Methods to Reduce Traffic Speed in High Pedestrian Areas

Final Report

Prepared by

Center for Transportation Research and Education

Iowa State University

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The purpose of this project was to evaluate the effectiveness of speed reduction techniques in high pedestrian areas. Using an expert advisory committee, promising strategies and potential test sites were identified for evaluation. Speed reduction techniques to be evaluated included removable pedestrian islands and pedestrian crossing devices and dynamic variable message signs. Data were collected at case study sites before and after the deployment of the speed reduction strategies. Data were collected using mobile traffic data collection units, which apply machine vision to collect data.

The "before" data indicated that the 85th percentile speeds, traditionally used as a guide in establishing reasonable speeds, were higher than the posted speed limits at all study sites. The data gathered after traffic calming techniques were employed provided the following results: Speed compliance increased by 15 to 25 percent at the study site employing removable pedestrian islands and pedestrian crossing signs. The study site employing a dynamic variable message sign did not experience a significant increase in speed compliance over the long term; this may have been due to the sign's lack of police enforcement.

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Prepared by

Ali Kamyab

Center for Transportation Research and Education
Iowa State University

Steve Andrle

Center for Transportation Research and Education
Iowa State University

Dennis Kroeger

Center for Transportation Research and Education
Iowa State University

Center for Transportation Research and Education
Iowa State University
2901 South Loop Drive, Suite 3100
Ames Iowa 50010

March 2002

Prepared for

Minnesota Department of Transportation
395 John Ireland Boulevard Mail Stop 330
St Paul Minnesota 55155

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EXECUTIVE SUMMARY

RESEARCH ISSUE

Many Minnesota counties are faced with the problem of high vehicle speeds through towns or resort areas that have significant pedestrian traffic. The purpose of this two-year research project was twofold: to evaluating the effectiveness of speed reduction techniques in high pedestrian areas and to provided traffic speed data to facilitate the validation of a traffic calming study conducted at the University of Minnesota's Human Factors Research Laboratory (HFRL) using the facility's driving simulator.

Speed data were collected at four selected study sites under their existing conditions (i.e., "no-treatment" or "before" condition). "After" data collections were conducted at two sites, Twin Lakes and Bemidji Lake, after the proposed speed reduction strategies were installed. Due to issues raised by Tofte's residents, the proposed construction there did not take place as scheduled. Instead of collecting "after" data at the Tofte and Schroeder sites, second "after" data conditions were collected at the Twin Lakes and Bemidji Lake sites to study the short-term *and* long-term impact of the strategies implemented there.

RESULTS

The traffic calming techniques employed at Twin Lakes consisted of removable pedestrian islands and pedestrian crossing signs. The curbs and signs were used to concentrate pedestrian street crossings at marked crosswalks. The combination of islands and signs created an urban effect that helped to reduce motorist speed.

The differences between the mean speeds and speed compliance rates recorded before and after the treatment deployment were found to be statistically significant on both directions of the roadway in Twin Lakes. The mean speeds at the Twin Lakes site after the installation of pedestrian islands and signs were about the posted speed limit, that is, 30 mph. The speed compliance increased over 15 and 25 percent in the eastbound and westbound directions, respectively. The long-term effect of deployed treatments in improving speed compliance was somewhat less than the short-term effect, but still 20 percent more effective than the existing (no-treatment) condition observed the year before.

A dynamic variable message sign that sent a single-word message (SLOW) to motorists traveling over the speed limit was installed at Bemidji Lake. The installation of the sign was to be coupled with initial police enforcement to convey the idea that speeds were being observed. However, no additional enforcement was provided to patrol the site. The site did not experience a significant increase in speed compliance over the long term.

CONCLUSIONS

The research study shows that the traffic calming strategy deployed in Twin Lakes was effective to significantly reduce the mean speed and improve speed limit compliance in both the short term and long term. According to local officials, several residents noted an obvious reduction in the speed and were pleased with the outcomes. The “after” data in Twin Lakes show that the observed 85th percentile speeds were still higher than the posted speed limit. Increasing the current posted speed limit is not advisable; thus, other speed reduction treatments in conjunction with the current ones should also be used to enhance pedestrian safety.

Despite proven effectiveness, the deployed speed reduction treatment in Bemidji Lake failed to lower the speed at the study site. The sign’s single-word message and its location as well as lack of initial enforcement were the primary reasons for such failure. The motorists’ disregard of the implemented treatment was evident as the sign was intentionally run over; a number of beer bottles and cans were also found under the sign.

1 INTRODUCTION

Many Minnesota counties are faced with the problem of high vehicle speeds through towns or resort areas that have significant pedestrian traffic. A number of techniques have been used to reduce speed in urban areas where the pedestrian/vehicle problem is more frequent, but little has been done to minimize these conflicts along rural roadways where the problem is much more severe. In December 1999, the Minnesota Local Road Research Board (LRRB) awarded the Center for Transportation Research and Education (CTRE) a research project to evaluate the impact of speed reduction strategies in high pedestrian areas (HPAs) in rural counties of Minnesota.

