced the most (49 percent).

Table 6. Recommended speed limits at Michigan sites where accidents decreased.

Site No.	85th Pct. Speed	Posted Limit Before	Posted Limit After	Illinois Method	Ohio Method	Oregon Method	Traffic Institute Method Minimum	Traffic Institute Method Refined
2804	44	45	35	40	45	45	45	55
2602	53	55	45	50	50	55	55	55
2805	54	50	45	50	50	55	55	55
2807	46	55	45	40	45	45	45	55
1551	36	25	35	30	40	35	35	35
2808	36	45	35	30	35	30	35	30
2304	49	55	45	45	45	50	50	55
1454	43	35	40	35	40	45	40	45
2102	42	40	35	35	40	40	40	35
2505	40	40	35	30	35	40	40	30
1755	49	45	50	45	50	50	50	55
2504	42	55	35	40	45	40	40	45
1452	34	25	35	30	40	30	35	25
2802	57	50	45	45	50	55	55	50
2101	42	45	40	40	45	40	40	40
2507	39	40	35	35	45	40	40	40
1451	35	25	45	35	50	35	35	45
1351	47	40	45	45	50	45	45	50

The data were further examined to determine if the limit recommended by the other methods was lower or higher than the speed posted and these results are also given in Table 8. The Illinois method recommended limits lower than those posted in Michigan at approximately 50 percent of the sites. This result was similar for both accident groups. All of the other methods recommended higher speed limits than those posted in Michigan at approximately 50 percent of the sites.

The reason the Illinois procedure generally recommended limits lower than posted in Michigan is because the procedure permits reducing the speed limit below the prevailing speed due to factors such as access points, pedestrian activity, parking, and accident history. At the majority of Michigan sites, driveways and other entrances along the roadway permit at least a 10 percent reduction in speed. Pedestrian activity, parking, and accident rate seldom influenced the recommended speed at the Michigan sites. Apparently, the Illinois method was developed for roadway sections that are more rural than the Michigan sites included in this study. If the access conflict rate criteria were revised to permit a higher number of entrances, the recommended speeds would be much closer to the speed limits set under the Michigan procedure.

The Ohio procedure also appears to have been developed for roadways that are more rural, i.e., less roadside development and traffic demand, than found at the majority of Michigan sites. For example, Michigan sites tended to have more total accidents and driveway accidents than listed on the Ohio criteria. However, because there are four speed variables (design speed, pace, 85th percentile, and test run) and only two accident variables, the net result tended to produce a higher speed limit than used in Michigan.

Table 7. Recommended speed limits at Michigan sites where accidents stayed the same or increased.

Site No.	85th Pct. Speed	Posted Limit Before	Posted Limit After	Illinois Method	Ohio Method	Oregon Method	Traffic Institute Method Minimum	Traffic Institute Method Refined
1151	51	45	55	45	55	50	50	55
2104	49	55	45	40	50	40	50	35
1751	39	35	40	30	40	30	40	30
2501	52	55	45	50	55	50	50	55
2506	29	30	25	25	35	25	30	25
2202	43	55	45	40	50	45	45	55
2302	52	55	45	45	50	50	50	50
2301	50	55	45	40	45	40	50	40
1756	40	35	40	35	40	40	40	40
1453	51	25	45	45	50	50	50	45
2903	46	50	45	40	40	45	45	45
2401	49	55	45	45	45	50	50	50
1252	45	25	50	45	55	45	45	55
1251	52	45	50	45	50	50	50	55
2904	57	55	50	55	50	55	55	55
2601	44	45	40	40	40	45	45	45
2203	53	55	50	50	55	55	55	55
2103	35	35	25	30	35	25	35	25
2811	49	50	45	40	45	45	50	40
2608	50	55	50	45	45	50	50	50
2806	48	55	45	45	50	50	50	55
1758	39	30	40	30	40	30	40	30
2803	41	40	35	35	40	40	40	40
2303	54	55	45	50	50	55	55	55
2809	50	55	45	45	50	50	50	45
2201	50	55	45	45	50	50	50	55
2402	53	55	50	50	50	55	55	50
1753	41	35	40	35	40	40	40	35
2607	39	50	40	30	40	35	40	35
1152	41	35	40	35	45	40	40	40
2603	51	55	50	45	50	50	50	50
2605	39	45	35	35	45	40	40	45
2609	50	55	50	45	45	50	50	55
2814	46	55	45	40	45	45	45	50
2810	52	55	45	45	45	50	50	45
1153	46	35	40	40	40	45	45	55
1752	49	45	50	45	50	50	50	55
2403	47	45	40	40	40	45	45	45
2604	32	35	30	25	35	25	30	25
2902	52	50	45	45	45	50	50	55
2812	42	45	35	35	40	40	40	40
1757	34	30	35	30	35	35	35	30
1154	52	45	50	45	40	50	50	55
2606	33	40	30	25	35	25	35	25
2502	52	50	45	50	50	50	50	55
1951	41	35	40	35	40	40	40	45
2813	42	45	40	35	40	35	40	45

Table 8. Results of comparing speed zoning methods.

Category	Illinois No.	Illinois Pct.	Ohio No.	Ohio Pct.	Oregon No.	Oregon Pct.	Traffic Institute Minimum No.	Traffic Institute Minimum Pct.	Traffic Institute Refined No.	Traffic Institute Refined Pct.
Sites Where Accidents Decreased										
Limit same as Michigan	6	33	6	33	5	28	8	45	4	22
Limit higher than Michigan	4	22	12	67	10	55	9	50	11	61
Limit lower than Michigan	8	45	0	0	3	17	1	5	3	17
Total	18		18		18		18		18	
Sites Where Accidents Did Not Change or Increased										
Limit same as Michigan	17	36	23	49	17	36	19	40	12	26
Limit higher than Michigan	5	11	20	43	20	43	26	55	25	53
Limit lower than Michigan	25	53	4	8	10	21	2	5	10	21
Total	47		47		47		47		47	

The Traffic Institute minimum method is primarily based on the prevailing speed of traffic. At approximately 50 percent of the sites studied, the method recommended a higher speed limit than used in Michigan primarily because some of the Michigan limits were set lower than the prevailing speed, and also due to rounding speeds to the nearest 5 mi/h increment. The refined method also tended to recommend higher speeds than were posted in Michigan, but this is primarily due to the weights placed on parking activity, roadway alignment, and accident rate. The refined method only recommended the same speed as the Michigan method at sites with parking, pedestrian activity, horizontal curves, and a high accident rate.

In general, if any of the other quantitative speed zoning methods had been used at the Michigan experimental sites, they would have only produced the same limit as posted in Michigan at less than half the sites, irrespective of whether accidents decreased or increased.

The primary question, however, is if any of the other methods had been used, would the result have improved safety and motorist compliance with speed limits? The results of the accident analysis and comparison of methods were used to address this issue.

Shown in Table 9 is the frequency with which each procedure recommended a speed limit within 5 mi/h of the 85th percentile speed and within 7 mi/h. Also shown is the number of times the recommended limit was more than 5 mi/h higher or lower than the limit posted in Michigan.

At 69 percent of the Michigan sites, the posted limit was within 5 mi/h of the 85th percentile speed. If the Illinois method were used at the Michigan sites, only 49 percent of the locations would be within this guideline. Both the Ohio and Oregon methods would produce limits within 5 mi/h of the 85th percentile speed at 77 and 86 percent of the sites, respectively. Because the Traffic Institute minimum method is based on prevailing speed, all of the sites would be posted within 5 mi/h of the 85th percentile speed.

Table 9. Comparison of recommended speeds.

Category	Illinois No.	Illinois Pct.	Ohio No.	Ohio Pct.	Oregon No.	Oregon Pct.	Traffic Institute Minimum No.	Traffic Institute Minimum Pct.	Traffic Institute Refined No.	Traffic Institute Refined Pct.
Recommended limit within 5 mi/h of the 85th percentile speed	32	49	50	77	56	86	65	100	38	58
Recommended limit within 7 mi/h of the 85th percentile speed	55	85	60	92	59	91	65	100	50	77
Recommended limit more than 5 mi/h from the Michigan posted speed limit	5	8	8	12	8	12	7	11	19	29

At the Michigan sites, 89 percent of the posted limits were within 7 mi/h of the 85th percentile speed. With the exception of the Traffic Institute refined method, all of the other methods recommended limits within 7 mi/h of the 85th percentile speed at approximately 90 percent of the sites.

Finally, the recommended speeds were compared for each method to determine the number of times the recommended limit deviated by more than 5 mi/h from the limit that was actually posted at the site. As shown in Table 9, the Illinois, Ohio, Oregon, and Traffic Institute minimum method were only greater than 5 mi/h at approximately 10 percent of the sites. The Traffic Institute refined method showed deviations greater than 5 mi/h at 29 percent of the sites.

In summary, the quantitative speed zoning methods investigated in this study generally did not recommend the same limit posted at the majority of Michigan sites. The Ohio, Oregon, and Traffic Institute minimum study produced limits within 5 mi/h of the 85th percentile speed at over 75 percent of the sites which is slightly better than the 69 percent used in Michigan. All methods, including the current Michigan procedure, produced speed limits within 7 mi/h of the 85th percentile speed at approximately 90 percent of the sites studied.

Based on the accident analysis, which indicated the greatest reduction in accidents occurred at sites with speed limits posted within 5 mi/h of the 85th percentile speed, the Illinois and Traffic Institute refined methods would not improve safety at the Michigan sites. The Ohio, Oregon, and Traffic Institute minimum method could be expected to produce about the same safety effects as the current Michigan method, however, there are other problems associated with using these methods as discussed on pages 42 through 44.

DRIVER COMPLIANCE

For a speed limit to be effective, the majority of motorists should voluntarily comply with the posted limit. While no firm value has been established, a speed limit based on the 85th percentile speed is most often quoted[6] as a limit which would provide reasonable compliance.

Voluntary driver compliance can be measured by examining the distribution of free-flow vehicle speeds collected at a site during favorable traffic, roadway, and weather conditions. While actual compliance at any given roadway site varies with the speed distribution and posted limit, two examples from the Michigan sites are provided for discussion purposes.

The cumulative speed distribution for a four-lane divided facility located in an urban fringe area is shown in Figure 5. The 85th percentile speed, as determined from a 24-hour measurement of all vehicles with at least a 4-second headway, was 53 mi/h and the posted limit was 50 mi/h. As shown in Figure 6, approximately 73 percent of the motorists currently drive at or below the posted speed. If a 5 mi/h enforcement tolerance was used at the site to account for measurement errors, then no more than 8 percent of the motorists would be targeted for enforcement activity.

Because numerous studies indicate that changing speed limits have little effect on changing the speed distribution,[24-27] for illustration purposes it was assumed that the speed distribution for the example would not change. Accordingly, if the speed limit at this site was lowered to 45 mi/h as suggested by the Illinois procedure, then only 40 percent of the motorists would voluntarily comply with the limit, and at least 25 percent would be targeted for enforcement. As shown in Figure 6, if the limit were set at 40 mi/h, approximately 60 percent of the motorists would be targeted for enforcement.

Shown in Figures 7 and 8 are the cumulative speed distribution and percent compliance for a four-lane undivided site where the 85th percentile speed was 47 mi/h and the speed limit was posted at 40 mi/h. Current compliance with the speed limit is 37 percent and 25 percent of the motorists are exceeding the speed limit by more than 5 mi/h. If the limit were raised to 45 mi/h, then 75 percent of the drivers would comply with the limit and less than 5 percent would be targeted for enforcement.

These examples serve to illustrate that typically a 5 mi/h difference in the posted speed has a dramatic effect on driver compliance. In general, if speed limits are set within 5 mi/h of the 85th percentile speed, then at a minimum, 67 percent of the motorists would be in voluntary compliance. If the speed limits were set within 7 mi/h of the 85th percentile speed, it is possible that only 40 percent of the motorists would comply.

The Illinois method and the Traffic Institute refined method clearly would not improve driver compliance if used at the majority of sites in Michigan. The Ohio method, as well as the Traffic Institute minimum method, would increase the number of sites posted within 5 mi/h of the 85th percentile speed and, accordingly, could be expected to improve compliance. The same result could be achieved in Michigan by simply adhering to the 5 mi/h guideline already established.

ASSESSMENT OF QUANTITATIVE METHODS

The final effort was to make an overall assessment of the quantitative speed zoning methods and identify the procedure(s) which best improves safety, driver compliance, and meets other criteria.

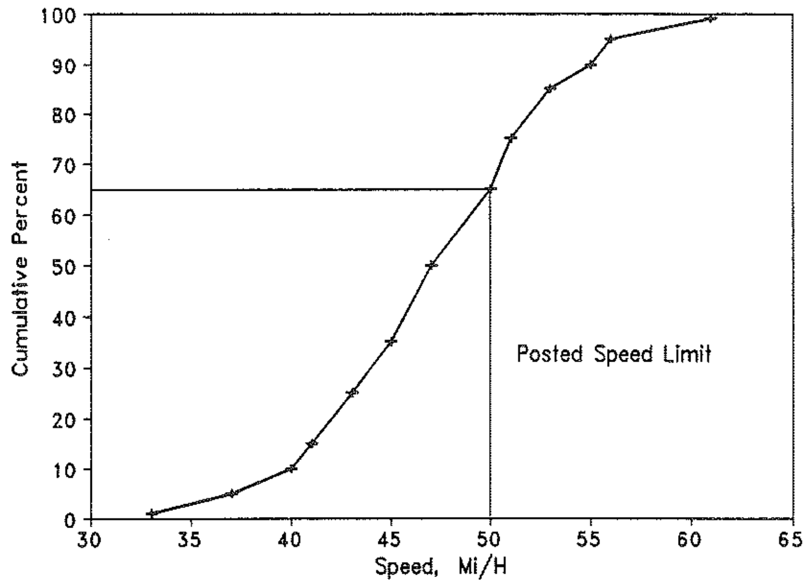

Figure 5. Cumulative speed distribution for a Michigan site posted at 50 mi/h.

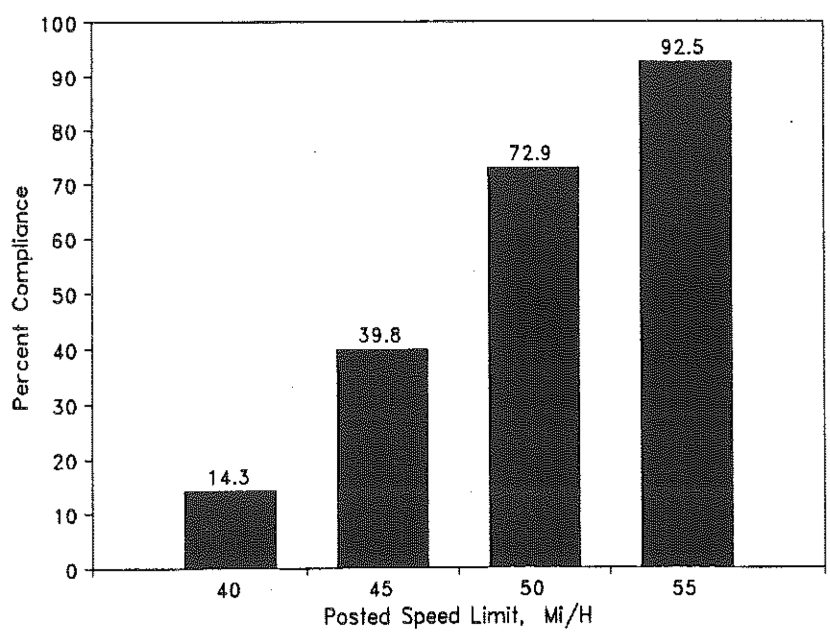

Figure 6. Motorist compliance at a Michigan site posted at 50 mi/h.

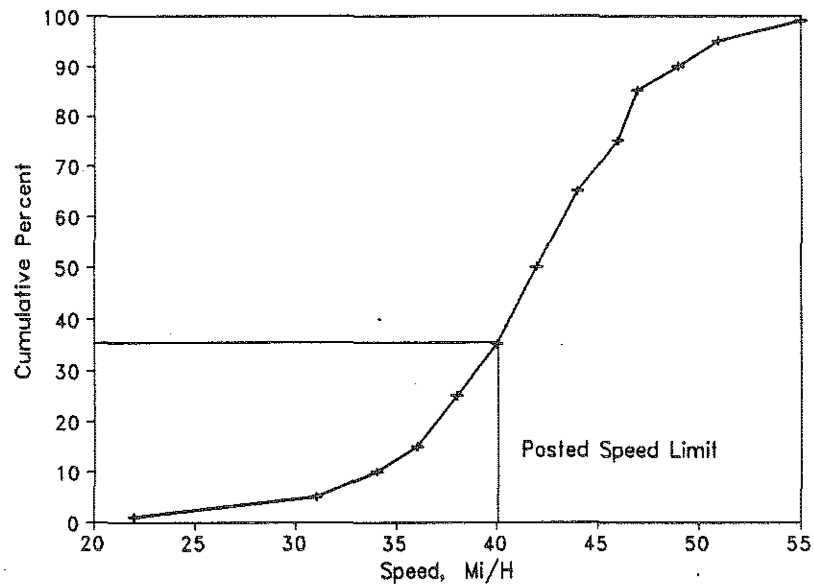

Figure 7. Cumulative speed distribution for a Michigan site posted at 40 mi/h.

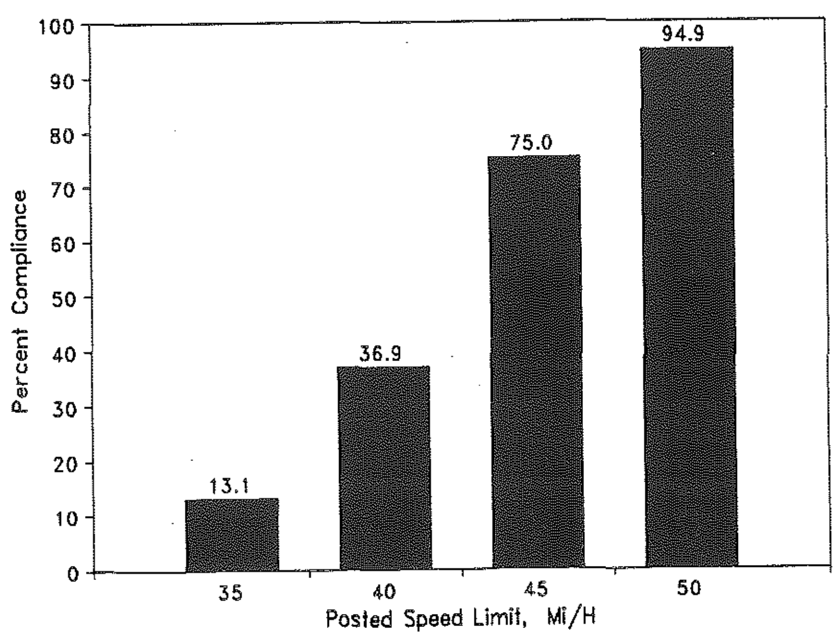

Figure 8. Motorist compliance at a Michigan site posted at 40 mi/h.

Based on the analysis of the data collected at the Michigan sites, the criteria for each method was rated as good, fair, or poor. A summary of the assessment is shown in Table 10. The criteria are defined and the results are discussed in the following sections.

Assessment Criteria

Safety Benefits

As the accident analysis indicated, the most favorable reduction in accidents occurred when speed limits were posted within 5 mi/h of the 85th percentile speed. Methods which recommended limits within 5 mi/h of the 85th percentile speed were graded as good. Methods which recommended limits similar to the current Michigan practice were rated as fair, while a poor rating was given to methods which recommended speeds much higher or lower than the current Michigan practice.

Minimize Accident Risk

A number of researchers[10, 12, 13, 28] found that a driver's risk of being involved in an accident is lowest when traveling between the upper and lower limits of the pace, referred to as the minimum risk band. The upper limit of the pace frequently coincides with the 85th percentile speed and at the most, is within 2 mi/h of the 85th percentile speed. Methods which recommended maximum speed limits in the upper region of the minimum risk band were rated as good. Methods which recommend limits below the upper region of the minimum risk band were rated as fair, and poor ratings were given to methods which recommended limits much higher or lower than the minimum risk band.

Voluntary Compliance

Voluntary driver compliance was rated as good when speed limits were set within 5 mi/h of the 85th percentile speed. Fair ratings were given to methods which recommended speeds within 7 mi/h of the 85th percentile speed, and poor ratings were given to methods that recommended limits much higher or lower than 7 mi/h.

Table 10. Assessment of speed zoning methods.

Category	85th Percentile ±5 Mi/H	85th Percentile ±7 Mi/H	Illinois	Ohio	Oregon	Traffic Institute Minimum	Traffic Institute Refined
Safety Benefits	Good	Fair	Poor	Fair	Fair	Good	Poor
Minimize Accident Risk	Good	Fair	Fair	Fair	Fair	Good	Poor
Voluntary Compliance	Good	Fair	Fair	Fair	Fair	Good	Poor
Reasonable and Fair	Good	Fair	Fair	Fair	Fair	Good	Poor
Repeatability	Good	Good	Fair	Fair	Good	Good	Poor
Reliability	Good	Good	Fair	Fair	Fair	Good	Poor
Easy to Use	Good	Good	Poor	Poor	Fair	Poor	Poor
Acceptability to Engineers	Good	Good	Fair	Fair	Fair	Fair	Poor
Acceptability to Public	Fair	Fair	Good	Good	Fair	Fair	Good
Cost-Effectiveness	Good	Good	Poor	Poor	Fair	Poor	Poor

Reasonable and Fair

A speed limit is generally considered reasonable and fair when set to reflect the speeds selected by the majority of responsible drivers. A limit is fair when it is set to permit the judicial system to effectively distinguish between reasonable drivers and high-risk drivers. Methods which place the posted speed within 5 mi/h of the 85th percentile speed were rated as good, while methods that do not meet this criteria were rated as fair. A poor rating was given to methods which set limits much greater than 5 mi/h above or below the 85th percentile speed.