The purpose of this two-year research project is twofold. In addition to evaluating the effectiveness of speed reduction techniques in high pedestrian areas, the project provided traffic speed data to facilitate the validation of a traffic calming study conducted at the University of Minnesota's Human Factors Research Laboratory (HFRL) using the facility's driving simulator. Traffic calming strategies, including colored pavement, architecture treatments (i.e., planting shrubs and bushes), and lighting poles, were developed in conjunction with the HFRL using the US 61 roadway layout through the city of Tofte. These strategies were scheduled to be implemented in Tofte in the summer of 2001.

Under the project's Technical Advisory Panel (TAP) direction, four study sites were selected. The first two selected study sites were used to conduct pedestrian-related speed control studies. These sites are located at resort areas in Twin Lakes (Mahnomen County) and Bemidji Lake (Beltrami County) where a high number of pedestrians are observed during the summer. Two other sites, located on the north shore of US Highway 61 in the cities of Tofte and Schroeder, were used to generate traffic data for the validation of HFRL driving simulator results.

Speed data were collected at the four selected study sites under their existing conditions (i.e., "no-treatment" or "before" condition) during July and August of 2000. Upon the approval of CTRE's proposed speed reduction techniques at the February 15, 2001, meeting of the project

TAP in Minneapolis, additional data were collected at the Mahnomen and Beltrami sites in the summer of 2001. The “after” data collections were conducted at the two sites after the proposed speed reduction strategies were installed in Twin Lakes and Bemidji Lake.

Due to issues raised by Tofte’s residents, the proposed construction did not take place as scheduled. Thus, to make better use of project resources, the project committee recommended that no more data collection be conducted at Tofte and Schroeder. Instead, “after” data conditions were collected on two occasions after implementation of the proposed speed reduction strategies (two weeks and six weeks) at locations in Twin Lakes and Bemidji Lake to study the strategies’ impact in the short-term and long-term.

The traffic calming techniques employed at Twin Lakes consisted of removable pedestrian islands and pedestrian crossing devices (signs). The combination of islands and signs created an urban effect that helped to reduce motorist speed. The curbs and signs were used to concentrate pedestrian street crossings at marked crosswalks.

A dynamic variable message sign that sent a single-word message to motorists traveling over the speed limit was installed at Bemidji Lake. The installation of the sign was to be coupled with initial police enforcement to convey the idea that speeds are being observed. Enforcement could then be reduced to normal levels, relying on the dynamic sign to give the illusion of enforcement. No additional enforcement, however, was provided to patrol the site.

Using CTRE’s two traffic data collection trailers, the traffic flow performance data (vehicle speed, headways, volume, etc.) were recorded in “before” and “after” conditions at the selected study sites. Using the Autoscope image processing technology, the recorded videotapes were analyzed to determine the vehicle types (i.e., passenger cars and nonpassenger cars), arrival times, and speeds of approaching vehicles. A number of significant parameters were obtained through the analysis of the speed data. Some of the parameters were computed directly from the data, while others were determined from a graphical analysis of the speed data.

Statistical comparisons were carried out to ascertain whether the differences of mean speeds and speed compliance rates, obtained in the “before” and “after” conditions at the Mahnomen and Bemidji sites, are statistically significant. Tukey’s *t*-test was utilized to determine significance of differences in the mean speeds at the 95 percent confidence level. As for speed compliance rates, the normal approximation to the binomial distribution was used to determine whether the changes in the rates were statistically significant.

The differences between the mean speeds and speed compliance rates recorded before and after the treatment deployment were found to be statistically significant on both directions of the roadway in Twin Lakes. On the other hand, the comparison of the “before” and first “after” data recorded in Bemidji Lake indicates no significant changes in the mean speeds observed in these two conditions. The primary reasons for the dynamic variable message sign’s lack of effectiveness in encouraging motorists to comply with the posted speed limit at the site in Bemidji Lake are the sign’s single-word message (i.e., SLOW), location, and most importantly, lack of enforcement.

This report is organized into seven chapters. Chapter1 provides an overview of the project. Chapter 2 is a literature review that contains a discussion of numerous issues associated with pedestrain safety in urban and rural areas and recommends applicable speed reduction strategies for high pedestrain rural areas. Chapter 3 presents the selected study cases. The development of experimental designs for collecting data at selected sites is discussed in Chapter 4. The selected speed reduction techniques are described in Chapter 5. Chapter 6 presents the collected data and statistical analyses outcomes. Conclusions are presented in Chapter 7, which contains a summary of research findings. Appendices A through F contain the sample memos and minutes of the committee meetings as well as cumulative percentage plots of collected speed data.

2 LITERATURE REVIEW

2.1 BACKGROUND

Pedestrian and vehicular conflicts along urban and rural roadways are dangerous situations where children, elderly, and persons impaired by alcohol suffer the most dire consequences (1). A pedestrian without protection is no match for a vehicle weighing over one ton traveling at speeds in excess of 55 mph. Inattention on behalf of the pedestrian, motorist, or a combination of both parties is frequently the cause of these crashes. An increase in awareness of either party will significantly reduce the frequency and severity of these collisions, saving many lives.