Repeatability

A method is repeatable when different engineers, using the same procedure at the same site, arrive at the same conclusion. Assuming accurate speed data are collected, the methods which consider the 85th percentile as the only factor in setting a speed limit were rated as good. Due to the number of factors that require subjective judgment, other methods were rated as fair or poor.

Reliability

A method is defined as reliable when it recommends the same limit at different locations with similar traffic and roadway conditions. Methods which used the 85th percentile speed as the only factor were rated as good. Depending upon the number of factors considered, the other methods were rated as fair or poor.

Easy to Use

Methods such as the current Michigan procedure method were rated as good because they are easy to apply as the 85th percentile speed is the primary factor considered. A method was rated as fair if little additional data were required. Methods which required a number of other factors that increase data collection activities and may necessitate training were rated as poor.

Acceptability to Engineers

The majority of engineers with the responsibility of speed zoning need a method that is related to safety and operations, based on site-specific conditions, and is easy to use. Methods that meet these objectives were rated as good. Other methods were rated as fair or poor depending upon the number of objectives met.

Acceptability to the Public

Speed and speed zoning is an issue that affects all road users and adjoining property owners. In the past, many engineers have informed the public that it is the policy to use the 85th percentile speed to set speed limits, but often did not explain the safety and operational benefits. It is the author's experience in discussing the issue with the average citizen that the public would prefer to see methods that encompass a whole series of factors that may be unique to their particular roadway. The Illinois, Ohio, and Traffic Institute refined method meet this requirement and were rated as good. However, it should be noted that having a large number of factors considered is of little value unless safety or operational benefits are realized.

Cost-Effectiveness

Speed zoning methods that require only the use of the 85th percentile speed were rated as good because they are less time consuming and have fewer personnel requirements than methods which require a number of factors. The Illinois, Ohio, and Traffic Institute minimum and refined methods are the most expensive procedures on a per site basis and were rated as poor. The Oregon method was rated as fair as the only additional data required was a statewide accident rate and accident data for the study site.

Discussion of Methods

The following discussion is a brief critique of the quantitative methods studied based on the application of the method at the Michigan experimental sites.

Illinois and Missouri Methods

The Illinois and Missouri methods require collection of the prevailing speed of free-flowing traffic, as well as accident rate, number and type of driveways, pedestrian activity, and parking. The methods are the same except Missouri uses a statistical test to determine if accident reductions can be achieved by lowering the speed limit below the prevailing speed. If the accident reduction is significant, up to a 10 percent reduction in the prevailing speed is permitted.

Using the 85th percentile speed and upper limit of 10 mi/h pace is redundant as these two points typically coincide. The average test run speed, when properly determined, is time consuming. In conducting several test runs at selected Michigan sites, it was found that this procedure produces highly variable results due to the volume and traffic control features present at a site. Using the average test run speed based only on a few runs can produce highly variable results which can affect the prevailing speed. In the interest of accuracy and cost, it would appear that proper determination of the 85th percentile speed would be a better measure of prevailing speed.

As previously mentioned, the access conflict rates included in the Illinois and Missouri procedure permitted speed reductions at the majority of Michigan sites. This generally means that applying the procedure in Michigan would establish speed limits approximately 5 mi/h less than the method currently used. At 8 percent of the sites, the combination of access conflict, high-accident rate, pedestrian activity, and parking permitted a speed limit of 9 mi/h less than the 85th percentile speed.

The use of the Illinois and Missouri methods are not recommended in Michigan due to the data collection requirements, the tendency of the methods to set lower speed limits based on inappropriate access conflict criteria, and poor driver compliance.

Ohio Method

The Ohio method is based on five road condition and five traffic experience factors. The value of the factors and the weight assigned to each factor was developed over thirty years ago and the original source is unknown. Attempts to redevelop the factors based on the July 1961 Institute of Traffic Engineers report[9] were not successful.

The apparent design speed is a factor that requires considerable engineering judgment. In most cases, the 85th percentile speed is used as a surrogate for design speed. The Ohio method also includes the pace and average test run speeds. As mentioned in the discussion of the Illinois and Missouri methods, when properly conducted, these speed estimates approximate the same value and, therefore, are redundant.

The Ohio method permits a higher value (100) and consequently, a higher speed limit on sections less than a half mile in length. On sections greater than a half mile in length, the value of the factor is 75, thus, a lower speed limit may be permitted. This weighting procedure appears contradictory and suggests that perhaps the length criteria have been reversed.

The accident criteria (total accidents and driveway or intersection accidents) given in the Ohio procedure generally includes values that are much lower than found at typical Michigan speed zones. In addition, determining the public highways and private access points is somewhat subjective because it requires counting commercial buildings and homes on both sides of the highway. This is an especially difficult task in urbanized areas.

While the Ohio method would provide safety benefits and increase voluntary compliance, it is not recommended because the repeatability and reliability of the method was questionable at some of the sites investigated. In addition, the method is considerably more time consuming and expensive than the current Michigan procedure.

As of this writing, Ohio is revising its speed zoning criteria and the weights assigned to each factor. An evaluation of the effects of the new method is planned by the Ohio Department of Transportation.

Oregon Method

The Oregon method establishes speed limits based on the algebraic summation of the 85th percentile speed and the difference between the accident rate for similar statewide sections and the accident rate for the site under investigation. When the accident rate at the site is above the statewide rate, the speed limit is set below the 85th percentile speed. No adjustment is made when the accident rate at the site is less than the statewide rate.

As the majority of Michigan sites included in this study were not high accident locations, the Oregon method generally recommended speed limits within 5 mi/h of the 85th percentile speed. Due to large differences between the statewide accident rate and the accident rate at the sites, speed limits of less than 25 mi/h were recommended at 3 Michigan locations.

While the method may be conceptually appealing, there is no evidence to suggest that the difference between the statewide accident rate and the site accident rate is related to setting a safe and reasonable speed limit. The Oregon procedure is not recommended for implementation in Michigan as it can produce unreasonably low speed limits at sites where the accident rate is much greater than the statewide rate.

Traffic Institute Methods

The minimum method requires determining the 85th percentile speed, upper limit of the pace, and conducting five test runs in each direction. Weighting factors are used to compute the average value of the speed limit. Physical characteristics (design speed, distance between intersections, and length of proposed zone) are used to establish the maximum limit. The recommended speed is the lower of the two values. As previously mentioned, determining prevailing speeds by this method is expensive, time consuming, and the results may not be reliable unless more test runs are conducted. Therefore, the method is not recommended for use in Michigan.

The refined method involves collecting considerable additional data such as the number of commercial and noncommercial driveways per mile, lane width, shoulder type, pedestrian and parking activity, horizontal alignment, and accident rates. When applied to the Michigan sites, the method recommended speed limits 10 mi/h greater than (below and above) the 85th percentile speed at 29 percent of the sites. Sites with 12-foot lanes, no parking or horizontal curves, and low accident rates had higher recommended speeds using this method.

Based on years of experience with the refined method, Nevada does not recommend a speed limit higher than the minimum study recommendation or less than the 67th percentile speed.

Due to the additional costs required for data collection, the subjectivity in selecting the various factors, and the reliability of the results, this method is not recommended for implementation in Michigan.

RECOMMENDED PROCEDURE

Based on the need to establish a speed limit that improves safety, is reasonable and fair, encourages voluntary compliance by the majority of drivers, is repeatable, reliable, easy to use, and cost-effective, it is recommended that speed limits in Michigan be set within 5 mi/h of the 85th percentile speed. While this is the current guideline used by the Department, the data collected in this study suggests that this guideline was not used at 31 percent of the experimental sites and 23 percent of the comparison sites. Additional safety and operational benefits could be realized if speed limits were always set within 5 mi/h of the 85th percentile speed.

Based on the results of this study, speed limits established by this method could be expected to provide a small (3.5 percent accident reduction) beneficial effect on safety. Also, at a minimum, 67 percent of the motorists would be in voluntary compliance with the speed limit. If a 5 mi/h enforcement tolerance were generally used, no more than 10 percent of the motorists would be targeted for enforcement action. This would provide the judicial system with an objective method of discriminating between a high-risk violator and a reasonable driver.

Perhaps the only difficulty with using the 85th percentile speed method to set speed limits is that it is not basically understood by the majority of citizens. To explain the safety impacts and other benefits of the method, a public informational brochure should be developed and distributed.

As previously mentioned, accurate measurement of the 85th percentile speed at a site is important so that the decision maker can use these data to establish a safe and reasonable speed limit. In the next chapter, the time and location effects were examined and recommendations offered to improve current data collection and analysis procedures.

DETERMINATION OF TIME OF DAY AND LOCATION EFFECTS

INTRODUCTION

Based on an analysis of accidents, driver compliance, and other data collected on Michigan roadways, it was recommended that speed zones be established within 5 mi/h of the 85th percentile speed. When, where, and how speed samples should be taken to estimate the 85th percentile speed is the subject of this chapter.

Research results and observations by traffic personnel have long indicated that vehicle speeds, including the 85th percentile speed, are significantly affected by the time of day and the location of the speed study station at which the data are collected. For example, Shumate and Crowther,[29] reported a definite speed variation over a 24-hour day that could not be accounted for by chance alone. Hill[30] found a decrease in vehicle speeds after traffic signals were installed; Grahn[31] and others[32-33] reported on the effects of horizontal curvature on speeds; and Harkey[34] examined the relationship between driveways and speeds.

While previous research indicates that speeds are affected by time and location, there are few guidelines that suggest how these factors should be taken into account when collecting data to establish speed limits. Most of the studies pertaining to time and location effects were conducted over 30 years ago, and there is little information available that describes how large the effects are and what errors they may introduce into the results of speed zoning studies.

The objective of this effort was to determine the effects that time and location of the speed survey station have on the 85th percentile speed. In addition to estimating the size of the effects, recommendations are offered to illustrate how the effects should be considered when collecting data to establish speed limits in Michigan.

METHOD

The effects of time, location, and other factors were examined by collecting speed data on selected sections of Michigan State Trunkline which were speed zoned during the period 1982 through 1986. The sections did not include interstate or other limited access roadways subject to the national 65 mi/h speed limit.

After selecting speed zones representative of geometric design, traffic volume, and geographic conditions in Michigan, the location of the speed sample stations in each zone was selected based on an analysis of accident data and roadway geometry. Automated equipment was used to collect speed data for a 24-hour period at each station using one-hour recording intervals. Other data, including volume, the number of residential and commercial entrances, etc., were also collected.

The time of day effects were examined by comparing the hourly variations in the 85th percentile speed over a 24-hour period at each of the monitoring stations. The location effects, such as proximity to intersections, was examined by collecting speed data near the intersection and comparing the results with speed data collected at other stations located within the zone.

SITE SELECTION

To determine time and location effects, speed zones established on the Michigan trunkline system during the years 1982 through 1986 were reviewed and sections selected to represent a variety of roadway conditions as listed below.

- Geometry and traffic volume, i.e., two-lane and multilane sites with a wide range of flow conditions.
- Posted speed limits, ranging from 25 to 50 mi/h.
- Roadside development, i.e., variations in the amount and type of land use.
- Intersections and type of control, i.e., minor and major intersections, both unsignalized and signalized.

A field review was conducted to select the monitoring stations within each zone. The stations were selected specifically to examine location effects based on the geometry in each zone and the results of the accident analysis. Accident data for the three-year period 1987 through 1989 were collected for each zone and analyzed by location, type of collision, and time of accident. Stations were placed at locations with both high-accident and low-accident frequency.

A description of the speed zones, along with selected accident data, are summarized in Table 11. The study consisted of collecting speed data at 80 sampling stations within the 28 speed zone sections.

Speed data at each monitoring station were collected for a 24-hour period during a typical weekday. Data were not collected during holiday periods or inclement weather. Multiple speed measurements were taken at several locations to examine day of the week and seasonal effects.

The speed data were collected with Sarasota VC-1900 roadside units using either pneumatic tubes or inductive loop mats as vehicle sensors. In all cases, the speed data were collected by direction of travel. While total volume data were collected, only the speeds of free-flow vehicles (vehicles with a headway of four seconds or more) were measured. The data were recorded in 1-hour intervals for a 24-hour period. A typical output of the speed data is shown in Table 12.

TIME EFFECTS

The time effects examined in this study include hour of day, day of week, and season. The analysis and results of each effect are given in the following sections.

Hour of Day Effects

All 80 sampling stations were used to estimate the effects of hour of day on the 85th percentile speed. A summary of the speed data collected at each monitoring station is given in Table 13.

Table 11. Description of study locations.

Route	County	Locality	Posted Speed Limit	Site Length	Number of Lanes	Number of Approaches Res.	Number of Approaches Comm.	Number of Approaches Street	Approaches Per Mile	Traffic Signals	Total Acc.	Acc. Rate 1 MVM	Predominate Accident Time	Predominate Accident Type	No. Sta	Stat Code	Acc. Type Stat	Acc. at Stat	Station Descrp.
M-28BR	Marquette	Ishpeming	40	0.653	2	0	6	4	15.3	0	21	6.16	13-18	RE, AG	1	3C	High	11	Int
M-28BR	Marquette	Ishpeming	25	1.315	2+PK	25	16	22	47.9	2	104	14.40	9-18	PK, RE, AG	3	1E	Low	2	Rural
																1W	High	8	Hospital
																2E	High	13	Int
M-35	Marquette	Negaunee	45	1.620	2	25	5	7	22.8	0	18	5.97	Varies	HO, FO	2	1N	Low	2	Rural
																1S	Low	1	Resid
US-41	Marquette	Marquette	40	0.725	4-Dv	0	27	7	46.9	1	120	6.51	14-18	RE, AG	2	2E	Low	3	Int
US-41	Marquette	Marquette	50	0.755	4-Dv	9	27	4	53.0	1	114	5.94	14-17	RE, AG		1E	Avg	20	Comm
US-2	Schoolcraft	Manistique	35	0.813	2	3	20	6	35.7	1 Flash Yellow	26	3.70	10-16	RE, AG, FO	3	1E	Low	1	Int
																1W	Low	1	Int
																3W	Low	1	Curve
US-2	Schoolcraft	Manistique	45	1.400	2	6	26	3	25.0	0	17	1.32	14-22	HO, RE	2	2E	Low	1	Motel
																2W	Low	1	Motel
M-94	Schoolcraft	Manistique	25	1.300	2	38	39	19	73.8	1 Flash Red	103	16.09	9-19	RE, AG, FO	3	1S	Low	1	Int,Comm
																1N	Low	1	Int,Comm
																2S	Low	0	Resid
M-75	Charlevoix	Boyne City	45	0.795	2	3	31	4	47.8	0	21	3.05	9-17	HO, RE, OT	3	1C	Low	1	Comm
																2N	Low	2	Curve
																2S	Low	1	Curve
US-31	Grand Trav.	Traverse	40	0.709	4-UDv	13	2	16	43.7	1	221	11.97	8-19	RE, AG	3	1N	Low	7	Int,Res
																1S	Low	7	Int,Res
																2S	High	14	Maj Int
US-31	Grand Trav.	Traverse	30	0.687	4-UDv	16	20	25	88.8	3	235	14.11	9-19	RE, AG	4	2N	High	19	Maj Int
																3N	High	40	Sig Int
																3S	High	40	Sig Int
																4N	Low	1	Church
BL-75	Otsego	Gaylord	50	1.695	4-TWL	9	76	13	57.8	1	63	2.03	11-19	AG, RE	5	1N	Low	1	Comm
																2N	Low	1	Comm
																1S	Low	1	Comm
																2S	Avg	6	Sig Int
																3S	Low	2	Comm
M-18	Roscommon	Denton	45	0.750	2	34	2	4	53.3	0	9	5.72	20-22	AM	1	1C	Low	0	Resid
M-18	Roscommon	Denton	40	0.769	2	15	12	10	48.1	0	11	1.68	Varies	AM, FO, RE	2	2N	Low	1	Resid
																2S	Low	1	Resid

Table 11. Description of study locations (continued).

Route	County	Locality	Posted Speed Limit	Site Length	Number of Lanes	Number of Approaches Res.	Comm.	Street	Approaches Per Mile	Traffic Signals	Total Acc.	Acc. Rate 1 MVM	Predominate Accident Time	Type	No. Sta	Stat Code	Acc. Type Stat	Acc. at Stat	Station Descrp.
M-55	Roscommon	Lake Twp	40	0.425	4-UDv	8	32	8	112.9	0	25	4.14	10-17	RE	1	3E	Low	2	Motel
M-55	Roscommon	Lake Twp	40	2.739	4-UDv	40	118	42	73.0	0	183	4.02	12-19	RE, FO, AG	1	2E	Low	1	Bank
M-55	Roscommon	Lake Twp	40	1.579	4-UDv	25	79	24	81.1	0	109	3.93	9-19	RE, AM, FO	2	1E	Low	1	Light
																1W	Low	1	Light
M-24	Lapeer	Lapeer	50	1.750	2	45	14	7	37.7	0	181	5.75	7-19	RE, AG, FO	5	4N	High	7	Int
																3S	Low	1	Resid
																3N	Low	1	Resid
																2S	High	12	Int
																2N	High	12	Int
M-24	Lapeer	Lapeer	50	0.500	2-TWL	3	32	3	76.0	1 Flash Yellow	33	4.36	Varies	FO, AM	2	1N	Avg	7	Comm
																1S	Avg	7	Comm
M-50	Lenawee	Tecumseh	40	0.619	2-TWL	6	51	5	100.2	1	102	7.53	11-21	RE, AG	3	3E	Low	1	Comm
																3W	Low	1	Comm
																4E	Low	4	Trans
M-50	Lenawee	Tecumseh	30	0.700	4-Dv	31	13	17	87.1	3	175	11.76	8-19	AG, RE	4	2E	Avg	4	Int,Res
																2W	Avg	4	Int,Res
																1E	Avg	6	Int,Res
																1W	Avg	6	Int,Res
M-36	Livingston	Hamburg	40	0.653	2	11	28	4	65.8	1	70	10.16	13-20	AG, RE, FO	3	1E	Low	3	Curve
																1W	Low	3	Curve
																2W	High	11	Cur, Com
M-36	Livingston	Hamburg	45	2.509	2	29	16	10	21.9	1 Flash Yellow	86	4.16	Varies	OT, FO, AG	4	3E	Low	1	Rural
																3W	Low	1	Rural
																4E	Low	2	Rural
																4W	Low	2	Rural
US-12	Washtenaw	Pittsfield	45	0.849	2	9	14	8	36.5	2	188	7.72	8-20	AG, RE	3	2W	Low	1	Comm
																2E	Low	1	Comm
																3E	High	9	Sig Int
US-12	Washtenaw	Pittsfield	45	1.340	2	15	19	12	34.3	1	114	3.41	10-19	RE, FO	3	3W	High	28	Sig Int
																1E	Low	1	Res
																1W	Low	1	Res
M-52	Washtenaw	Chelsea	45	0.683	2	13	0	6	27.8	0	5	0.56	Varies	RE	5	2N	Low	0	Int
																2S	Low	0	Int
																3N	Low	0	Resid
																1N	Low	0	Resid
																1S	Low	0	Rural

Table 11. Description of study locations (continued).

Route	County	Locality	Posted Speed Limit	Site Length	Number of Lanes	Number of Approaches Res.	Comm.	Street	Approaches Per Mile	Traffic Signals	Total Acc.	Acc. Rate 1 MVM	Predominate Accident Time	Type	No. Sta	Stat Code	Acc. Type Stat	Acc. at Stat	Station Descrp.
US-24	Wayne	Flat Rock	50	1.967	4-UDv	20	64	12	48.8	2	232	4.85	12-20	RE, AG, FO	6	4S	Low	1	Light
																3S	Low	1	Light
																2S	High	16	Motel
																2N	Low	1	Comm
																1N	Low	2	Cemetery
																1S	Low	1	Rural
I-75 Conn	Wayne	Woodhaven	50	1.500	4-TWL	21	25	4	33.3	0	98	4.36	Varies	AG, RE, FO	4	1N	Low	0	Rural
																2N	Low	1	Int
																2S	Low	2	Int
																1S	Low	0	Rural
28 Sections				31.799 Miles											80 Stations				

Note: The following abbreviations are used in the table.

Number of Lanes
- PK=Parking
- Dv=Divided
- UDv=Undivided
- TWL=Two-Way Left-Turn Lane

Accident Type
- RE=Rear End
- AG=Angle
- PK=Parking
- HO=Head On
- FO=Fixed Object
- AM=Animal
- OT=Overturned

Table 12. Typical speed data collected at a monitoring station.

SITE NUMBER - 02402S   AREA AND ROAD TYPE - Urban Transition Two-Lane With TWLTL

STATE - Michigan   JURISDICTION - Lapeer County (Mayfield Twp.)

ROUTE - M-24 MP 2.34   DIRECTION - Southbound   CHANNEL NUMBER - 1

SPEED LIMIT - 50 MPH   FREE-FLOW GAP = > 4 Seconds   LONG VEHICLE LENGTH = 0 Feet

BEGINNING DATE - October 31, 1990   RECORDING INTERVAL - 1 Hour

ALL VEHICLES

END TIME PERIOD	MEAN SPEED MPH	STD DEV MPH	TOTAL VOL.	FREE FLOW VOL.	PCT. FREE FLOW	PERCENTILE SPEEDS, MPH 1	5	10	15	25	35	50	65	75	85	90	95	99	PERCENT EXCEEDING SPEED LIMIT BY (MPH) 0	5	10	15	20	10 MPH LL	10 MPH UL	PACE PCT.	SKEW. INDEX
1500	47.6	7.2	499	298	59.7	23	33	40	42	45	48	50	51	52	54	55	57	60	40.9	8.1	0.7	0.0	0.0	47	56	66.1	0.63
1600	47.5	8.6	773	497	64.3	20	26	37	42	46	48	50	52	53	55	56	58	62	43.7	12.3	2.0	0.2	0.0	47	56	63.8	0.48
1700	47.4	7.8	435	260	59.8	22	28	39	41	45	47	50	51	53	55	56	58	60	42.3	12.3	0.8	0.0	0.0	47	56	62.7	0.60
1800	47.6	7.6	366	260	71.0	20	28	40	43	46	48	50	51	52	54	55	57	59	43.1	8.8	0.8	0.0	0.0	46	55	68.8	0.60
1900	47.1	6.7	298	211	70.8	23	32	42	43	45	47	49	50	51	53	55	56	58	31.3	5.7	0.0	0.0	0.0	43	52	70.6	0.71
2000	47.2	8.8	178	151	84.8	22	25	38	42	46	47	49	51	53	55	57	58	61	39.1	13.9	2.0	0.0	0.0	44	53	63.6	0.53
2100	47.6	7.9	218	176	80.7	21	26	41	43	46	48	50	51	52	54	56	57	60	39.2	11.4	1.1	0.0	0.0	47	56	69.3	0.43
2200	48.8	6.4	201	167	83.1	23	42	43	45	47	48	50	51	53	55	55	58	62	41.9	10.2	1.8	0.0	0.0	46	55	73.1	0.86
2300	49.1	7.8	157	127	80.9	19	29	42	43	46	49	51	53	55	56	57	58	63	50.4	22.0	2.4	0.8	0.0	48	57	66.9	0.67
0	50.3	6.7	94	85	90.4	24	37	44	47	49	50	51	52	55	56	57	60	63	50.6	20.0	4.7	1.2	0.0	48	57	71.8	0.84
100	47.0	9.3	36	35	97.2	22	23	34	40	45	47	50	51	53	56	57	57	59	40.0	20.0	0.0	0.0	0.0	47	56	60.0	0.41
200	47.3	8.1	35	32	91.4	30	36	37	38	41	44	49	52	53	54	55	56	68	40.6	9.4	6.3	3.1	0.0	47	56	53.1	0.70
300	48.9	9.2	30	30	100.0	21	22	40	44	47	48	51	53	55	56	57	58	64	53.3	16.7	3.3	0.0	0.0	47	56	66.7	0.39
400	50.7	6.6	41	39	95.1	24	40	46	47	48	50	52	53	55	56	57	60	66	56.4	23.1	5.1	2.6	0.0	47	56	71.8	0.92
500	50.1	6.3	268	182	67.9	20	41	43	45	48	50	52	53	55	56	57	59	63	59.3	17.6	2.2	0.0	0.0	47	56	70.9	0.67
600	51.2	6.2	523	271	51.8	26	40	45	47	50	51	52	54	55	57	57	59	62	68.3	22.5	3.7	0.0	0.0	48	57	74.5	0.88
700	50.4	6.3	683	312	45.7	23	42	45	47	49	50	51	53	55	56	57	58	63	55.8	17.0	2.2	0.3	0.0	48	57	75.6	0.92
800	50.5	6.9	625	320	51.2	23	39	45	47	49	50	52	53	55	56	57	59	62	62.2	23.4	3.1	0.0	0.0	48	57	74.7	0.75
900	49.4	7.6	522	283	54.2	22	30	42	45	48	50	51	53	55	56	57	58	61	55.1	19.1	1.8	0.0	0.0	48	57	70.0	0.78
1000	46.9	8.8	481	271	56.3	21	25	31	42	46	47	49	51	52	54	55	57	61	39.5	10.0	1.8	0.0	0.0	46	55	65.7	0.53
1100	47.4	7.8	422	260	61.6	22	28	38	42	45	47	50	51	52	55	55	57	61	40.8	9.6	1.9	0.0	0.0	44	53	63.8	0.50
1200	46.9	8.2	397	262	66.0	21	25	38	42	45	47	49	51	52	54	55	56	59	38.9	8.8	0.4	0.0	0.0	47	56	67.2	0.52
1300	47.7	6.9	419	272	64.9	24	34	40	43	45	47	50	51	52	54	55	56	61	40.8	7.4	1.5	0.0	0.0	44	53	68.8	0.67
1400	46.9	7.4	499	293	58.7	20	30	39	42	45	47	49	51	52	53	55	56	58	36.5	6.5	1.0	0.0	0.0	44	53	68.3	0.63
TOTALS																											
PERIODS 24	48.3	7.6	8200	5094	62.1	22	30	41	44	47	48	50	52	53	55	56	58	61	46.2	13.1	1.8	0.1	0.0	47	56	66.9	0.74

Table 13. Summary of speed data.

Route	County	Locality	Posted Speed Limit	Stat Code	Station Descrp.	Volume Counted	85th Pct. Speed	24-Hr 85th Low	24-Hr 85th High	24-Hr Diff.	8AM-5PM 85th Low	8AM-5PM 85th High	8-5 Diff.	Speed Std. Dev.	Pct. Pace	Skew Index
M-28BR	Marquette	Ishpeming	40	3C	Int	4,770	42	40	44	4	42	43	1	8.1	55.6	0.67
M-28BR	Marquette	Ishpeming	25	1E	Rural	2,123	38	35	40	5	37	40	3	5.0	75.6	0.92
				1W	Hospital	2,507	33	30	35	5	32	35	3	4.3	77.3	1.08
				2E	Int	2,108	32	29	33	4	31	33	2	4.2	80.0	0.91
M-35	Marquette	Negaunee	45	1N	Rural	850	53	49	57	8	51	57	6	8.0	57.1	0.78
				1S	Resid	855	50	47	53	6	47	52	5	7.3	57.9	0.90
US-41	Marquette	Marquette	40	2E	Int	1,860	51	48	52	4	51	52	1	6.1	67.1	0.94
US-41	Marquette	Marquette	50	1E	Comm	11,610	53	50	59	9	51	56	5	6.0	61.2	1.00
US-2	Schoolcraft	Manistique	35	1E	Int	3,188	51	50	52	2	50	52	2	8.3	61.4	0.75
				1W	Int	4,398	47	45	51	6	45	49	4	9.3	61.9	0.48
				3W	Curve	3,947	49	47	56	9	47	50	3	7.1	63.4	0.89
US-2	Schoolcraft	Manistique	45	2E	Motel	4,194	54	51	58	7	52	55	3	6.8	67.7	0.78
				2W	Motel	3,927	54	51	58	7	52	55	3	7.8	67.9	0.64
M-94	Schoolcraft	Manistique	25	1S	Int,Comm	2,248	32	31	36	5	31	36	5	7.4	54.9	0.86
				1N	Int,Comm	1,940	32	30	36	6	30	34	4	5.6	69.3	0.93
				2S	Resid	1,676	36	33	38	5	35	38	3	5.1	72.2	1.00
M-75	Charlevoix	Boyne City	45	1C	Comm	7,917	47	45	55	10	45	49	4	6.4	62.4	1.00
				2N	Curve	4,170	45	44	50	6	44	48	4	7.8	59.7	0.58
				2S	Curve	4,485	40	35	42	7	38	42	4	4.9	72.0	0.92
US-31	Grand Trav.	Traverse	40	1N	Int,Res	11,890	45	44	47	3	45	46	1	5.6	71.1	1.00
				1S	Int,Res	10,714	45	44	47	3	44	46	2	5.0	70.5	1.00
				2S	Maj Int	10,134	43	41	45	4	41	43	2	5.1	71.0	1.00
US-31	Grand Trav.	Traverse	30	2N	Maj Int	11,073	43	42	52	10	42	44	2	5.6	65.3	1.00
				3N	Sig Int	11,451	40	38	44	6	38	40	2	8.5	61.7	0.59
				3S	Sig Int	10,981	38	37	43	6	37	39	2	9.0	53.5	0.64
				4N	Church	9,897	41	40	44	4	40	43	3	5.1	71.6	1.00
BL-75	Otsego	Gaylord	50	1N	Comm	8,342	55	51	57	6	54	56	2	7.4	63.6	0.78
				2N	Comm	5,549	53	49	55	6	51	55	4	7.0	64.3	0.89
				1S	Comm	8,367	51	49	58	9	49	53	4	7.9	45.4	0.96
				2S	Sig Int	8,069	50	48	57	9	48	53	5	7.1	51.0	1.00
				3S	Comm	8,868	53	52	57	5	52	53	1	5.8	67.4	1.00
M-18	Roscommon	Denton	45	1C	Resid	1,917	53	49	58	9	51	56	5	7.3	53.0	1.00
M-18	Roscommon	Denton	40	2N	Resid	3,896	46	40	56	16	40	46	6	5.3	69.3	1.07
				2S	Resid	4,325	51	49	56	7	49	53	4	5.9	67.2	1.00
M-55	Roscommon	Lake Twp	40	3E	Motel	6,484	47	45	50	5	46	48	2	6.3	65.4	0.94
M-55	Roscommon	Lake Twp	40	2E	Bank	7,591	48	46	50	4	47	49	2	5.6	68.1	0.88
M-55	Roscommon	Lake Twp	40	1E	Light	8,022	50	48	55	7	49	50	1	5.5	69.1	0.93
				1W	Light	7,975	50	45	54	9	48	50	2	5.3	71.3	0.93
M-24	Lapeer	Lapeer	50	4N	Int	9,491	53	50	55	5	52	55	3	10.8	60.2	0.41
				3S	Resid	8,216	58	56	59	3	57	59	2	5.1	75.6	1.14
				3N	Resid	8,044	59	57	61	4	58	60	2	5.1	74.7	0.92
				2S	Int	8,200	55	53	57	4	53	55	2	7.6	66.9	0.74
				2N	Int	8,226	55	53	58	5	53	57	4	10.1	59.8	0.44
M-24	Lapeer	Lapeer	50	1N	Comm	6,919	58	56	62	6	57	61	4	6.4	67.9	0.82
				1S	Comm	845	55	55	55	0	55	55	0	7.5	66.9	0.67
M-50	Lenawee	Tecumseh	40	3E	Comm	9,987	42	40	45	5	40	44	4	5.5	74.8	0.86
				3W	Comm	9,978	41	40	45	5	40	43	3	5.5	72.0	0.93
				4E	Trans	10,099	42	40	44	4	42	44	2	4.4	78.7	1.00
M-50	Lenawee	Tecumseh	30	2E	Int,Res	9,707	39	37	40	3	39	40	1	4.1	80.5	1.00
				2W	Int,Res	10,058	40	38	42	4	39	41	2	4.7	78.6	1.08
				1E	Int,Res	7,675	36	35	38	3	35	38	3	4.0	82.2	1.09
				1W	Int,Res	8,284	37	35	39	4	36	38	2	4.2	82.2	0.91
M-36	Livingston	Hamburg	40	1E	Curve	4,820	50	49	52	3	49	51	2	4.2	79.7	1.00
				1W	Curve	4,592	53	50	55	5	52	55	3	5.0	74.3	1.00
				2W	Cur, Comm	5,127	43	42	47	5	42	45	3	7.3	58.3	0.73
M-36	Livingston	Hamburg	45	3E	Rural	3,762	49	47	50	3	47	49	2	4.5	81.6	0.83
				3W	Rural	3,670	48	46	51	5	47	50	3	4.9	74.5	0.92
				4E	Rural	2,236	56	53	60	7	53	60	7	5.6	63.4	1.13
				4W	Rural	2,532	60	58	62	4	58	61	3	5.7	66.4	1.06

Table 13. Summary of speed data (continued).

Route	County	Locality	Posted Speed Limit	Stat Code	Station Descrp.	Volume Counted	85th Pct. Speed	24-Hr 85th Low	24-Hr 85th High	24-Hr Diff.	8AM-5PM 85th Low	8AM-5PM 85th High	8-5 Diff.	Speed Std. Dev.	Pct. Pace	Skew Index
US-12	Washtenaw	Pittsfield	45	2W	Comm	13,092	53	50	59	9	50	53	3	6.3	68.4	0.94
				2E	Comm	13,284	52	48	59	11	48	52	4	6.3	63.2	0.89
				3E	Sig Int	13,594	50	45	56	11	45	50	5	9.5	47.0	0.74
US-12	Washtenaw	Pittsfield	45	3W	Sig Int	11,403	51	50	55	5	50	53	3	6.0	68.6	0.88
				1E	Res	11,762	55	53	57	4	53	56	3	8.0	65.5	0.78
				1W	Res	11,268	55	53	57	4	53	55	2	7.0	69.6	0.78
M-52	Washtenaw	Chelsea	45	2N	Int	5,931	46	43	48	5	45	48	3	5.6	72.7	0.86
				2S	Int	5,882	48	43	50	7	47	50	3	4.9	74.4	1.08
				3N	Resid	5,754	50	46	51	5	50	51	1	4.9	73.9	0.86
				1N	Resid	5,573	55	48	58	10	54	58	4	5.2	68.5	0.93
				1S	Rural	5,510	57	53	59	6	57	59	2	5.6	66.0	1.13
US-24	Wayne	Flat Rock	50	4S	Light	11,103	55	52	57	5	54	56	2	5.9	63.7	0.82
				3S	Light	7,474	54	51	56	5	53	55	2	6.1	67.1	0.94
				2S	Motel	11,484	55	52	58	6	54	55	1	7.8	64.5	0.80
				2N	Comm	9,172	57	55	59	4	55	57	2	6.0	64.9	0.94
				1N	Cemetery	13,312	57	55	58	3	56	57	1	6.3	65.9	1.00
				1S	Rural	12,577	57	56	58	2	56	58	2	5.3	70.6	1.00
I-75	Wayne	Woodhaven	50	1N	Rural	6,846	61	58	63	5	60	62	2	6.2	64.2	0.88
Conn				2N	Int	6,894	59	56	61	5	58	61	3	7.9	57.8	0.80
				2S	Int	6,322	60	54	61	7	57	61	4	6.1	68.7	0.88
				1S	Rural	8,064	61	55	63	8	59	63	4	5.6	68.1	0.93
28 Sections										5.7 Avg.			2.9	Avg.		

To examine time of day effects at a station, the 85th percentile speeds were plotted by hour of the day. The plot for each station was compared to plots for other stations to identify trends and/or differences. Prior to presenting the results, an example illustrating the method is shown below.

Shown in Figure 9 are the 85th percentile speeds by hour, as well as the 24-hour 85th percentile speed for monitoring station 1E located on US-41 near Marquette. The hourly 85th percentile speed is the 85th percentile speed of all free-flow vehicles recorded during a one-hour period. For example, as shown in Figure 9, between midnight and 1:00 a.m., the 85th percentile speed is 51 mi/h. The 24-hour 85th percentile speed is the 85th percentile speed of all free-flow vehicles recorded during a 24-hour period. In Figure 9, the 24-hour 85th percentile speed is 53 mi/h, which is represented by a horizontal line.

The hourly 85th percentile speeds at this site vary considerably depending on time of day. During the 24-hour period, there was a 9 mi/h (from 50 to 59 mi/h) difference in the hourly 85th percentile speed. As shown in Figure 10, the mean speed also varies at this location, closely paralleling the fluctuations in the 85th percentile speed. Other parameters of the speed distribution follow these general patterns.

The hourly 85th percentile speeds at this site are higher than the 24-hour 85th percentile speed during the hours 3:00 a.m. to 11:00 a.m. The hourly speeds are lower than the 24-hour 85th percentile speed from 1:00 p.m. throughout the rest of the day. If speed data were taken at this site during the morning hours, the sample would tend to overestimate the 24-hour 85th percentile speed; however, if the data were collected in the afternoon, the 85th percentile speed would be underestimated.

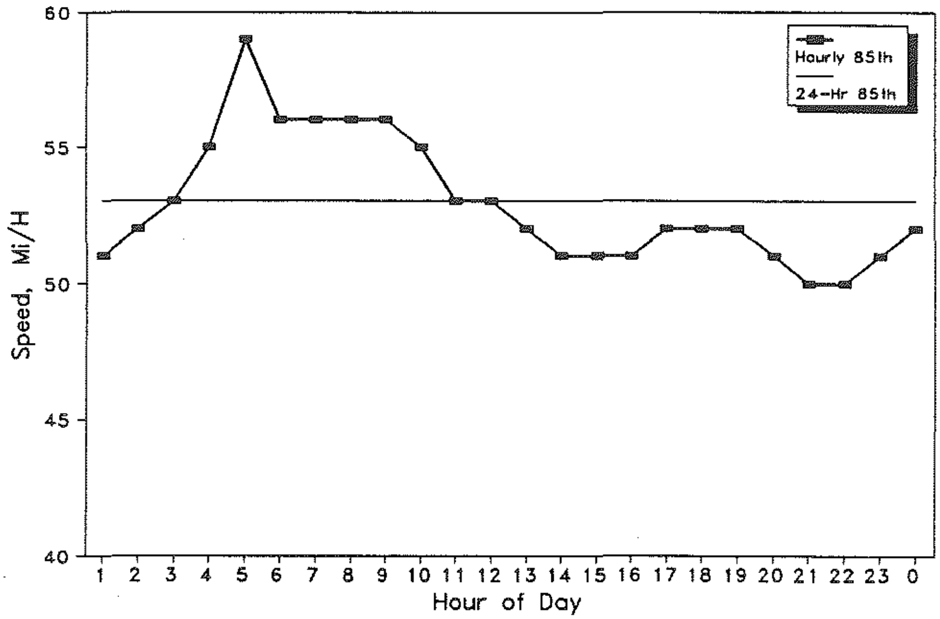

Figure 9. Variation in the 85th percentile speed by time of day at station 1E located on US-41 near Marquette.

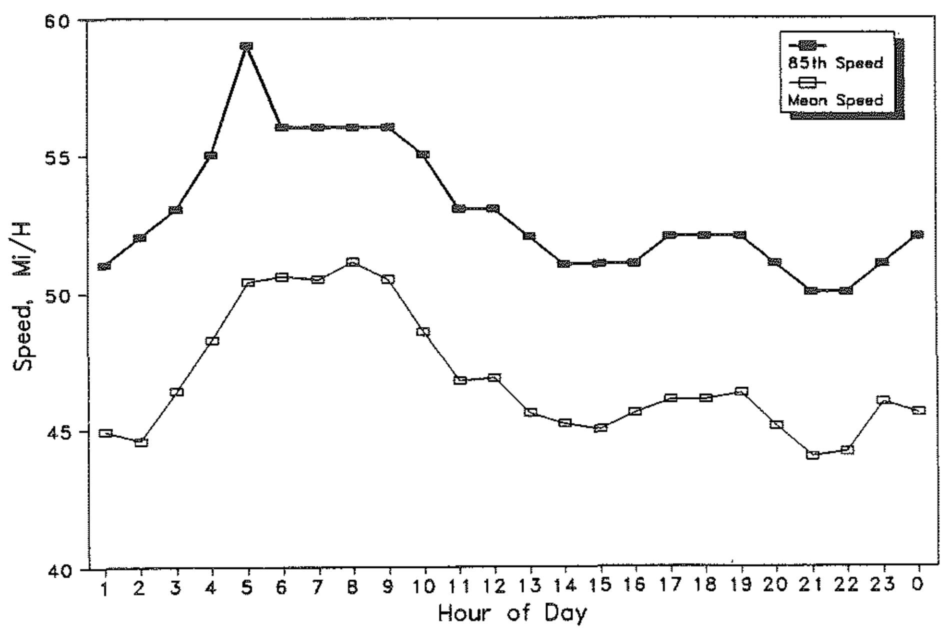

Figure 10. Variation in the 85th percentile and average speed by time of day at station 1E located on US-41 near Marquette.

The variations in the hourly 85th percentile speeds appear to be directly related to fluctuations in volume at the location. For example, shown in Figure 11 are the hourly volume counts for site 1E along with the hourly 85th percentile speeds. In the early morning hours when the traffic volumes are extremely light, the hourly 85th percentile speeds are approximately 3 mi/h higher than the 24-hour 85th percentile speed. As the volume increases above 600 vehicles per hour, there is a corresponding decrease in the hourly 85th percentile speeds. During the hours with the highest volume, the hourly 85th percentile speeds are approximately 2 mi/h lower than the 24-hour 85th percentile speed.