Pedestrians are involved in less than one percent of all accidents, but yet they account for 18 percent of highway fatalities (2). A study released in 1988 found that approximately 80,000 pedestrians within the United States are injured every year from being impacted with an automobile (3). This number, however, has increased according to a 1993 study that found that approximately 90,000 pedestrians are injured from being impacted with a vehicle (4). The 1993 study had also indicated that the number of fatalities caused by pedestrian/vehicle crashes has decreased from 8,000 to 5,500 over the same period.

Many Minnesota counties are faced with the problem of high vehicle speeds through towns or resort areas that have significant pedestrian traffic. A number of techniques have been used to reduce speed in urban areas where the pedestrian/vehicle problem is more frequent, but little has been done to minimize these conflicts along rural roadways where the problem is much more severe.

Traditional methods for increasing pedestrian safety include, but are not limited to, the installation of advisory signs, rumble strips, additional lighting, wider shoulders, and traffic calming techniques such as speed bumps, chicanes, and street closures. This report examines the current speed reduction practices at pedestrian areas and provides a review of relevant literature with respect to the following issues:

- vehicle and pedestrian conflicts along rural and urban roadways
- vehicle/pedestrian separation techniques
- countermeasures for improving pedestrian and vehicle safety along rural and urban roadways

2.2 VEHICLE/PEDESTRIAN CONFLICTS IN RURAL/URBAN AREAS

Most pedestrian/vehicle collisions occur in urban areas, where there is the greatest concentration of vehicles and pedestrians. Approximately five out of six injuries and two out of three fatalities occur in urban areas. The ratio of fatalities to injuries, however, is approximately three times greater in rural areas than in urban areas. This is primarily due to higher vehicle speeds that occur in rural areas (5).

In 1991, it was estimated that crashes involving pedestrians and bicyclists accounted for 27.9 percent of all crashes in urban areas (6). The main cause of these accidents stems from the sharing of right-of-way without appropriate traffic controls. In addition, speed limits in urban areas may not be compatible with the surrounding land use. This problem is complicated when motorists perceive that traveling 5 to 10 miles over the limit is allowable. Speed, however, is a less critical element in urban areas than in rural areas.

The higher traffic speeds of rural roads and the concentration of vehicles in urban areas are two significantly different problems associated with pedestrian safety. The higher speeds of rural roads present motorists and pedestrians with a greater safety threat than do the speeds on urban roadways, but at the same time the congestion and environment of urban roadways lessens expectancy, or the ability to detect change for the motorist.

It is believed pedestrian accidents most frequently occur in urban areas, but yet 40 percent of pedestrian fatalities and 15 percent of injuries occur in nonurban areas (7). A more recent study, however, indicates a decrease in the number of rural pedestrian fatalities (8). According to this study, 70 percent of pedestrian fatalities are occurring on urban roadways, leaving 30 percent occurrence on rural roadways.

A Washington state study indicates that the number of collisions was higher in urban areas, but the collisions were perhaps more severe in rural locations (3). The study includes 5,248 state residents who were involved in pedestrian/vehicle collisions over a three-year period. The increased safety concern of rural collisions as compared to urban collisions stems from higher vehicle speeds in rural areas, in addition to the time it takes to receive medical care.

Furthermore, the article indicates that the risk of a pedestrian dying in a rural collision is more than twice as much as a pedestrian struck in an urban area. The likely cause of the increased death rate for rural pedestrians is due to the more lengthy time period for which emergency personnel need to reach the pedestrian (3).

Safety of motorists traveling on local rural roadways is significantly worse than the safety of motorists traveling on other roadways. Rural local roadways consist of paved and unpaved roadways. In 1992, rural local roadways observed approximately 2.26 deaths per million-vehicle-kilometer. This is a difference of 1.29 deaths per year per vehicle-kilometer, as compared to the 0.97 fatal-crash rate reported for all other highways (9).

Rural unpaved roadways are even more unsafe than urban and rural paved roadways. The safety of unpaved rural roadways is compromised by the fact that these roadways do not have the geometric design standards of paved roadways. Although crash trends for unpaved roadways are not available, a study conducted in Wyoming found that vehicle crash rates, based on volume for selected unpaved roadways, were more than five times higher than all other roads within the state (9).

Pedestrian/vehicle conflicts along rural roads are affected by a number of variables. These variables usually include, but are not limited to, factors pertaining to the motorist and/or pedestrian awareness, roadway lighting, type of roadway, socioeconomic situations, and an individual’s transportation needs.

2.3 VEHICLE/PEDESTRIAN SEPARATION TECHNIQUES

Research indicates that when possible pedestrians will likely take the most direct path to their destination. When crossing the street, pedestrians follow this same behavior. Pedestrians are unlikely to go out of their way to cross at an intersection when their destination can be more easily reached by crossing the street at some other location. This causes a conflict between pedestrians and vehicles since both are using the roadway at the same moment. In a study of 5,797 pedestrian fatalities, 38.1 percent were attributed to pedestrians crossing the roadway (6). To reduce the frequency of conflicts caused by improper crossing, a number of vehicle/pedestrian separations are suggested as countermeasures.