Results

As described above, hourly volumes and 85th percentile speeds, as well as the 24-hour 85th percentile speed, were plotted for each station and the results were examined to identify similarities and differences. Several summary statistics are shown in Table 13 for each monitoring station. First, the 24-hour 85th percentile speed is given along with total volume recorded at the location. Next, the lowest and highest hourly 85th percentile speeds recorded during the 24-hour day, along with the difference between these values, are listed. As current practice in Michigan frequently requires collecting speed data between 8:00 a.m. and 5:00 p.m., the lowest and highest 85th percentile speeds during this period were recorded, as well as the difference between the values.

The difference between the lowest and highest hourly 85th percentile speeds provides an indication of the size of the variation due to hour of day. However, speed data are taken to estimate the 24-hour 85th percentile speed and not any particular hour. To determine the maximum variation between the hourly 85th percentile speed and the 24-hour 85th percentile speed, the difference between

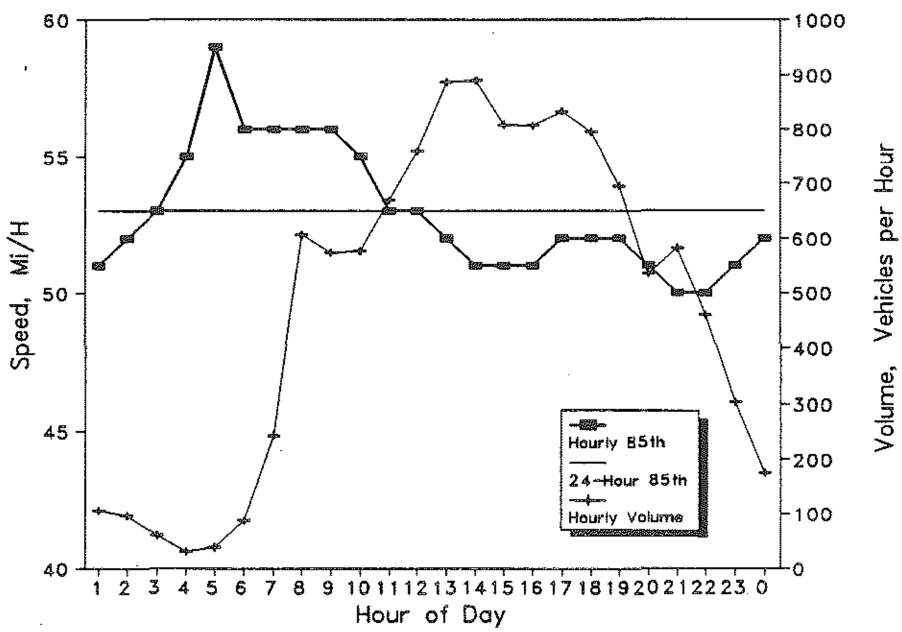

Figure 11. Hourly variations in volume and 85th percentile speed at station 1E located on US-41 near Marquette.

the 24-hour 85th percentile speed was subtracted from the lowest and highest hourly speed. This difference was also examined for the time period between 8:00 a.m. and 5:00 p.m. and the results are shown in Table 14. The results of the analyses are summarized below.

1. Significant differences in hourly 85th percentile speeds were found at the stations examined in this study. Due to the large sample sizes, the results are statistically significant, however, with large samples, differences less than 1 mi/h are significant. The practical significance of the results is discussed below.

2. As shown in Table 13, the average difference for all monitoring stations between the lowest and highest hourly 85th percentile speed was 5.7 mi/h. During the period 8:00 a.m. to 5:00 p.m., the difference was only 2.9 mi/h. This means that if speeds were collected for any hour between 8:00 a.m. and 5:00 p.m., the maximum variation due to time trends in a sample would, on average, be about 3 mi/h.

3. Speed data should be collected to estimate the 24-hour 85th percentile speed. As shown in Table 14, when the difference between the 24-hour 85th percentile and the lowest and the highest hourly 85th percentile speeds was determined, it was found that at a typical station the maximum lowest variation was about 2.5 mi/h during a 24-hour period. The highest variation was about 3.2 mi/h. In other words, if speed data were collected for any hour period during a 24-hour day, on average, the sample may produce an 85th percentile speed 2.5 mi/h lower than the 24-hour 85th percentile speed or 3.2 mi/h higher than the 24-hour 85th percentile speed.

4. As shown in Table 14, when the period 8:00 a.m. to 5:00 p.m. was considered, the lowest variation was approximately 1.5 mi/h and the highest was also 1.5 mi/h. This result means that at an average monitoring station in Michigan where data are collected during the day, the hourly variations due to time of day effects produce an error of approximately 1.5 mi/h above or below the 24-hour 85th percentile speed. This is the average error, as there were stations with errors less than and greater than this value.

Table 14. Average difference between the lowest and highest hourly 85th percentile speed and the 24-hour 85th percentile speed.

Category	No. Stations	Difference, Mi/H 24-Hour Day Lowest	Difference, Mi/H 24-Hour Day Highest	Difference, Mi/H 8 a.m. to 5 p.m. Lowest	Difference, Mi/H 8 a.m. to 5 p.m. Highest
Two-Lane	48	-2.6	3.3	-1.6	1.6
Multilane	32	-2.4	3.0	-1.3	1.1

5. Attempts to develop a mathematical model that could be used to predict the variation from the 24-hour 85th percentile speed for any given hour were not fruitful. In this data set there are too few similarities or trends that can be used to predict the speed difference for any particular time period. Some general trends are noted below.

6. With the exception of a few stations, the highest hourly 85th percentile speeds occurred in the early morning hours between 1:00 and 7:00 a.m. At a typical station, the 85th percentile speeds were approximately 2 to 4 mi/h higher than the 24-hour 85th percentile speed. This condition occurred under extremely low-volume conditions. An exception to this trend was found at the I-75 Connector site located near Woodhaven. These data are presented later in this section.

7. At several stations where the traffic volume remained high during the day, there was a tendency for the hourly 85th percentile speeds to run between 1 and 2 mi/h lower than the 24-hour percentile speed. This trend is shown in Figures 12 and 13 and appears to occur when the volumes are greater than 400 vehicles per hour on two-lane highways and 600 vehicles per hour on four-lane highways.

8. At several of the stations with highly directional volume distributions, there was a tendency for the hourly 85th percentile speeds to increase during the peak-flow period. Shown in Figures 14 and 15 are the inbound and outbound volumes and 85th percentile speeds for stations located on the I-75 Connector near Woodhaven. Note that this location also had lower percentile speeds during the early morning hours which is contrary to the trend at the majority of sites.

9. Although atypical, at a few of the monitoring stations, as shown in Figure 16, a morning and afternoon peak flow period occurred for the same direction of travel. During the morning peak, there was very little variation in the hourly 85th percentile speeds. During the afternoon peak, the hourly 85th percentile speeds decreased approximately 3 mi/h below the 24-hour 85th percentile speed. During the day between the two peak periods, the hourly 85th percentile speeds closely approximated the 24-hour 85th percentile speed.

Discussion of Results

Analysis of the speed data collected in this study indicate there are significant differences in the hourly 85th percentile speed by time of day. The differences appear to be directly related to volume; the hourly 85th percentile speeds tend to be higher between 1:00 and 7:00 a.m. when the volumes are low. As mentioned above, there are other variations, but they appear to be site-specific and do not permit general conclusions to be drawn.

Overall, the differences between the hourly 85th percentile speed and the 24-hour 85th percentile speed are smallest when data are collected between the hours of 8:00 a.m. and 5:00 p.m. While some variations exist, at the average station, the maximum error expected would be 1.5 mi/h, either above or below the actual 85th percentile speed.

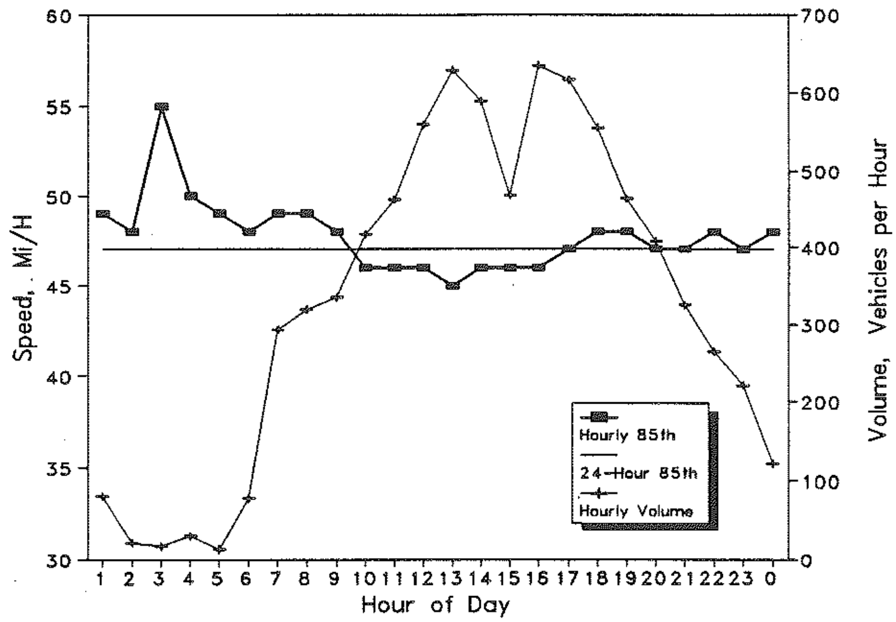

Figure 12. Hourly variations in volume and 85th percentile speed at station 1C located on M-75 near Boyne City.

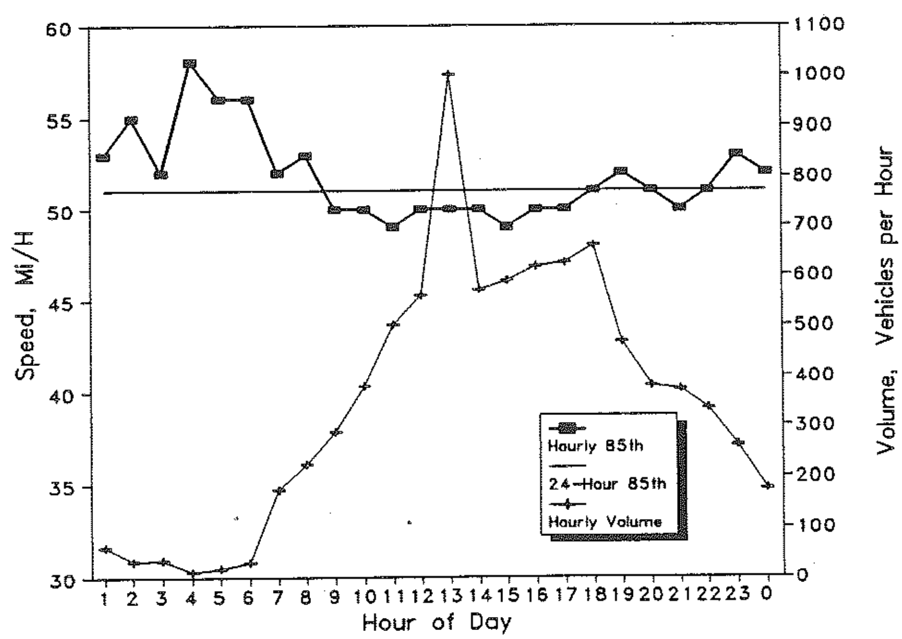

Figure 13. Hourly variations in volume and 85th percentile speed at station 1S located on BL-75 near Gaylord.

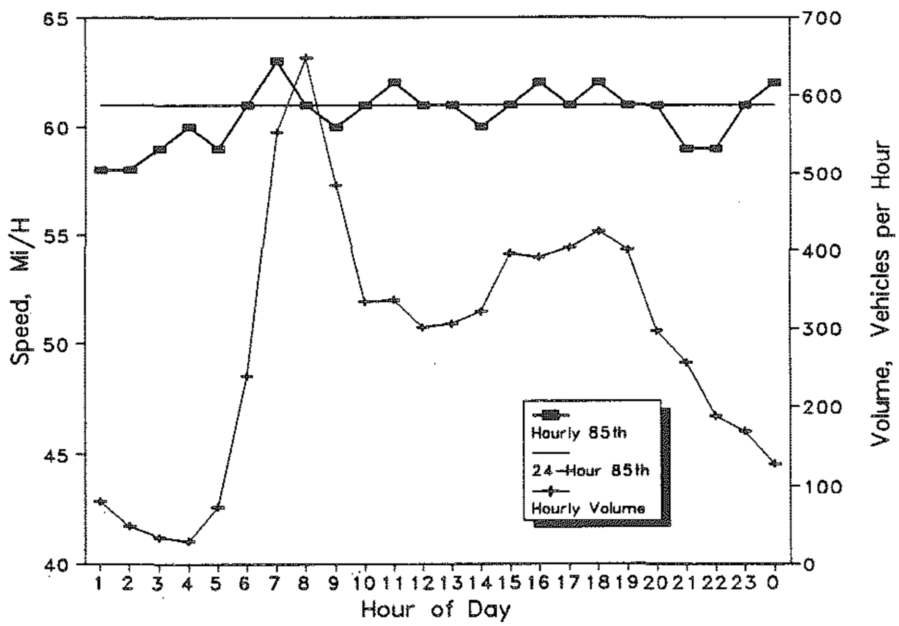

Figure 14. Hourly variations in volume and 85th percentile speed at a station with a high morning peak period volume.

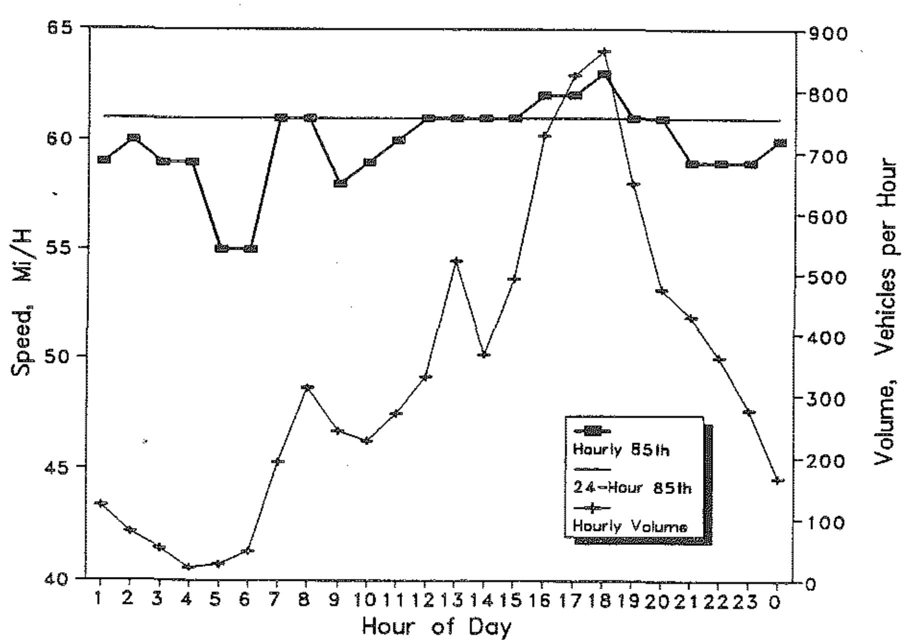

Figure 15. Hourly variations in volume and 85th percentile speed at a station with a high evening peak period volume.

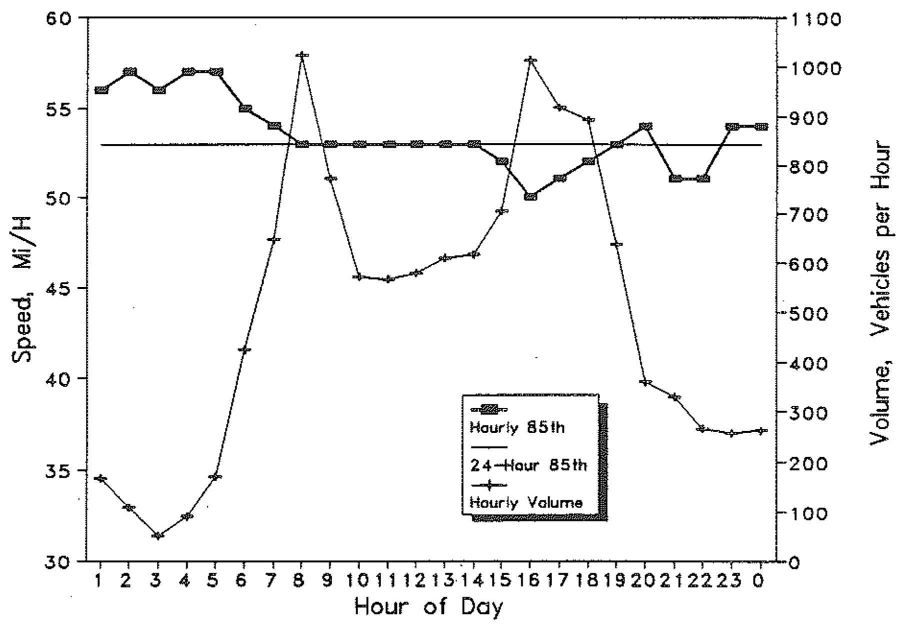

Figure 16. Hourly variations in volume and 85th percentile speed at a station with a high morning and evening peak period volume.

Whether an average error of 1.5 mi/h would make a significant difference in posting a speed limit is debateable. For example, if the actual 24-hour 85th percentile speed at a site was 43 mi/h, an error of 1.5 mi/h would mean that the sample 85th percentile could be between 41.5 and 44.5 mi/h, suggesting either a 40 mi/h or 45 mi/h posted limit. If, however, the actual 24-hour 85th percentile speed was 45 mi/h, the sample 85th percentile could range between 43.5 and 46.5 mi/h, thus, a 45 mi/h limit would be posted.

There are only two ways to minimize the time of day effects when data are collected to determine the 85th percentile speed. The only way to effectively minimize the errors is to use automated equipment and collect data for a 24-hour period which would produce the 24-hour 85th percentile speed. The second and less desirable method involves taking random samples of speed data at the same site in both the morning and afternoon. With the second method, the opportunity exists of underestimating the 85th percentile by approximately 1 mi/h at sites where volumes remain above 500 vehicles per hour per direction. Also, taking random speed samples at the same site throughout the day is not usually a practical cost-effective alternative.

Day of Week Effects

An estimate of the effects that different days of the week have on the 85th percentile speed was obtained by collecting speed data at four stations on a high-volume two-lane site. The roadway section is located on US-12 in Pittsfield Township where the posted speed limit is 45 mi/h.

Shown in Table 15 are the average and 85th percentile speeds, and volumes by day of the week. These data are plotted in Figure 17 for site 2W. While there are variations in traffic volumes at all sites, there are few differences in the 85th percentile speeds by day of the week. Traffic volumes were heaviest on Friday, lower than other weekday volumes on Saturday, and lowest on Sunday. Differences in average speed by day of the week, although statistically significant, were less than 1 mi/h. While the speeds are statistically significant, this is primarily due to the large sample sizes. A difference of less than 1 mi/h has little real significance when using these data to post speed limits.

The 85th percentile speed was generally the same for each day of the week with few exceptions. No pattern or trend was observed.

To examine the validity of these observations, speed data for selected days of the week were collected for stations on M-36 near Hamburg and M-52 at Chelsea. The results of these data also suggest that average and 85th percentile speeds differ by less than 1 mi/h due to the day of the week.

In summary, day of the week does not appear to have an important effect on the 24-hour 85th percentile speed. When free-flow vehicle speeds are collected for a 24-hour period on any day of the week, the overall effect on the 85th percentile speed is estimated to be 1 mi/h or less.

Table 15. Day of the week effects.

Station	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1E							
Average Speed	48.8	48.9	49.2	48.6	48.1	49.5	49.1
85th Percentile	56	56	56	56	56	57	56
Volume	10,680	10,793	10,741	10,973	11,665	9,631	8,421
1W							
Average Speed	49.8	49.7	49.7	49.7	48.6	49.1	49.4
85th Percentile	56	56	56	56	56	56	56
Volume	10,230	10,227	10,331	10,541	11,401	9,289	7,135
2E							
Average Speed	46.0	46.2	46.5	45.8	45.8	47.1	46.1
85th Percentile	52	53	53	52	52	53	53
Volume	12,086	12,367	12,274	12,598	12,993	10,480	9,216
2W							
Average Speed	48.3	48.5	48.4	48.1	47.9	48.7	48.3
85th Percentile	54	54	54	54	53	54	54
Volume	11,917	12,257	12,252	12,587	13,081	10,621	7,833

Note: Data collected for a 24-hour period during October 22-28, 1990.
Two-lane site - US-12 Pittsfield Township.
Posted speed limit = 45 mi/h.