There are four types of separations possible for eliminating pedestrian-vehicle conflicts:

1. **Horizontal separation—**Horizontal separations are systems that accommodate pedestrian movements adjacent and at grade to vehicular movements. Features such as sidewalks, landscaping, and high curbs, are used to separate the different modes.

2. **Time separation—**Time separation simply implies that the use of the roadway varies depending on time. Pedestrians and vehicles may use the roadway at different times during the day. For instance, vehicles may use a roadway during the morning and afternoon rush hours but may be prohibited from using it during the rest of the day.

3. **Vertical separation—**Vertical separation displaces motorized traffic vertically from nonmotorized traffic. Overpasses, skywalks, underpasses, and other vertical separations may help enhance pedestrian circulation and safety by eliminating conflicts between pedestrians and vehicles (8). The costs of these facilities, however, limit their use. Typically these facilities are only used for high pedestrian areas, where crossing is extremely dangerous.

4. **Soft separation—**Soft separation is similar to traffic calming in that it does not separate pedestrians from vehicular traffic. Instead, vehicular traffic is relaxed using a

variety of techniques so that pedestrians can use the roadway facility in conjunction with vehicles. Soft separation techniques are often used in existing or newly developed areas, where the existing right-of-way is unable to accommodate the separation of modes. This application is intended to provide safety, equity, comfort, and convenience to a wide area. Traffic calming techniques such as road bumps, bends along the roadway, raised crossings, and street planters are used reduce vehicular speed.

A 1993 study addressed this problem in another country—South Africa. In 1993, 4,388 pedestrians in South Africa were struck by vehicles while walking in the roadway (10). The primary cause of these accidents was the lack of sidewalks in South Africa. During dry weather conditions, pedestrians often use the gravel shoulder. During rainy conditions, shoulders become saturated and muddy, thus causing pedestrians to walk on the roadway. To alleviate these problems, guidelines for providing footpaths in urban areas were developed. The guidelines considered the following:

- cost of the facility
- traffic volume and speed
- number of pedestrians using the route
- availability of street lighting
- pedestrian accidents at night
- future pedestrian needs

2.4 GENERAL PEDESTRIAN SAFETY COUNTERMEASURES

There are a number of different countermeasures used to improve pedestrian safety. The effectiveness of the countermeasures varies with location and use. In this section, various countermeasures that may improve pedestrian safety are discussed.

2.4.1 Traffic Calming

The use of traffic-calming techniques has been popular and successful in many European countries since the 1960s and has recently gained popularity in the United States. Traffic calming can be defined as "the physical and psychological designs, backed by appropriate signage, that help to control or manage vehicular traffic volumes and speeds, wherever appropriate, to ensure a more equitable use of the streets as public places" (6).

The primary objective of traffic calming is to improve road safety by reducing the number of accidents for all types of users, especially pedestrians, and bicyclists. Traffic calming techniques are intended to reduce speed, control volumes, increase transit access, encourage bicycle use, and to reclaim the street as a multi-use public space. These techniques are low-cost solutions that can be adopted by communities with financial constraints (6).

As stated earlier in urban areas engineering improvements such as sidewalks, crosswalks, and street lighting are common. Sidewalks and crosswalks are not common in rural areas, but measures such as rumble strips, flashing warning signs, and chicanes can be considered.

2.4.2 Educational Campaigns

Educational campaigns may help alleviate some pedestrian/vehicle conflicts. Educational campaigns may help increase motorist and/or pedestrian awareness so these conflicts can be minimized. Motorists should be made aware that pedestrian movements are unpredictable and that they should never try to be predicted.

In a four-year public information campaign in Seattle, Washington, the public was informed about crosswalk laws (1). The public was made aware of the program through local papers, signs, and various pamphlets.

In addition to public information campaigns, increased police presence was implemented to enforce newly implemented crosswalk laws. Four different campaigns were launched to implement the new crosswalk laws. The first campaign was conducted citywide, lasting from the summer of 1990 to the fall of 1991. During this period, approximately 3,600 citations were issued to motorists. The overall level of compliance, however, did not change. The second campaign was conducted in five neighborhoods from September 1992 to January 1993. During this period, there was a noticeable improvement compared to the before observations, but the majority of vehicles were still not stopping for the pedestrians. The third campaign was also conducted in five neighborhoods, from July 1993 to October 1993. The results of this campaign, indicated that 90 percent of the citations had been written in two of the five neighborhoods.

The fourth and most recent campaign enforced crosswalk laws at two intersections. The intersections were similar to each other in that they were both four-lane arterials with a posted speed limit of 30 mph and had similar afternoon peak traffic volumes. Both intersections were marked with painted crosswalks, advance warning signs, and overhead flashing beacons. Results from this campaign contradict the results of the previous three campaigns in that motorists seemed to disregard the pedestrian safety measures. The study was unable to demonstrate whether police presence significantly or consistently increased drivers’ willingness to stop for pedestrians.

2.4.3 Police Presence

The presence of law enforcement can significantly improve driving behavior. It is, however, impossible to station police officers in every location where there is a need for pedestrian safety improvement. Furthermore, motorists resume their driving behavior when law enforcement is no longer present (6). Thus, the impact of law enforcement in improving the pedestrian safety will be short lived.

2.4.4 Rumble Strips

Rumble strips are effective in increasing motorist awareness. Motorists may become unaware of roadway conditions, due to distraction, daydreaming, fatigue, or drowsiness. If a motorist loses awareness, the rumble strips transmit sound and vibration as the vehicle rolls over the rumble strip. This alerts the motorist and reduces ran-off-the-road crashes involving pedestrians walking along the roadside.

Typically, rumble strips are located at the end of freeways, approaching tollbooths, construction zones, and on freeway shoulders. The state of Iowa uses sets of three rumble strips to alert motorists approaching stop signs or rural roads. The City of Phoenix experimented with rumble strips of various designs at crosswalks. The Phoenix case study follows:

In the 1980s, the City of Phoenix, Arizona, began an experiment that tried to increase pedestrian safety near crosswalks. At first, the city experimented with flashing warning lights and concluded that they have little impact on motorist behavior. In response to task force recommendations the City of Phoenix conducted another study that used rumble strips to alert motorists of an approaching stop along a curve. The rumble strips were successful at reducing collisions but failed to eliminate them entirely. Therefore, the City of Phoenix continued with this study to determine a way of achieving a good rumble effect for motorists (11).

The City of Phoenix was interested in two rumble strip designs—plastic rumble bars and ceramic markers. Each of the designs was tested over a period of three years to determine the best rumble effect.

The ideal spacing for the plastic rumble bars was one foot for every 10 mph. Therefore, a roadway with a posted speed limit of 40 mph had a series of rumble bars spaced four feet from each other. The series of rumble bars were placed at a distance seven times the posted speed limit in advance of the crosswalk. On roadways with a posted speed limit of 40 mph, rumble bars were place 280 feet in advance of the crosswalk (11).

The ceramic markers were semisphere objects approximately four inches in diameter and three-quarters inches in height. As was the case with the rumble bars, the ceramic markers were placed seven times the posted speed limit in advance of the crosswalk. The layout for the markers was coordinated so that there were eight rows of five ceramic markers (see Figure 2.1). Markers in each row were spaced two feet from each other, and rows were spaced one foot from each other (11).

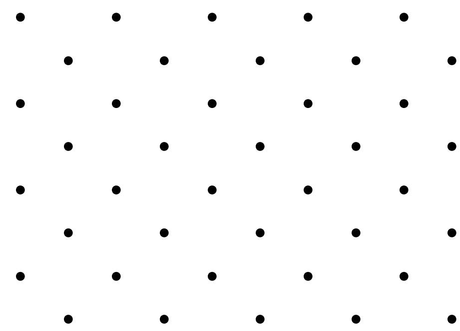

Figure 2.1 Layout of Ceramic Markers—Phoenix Case Study

The study was conducted at 19 uncontrolled crosswalks, 10 of which were located near schools. The other nine sites were located along bike paths, crosswalks with a high concentration of senior citizens, and crosswalks near hospitals.

Citywide pedestrian collisions were 11 percent lower during the three years following the start of the study. The number of crashes, however, was not reduced at the 19 study sites. The City of Phoenix concluded that using rumble strips was not an adequate method to increase safety. Overall, pedestrian accidents were lower at five of the crosswalks, greater at three of the crosswalks and unchanged at the remaining 11 crosswalks (11).

2.4.5 Street Lighting

More than half of all fatal pedestrian crashes occur at night (12). The installation of street lights may help motorists detect pedestrians along roadways. This increases pedestrian conspicuity and in turn reduces the number of associated crashes. A research report has suggested that improving roadway lighting would reduce crashes occurring at night by 11.5 percent (13).

A pedestrian safety study in Denmark found that roadways with a speed limit of 50 km/hr (34 mph) or less had only a three percent difference in the distribution of pedestrian injuries between different daylight and night conditions. Roadways with speed limits exceeding 50 km/hr (34 mph), however, have a difference of 15 percent between day and night conditions. The study suggested that installing roadway lighting on roadways with a speed limit exceeding 50 km/hr

(34 mph) will result in a 45 percent reduction in pedestrian injuries occurring in darkness. Similar studies report a reduction between 35 to 43 percent in the number of pedestrian crashes occurring in darkness (14).

2.3.6 Promontory and Pedestrian Refuge Islands

A promontory is the extension of the curb and sidewalk into the roadway at an intersection to narrow the crosswalk and make pedestrians more visible to drivers. The use of promontories to improve pedestrian conspicuity has been successful at urban intersections where pedestrians are hidden by parked vehicles. A 1987 study in Nottinghamshire County, England, increased pedestrian visibility by introducing a promontory at a signalized intersection (15). The existing three-lane roadway was reduced to a two-lane roadway after the installation of the promontory. This, however, had a minimum effect on existing traffic as the third lane was exclusively used by parked cars and buses.