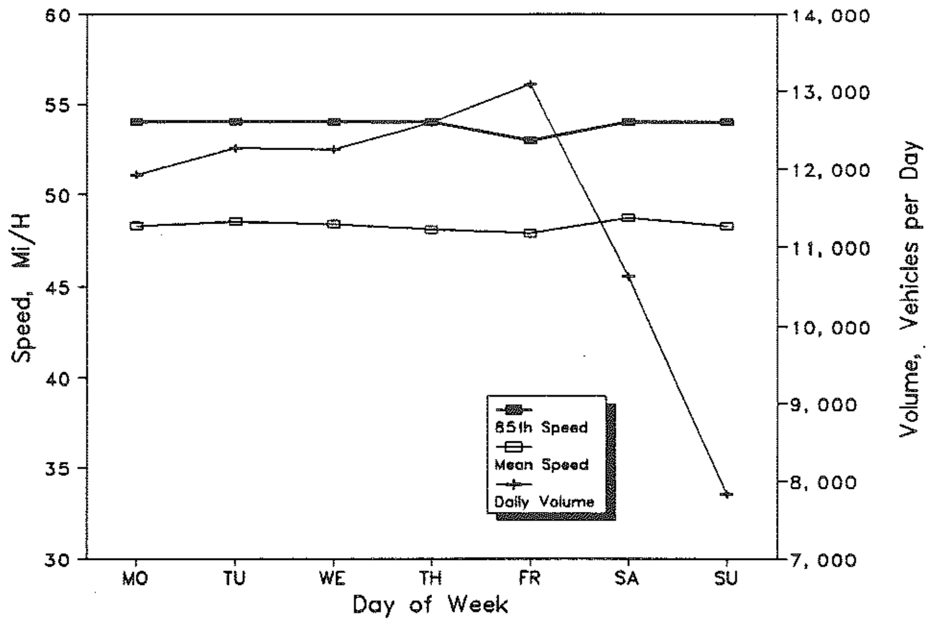

Figure 17. Day of the week effects on speed and volume at station 2W located on US-12 in Pittsfield Township.

Seasonal Effects

An estimate of the effects that different seasons have on the 85th percentile speed was obtained by collecting speed data for a 24-hour period on the same day of the week during March, July, October, and December 1990. These data are shown in Table 16. The speeds and volumes are plotted for station 2E in Figure 18.

The data indicate that volumes are highest in July and the 24-hour 85th percentile speeds are approximately 1 mi/h lower in July. Seasonal effects were also examined at two Michigan sites during a recent FHWA study.[24] The results of the seasonal effects are shown in Table 17. The 24-hour 85th percentile speeds at these rural sites varied by 2 mi/h with May and July having the lowest speeds.

In conclusion, it appears that season has a small effect on the 85th percentile speed. During the summer months, the 24-hour 85th percentile speeds appear to be 1 to 2 mi/h lower than 85th percentile speeds collected during other times of the year. This finding may be due to the additional volume on the roadway during the summer period, and possibly, the composition of traffic during this time. For example, in addition to the normal work trips, recreational travelers may be influencing a small decrease in free-flow speeds.

Table 16. Seasonal effects.

Station	March 3-28-90	July 7-25-90	October 10-24-90	December 12-12-90
1E				
Average Speed	48.8	48.4	49.0	50.0
85th Percentile	55	55	56	57
Volume	10,921	11,762	10,821	10,417
1W				
Average Speed	50.0	48.3	49.7	49.1
85th Percentile	57	55	56	56
Volume	10,350	11,268	10,470	9,897
2E				
Average Speed	46.6	46.0	46.0	46.4
85th Percentile	53	52	52	53
Volume	12,036	13,284	12,541	12,309
2W				
Average Speed	47.9	47.1	48.4	47.1
85th Percentile	54	53	54	53
Volume	11,722	13,092	12,473	12,011

Note: Data collected for a 24-hour period on Wednesday.
Two-lane site - US-12 Pittsfield Township.
Posted speed limit = 45 mi/h.

Table 17. Seasonal effects on rural two-lane highways.

Site	Oct. 8, 1987	Jan. 28, 1988	May 12, 1988	July 14, 1988	Oct. 13, 1988
M-52 1.89 Miles South of I-96					
Average Speed	60.6	60.0	59.5	59.6	60.2
85th Percentile	68	67	66	67	67
Volume	3,057	2,439	3,060	3,210	3,392
M-52 2.56 Miles South of I-94					
Average Speed	56.6	57.1	57.1	55.7	58.1
85th Percentile	63	63	63	62	64
Volume	4,369	3,945	5,140	4,921	5,208

Note: Data collected for a 24-hour period on Thursday.
Posted speed limit = 55 mi/h.

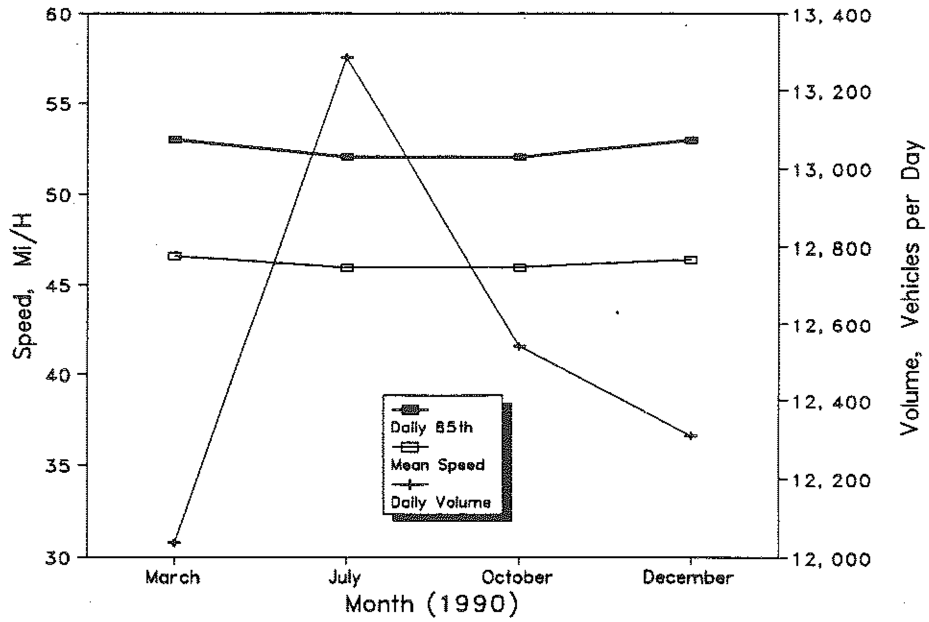

Figure 18. Effects of season on speed and volume at station 2E located on US-12 in Pittsfield Township.

Summary of Time Effects

The data collected in this study suggest that the 85th percentile speed at a station is effected by the hour of the day the data are collected. When speed data are collected between 8:00 a.m. and 5:00 p.m., the sample may produce an 85th percentile speed that is 1.5 mi/h lower or higher than the 24-hour 85th percentile speed at the site. Day of the week does not appear to have an effect on the 85th percentile speed. Data collected during the summer may have an 85th percentile speed from 1 to 2 mi/h lower than the 85th percentile speeds collected during other times of the year.

There appears to be little agreement in the literature regarding fluctuations in spot speeds due to time effects. In a review of the literature, Oppenlander[35] cited a number of investigators who found no significant differences in spot speeds during different hours of the day; however, other investigators reported a reduction in average speed between early morning hours and late evening hours. Disagreements were also noted with respect to days of the week. Some investigators reported no significant variation in vehicle speeds for different days of the week, while others observed lower speeds on Sunday. There appears to be general agreement that average speeds are highest in fall and winter and lowest in the summer.

It should be noted that in the studies cited by Oppenlander, none of the investigators used automated equipment; thus, sampling techniques were used to estimate time effects. This problem was overcome in this study with the use of the VC-1900 roadside units which allowed collection of 24-hour data.

LOCATION EFFECTS

The effects of the location of the speed monitoring station on the 85th percentile speed was examined by placing selected sampling stations within a speed zone based on the results of the accident analysis and the geometry in each zone. Specific location effects examined were intersections, commercial and residential driveways, and horizontal curves. Descriptions of the stations were given in Table 11 and the speed data were summarized in Table 13.

It should be noted that many geometric, traffic, and environmental factors influence the 85th percentile speed on a roadway. The purpose of the observations reported in this section was to estimate the effects of a particular feature relative to other existing features.

An examination of the 24-hour 85th percentile speeds collected at the various stations indicate that location does have an effect on the 85th percentile speed. In general, stations located near intersections, commercial and residential driveways, and horizontal curves have lower 85th percentile speeds. The speed differences typically ranged from 2 to 5 mi/h. Accordingly, the selection of the location of the speed monitoring station within a speed zone is an important consideration when determining the 85th percentile speed for the zone. Typical observations noted at selected stations are summarized below.

Intersection Effects

As expected, the 85th percentile speed at sampling stations located in the proximity of signalized intersections are much lower than speeds either upstream or downstream from the signal. The 85th percentile free-flow speeds at stations located within 300 feet of a signalized intersection appear to be 5 to 7 mi/h lower than speeds at adjacent stations on a high-volume four-lane undivided highway. Speeds at a signalized intersection located on a four-lane roadway with a two-way left-turn lane were between 1 and 2 mi/h lower than nearby stations. On a high-volume two-lane roadway, the speeds near the signals range from 2 to 4 mi/h below the 85th percentile speeds at nearby stations.

Unsignalized intersections also have an effect on the 85th percentile speed, however, to a smaller degree than signalized intersections. It also appears that the effect is primarily due to free-flow turning volume at the intersection which was not specifically measured in this study. For example, on 3 four-lane highways, the 85th percentile speeds were approximately 2 mi/h less than the speed recorded at nearby sites without intersections. On two-lane roadways, intersection effects on the 85th percentile speeds ranged from 2 to 6 mi/h. These observations indicate that motorists driving at their desired speed slow down in the vicinity of major intersections.

In summary, to obtain realistic 85th percentile speeds on a roadway containing major signalized and unsignalized intersections, speed monitoring stations should be located no closer than 500 feet from the intersecting roadways.

Commercial and Residential Development Effects

To examine the effects of roadside development on the 85th percentile speed, stations were located at specific commercial and residential driveways and at locations with little or no driveway activities. The results of these observations indicate that commercial and residential development appears to have a small effect on the 85th percentile speed.

The data suggest that the 85th percentile speeds are affected by the number of driveways per mile and the volume at a specific driveway. For example, on two-lane roadways, a 5 mi/h reduction in the 85th percentile speed was observed at a hospital where the number of driveways was 48 per mile. A 2 mi/h reduction was found at a motel where the number of driveways per mile was 49. A 2 mi/h reduction was also found in an area with a mix of commercial development where the number of driveways per mile was 34.

Residential development also has an effect on the 85th percentile speed. A reduction of 3 mi/h was found at one site with 23 driveways per mile.

Although this study was not designed to produce a mathematical model of the relationship, in general, it appears that the higher the number of approaches per mile, the lower the 85th percentile speed.

An analysis of the selected sampling stations examined in this study suggests that realistic 85th percentile speeds on a section can be obtained by locating sampling stations within and outside of areas of residential and commercial development. Stations should not be located specifically at high volume driveways where free-flow turning vehicles could produce an 85th percentile speed that is much lower than found at other points on the roadway.

Horizontal Curve Effects

The number of severe horizontal curves on the sections of the state trunkline system included in this study was quite limited. Within the zones selected for study, only three sections had horizontal curves with advisory speeds posted less than the speed limit.

On a 45 mi/h zone located on M-75 near Boyne City, a horizontal curve is posted for the maximum safe speed of 35 mi/h. Monitoring stations located at 300 feet from the beginning point of the curve revealed that 85th percentile speeds going into the curve were 2 mi/h lower than speeds on the tangent section. Vehicle speeds coming out of the curve were 7 mi/h lower than the tangent section. At another site, a 5 mi/h reduction in speeds was observed in a curve posted for 35 mi/h. On another rural two-lane site, stations located within a combination of horizontal curves had speeds approximately 11 mi/h lower than stations on tangent sections.

As indicated by the data collected in this study and by other investigators, horizontal curves can greatly affect vehicle speeds. In particular, the degree of curve has a direct effect on the 85th percentile speed. Generally, speed zone stations should not be located within 500 feet of the beginning or ending of a horizontal curve if the degree of curve requires than an advisory speed be posted for the curve. Speed stations located within horizontal curves, however, are appropriate when advisory speeds are not required.

OTHER EFFECTS

In addition to time and location effects, the observations conducted during this investigation suggests that other factors can affect the 85th percentile speed obtained at a monitoring station. A summary of these effects is given below.

Accident Effects

The speed monitoring stations used in this study were selected based on an accident analysis conducted within each speed zone. Accordingly, high and low accident locations were selected along with locations with a high and low number of specific accident types, i.e., driveway related versus nondriveway related accidents.

Only 7 of the 28 speed zones examined in this effort had accident rates higher than the statewide rate for similar facilities. Overall, high accident locations on the study sections occurred at intersections and commercial entrances with high turning volumes. In addition, sections with a high number of approaches per mile and traffic signals had higher accident rates than other sections. Attempts to develop correlations between the number of driveways and the accident rate were not successful. Although not measured in this study, it appears that turning volume and geometric design are more important indicators of the accident rate than the total number of approaches.

The question of how accident data should be used in determining the appropriate speed limit to post on a roadway was examined based on observations made on the study sections. The following suggestions are offered for consideration.

- A routine accident analysis should be conducted whenever a speed zone section is selected for study or reexamination. The analysis should include a summary of accidents by collision type, severity, light condition, roadway surface condition, and time of day. The purpose of the analysis is to identify locations with abnormally high-accident characteristics such as rear end accidents, wet pavement accidents, etc.

- A field review should be conducted to subjectively examine roadway and traffic conditions at locations with abnormal accident characteristics. The objective of the field review is to identify high-risk maneuvers and/or roadway conditions that may be a contributing factor to the accident problem.

- If the high-accident location is confined to a specific roadway feature such as an intersection or horizontal curve, an advisory speed should be considered in lieu of altering the speed limit on the entire section.

- When large differences in speed exist, consideration should be given to recommending safety improvements such as providing turning lanes, etc. that would separate low-speed and high-speed vehicles.

- As reported in this study, artificially lowering the speed limit generally will not reduce accidents and, accordingly, should not be considered as a safety improvement.

Free-Flow Versus All Vehicle Speed Effects

The 85th percentile speed at a location is based on a sample of free-flow vehicle speeds. A vehicle with a headway of four seconds is defined as a free-flow vehicle. With a four second headway, the driver is free to select vehicle speed based on roadway and environmental conditions and is not impeded by other vehicles. To examine the effects that measuring the speed of all vehicles versus free-flow vehicles has on the 85th percentile speed, all vehicle and free-flow vehicle speed data were collected at two sites on US 12 in Pittsfield Township. As previously mentioned, this is a high-volume two-lane roadway. The results are shown in Table 18. Based on this limited sample, it appears that all vehicle 85th percentile speeds are approximately 2 mi/h lower than free-flow 85th percentile speeds.

Data Collection Effects

It is well known that errors associated with speed data collection can affect the 85th percentile speed. These errors fall into the basic categories of human error, equipment error, and hidden error. Human errors include how the vehicles are selected (selecting a large proportion of high-speed vehicles), sample size, recording errors, and use of the equipment (instrument calibration). Equipment or measurement error is usually quite small, 1 mi/h or less, unless the instrument has been damaged or not periodically calibrated. Hidden errors include bias introduced by the observer and/or use of the equipment. For example, when radar is used in a stationary position, this information is frequently transmitted to other vehicles in the stream via headlight signals, CB radio communications, and radar detectors.

This study did not specifically address any of the specific sources of error or bias in data collection. However, by comparing speeds collected at the sample stations with speeds collected by the Department of Transportation, the magnitude of the differences can be examined. For example, by comparing the average 85th percentile speeds collected by the Department of Transportation with the 85th percentile speeds collected at the 28 zones in this study, it appears that the DOT's estimate of the 85th percentile speed is approximately 3 mi/h less than the speeds recorded by the automated equipment. While some differences at specific sites can be expected due to changes in roadside development which occurred after the DOT collected the speed data, and possibly other factors, the systematic bias appears unusual.

Table 18. All vehicle versus free-flow vehicle speeds.

Station	All Vehicle Volume	All Vehicle 85th	Free Flow Volume	Free Flow 85th
2E	13,396	50	13,284	52
3E	13,319	48	13,594	50

Further investigation was conducted at two zones to compare the speeds collected at the same station during the same time period. The results of the data collected by the Department was compared to the results obtained with automated equipment. Speed data collected at five stations on one section indicated consistently that speeds were 3 to 4 mi/h lower using the current DOT method. At two stations at another location, speeds were from 3 to 5 mi/h lower using the current DOT method. These differences are greater than can be accounted for by the effects of time alone. In other words, the data collection method is most likely creating this systematic difference.

The primary source of the bias is most likely attributed to the use of radar, especially during periods of high volume when it is difficult to select specific free-flow vehicles. It is not possible to isolate errors due to sampling technique versus hidden error, thus, specific recommendations for improving speed data collection with radar are not given.

Due to the time of day effects previously discussed and the bias problem mentioned above, the use of radar for collecting speed data to set speed limits is not recommended. It is simply not cost-effective to use radar to sample speeds at the same site throughout the day. In addition, conventional radar offers no method of determining the true speeds of vehicles with radar detectors. Finally, radar only permits collection of sample vehicle speeds. Automated equipment, provides more efficient and accurate collection of vehicle speeds and other traffic data such as volume.

Although the use of radar is strongly discouraged, it is recognized that the Department or other agencies may continue to use radar for speed data collection on a limited basis. The following general guidelines should be observed when collecting speed data with radar devices.

Guidelines for Using Radar to Collect Spot Speed Data

- The observer, equipment, and vehicles should be inconspicuous to the traffic stream.

- The vehicle should be parked well off the roadway in order not to influence driver behavior. However, as the greatest accuracy is obtained when the angle between the radar device and the path of the oncoming vehicle is zero, the location should be selected to minimize the cosine effect. The cosine effect always introduces a systematic bias, i.e., the measured speeds are always less than the actual speeds. The following values should be used to correct speeds due to the cosine error.

Angle	Correction Factor	Percent Error
1°	0.999	-0.1
5°	0.996	-0.4
10°	0.984	-1.6
15°	0.965	-3.5
20°	0.939	-6.1
25°	0.906	-9.4
30°	0.866	-13.4
35°	0.819	-18.1
40°	0.776	-22.4
45°	0.707	-29.3

The actual vehicle speeds should be determined using the following formula.

$$\text{True Vehicle Speed} = \frac{\text{Radar Measured Speed}}{\text{Correction Factor}}$$

- The accuracy of the radar meter should be checked with a tuning fork prior to and after data collection.

- The speed of smaller vehicles should not be measured in the presence of large vehicles. The large surface areas of trucks can cause erroneous reading for smaller vehicles.

- Random sampling of vehicles should always be practiced.

As automated equipment is available by the Department for speed data collection, use of this equipment in lieu of radar is strongly recommended. The following guidelines are offered to minimize measurement errors associated with automated equipment.

Guidelines for Using Automated Equipment

- Spacing between the sensors, i.e., pneumatic tubes, should be standardized (the same spacing should be used at all locations) and written on the roadside unit to reduce errors associated with measuring and/or programming the unit.

- Pneumatic tubes should be placed to record traffic flow in only one direction of travel. Erroneous readings can occur when the tubes are deployed in bidirectional traffic, especially when using Sarasota roadside units.

- Pneumatic tubes should be stored and deployed in pairs to insure the same wear occurs on both tubes. When one tube fails, the pair should be replaced.

- It is imperative that both pneumatic tubes be exactly the same length. Prior to deployment, the tube lengths should be checked and corrections made when necessary.

One Lane Versus Multilane Effects

Due to the phenomenon known as dead time (the time a vehicle is over the sensor), it is well known that the use of pneumatic tubes and/or loop detectors underestimates the actual number of vehicles on the roadway. On multilane highways, undercounting can be minimized by placing the sensors on one lane instead of all lanes in the same direction of travel.

The effects of collecting speed data on one lane versus both lanes were examined at three sites. At all three locations, the 85th percentile speeds measured on one lane were either the same or less than 2 mi/h of the speeds measured on both lanes. In general, speeds were 1 mi/h lower when one lane of traffic was used instead of two.

25 Mi/H Speed Zones

While the sample sizes are limited, it was noted that speed data collected in 25 mi/h speed zones by the Department of Transportation and during this study, produced 85th percentile speeds of 29 mi/h or higher. This result indicates that a minimum speed zone of 30 mi/h is more appropriate for improving safety and driver compliance than the 25 mi/h minimum limit currently used.

RECOMMENDED PROCEDURE

The effects that time, location, and other factors have on the 85th percentile speed were specifically examined in this task. Recommendations for considering these factors when establishing speed limits are given below.

- When speed data are collected for any hour between 8:00 a.m. and 5:00 p.m., the sample may produce an 85th percentile speed that is 1.5 mi/h lower or higher than the 24-hour 85th percentile speed at that location. Day of the week does not appear to have an effect on speeds. Data collected during the summer may have an 85th percentile speed approximately 1 to 2 mi/h lower than 85th percentile speeds collected during other times of the year.

  To minimize the effect that hour of the day has on the 85th percentile speed, it is recommended that automated equipment be used at the speed survey stations to collect data for a 24-hour period. When 24-hour surveys are not feasible, the data should be collected beginning at 8:00 a.m. and ending at 5:00 p.m. Although the use of radar is discouraged, if radar studies are conducted, then samples should be taken at the same location during morning and afternoon periods.

- Intersections, residential and commercial development, and horizontal curves affect the 85th percentile speed. The effects range from 2 to 7 mi/h.

  Speed data should not be collected within 500 feet of signalized and other major intersections or horizontal curves. In commercial and residential areas, stations should be placed both within the developed area and outside the limits of development.