During the period from 1987 to 1989, the promontory was temporary. After this period, the temporary promontory was removed and a permanent promontory was built. Pedestrian movements at the signalized intersection were further improved through the use of guardrails. The guardrails were installed at the intersection to direct pedestrians to the promontory, helping to prevent crossings at locations where pedestrians could not be easily seen. The promontory design was successful in reducing pedestrian accidents from four accidents per year to only one accident per year (15).

Pedestrian islands (i.e., raised medians) within intersections may also be beneficial for improving pedestrian safety. Pedestrians may use raised or painted islands to cross streets more easily. These islands allow pedestrians to stand in the middle to allow vehicles to pass instead of crossing the entire street at one time. Generally, pedestrian islands are used on high-speed, wide streets where signal timing does not allow for easy pedestrian movements (8).

2.4.7 Sidewalks

The sidewalk is the most fundamental method used to separate pedestrians from vehicular traffic. The risk to pedestrians in areas without sidewalks was reported to be more than twice as high as in areas with sidewalks (16). For sidewalks to be effective they must be set back from vehicular traffic, easily assessable, free of hazards, and adequately lighted at night (8).

2.4.8. Special Signs

A variety of different traffic signs has been used to improve traffic flow and safety. A study of strong yellow-green (SYG) signs has proven that these signs moderately improve pedestrian safety at midblock pedestrian crossings under daylight conditions. Research, however, has shown that most motorists do not stop regardless of the signing used. Novelty signs with special messages, images, or colors have not been very successful, either. The novelty of these signs quickly wears off, and the previous driving behavior continues (6).

A research study was conducted from August 1993 to October 1994 to evaluate the effectiveness of fluorescent SYG pedestrian warning signs in improving pedestrian safety (17). The research study was conducted at numerous locations within Raleigh, Durham, and Fayetteville, North Carolina. Study locations were confined to areas specified as campus, central business district, recreational, or shopping. Other factors considered in the selection of study sites included

- presence of unsignalized midblock crossings
- sufficient vehicle and pedestrian volumes to accurately determine the effectiveness of the SYG signs
- existence of pedestrian or bicycle warning signs
- proximity to a comparison site with similar characteristics

The North Carolina study sought to answer three questions:

1. How does the legibility of SYG signs compare to other signs in various light conditions and surroundings?

2. Does increased conspicuity translate into increased awareness?
3. What are the popular opinions of road users to the SYG signs?

The research compared existing signs to SYG signs at unsignalized and midblock crossings. Existing signs were found to be in good to new condition before the collection of the before data. Data collection was done in daylight so vehicle headlights would not influence the reflectivity of the SYG signs. An attempt was made to limit the size and shape of the SYG signs to that of the signs being replaced. After the existing signs were replaced with the SYG signs, a 30-day buffer period was allocated to allow motorists to adjust to the new signs and to minimize any novelty effects the signs had on motorists (17).

The study concluded that SYG signs have a minimal effect on improving pedestrian safety at unsignalized midblock crossings under daylight conditions. Regardless of the type of sign being used, 60 to 95 percent of motorists did not slow or stop for pedestrians. Saturation of SYG signs could also reduce a motorist's ability to detect other area signs. This effect is similar to the effect when a large number of oversized signs are placed along a roadway (17).

2.4.8 Pedestrian Warning Flashers

Pedestrian warning flashers are devices that are used to alert motorists to unexpected conditions. Typically, these devices are used to improve safety on high-speed rural roadways, along curves, or at some other unexpected feature.

Research studies have indicated that pedestrian warning flashers are ineffective for improving pedestrian safety in urban areas, especially near schools (18). The studies indicate that flashing beacons or flashing lights do not modify motorist behavior or reduce speeds to the posted speed limit.

In one study, conducted in 48 school zones in Fairfax, Virginia, and Hamilton Township, New Jersey, it was found that motorists selected a speed close to the speed limit when flashers were not operating but paid little attention to the speed limit when flashers were operating. In the majority of cases, pedestrian warning flashers reduced speeds by less than three mph (18).

Two locations near a school were selected for the Fairfax, Virginia, study. The two locations were approximately 1,500 feet from each other and were located at school crosswalks. The first location was upstream from the second and revealed that the pedestrian warning flasher reduced motorists' speeds by less than three mph. The second location had recorded a two mph increase in speeds. The increase in speeds from the first location to the second may have been a result of motorists recovering lost time from slowing for the first pedestrian flasher.

In another location, in Hamilton Township, New Jersey, it was found that warning flashers had little to no effect on vehicle speeds. In some cases, vehicle speeds were found to be slightly greater when flashing and no pedestrians were present.

In a similar study, the Arizona Department of Transportation concluded that pedestrian warning flashers are ineffective and sometimes counterproductive in improving safety in urban areas (19).