  A review of current speed zone locations established in the State of Michigan on selected sections of roadway was made and the results indicate that both the number of stations and their locations adequately reflect the intent of these recommendations. In other words, speed survey locations are placed whenever there are geometric changes on a section, i.e., transitioning from two lanes to four, at midblock locations, and within areas of development. The survey stations were located more than 500 feet from signalized and other major intersections. Furthermore, prior to conducting a recheck, the stations are revised when necessary to reflect changes in geometry and/or roadside development. It is important that this practice continue.

- An accident analysis should be conducted as a routine part of a speed zoning investigation. The location and type of any abnormally high accident pattern should be identified and reviewed in the field to determine possible causes of the accident problem. When speed related factors such as large speed differences between turning and through vehicles are identified, recommendations should be made to either separate the traffic flows or warn motorists of a problem. Speed zoning will not address accident problems of this type.

- Data collected at selected sites during this study suggest that the current method used by Michigan of collecting speed data with radar may be producing an error of 3 to 4 mi/h lower than the actual 85th percentile speed. Whether this error is attributable to observer bias, equipment error, or the survey station being detected by motorists, was not examined.

  To minimize data collection errors, it is recommended that use be made of automated equipment in lieu of radar.

- Analysis of the speed data collected in a zone should begin by recording the data on the study plan as is currently practiced. As long as the 85th percentile speeds are approximately the same, the recommended speed should normally be the nearest value which ends in 5 or 0 (within 5 mi/h of the 85th percentile speed). When the 85th percentile speeds at the locations vary by more than 5 mi/h, separate zones should be considered. Conditions such as horizontal curves or intersections, warranting advisory speeds below the recommended limit should be considered at this time.

FIELD VALIDATION OF RECOMMENDED PROCEDURE

INTRODUCTION

Based on previous efforts, it was recommended that speed zones on Michigan roadways be set within 5 mi/h of the 85th percentile speed. In order to account for time and other effects, it was recommended that automated speed data collection equipment be used to collect data for a 24-hour period. The speed sampling locations should be selected based on the results of an accident analysis, the geometry in the zone, and to reflect the type and amount of roadside development.

The objective of this effort was to conduct a field validation of the recommended procedure. The validation included an analysis of accident data at each site, collection of speed data, and an analysis to recommend the appropriate speed limit. Recommendations are offered for implementing the recommended procedure in Michigan.

METHOD

The field validation was conducted at 13 speed zones located in southeastern Michigan. The sampling stations in each zone were selected based on the results of an accident analysis, the geometry in each zone, and roadside development. Automated equipment was used to collect speed data for a 24-hour period at each station. Although not needed to reach a speed limit decision, other data, including the number of residential and commercial driveways, street approaches, etc., were only collected to describe the characteristics of the sites.

Following data collection, the speed data were analyzed and used to recommend a proposed speed limit for each zone. The results were compared with the existing speed limit. Due to time limitations, a before and after accident analysis was not conducted to examine the effects of the recommended procedure on safety.

DATA COLLECTION

To validate the recommended speed zone procedure, a sample of 13 speed zone locations was selected in the southeast Michigan area. The sections represent a variety of geometric conditions, traffic volume, posted speed limits, and roadside development.

After the study speed zones were selected, accident data for the three-year period 1987 through 1989 were collected for each site and analyzed by location, type of collision, and time of accident. Using the results of the accident analysis, a field review was made to select speed survey stations. It should be noted that the majority of sites did not have high-accident locations, thus, the accident analysis played a small role in the actual selection of survey stations. During the field review, the stations were placed at locations representative of the geometric conditions and roadside development in the zone.

A description of the speed zones, along with selected accident data, are summarized in Table 19. Speed data were collected at 43 stations located within the 13 speed zone sections. The data at each monitoring station were collected with Sarasota VC-1900 roadside units using pneumatic tubes as vehicle sensors for a 24-hour period during a typical weekday.

Speed data at each station were collected for one direction of travel. Only the speeds of free-flow vehicles (vehicles with a headway of four seconds or more) were used to determine the 85th percentile speed.

A summary of the speed data collected at each monitoring site is given in Table 20. As can be observed by examining Table 20, the time of day effects for the validation sites are similar to the average time effects reported in the previous task. This reinforces the need to collect speed data throughout the day and not just one sampling period.

RESULTS

Following data collection, an analysis was conducted to determine the numerical value of the speed limit for each zone. While the recommended speed limit should be within 5 mi/h of the 85th percentile speed, there are several considerations that must be made when reaching a decision. General guidelines that were used to analyze the speed data in each zone are listed in Table 21.

The guidelines outlined in Table 21 were used to reach a speed limit decision at each of the validation sites. The results of the analysis are shown in Table 22.

It should be noted in Table 22 that the site on M-81 at Caro was subdivided into two zones based on the results of the 85th percentile speeds and the field review. For the same reason, the site on M-50 in Summit Township was also subdivided into two zones.

The suggested speed limit column given in Table 22 is the speed limit that should be posted if the only criteria was the 85th percentile speed. This would have resulted in 60 mi/h limits in two zones which, of course, is not permitted under current state law. The recommended speed limit column reflects the speed limit that should be posted based on considerations such as length of zone and state law.

Based on the analysis conducted at the validation sites, the use of the 85th percentile criterion provides speed zones which should improve safety and driver compliance. In the 13 zones examined in the validation effort, speed limits in 4 zones would remain the same, the limit would be lowered by 5 mi/h in 1 zone, raised by 5 mi/h in 5 zones, and raised by 10 mi/h in 3 zones. This is a small sample and may not be representative of the actual result if the process were implemented statewide. The reader should keep in mind that these zones were especially selected for research purposes to provide a variety of conditions and not to provide an estimate of whether speed limits on existing zones should be raised or lowered.

To illustrate how the guidelines listed in Table 21 were used to recommend the posted speed limits given in Table 22, a brief discussion of selected zones is given on pages 80 and 81.

Table 19. Field validation study locations.

Route	County	Locality	Posted Speed Limit	Site Length	Number of Lanes	Number of Approaches Res.	Comm.	Street	Approaches Per Mile	Traffic Signals	Total Acc.	Acc. Rate 1 MVM	Predominate Accident Time	Type	No. Stat	Stat Code	Acc. Type Stat	Acc. at Stat	Station Descrp.
M-81	Tuscola	Caro	55	3.081	2	15	29	9	17.2	0	123	3.52	8-19	RE, AM, AG	7	1E	Low	3	Rural
																1W	Low	1	Lt Res
																2E	Avg	5	Comm
																2W	Low	1	Comm
																3E	Avg	5	Shp Ctr
																3W	Avg	5	Shp Ctr
																4W	Low	1	Comm
M-36	Ingham	Dansville	45	0.284	2	7	1	2	35.2	0	0	0.00	NA	NA	2	1E	Low	0	Trans
																1W	Low	0	Trans
M-36	Ingham	Dansville	45	0.284	2	4	5	0	31.7	0	2	4.72	Varies	FO, HO	2	2E	Low	0	Trans
																2W	Low	0	Trans
M-50	Jackson	Brooklyn	30	0.230	2	3	14	5	95.7	0	37	9.97	11-18	RE, AG	2	1N	Low	2	Comm
																1S	Low	2	Comm
M-50	Jackson	Brooklyn	40	0.300	2	2	9	2	43.3	1	28	8.02	11-18	RE, AG	2	2N	Low	2	Comm
																2S	Low	2	Comm
M-50	Jackson	Summit Twp	45	1.005	2	8	4	10	21.9	0	35	3.01	7-18	RE, AG, FO	4	1E	Low	1	Ramp
																1W	Low	1	Ramp
																2E	Low	1	Ramp
																2W	Low	1	Ramp
US-223	Lenawee	Adrian	45	0.582	4-TWL	0	27	3	51.5	1	87	6.01	11-20	RE, AG	4	1E	Low	2	Shp Ctr
																1W	Low	2	Shp Ctr
																2E	Low	2	Shp Ctr
																2W	Low	2	Shp Ctr
M-50	Lenawee	Tecumseh	40	0.619	2-TWL	4	56	4	103.4	1	102	7.70	11-21	RE, AG	4	1E	Avg	5	Comm
																1W	Avg	5	Comm
																2E	Low	2	Light
																2W	Low	2	Light
M-36	Livingston	Hamburg	45	1.195	2	6	12	3	17.6	0	39	4.63	Varies	AG, AM	4	1E	Low	1	Rural
																1W	Low	1	Rural
																2E	Low	0	Res
																2W	Low	0	Res
M-59	Livingston	Howell	45	0.980	2	16	12	10	38.8	1	98	6.61	15-21	RE, AG, FO	4	1E	Avg	4	Res
																1W	Avg	4	Res
																2E	Low	2	Int
																2W	Low	1	Int

Table 19. Field validation study locations (continued).

Route	County	Locality	Posted Speed Limit	Site Length	Number of Lanes	Number of Approaches Res.	Number of Approaches Comm.	Number of Approaches Street	Approaches Per Mile	Traffic Signals	Total Acc.	Acc. Rate 1 MVM	Predominate Accident Time	Predominate Accident Type	No. Stat	Stat Code	Acc. Type Stat	Acc. at Stat	Station Descrp.
M-125	Monroe	Monroe	45	0.963	4-TWL	22	21	12	57.1	0	89	6.08	11-17	RE, AG	2	1N	Avg	4	Comm
																1S	Avg	4	Comm
M-125	Monroe	Monroe	35	1.124	4-TWL	4	89	12	93.4	3	299	12.81	10-19	RE, AG	2	2N	High	8	Int
																2S	High	8	Int
M-52	Washtenaw	Chelsea	45	0.859	2-TWL	2	37	11	58.2	0	87	6.38	13-18	RE, AG	4	1N	Low	1	Rural
																2N	Low	1	Comm
																2S	Low	1	Comm
																1S	High	7	Shp Ctr
13 Sections				11.506 Miles											43 Stations				

Note: The following abbreviations are used in the table.

Number of Lanes
TWL=Two-Way Left-Turn Lane

Accident Type
RE=Rear End
AG=Angle
PK=Parking
HO=Head On
FO=Fixed Object
AM=Animal
OT=Overturned
NA=Not Applicable

Table 20. Summary of speed data for field validation locations.

Route	County	Locality	Posted Speed Limit	Stat Code	Station Descrp.	Volume Counted	85th Pct. Speed	24-Hr 85th Low	24-Hr 85th High	24-Hr Diff.	8-5 PM 85th Low	8-5 PM 85th High	8-5 Diff	Std. Dev.	Speed Pct. Pace	Skew Index
M-81	Tuscola	Caro	55	1E	Rural	2,741	61	60	64	4	60	62	2	5.2	71.9	0.86
				1W	Lt Res	4,220	62	60	67	7	60	61	1	6.0	66.5	0.82
				2E	Comm	4,970	57	55	67	12	55	57	2	7.6	61.1	0.80
				2W	Comm	5,178	59	56	64	8	56	58	2	7.2	60.4	0.84
				3E	Shp Ctr	5,419	55	52	61	9	52	56	4	11.3	49.8	0.53
				3W	Shp Ctr	5,634	56	52	62	10	52	55	3	11.1	48.9	0.59
				4W	Comm	6,707	50	47	55	8	47	50	3	6.4	60.3	1.00
M-36	Ingham	Dansville	45	1E	Trans	1,181	53	47	56	9	50	56	6	6.6	64.5	1.00
				1W	Trans	1,241	54	50	56	6	52	55	3	6.7	62.5	0.89
M-36	Ingham	Dansville	45	2E	Trans	681	57	52	60	8	52	58	6	7.2	57.3	0.90
				2W	Trans	820	57	54	59	5	54	59	5	7.2	55.6	0.95
M-50	Jackson	Brooklyn	30	1N	Comm	7,368	35	33	40	7	33	36	3	4.7	76.0	1.00
				1S	Comm	7,608	36	34	40	6	34	36	2	4.6	77.4	1.00
M-50	Jackson	Brooklyn	40	2N	Comm	1,846	47	45	50	5	46	47	1	5.9	66.4	0.94
				2S	Comm	5,316	46	42	51	9	42	48	6	7.0	52.6	0.86
M-50	Jackson	Summit Twp	45	1E	Ramp	5,291	50	45	51	6	49	51	2	7.1	58.9	0.73
				1W	Ramp	3,379	55	51	56	5	54	56	2	5.3	69.0	0.93
				2E	Ramp	4,713	58	55	60	5	57	59	2	5.5	67.0	1.07
				2W	Ramp	4,469	57	56	59	3	57	58	1	5.8	63.3	0.94
US-223	Lenawee	Adrian	45	1E	Shp Ctr	7,890	48	45	50	5	45	49	4	5.9	60.9	0.94
				1W	Shp Ctr	11,352	46	43	50	7	43	48	5	6.2	60.7	1.00
				2E	Shp Ctr	9,090	50	47	52	5	47	50	3	8.2	55.3	0.69
				2W	Shp Ctr	10,448	47	44	50	6	44	48	4	9.3	45.5	0.74
M-50	Lenawee	Tecumseh	40	1E	Comm	6,796	42	39	46	7	41	45	4	6.0	63.7	0.82
				1W	Comm	5,101	45	43	48	5	43	48	5	6.6	60.3	0.74
				2E	Light	9,769	42	39	44	5	41	43	2	5.3	76.3	0.86
				2W	Light	8,438	42	39	45	6	41	43	2	5.8	72.2	0.93
M-36	Livingston	Hamburg	45	1E	Rural	2,908	57	53	59	6	56	59	3	5.3	69.5	1.14
				1W	Rural	3,220	59	56	61	5	59	61	2	5.5	64.9	1.00
				2E	Res	3,156	54	50	56	6	53	56	3	5.7	67.6	1.00
				2W	Res	3,395	54	51	56	5	53	55	2	5.4	68.7	0.88
M-59	Livingston	Howell	45	1E	Res	6,903	52	50	57	7	50	52	2	6.3	64.9	0.89
				1W	Res	6,667	52	50	60	10	50	53	3	5.6	68.3	1.00
				2E	Int	5,555	56	53	63	10	55	57	2	6.6	65.1	0.89
				2W	Int	6,195	58	56	64	8	56	59	3	6.5	63.7	1.06
M-125	Monroe	Monroe	45	1N	Comm	2,465	49	46	51	5	48	50	2	8.8	60.8	0.50
				1S	Comm	6,937	49	47	51	4	47	50	3	7.5	57.2	0.73
M-125	Monroe	Monroe	35	2N	Int	2,547	45	40	47	7	45	47	2	5.8	66.0	0.93
				2S	Int	9,483	44	42	46	4	42	45	3	5.6	68.8	0.88
M-52	Washtenaw	Chelsea	45	1N	Rural	4,214	56	52	58	6	54	57	3	8.6	47.7	0.80
				2N	Comm	7,249	43	39	47	8	39	44	5	6.5	56.7	0.95
				2S	Comm	8,082	43	40	47	7	40	45	5	7.9	50.5	0.75
				1S	Shp Ctr	7,872	48	46	51	5	46	49	3	5.3	69.4	0.93
13 Sections										6.5 Avg.			3.0	Avg.		

Table 21. Guidelines for setting speed limits.

- The speed limit should be set within 5 mi/h of the 85th percentile speed.
- The beginning and ending of each speed zone should be at a point obvious to the motorist such as a change in geometry, roadside development, etc. Jurisdictional boundaries such as city or township lines may be an inappropriate location for a speed zone change.
- The use of short (less than 0.20 mile) transition zones is discouraged. The majority of reasonable motorists adjust speed based on conditions and not on artificially low or high speed limits.
- Within each zone it is desirable that features such as design, roadside development, etc. be consistent as homogeneous sections tend to encourage similar operating speeds. It is not always practical to subdivide a roadway section into homogeneous zones because this could result in a number of short sections with various speed limits.
- The speed limit on the entire zone should not be based on one special condition such as a horizontal curve or intersection. When appropriate, advisory speeds should be used at these locations.
- Combining individual 85th percentile speeds in a zone to arrive at an average or composite figure is discouraged. It is also not necessary to collect speed data for both directions of travel at the same survey station. A more representative sample can be obtained by spreading the stations throughout the zone.
- The 85th percentile speed at each individual survey station should be compared to speeds at other stations in the zone. If the individual 85th percentile speeds vary by more than 5 mi/h, consideration should be given to providing separate zones if this does not result in short section lengths.
- Michigan law and Congressional directives establish the maximum speed limit on nonlimited access highways of 55 mi/h. On some rural sections 85th percentile speeds exceed 55 mi/h which creates a problem when using the 85th percentile speed to set speed limits in areas of transition from rural to urban conditions. Until realistic zoning is used on all highways, engineering judgement must be employed to set speed limits in rural to urban transition areas.

Table 22. Summary of validation study.

Site Description	Existing Speed Limit	Range of 85th Percentile Speeds	Suggested Speed Limit*	Recommended Speed Limit**
M-81 Caro				
West of Dixon Road	55	61-62	60	55
East of Dixon Road	55	55-59	55	50
M-36 Dansville (West)	45	53-54	55	50
M-36 Dansville (East)	45	57-57	55	55
M-50 Brooklyn	30	35-36	35	30
M-50 Brooklyn	40	46-47	45	45
M-50 Summit Twp.				
West of Napoleon Twp.	45	50-55	50	50
East of Napoleon Twp.	45	57-58	60	55
US-223 Adrian	45	46-50	45	45
M-50 Tecumseh	40	42-45	40	40
M-36 Hamburg	45	54-59	55	55
M-59 Howell	45	52-58	50	50
M-125 Monroe	45	49-49	50	50
M-125 Monroe	35	44-45	45	45
M-52 Chelsea	45	43-48	45	45

Notes: * Based only on the 85th percentile speeds.
** Based on the 85th percentile speeds and other considerations.

M-81 Caro

This two-lane section is predominantly rural in nature, west of Dixon Road. East of Dixon Road to the Caro limits is an area of predominantly commercial development. The current speed limit is 55 mi/h.

Speed data collected at stations west of Dixon Road revealed that the 85th percentile speeds are between 61 and 62 mi/h. East of Dixon Road the 85th percentile speeds range from 55 to 59 mi/h. An 85th percentile speed of 50 mi/h was recorded at the Caro limit which is posted at 45 mi/h. While the speed limit signs reflect that 55 mi/h is appropriate throughout the section, the majority of motorists have reduced their speed in the commercial area. In fact, during the afternoon near the Caro Shopping Center, the 85th percentile speed drops as low as 52 mi/h.

In other words, the current speed limit suggests that the speeds throughout the section would be homogeneous; however, motorists recognize that the roadside features have changed and have adjusted their speeds accordingly.

If the speed zoning decision was based only upon setting speed limits near the 85th percentile speed, a 60 mi/h limit would be posted west of Dixon and a 55 mi/h limit would be posted east of Dixon. As current law prohibits speed limits above 55 mi/h, the engineer could simply leave the entire zone posted at 55 mi/h. However, this would not reflect the fact that motorists have actually reduced their speed in the commercial section. Based on this consideration, a 55 mi/h zone is recommended west of Dixon Road and a 50 mi/h zone is recommended for the commercial area.

The importance of conducting a field review to select survey stations and using automated equipment to collect speed data for a 24-hour period was reinforced at this location. First, the accident analysis did not reveal any particular high-accident locations in the zone. During the field review, accident debris at the site, as well as observations of turning maneuvers, indicated high-risk conditions, especially in the vicinity of the shopping center. Second, the capacity on this two-lane roadway has been exceeded, especially during the afternoon hours. This problem is clearly reflected in the hourly variations in the 85th percentile speed at all stations located in the commercial area. Accordingly, if speeds were only obtained for a short period in the afternoon, the resulting 85th percentile speed would be considerably lower than the 24-hour 85th percentile speed.

M-36 Dansville

Dansville is a small village in a rural area. The 85th percentile speeds outside the village are approximately 60 mi/h which exceeds the 55 mi/h maximum limit. Short (1,500 feet) 45 mi/h transition zones were placed both east and west of the village limits in an apparent effort to slow traffic. The 85th percentile speeds in the western zone range from 53 to 54 mi/h and speeds in the eastern zone, which is more rural in nature, were 57 mi/h.

Under the 85th percentile criteria, both zones should be posted at 55 mi/h. However, using a 55 mi/h limit does not adequately reflect to motorists the fact that speeds were actually reduced by approximately 7 mi/h in the western zone and 3 mi/h in the eastern zone. It was recommended that a 50 mi/h zone be used west of the village as 50 mi/h is still within the 5 mi/h limit of the 85th percentile speed.

A transition zone east of Dansville is not recommended as the 85th percentile speeds were 57 mi/h. Traffic volume and roadside development is substantially less in this zone and this is reflected in the motorists choice of speed. Accordingly, the 55 mi/h limit should be extended to the eastern town limit.

M-50 Brooklyn

Two short zones were selected on M-50 in Brooklyn to examine the effects that varying roadway geometry has on the selection of a speed limit. Currently, a 0.57 mile section of M-50 in Brooklyn is posted at 30 mi/h with a 40 mi/h transition zone located south of Brooklyn.

Speeds collected in the southern section of the 30 mi/h zone reflect an 85th percentile speed of between 35 and 36 mi/h. However, speeds collected near the center of the zone where the roadway is divided suggests 85th percentile speeds of 32 mi/h. Commercial development throughout the zone is homogeneous.

Based on 85th percentile speeds, the 0.57 mile section could be subdivided into a 0.20 mile southern section with a 35 mi/h limit, and a 0.37 mile northern section with a 30 mi/h limit. As development along the roadway is homogeneous, subdivision of the sections is not a reasonable alternative. It was recommended that the existing 30 mi/h zone be retained. The 85th percentile speeds in the southern section are still within the 5 mi/h criteria.

Speeds in the 40 mi/h transition zone clearly indicate that the posted limit should be raised to 45 mi/h.

M-50 Summit Township

This 45 mi/h zone encompasses the US-127 interchange. Speed data collected in the vicinity of the ramps indicates the 85th percentile speeds range from 50 to 55 mi/h. East of the ramps, the 85th percentile speeds range from 57 to 58 mi/h. To adequately reflect existing conditions, the speed in the interchange area (west of the Napoleon Township line) should be raised to 50 mi/h. East of the Napoleon Township line the speed limit should be raised to 55 mi/h.

M-36 Hamburg

This existing 45 mi/h limit runs from Lemen Road to US-23. Although horizontal curves predominate the alignment west of Lemen Road, the alignment on this zone is tangent and the roadside development is light. The 85th percentile speeds range from 54 to 59 mi/h. Due to prevailing speeds, it was recommended that the speed limit be raised to 55 mi/h.

Impacts of Posting Realistic Speed Limits

Following data collection, the speed distribution can be used to examine the effects of various posted limits on driver compliance. For example, approximately 60 percent of the motorists exceed the existing 45 mi/h limit west of Dansville. If the speed limit is raised to 50 mi/h as recommended, approximately 30 percent of the motorists would exceed the speed limit, and only 8 percent would exceed the speed limit by 5 mi/h. It is recommended that this type of analysis be conducted and reported for each new speed survey and when rechecks are conducted.

RECOMMENDED PROCEDURE

Field studies conducted at 13 selected speed zone locations illustrate the validity of the recommended speed zoning procedure. The recommended procedure was developed in previous tasks and is summarized below for the benefit of the reader.

Recommended Speed Zoning Procedure

1. Speed limits should be posted within 5 mi/h of the 85th percentile speed.

2. The 85th percentile speeds should be determined by using automated equipment to collect the data for a 24-hour period. At a minimum, the data should be collected between 8:00 a.m. and 5:00 p.m. at each survey station.

3. The location of the survey stations should be based on an analysis of the accidents reported for a three-year period, the geometry in each zone, and roadside development.

4. The data should be analyzed in accordance with the guidelines given in Table 21, page 78, to determine the appropriate speed limit.

The speed zoning procedure currently practiced by the Michigan Department of Transportation and the Michigan State Police is not dramatically different from the recommended procedure. Clearly, the accident, driver compliance, cost-effectiveness, and other data suggest that the Michigan procedure is superior to those used in the states examined in this study. The Michigan procedure provides tangible benefits for road users and adjacent property owners.

The use of automated equipment is strongly recommended to minimize errors associated with time of day effects and current data collection methodology. The automated equipment is available and is currently used on a limited basis for speed zone studies.

SUMMARY OF FINDINGS

The pertinent findings of this study are:

1. The 85th percentile speed is the primary factor states use in setting speed limits.

2. In addition to the 85th percentile speed, other major factors considered by the majority of states include roadside development, accident experience, posted limits on adjacent zones, the upper limit of the 10 mi/h pace, roadway alignment and sight distance.

3. Engineering judgement is the primary tool used to weigh the importance of the various factors and to determine the numerical value of the speed limit. Frequently, the process is quite subjective which leads to arbitrarily posted limits.

4. Very few evaluations of the effectiveness of speed zoning procedures on improving safety and increasing driver compliance have been performed.

5. The available evidence suggests that posting limits in the region of the 85th percentile speed minimizes accident involvements and provides acceptable driver compliance. There is no information that suggests including other factors in setting speed limits would provide additional safety or compliance benefits.

6. An analysis of accidents at 68 Michigan sites where speed limits were changed and 86 comparison sites revealed that the current speed zoning method practiced in Michigan reduced total accidents by 2.2 percent. The level of confidence of this estimate is 62 percent. The 95 percent confidence interval for this estimate ranges from an accident reduction of 7 percent to an accident increase of 3 percent. The analysis revealed that this effect was not consistent from site to site.

7. Contrary to popular belief, the analyses indicate that raising speed limits does not increase accidents (in fact, accidents decreased by 3 percent). Lowering speed limits arbitrarily below the 85th percentile speed does not reduce accidents.

8. The most beneficial safety effect occurred when speed limits are posted within 5 mi/h of the 85th percentile speed. At sites posted near the 85th percentile speed, accidents were reduced by 3.5 percent. The level of confidence of this estimate is 73 percent. At sites where the speed limit was posted more than 5 mi/h below the 85th percentile speed, there was a 0.47 percent increase in accidents; however, this result is not statistically significant.

9. Speed limits posted at approximately 31 percent of the Michigan sites were not within 5 mi/h of the 85th percentile speed.

SUMMARY OF FINDINGS (CONTINUED)

10. The quantitative methods used by the other states examined in this study produced the same limit as posted at less than half of the Michigan sites, irrespective of whether accidents decreased or increased at the site.

11. At a typical Michigan site, a 5 mi/h difference in posted speed has a dramatic effect on driver compliance. If limits are set within 5 mi/h of the 85th percentile speed, at a minimum, 67 percent of the motorists would be in voluntary compliance. When limits are set within 7 mi/h, it is possible that only 40 percent compliance would be achieved.

12. An assessment of selected quantitative speed zoning methods used in other states was made based on safety, driver compliance, cost-effectiveness, and other criteria. Based on the assessment, the current Michigan procedure of posting limits within 5 mi/h of the 85th percentile speed was found to be superior to the other speed zoning methods examined.

13. Significant differences in hourly 85th percentile speeds were found at the survey stations on Michigan roadways examined in this study. The average difference for all monitoring stations, between the lowest and highest hourly 85th percentile speed, was 5.7 mi/h. The lowest variation in hourly 85th percentile speeds occurred between the hours of 8:00 a.m. and 5:00 p.m. When data are collected between 8:00 a.m. and 5:00 p.m., the hourly variations due to time of day can produce an error of approximately 1.5 mi/h above or below the 24-hour 85th percentile speed.

14. At the four locations studied, the 85th percentile speeds were generally the same for each day of the week including weekends.

15. During the summer months, 85th percentile speeds appear to be 1 to 2 mi/h lower than the 85th percentile speeds reported during other times of the year.

16. Signalized intersections appear to reduce 85th percentile speeds between 2 and 7 mi/h. Unsignalized intersections appear to have a smaller effect on the 85th percentile speed than signalized intersections, however, turning volume probably has a major effect on the 85th percentile speed.

17. Commercial and residential development appear to lower the 85th percentile speed between 2 and 5 mi/h.

18. The method used by the Michigan Department of Transportation to collect speed data appears to have a significant effect on the 85th percentile speed. Based on selected samples, it appears that the Department's estimate of the 85th percentile speed is approximately 3 mi/h lower than the speed recorded by automated equipment.

CONCLUSIONS

1. The current Michigan practice of posting speed limits within 5 mi/h of the 85th percentile speed has a beneficial effect, although small, on reducing total accidents, but has a major beneficial effect on providing improved driver compliance.

2. Posting speed limits more than 5 mi/h below the 85th percentile speed does not reduce accidents and has an adverse effect on driver compliance.

3. The accident analysis revealed that the speed limit changes on Michigan roadways produced a small effect on total accidents, and these effects varied from location to location. Consequently, speed zoning should not be used as the only corrective measure at high-accident location in lieu of other safety improvements.

4. Safety and driver compliance benefits could be realized if speed limits were always set within 5 mi/h of the 85th percentile speed.

5. The quantitative speed zoning methods or other factors used by the other states examined in this study would not improve safety and driver compliance if implemented on Michigan roadways.

6. The 85th percentile speed varies by hour of the day. Speed samples taken for a short period at a survey site can overestimate or underestimate the 24-hour 85th percentile speed by 1.5 mi/h or more.

7. The current use of radar to collect speed data in Michigan appears to underestimate the 85th percentile speed by approximately 3 mi/h.

8. In order to insure compatibility between design and realistic operating speeds on new or reconstructed roadway projects, design and traffic engineers should discuss the proposed design conditions and probable operating speeds in the preliminary design period to select an appropriate design speed.

9. Field studies conducted at 13 selected Michigan speed zone sites illustrate the validity of setting speed limits within 5 mi/h of the 85th percentile speed.

10. The speed zoning procedure recommended in this study is not dramatically different from the speed zoning method currently practiced by the Michigan Department of Transportation and the Michigan State Police.

11. The use of automated equipment to collect 24-hour speed samples is strongly recommended to minimize errors associated with time of day effects and current speed data collection methodology.

RECOMMENDATIONS

1. The following speed zoning procedure is recommended for implementation in Michigan.

   - Speed limits should be posted within 5 mi/h of the 85th percentile speed.

   - An accident analysis should be conducted as a routine part of speed zone investigations. The analysis should identify abnormally high accident characteristics and problem locations. A field review should be conducted to identify possible causes and develop recommendations for improvements. Speed zoning, per se, should not be used as a countermeasure to address abnormally high accident situations.

   - To minimize time of day effects and data collection errors, 85th percentile speeds should be determined by using automated equipment to collect data for a 24-hour period.

   - The location of the survey stations should be based on the geometry in each zone and roadside development. Stations should not be placed within 500 feet of isolated major intersections or horizontal curves.

   - The data should be analyzed in accordance with the guidelines listed below to determine the appropriate speed limit.

2. The following guidelines should be used for setting speed limits.

   - The posted speed limit should be set within 5 mi/h of the 85th percentile speed.

   - The beginning and ending of each speed zone should be at a point obvious to the motorist such as a change in geometry, roadside development, etc. Jurisdictional boundaries such as city or township lines may be an inappropriate location for a speed zone change.

   - The use of short (less than 0.20 mile) speed zones and transition zones is discouraged. The majority of reasonable motorists adjust their speed based on environmental and traffic conditions and not on artificially low or high posted speed limits.

   - Within each zone it is desirable that features such as design, roadside development, etc. be consistent as homogeneous sections tend to encourage similar operating speeds. It is not always practical to subdivide a roadway section into homogeneous zones because this could result in a number of short sections with various speed limits.

   - The speed limit on the entire zone should not be based on one special condition such as an isolated horizontal curve or intersection. When appropriate, advisory speeds should be used at these locations.

RECOMMENDATIONS (CONTINUED)

- Combining individual 85th percentile speeds in a zone to arrive at an average or composite figure is discouraged. It is also not necessary to collect speed data for both directions of travel at the same survey station. A more representative sample can be obtained by spreading the stations throughout the zone.

- The 85th percentile speed at each individual survey station should be compared to speeds at other stations in the zone. If the individual 85th percentile speeds vary by more than 5 mi/h, consideration should be given to providing separate zones if this does not result in short section lengths.

- Michigan law and Congressional directives establish a 55 mi/h maximum speed limit on nonlimited access highways. On some rural highways, 85th percentile speeds exceed 55 mi/h. This creates a problem when using the 85th percentile speed to set speed limits in areas that transition from rural to urban conditions. Until realistic zoning is used on all highways, engineering judgement must be employed to set speed limits in transition areas.

3. To improve public understanding of the safety impacts and other benefits of using the 85th percentile speed to set speed limits, a public informational brochure should be developed for distribution.

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APPENDIX A - SURVEY RESULTS

Return To:

Mr. Martin R. Parker, Jr., P.E.
Martin R. Parker & Associates, Inc.
38549 Laurenwood Drive
Wayne, Michigan 48184-1073

Jurisdiction 49 States, District of Columbia, Guam, and Puerto Rico

MICHIGAN COMPARISON OF SPEED ZONED ZONING METHODS

PART I. METHOD USED TO DETERMINE MAXIMUM SPEED LIMITS.

1. Which of the following factors are obtained and used in your engineering and traffic investigation to determine what numerical speed limit to post on highways under your jurisdiction? (Circle each factor that is used).

2 a. 90th percentile speed
52 b. 85th percentile speed
11 c. 50th percentile speed
34 d. Pace
27 e. Design speed of the facility
33 f. Length of zone and posted limits on adjacent zones
45 g. Type and amount of roadside development
22 h. Pedestrian volumes
15 i. Number of signalized intersections on roadways
6 j. Percentage of commercial vehicles
18 k. Traffic volume
26 l. Pavement and shoulder widths
31 m. Horizontal and vertical alignment
14 n. High percentage of drivers exceeding existing limit
24 o. Average test run speed
44 p. Accident experience
21 q. Presence of parking and loading zones
30 r. Sight distance
16 s. Unexpected conditions
18 t. Hazardous locations within zone
15 u. Other. Please specify. Road surface, neighborhood safety, presence of schools, etc.

2. Does your agency have a written procedure describing the method used to set maximum speed limits?

24 YES --->Please enclose a copy and skip to Question 5. (22 enclosed copy of procedures)
26 NO

3. Briefly describe the procedure used by your agency to determine the numerical value of the speed limit to post.

See Appendix B

4. Which of the factors circled in Question 1 are used in a numerical formula or rule-of-thumb process to determine the value of the speed limit? List each factor used and briefly describe the method. For example, if accident experience is considered, how is it numerically used to set the speed limit?

Factor	*Numerical Process Or Rule-Of-Thumb*
	See Appendix B

5. What is the scientific basis or rationale used for selecting factors and the value of each factor in your speed zoning method? Please cite specific research or operational reports, or describe the rationale used.

Manual on Uniform Traffic Control Devices
ITE Transportation and Traffic Engineering Handbook
Traffic Institute (Northwest) Speed Zoning Methodology
ITE Informational Report on Speed Zoning, 1961
Risk of an accident involvement is lowest at 85th percentile speed.

6. After your engineering data and method is used to determine the value of the speed limit, are any further adjustments or rule-of-thumb deviations from the procedure made?

17 YES 28 NO

7. If your answer to Question 6 is Yes, please list adjustments typically made and the usual reasons for those adjustments.

Adjustment	*Reason*
Accident History	Typical adjustments were from 3 to 9 mi/h
Sight Distance	downward depending upon site conditions.
Pedestrian Activity	Engineering judgment was used to make the change.

8. Please describe any problems you have experienced in using your method for setting maximum speed limits on highways under your jurisdiction.

Current methodology is too subjective which complicates training new personnel.
Difficult to explain method to the public, politicians, and local officials.
Radar detectors identify study sites.
Most officials and the public believe a lower limit is safer.

9. Which agency is empowered to establish or revise speed limits in your jurisdiction?

42 a. State highway and/or state enforcement agency
8 b. Local administrative agency
1 c. Local enforcement agency
4 d. Both state and local agencies
3 e. Local agency with state agency approval
0 f. State Police or state enforcement agency
6 g. Other. Please specify. State Traffic Commission, State Transportation Board

PART II. EVALUATIONS OF CURRENT SPEED ZONING METHODS

10. Have any evaluations been conducted of your speed zoning method, such as before and after studies, to examine the effect of the method/procedure on accidents, driver compliance, average speeds, etc.?

37 NO
12 YES ---> Please enclose a copy of the evaluation report or list the report title, agency, and date.

Informal observations, FHWA ongoing study, MSU study

11. Does your organization have any planned, ongoing, or recently completed studies involving the development of procedures or criteria for establishing speed limits?

45 NO
3 YES ---> Please list the objectives, scope, and agency conducting the study:

FHWA ongoing study on Effects of Raising and Lowering Speed Limits.
Kansas is planning to study effects of altering speed limits.

PART III. SPEED DATA COLLECTION METHOD

12. If your agency has a written procedure for collecting speed and other data needed to set maximum speed limits, please enclose a copy of your manual and skip to Question 14. Otherwise, describe your method for each item listed below.

   a. Number of monitoring stations or spacing of stations?
   Select enough stations to represent speed profile.
   Urban - Every block to 0.25 mile.
   Rural - 1 mile to where road conditions change.

   b. Vehicles monitored? (Circle number).
   5 1 All vehicles
   41 2 Free-flow vehicles only

   c. Vehicle selection method? For example, every nth vehicle (second, third, etc.)
   3 None, 5 Lead vehicle of platoon, 6 Judgement,
   8 All free flow vehicles, 4 Random

   d. Vehicle types recorded? (Circle number).
   3 1 Passenger cars only
   9 2 Cars, trucks, and buses recorded separately
   30 3 All vehicles
   4 4 Other Cars and trucks, Cars and Buses

   e. Minimum number of vehicles sampled?
   Ranged from 50 to 250. Majority of respondents use 100 vehicles or 2 hours.

   f. Days speed data collected? (Circle all that apply)
   MON TUE WED THUR FRI SAT SUN

   g. Time periods data collected?
   Monday thru Friday, off-peak, daytime, dry roadway.

13. What type(s) of equipment does your agency use to collect speed data for setting maximum speed limits? (Circle all that apply.)

   1 a. Stopwatch
   5 b. Moving vehicle
   31 c. Radar Describe type Portable, Hand-held
   5 d. Automated speed classifier with road tubes. Tube spacing? 6 ft. 3 in. to 16 ft.
   0 e. Automated speed classifier with temporary loops. Loop spacing? ________
   0 f. Other ________________________________

14. Additional comments:

   Would appreciate a copy of the study results.

   Any method of speed zoning that does not take into account the functional classification of the roadway is doomed to failure. Arterials must be set near 85th percentile; collectors and local roads, less so as their primary function is local access.

15. Please provide the name and telephone number of a person in your agency that we can contact regarding your speed zoning method.

   Name ________________________ Telephone ____________________

APPENDIX B - SPEED ZONING METHODS

State	Major Factors Considered	Method
Alabama	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrians Road width Alignment Accident experience Sight distance Unexpected conditions	Generally, the 85th percentile speed is the governing factor, however, this may be adjusted by the influence of other factors. Adjustments are made based on a subjective evaluation of the factors.
Alaska	85th percentile speed Pace Roadside development Alignment Sight distance Accident experience Neighborhood safety Pedestrian activity	Speed limits shall be basically established at or near the 85th percentile speed. The speed limit may be modified downward by a 5 mi/h increment based on consideration of other factors.
Arizona	85th percentile speed Adjacent zones Roadside development Signalized intersections Traffic volume Roadway width Alignment Accident experience Sight distance Surface condition	Speed limits are set as near as practical to the 85th percentile speed. Any of the factors considered may affect the final speed limit.
Arkansas	85th percentile speed Adjacent zones Roadside development Signalized intersections Traffic volume Roadway width Alignment Accident experience Hazardous location	The factors are considered along with an evaluation of posted speeds in areas with similar features and used as a guide in selecting the appropriate speed limit.
California	Prevailing speed Unexpected conditions Accident experience	Speed limits are established at or near the 85th percentile speed. When roadside development results in traffic conflicts and unusual conditions not apparent to drivers, speed limits somewhat below the 85th percentile may be warranted. On local roads, in matching existing conditions with traffic safety needs of the community, engineering judgment may indicate the need for a further reduction of 5 mi/h.
Colorado	85th percentile speed Pace Roadside development Signalized intersections Alignment Accident experience	Under ideal conditions, the speed limit should be near the 85th percentile speed. Accident experience, along with other factors, are considered using experience and engineering judgment.

APPENDIX B - SPEED ZONING METHODS (CONTINUED)

State	Major Factors Considered	Method
Connecticut	85th percentile speed Design speed Roadside development Pedestrian activity Signalized intersections Traffic volume Roadway width Alignment Accident experience Sight distance	The speed limit is determined by analysis of all factors and, in most cases, should be close to the 85th percentile speed. If a section has several accidents related to speed, a determination should be made concerning corrective action, i.e., reduce speed, additional enforcement, or further study for geometric improvements.
Delaware	85th percentile speed 50th percentile speed Pace Design speed Roadside development Pedestrian volume Sight distance	The 85th percentile is used to set speed limits, however, other factors may reduce the posted speeds towards the 50th percentile.
District of Columbia	85th percentile speed Design speed Adjacent zones Average test run	The speed limit should not exceed the 85th percentile or design speed. Other factors are considered, along with an evaluation of zones on similar facilities.
Florida	85th percentile speed Pace Average test run Accident experience	The speed limit should not differ from the 85th percentile speed or upper limit of the pace by more than 3 mi/h and it shall not be more than 8 mi/h less. A limit of 4 to 8 mi/h less must be supported by a supplemental investigation which reveals roadside features not obvious to the normal prudent driver, or that other traffic controls have been tried but found ineffective. Accident experience should be considered, but a realistic speed limit is conducive to lowering accident potential.
Georgia	85th percentile speed Adjacent zones Roadside development	The 85th percentile speed rounded to the nearest 5 mi/h should normally be used to set the limit. Heavy development (frequent driveways) or an increasing level of development may be used in borderline cases to justify rounding down from the 85th percentile. Not more than a 10 mi/h drop from the adjacent zone is permitted.
Guam	85th percentile speed Design speed Adjacent zones Roadside development Traffic volume Roadway width Alignment Accident experience Sight distance Unexpected conditions Hazardous locations	All factors are considered in posting speed limits. The maximum speed limit on the island is 45 mi/h.
Hawaii	85th percentile Design speed Roadside development Pedestrian volume Signalized intersections Traffic volume Alignment Accident experience	All factors are considered based on engineering judgment and used to set the speed limit.