2.4.9 Crosswalk/Roadway Pavement Markings

Pavement markings may reduce crashes involving roadside pedestrians and disabled vehicles. Roadway markings, especially pavement edge markings, are frequently not present at pedestrian/vehicle crash sites (12). Pavement edge markings help the pedestrian and vehicle stay on the appropriate travel ways.

Another study sought to determine the effectiveness of reducing crash rates on two-lane, rural roadways by applying center pavement markings (20). Center markings were applied to roadways with 500 or less vehicles per day as well as roadways with less than 10-foot lane widths and 1,000 vehicles per day observed traffic. This study concluded that the application of center lane markings in each of these cases increased crash rates.

Crosswalk markings are widely used at signalized and nonsignalized intersections. Crosswalks are provided to alert motorists that they are approaching an area of roadway where pedestrians are likely to cross. Crosswalk markings are typically placed at signalized intersections with heavy pedestrian movements, midblock crossings controlled by traffic signals, and near schools, where children are likely to cross the street. The main disadvantage of crosswalks is that they tend to give the pedestrian a false sense of safety.

2.5 SPECIFIC PEDESTRIAN/VEHICLE CRASHES AND COUNTERMEASURES

Most pedestrian accidents are caused by inattention on behalf of pedestrians and/or drivers. Measures to improve safety must try to increase alertness for both parties involved. Most studies suggest implementing specific engineering improvements may help, but other nonengineering approaches may also improve motorist and pedestrian safety. In this section, specific types of pedestrian/vehicle conflicts will be discussed and countermeasures used to reduce the frequency of each specific conflict will be provided.

2.5.1 Midblock Dash Crash

This type of midblock crash involves pedestrians running into a residential road. This crash type does not typically occur as a result of a pedestrian appearing suddenly; rather, the motorists see the pedestrian but mistake the pedestrian's next movement (13).

Midblock conflicts constitute 26.4 percent of vehicle/pedestrian crashes recorded in six states (4). Crash data from the states of California, Florida, Maryland, Minnesota, North Carolina, and Utah were collected and analyzed. Among the 13 midblock crash types, the midblock dash occurs most frequently.

Countermeasure

- Educate motorists and pedestrians of typical actions. For example, motorists are often unaware of pedestrian actions, especially with younger children (13).

2.5.2 Dart-Out First Half and Dart-Out Second Half

The dart-out first half pedestrian/vehicle collision type involves a person, usually a child, who runs out into a two-lane, residential street during the late afternoon (13). The pedestrian often appears suddenly from a stationary object such as a parked car. This accident type typically occurs on urban, two-lane roadways but may also be observed on local streets. A contributing factor to some of these crashes is ice cream vendors.

The dart-out second half crash type also involves pedestrians running into a local two-lane, residential street. This differs from the previous crash type, since pedestrians are usually successful at crossing the street.

Countermeasures

- Initiate educational campaigns directed at children nine years old or younger.
- Remove parked cars, trees, bushes, etc., that are located near the roadway to improve sight distance.
- Install signs or warning lights to warn motorists of the presence of children.
- Install pedestrian barriers to prevent children from running into the roadway.
- Stop pedestrians from crossing midblock by installing median barriers.

2.5.3 Intersection Dash

The intersection dash involves a pedestrian, usually a child, who runs across the roadway at an intersection. The motorist is usually traveling straight and is usually aware of the pedestrian but misinterprets his/her actions (13).

Countermeasures

- Install or improve roadway lighting.
- Provide signed and illuminated marked crosswalks where warranted.
- Educate pedestrians of the dangers of running into an intersection.

2.5.4 Vehicle Turn/Merge with Attention Conflict

This crash involves a vehicle turning, preparing to turn, or just completing a turning movement. The motorist is paying attention to area traffic and does not see the pedestrian. Often the pedestrian is not aware of the motorist's intention and is then struck by the vehicle. These crash types usually occur at very busy intersections, on multilane highways. Often, these crashes are deemed "hit and run" since the motorist is unaware that he/she has struck a pedestrian (13).

Countermeasure

- Improve pedestrians' signal phase.

2.5.5 Walking along the Roadway Conflict

A walking along roadway conflict usually occurs when a pedestrian is walking along a two-lane roadway in a residential or rural location. Typically these accidents occur when the pedestrian is walking with traffic at night.

A study involving six states found that pedestrian/vehicle collisions involving persons walking along the roadway constituted 7.9 percent (400 of 5,073) of all pedestrian-motor vehicle crashes. Out of the 400 walking-along-roadway crashes, 69 percent involved pedestrians walking with traffic and 21 percent involved pedestrians walking against traffic. The remaining nine percent of crashes may have involved a variety of different pedestrian actions such as standing, running, or entering the roadway (21).