<table>
<tr><th>State</th><th>Major Factors Considered</th><th>Method</th></tr>
<tr><td>Hawaii
(Continued)</td><td>Parking zones
Sight distance
Hazardous locations</td><td></td></tr>
<tr><td>Idaho</td><td>85th percentile speed
Pace
Roadside development
Average test run
Sight distance</td><td>The 85th percentile speed is a primary factor for selecting speed limits. The speed limit should be compatible with safe stopping sight distance. The engineer uses judgment and experience when considering any deviation from the 85th percentile.</td></tr>
<tr><td>Illinois</td><td>Prevailing speed
Accident rate
Access control
Pedestrian activity
Parking</td><td>The speed limit should not differ from the prevailing speed by more than 3 mi/h unless justified by supplementary investigations. The prevailing speed is the average of the 85th percentile speed, upper limit of pace, and average test run speed. The study may include any or all of the following conditions:

1. If the accident rate is 50 percent higher than the state-wide rate for the same highway classification, the prevailing speed may be reduced by 5 percent. If the accident rate is more than twice the statewide rate, the prevailing speed may be reduced by 10 percent.

2. The effect of driveways and other entrances will be determined by using an access conflict number. The access conflict number is based on the number and type of driveways. Based on the access conflict number, the prevailing speed may be reduced by the percentages indicated below:

<table><tr><th>Access Conflicts Per Mile</th><th>Prevailing Speed Reduction Percent</th></tr><tr><td>0 - 40</td><td>0</td></tr><tr><td>41 - 60</td><td>5</td></tr><tr><td>61 or more</td><td>10</td></tr></table>
3. The prevailing speed may be reduced by 5 percent where no sidewalks are provided and the total pedestrian traffic exceeds 10 per hour for any 3 hours within any 8-hour period. The prevailing speed may also be reduced by 5 percent where sidewalks are located immediately behind the curb.

4. Where parking is permitted adjacent to the traffic lanes, the prevailing speed may be reduced by 5 percent.

After applying the percentage corrections, in no case shall the resulting speed limit differ from the prevailing speed by more than 9 mi/h or 20 percent of the prevailing speed, whichever is less.</td></tr>
<tr><td>Indiana</td><td>85th percentile speed
90th percentile speed
50th percentile speed
Pace
Design speed
Adjacent zones
Roadside development
Percent exceeding limit
Accident experience
Sight distance</td><td>Speed limits should normally be established at the first 5 mi/h increment at or above the 85th percentile speed unless there are hidden hazards of an exceptional nature, as revealed by accident experience and by study of the location. The limit should not normally be established more than 7 mi/h below or 5 mi/h above the 85th percentile speed. The posted limit should not exceed the design speed.</td></tr>
</table>

State	Major Factors Considered	Method
Iowa	85th percentile speed Pace Adjacent zones Roadside development Roadway width Alignment Average test run Parking zones Sight distance Unexpected conditions Hazardous locations	The primary factor considered is the 85th percentile speed. Adjustments to the speed limits are made in accordance with the factors in the ITE recommended procedure. Since the procedure is not an exact science, there is some room for compromise and adjustment within good engineering judgment and practice.
Kansas	85th percentile speed Pace Design speed Adjacent zones Roadside development Accident experience	The speed limit is set to the 85th percentile speed or upper limit of the pace rounded to the nearest 5 mi/h increment.
Kentucky	85th percentile speed Roadside development Accident experience Roadway conditions	Generally, the appropriate numerical limit will approximate the prevailing 85th percentile speed.
Louisiana	85th percentile speed 50th percentile speed Design speed Adjacent zones Roadside development Pedestrian volume Roadway width Accident experience Parking zones	While all factors are considered, the 85th percentile speed is the principal factor that is used as a guide in establishing the speed limit. Additionally, the numerical value of the speed limit should not be set below the upper limit of the pace.
Maine	85th percentile speed 50th percentile speed Design speed Roadside development Roadway width Alignment Average test run Accident experience Sight distance Unexpected conditions	The speed zoning methodology developed by the Traffic Institute, Northwestern University, was modified to fit conditions in the state.
Maryland	85th percentile speed Design speed Adjacent zones Roadside development Accident experience Sight distance Unexpected conditions	Generally, speed limits are set at the 85th percentile speed raised to the nearest 5 mi/h increment. Consideration of other factors may require setting the speed limit to the nearest 5 mi/h increment lower than the 85th percentile speed.
Massachusetts	85th percentile speed 50th percentile speed Pace Adjacent zones Roadside development Traffic volume Pavement width Alignment	The numerical speed limit should be as close to the 85th percentile speed as possible, taking into account other factors such as a high accident frequency. If a high accident frequency exists, the posted speed limit may be reduced by no more than 7 mi/h from the 85th percentile speed.

State	Major Factors Considered	Method
Massachusetts (Continued)	Drivers exceeding limit Average test run Accident experience Parking zones Sight distance Unexpected conditions Hazardous locations	
Michigan	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Signalized intersections Commercial vehicles Traffic volume Roadway width Alignment Drivers exceeding limit Average test run Accident experience Parking zones Sight distance Unexpected conditions Hazardous locations	The 85th percentile speed is the major factor used in setting the speed limit. All other actors are considered based on engineering judgment. The posted limit may be rounded up or down to the nearest 5 mi/h for signing purposes.
Minnesota	85th percentile speed Pace Accident experience	If the roadway has satisfactory accident experience and no conditions which would confuse or surprise the motorist, speed limits should be established at the 85th percentile speed or upper limit of the pace, whichever is higher. The limit may be set 5 mi/h under the upper limit of the pace if there is a bad accident history involving accidents of a type that could be eliminated or reduced by enforcement of a lower limit.
Mississippi	85th percentile speed Pace Design speed Roadside development Average test run Accident experience Sight distance	After considering all factors, the speed limit is selected near the 85th percentile, which must be within the pace and compatible with adjacent zones. If the engineers feel a reduction is warranted, the speed limit may be set 5 mi/h below the 85th percentile speed if the result is within the pace.
Missouri	Prevailing speed Accident rate Access control Pedestrian activity Parking	The speed limit should not differ from the prevailing speed by more than 3 mi/h unless justified by supplementary investigations. The prevailing speed is the average of the 85th percentile speed, upper limit of the pace, and average test run speed. The study may include any or all of the following conditions: 1. If the accident rate is 50 percent higher than the state-wide rate for the same highway classification, the prevailing speed may be reduced by 5 percent. If the accident rate is more than twice the statewide rate, the prevailing speed may be reduced by 10 percent. 2. The effect of driveways and other entrances will be determined by using an access conflict number. The access conflict number is based on the number and type of driveways. Based on the access conflict number, the prevailing speed may be reduced by the percentages indicated below:

APPENDIX B - SPEED ZONING METHODS (CONTINUED)

State	Major Factors Considered	Method
Missouri (Continued)		Access Conflicts Per Mile / Prevailing Speed Reduction Percent: 0 - 40: 0 41 - 60: 5 61 or more: 10 However, before a reduction can be made due to driveway conflict number, the accident reduction must be statistically significant as tested by the Poisson curve. 3. The prevailing speed may be reduced by 5 percent where no sidewalks are provided and the total pedestrian traffic exceeds 10 per hour for any 3 hours within any 8-hour period. The prevailing speed may also be reduced by 5 percent where sidewalks are located immediately behind the curb. 4. Where parking is permitted adjacent to the traffic lanes, the prevailing speed may be reduced by 5 percent. After applying the percentage corrections, in no case shall the resulting speed limit differ from the prevailing speed by more than 10 mi/h.
Montana	85th percentile speed Roadside development Pedestrian traffic Road width Alignment Accident experience Sight distance School crossing	Experience has shown that speed limits based on prevailing speed and the accident rate are of extreme importance and these two factors are given primary consideration.
Nebraska	85th percentile speed Pace Adjacent zones Roadside development Signalized intersections Traffic volume Drivers exceeding limit Average test run Accident experience Parking zones Sight distance	All factors are considered, particularly the 85th percentile speed, upper limit of the pace, percentage of drivers exceeding the speed limit, and accidents. Engineering judgment is used in deciding the numerical limit of the speed zone.
Nevada	Prevailing speed Roadside development Design speed Roadway width Alignment Pedestrian activity Road class Parking zones Accident rate	The speed zoning methodology developed by the Traffic Institute, Northwestern University, is used to establish speed limits. A minimum study, which considers the prevailing speed (85th percentile, upper limit of pace, and average test run), is conducted. In approximately 90 percent of the studies, the refined method is used, which considers other factors. The analysis requires adding or subtracting from the prevailing speed based on the value of factors listed in a series of tables. Due to the subjectivity introduced in considering the influencing factors which may suggest a speed greater or less than 10 mi/h from the 85th percentile speed, the current practice is to not recommend a speed limit higher than the minimum study recommendation (prevailing speed). Also, a speed limit below the 67th percentile speed is not recommended.

APPENDIX B - SPEED ZONING METHODS (CONTINUED)

State	Major Factors Considered	Method
New Hampshire	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Signalized intersections Traffic volume Accident experience Unexpected conditions Hazardous locations	Speed limits are established on the basis of an engineering and traffic investigation. Speed limits for roadways with reasonable accident records should be set at the 85th percentile or upper limit of the pace, whichever is higher. Speed limits are acceptable at 5 mi/h below the upper limit of the pace where the accident incidents are of a type that would be affected by enforcement of a lower speed limit.
New Jersey	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Roadway width Alignment Average test run Accident experience Parking zones Sight distance Lack of sidewalks	After a field investigation is conducted, the value closest to the 85th percentile speed is chosen. Typically, the numeric value of the limit is set to the next lowest 5 mi/h increment.
New Mexico	85th percentile speed 50th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Alignment Drivers exceeding limit Average test run Accident experience Parking zones Sight distance Hazardous locations Signals in high-speed areas	Basically, speed limits are set at the 85th percentile speed unless other conditions, such as design speed, dictate otherwise. Also, the limit may be set lower if the accident rate is higher than the average accident rate. The speed limit is usually set within the pace.
New York	85th percentile speed Pace Adjacent zones Roadside development Signalized intersections Roadway width Alignment Accident experience Sight distance Roadway conditions	The 85th percentile speed should be used to set the speed limit to the nearest 5 mi/h. Other limits may be established in exceptional cases, providing they are supported by good reasoning which firmly indicates that conditions are unusual and that the 85th percentile speed is not applicable in a particular incidence. Speed limits set below the 85th should not be lower than 3 mi/h below the upper limit of the pace, or not lower than the 67th percentile speed. Speed limits set higher than the 85th percentile should not be more than 5 mi/h above the upper limit of the pace.

State	Major Factors Considered	Method
North Carolina	85th percentile speed Pace Design speed Adjacent zones Roadside development Commercial vehicles Traffic volume Roadway width Alignment Accident experience	The proper numerical speed limit is set following an engineering and traffic investigation by considering factors listed in the MUTCD. Engineering judgment is used to consider factors in setting the speed limit.
North Dakota	85th percentile speed 50th percentile speed Pace Design speed Adjacent zones Roadside development Traffic volume Drivers exceeding limit Accident experience Sight distance	The 85th percentile speed and design speed, in conjunction with other factors, are used to set the speed limit. Engineering judgment is used to consider the other factors.
Ohio	Prevailing speed Design speed Length of zone Roadside development Accident experience	Basically, the ITE Handbook procedure, refined some 30 years ago is used to determine where speed zoning is needed and what limits should be established. The procedure consists of collecting data for 10 factors and assigning a value to each factor. The average value of the factors determines the warranted speed. As of June 1992, the Ohio DOT is revising its speed zoning method. The new method uses the same factors, but they are refined and weighed differently. An evaluation will be conducted of the new method.
Oklahoma	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Signalized intersections Roadway width Alignment Average test run Parking zones Unexpected conditions Hazardous locations Average speed	All factors are considered using engineering judgment to select the numerical value of the speed limit.
Oregon	85th percentile speed Adjacent zones Pace Percent exceeding limit Accident experience Local attitudes Public testimony	On state roads the safe speed is established as the algebraic summation of the 85th percentile speed and the difference in the accident rate for similar sections and the accident rate for the section being considered. The speed limit shall not vary more than 5 mi/h above or below this value. On local roads the speed limit is set at the nearest 5 mi/h increment to the 85th percentile speed. The recommended speed on local roads may be reduced if the accident rate indicates it is necessary, but should not normally be set more than 10 mi/h below the 85th percentile speed.

State	Major Factors Considered	Method
Pennsylvania	85th percentile speed Accident experience Sight distance	The speed limit should be set within 5 mi/h of the average 85th percentile speed or the safe running speed on the section, except the limit may be reduced up to 10 mi/h below these values if any of the following conditions are satisfied: 1. A major portion of the highway has stopping sight distance below the minimum values. 2. The available corner sight distance on a number of side roads is less than the appropriate minimum stopping sight distance. 3. An accident analysis indicates that the majority of accidents are related to excessive speed and the 3-year accident rate is greater than the rate shown below: Highway Type — Accident Rate, MVM Urban expressway — 1.35 Urban highway — 3.70 Rural freeway — 0.75 Rural highway — 3.25
Puerto Rico	85th percentile speed Traffic volume Roadway width Alignment Drivers exceeding limit Accident experience	In most situations the speed limit is posted within the range 5 mi/h above or below the 85th percentile speed.
Rhode Island	85th percentile speed Roadside development Roadway width Alignment	Speed studies are performed by a consultant who recommends a maximum limit. The speed limit is approved or changed by the State Traffic Commission. Engineering judgment is used to set the maximum speed limit.
South Carolina	85th percentile speed Design speed Adjacent zones Roadside development Pedestrian volume Signalized intersections Commercial vehicles Traffic volume Roadway width Alignment Average test run Accident experience Parking zones Sight distance	Typically, the 85th percentile speed is used to set the limit. Other factors are informally considered based on the traffic engineer's judgment.

APPENDIX B - SPEED ZONING METHODS (CONTINUED)

State	Major Factors Considered	Method
South Dakota	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Commercial vehicles Roadway width Alignment Drivers exceeding limit Average test run Accident experience Sight distance Unexpected conditions Hazardous locations	Engineering judgment is used to determine the value of the speed limit based on consideration of recorded speeds and other factors.
Tennessee	90th percentile speed 85th percentile speed 50th percentile speed Pace Design speed Roadside development Adjacent zones Signalized intersections Commercial vehicles Traffic volume Roadway width Alignment Average test run Accident experience Parking zones Sight distance Unexpected conditions Hazardous locations	Speed limits are set by using engineering judgment to consider all the factors. The major factors given the most consideration are 85th percentile speed, roadway alignment, accident experience, roadside development, and traffic volume.
Texas	85th percentile speed Design speed Adjacent zones Roadside development Alignment Average test run Accident experience Hazardous locations	Normally, the 85th percentile speed is used to establish the speed limit rounded to the nearest value which ends in a 5 or 0 for posted purposes. Posted speeds may be as much as 7 mi/h below the 85th percentile speed for high accident locations (where the accident rate is higher than the statewide average rate).
Utah	85th percentile speed Pace	The speed limit is set 6 mi/h above or below the 85th percentile speed.
Vermont	85th percentile speed 50th percentile speed Pace Design speed Adjacent zones Roadside development Traffic volume Roadway width Accident experience Sight distance	While all factors listed in the MUTCD are considered, the speed limit should be posted to the nearest 5 mi/h increment to the 85th percentile or upper limit of the pace, whichever is lower, less 3 mi/h and never below the lower limit of the pace. The speed limit may be set lower if the section has high accident experience or contains a school zone. The speed limit may be raised or lowered to provide continuity of limits with adjacent zones.

APPENDIX B - SPEED ZONING METHODS (CONTINUED)

State	Major Factors Considered	Method
Virginia	85th percentile speed 50th percentile speed Pace Adjacent zones Roadside development Pedestrian volume Signalized intersections Roadway width Alignment Drivers exceeding limit Average test run Accident experience Parking zones Sight distance Unexpected conditions Hazardous locations	Engineering judgment is used to consider all of the factors including the 85th percentile speed. The speed limit may be adjusted based on how the limit fits into the overall roadway corridor.
Washington	85th percentile speed Pace Roadside development Pedestrian volume Signalized intersections Roadway width Alignment Average test run Accident experience Parking zones Sight distance	The major factor considered in setting the speed limit is the 85th percentile. The other factors have some influence on the 85th percentile speed. Speed limits are normally posted at the 85th percentile or up to 5 mi/h lower than the 85th percentile.
West Virginia	85th percentile speed Pace Design speed Adjacent zones Roadside development Pedestrian volume Roadway width Alignment Drivers exceeding limit Average test run Accident experience Parking zones Sight distance Unexpected conditions Hazardous locations Setback distance	After considering all factors, the speed limit is established within 3 to 4 mi/h of the 85th percentile speed. The speed limit should be within the pace.
Wisconsin	85th percentile speed 50th percentile speed Adjacent zones Roadside development Pedestrian volume Traffic volume Roadway width Alignment Drivers exceeding limit Average test run Accident experience Parking zones Unexpected conditions Hazardous locations Urban/rural cross-section	Ideally, the speed limit should be set at the 85th percentile speed. However, actual practice usually prescribes a lower limit. Roadside development is one of the major reasons for lower speed limits.

APPENDIX C - PAIRED COMPARISON RATIO METHOD USING RAISE SPEED LIMIT SITES

Site No.	Treatment Accidents Before	Treatment Accidents After	Comparison Accidents Before	Comparison Accidents After	Comparison Ratio C	B*	Percent Change	Z	L	w	wL	$(L-Lt)^2$	$w(L-Lt)^2$	wL^2
1151	5	5	4	1	0.25	1.25	300.0	1.08	1.3863	0.6061	0.8402	2.0087	1.2174	1.1647
1152	8	22	13	12	0.92	7.38	197.9	1.90	1.0916	3.0238	3.3009	1.2603	3.8109	3.6034
1153	94	120	318	345	1.08	101.98	17.7	1.03	0.1627	39.9763	6.5043	0.0375	1.4998	1.0583
1154	56	114	248	344	1.39	77.68	46.8	2.09	0.3836	29.7900	11.4285	0.1719	5.1212	4.3843
1251	1	6	6	7	1.17	1.17	414.3	1.35	1.6376	0.6774	1.1093	2.7842	1.8861	1.8167
1252	2	6	9	8	0.89	1.78	237.5	1.28	1.2164	1.1077	1.3474	1.5560	1.7235	1.6390
1351	4	3	10	18	1.80	7.20	-58.3	-1.02	-0.8755	1.3534	-1.1848	0.7131	0.9652	1.0373
1451	1	0.5	8	2	0.25	0.25	100.0	0.36	0.6931	0.2759	0.1912	0.5244	0.1447	0.1325
1452	14	4	14	5	0.36	5.00	-20.0	-0.29	-0.2231	1.6867	-0.3764	0.0369	0.0623	0.0840
1453	3	2	17	3	0.18	0.53	277.8	1.20	1.3291	0.8160	1.0846	1.8499	1.5095	1.4415
1454	64	58	40	73	1.83	116.80	-50.3	-2.62	-0.7000	13.9733	-9.7816	0.4476	6.2545	6.8473
1551	140	124	245	300	1.22	171.43	-27.7	-2.15	-0.3239	44.2041	-14.3170	0.0858	3.7922	4.6371
1751	53	53	130	145	1.12	59.12	-10.3	-0.48	-0.1092	19.1114	-2.0870	0.0061	0.1169	0.2279
1752	25	53	338	419	1.24	30.99	71.0	2.12	0.5366	15.5731	8.3564	0.3221	5.0168	4.4840
1753	48	61	2403	2909	1.21	58.11	5.0	0.25	0.0486	26.3250	1.2789	0.0063	0.1667	0.0621
1754	12	8	113	155	1.37	16.46	-51.4	-1.53	-0.7215	4.4716	-3.2263	0.4768	2.1321	2.3278
1755	47	44	122	150	1.23	57.79	-23.9	-1.12	-0.2726	16.9874	-4.6303	0.0584	0.9914	1.2621
1756	64	66	140	163	1.16	74.51	-11.4	-0.58	-0.1213	22.6992	-2.7542	0.0082	0.1853	0.3342
1757	90	143	268	274	1.02	92.01	55.4	2.76	0.4409	39.2386	17.3001	0.2227	8.7373	7.6275
1758	109	119	126	221	1.75	191.18	-37.8	-2.74	-0.4741	33.2900	-15.7830	0.1964	6.5366	7.4828
1951	1000	1089	764	890	1.16	1164.92	-6.5	-1.02	-0.0674	229.8444	-15.4901	0.0013	0.3046	1.0439
Totals	1840.0	2100.5	5336.0	6444.0		2237.54				545.0314	-16.8889		52.1751	52.6984

Comparison Ratio = Ratio of Comparison site after accidents to before accidents.
B* = Treatment before accidents multiplied by the comparison ratio.
Change = Percent change in treatment accidents from before to after.
L = Log Odds Ratio
w = Weighting Coefficient
Lt = Weighted average log odds ratio = -0.0310
Ut = Antilogarithm of the weighted average log odds ratio = 0.9695
Et = Apparent change in accidents in percent = -3.05
Lse = Standard error of the weighted average log odds ratio = 0.0428
Z = Standard normal Z test = -0.72
Lowlm = 95% Lower confidence limit in percent = -10.86
Upplm = 95% Upper confidence limit in percent = 5.44

Chi-square summary to assess the homogeneity of treatment effect

Source	X^2	Degrees of Freedom
Treatment	0.52	1
Homogeneity	52.18	20
Total	52.70	21

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