The analysis of the 400 walking along roadway crashes found a series of different variables that may be linked to these crash types. Some of the more common variables linked to these crash types are (21) as follows:

- pedestrians ages 15 to 44
- alcohol involvement by the pedestrians and motorists
- rural two lane roads

- dark conditions with no lights
- rural interstates

A similar study involving walking along roadway crashes was conducted in Wake County, North Carolina (22). This study was conducted over a four-year period, from 1993 to 1996. During this period, 711 crashes were identified, in which 6.61 percent or 47 crashes were attributed to walking along the roadway. It was further determined that approximately 77 percent of walking-along-roadway collisions involved pedestrians walking with traffic and 23 percent involved pedestrians walking against traffic.

The Wake County study also researched the impacts of housing stock, families, unemployment, vehicle volumes, and roadway shoulders on walking-along-roadway crash occurrences. Contrary to the common belief that higher number of vehicles and/or pedestrians in an area may increase the likelihood of pedestrian/vehicle conflicts, the study found no relationships between the number of pedestrian crashes and vehicle volumes (22).

Furthermore, the study found that grassy or unpaved shoulders are often considered safer locations for pedestrians to walk compared to paved shoulders. An unpaved gravel shoulder will cause noise, alerting the pedestrian that a vehicle has crossed onto the shoulder. Tests conducted in Wake County found that roadways with unpaved shoulders are 89 percent less likely to be prone to walking along roadway crashes (22).

Countermeasures

Suggested countermeasures to improve roadway safety for pedestrians walking along roadways are supported by the research conducted in Wake County, North Carolina:

- Improve or provide roadway lighting.
- Improve vehicular lighting.
- Provide pavement edge markings.
- Provide sidewalks or shoulders.

- Run educational campaigns that encourage pedestrians to walk against traffic as opposed to walking with traffic.

2.6 WORK ZONE SPEED CONTROL MEASURES

CTRE has recently completed a comprehensive examination of the existing and proposed methodologies being applied to control speeds in work zones (23). The strategies ranged from posting regulatory and advisory speed-limit signs to using the latest radar technologies to reduce speeds at work zones. Furthermore, the most promising work zone speed-control strategies were evaluated at rural sites in Iowa (24).

It is believed some of work zone speed-control strategies would also be applicable to high pedestrian areas in rural Minnesota counties. A few of these strategies are listed below:

2.6.1 Drone Radar

Drone radar is an electronic radar system that transmits in the microwave-frequency band. Vehicles equipped with radar detection devices perceive transmitted radar signals from the drone as the presence of police enforcement. In response, believing that a police car is nearby, these vehicles reduce their speeds, which in turn causes other vehicles to slow down. The purpose of using drone radar in a speed reduction program is to reduce the 85th percentile speed, rather than the average speed, because it is assumed that the fastest group of drivers is more likely to possess radar detectors. Drone radar devices can be strategically attached to a variety of objects, including speed limit sign masts.

2.6.2 Speed Monitoring Displays

Speed monitoring displays use a radar device to determine speeds of approaching vehicles and display the detected speeds. The display boards are not generally used to enforce the speed limits and issue citations. The assumption is that motorists will drive slower once they are aware of their speed.

2.6.3 Dynamic Variable Message Signs

Dynamic variable message signs are signs that trigger when a speeding motorist approaches. The messages will advice the motorists to reduce their speeds and drive more cautiously.

2.7 SUMMARY

Pedestrian/vehicle conflicts are dangerous situations in which pedestrians usually suffer the worst consequences. Although these conflicts are more frequent in urban areas, they are typically more severe in rural locations. Since pedestrians are more likely to be struck by a vehicle in an urban location, rural pedestrian/vehicle conflicts have been studied less often. Many of the recommended countermeasures used to deter rural pedestrian crashes deal with improvements to roadway lighting, pavement markings, and roadway geometry. Urban pedestrian/vehicle conflicts, however, have been studied in much more detail. Suggested countermeasures used to reduce the frequency and severity of these conflicts include grade separation, traffic calming, and educational techniques.

3 CASE STUDIES

Under direction of the project's Technical Advisory Panel, four study sites were selected. The first two selected study sites were used to conduct pedestrian-related speed control studies. These sites are located at resort areas in Mahnomen and Beltrami Counties where a high number of pedestrians are observed during the summer. Two other sites, located on the north shore of US Highway 61, are to be used for the validation of HFRL driving simulator results.

3.1 PEDESTRIAN STUDIES

3.1.1 Twin Lakes, Mahnomen County

The Mahnomen site is on the Minnesota County State Aid Highway (CSAH) 4 in the southeast lakes area of the county. It is located south of Nay-tah-waush between the densely populated areas of North and South Twin Lakes. This two-lane highway has a 24-foot surface width with an 8-foot paved shoulder on each side. The average daily traffic (ADT) is 900 vehicles. During the summer a high number of pedestrians are observed walking on the shoulders. The posted speed limit reduces traffic speed from 55 to 40 mph before entering the 30-mph speed zone through the area.

3.1.2 Bemidji, Beltrami County

The Beltrami site is a two-lane highway located on the north of Lake Bemidji on Minnesota CSAH 20. The highway goes through a 35-mph, populated residential area with unpaved four-feet shoulders. High pedestrian/bicyclist traffic activities are observed on the highway during the summer. The reported ADT is 1,500 vehicles.

3.2 SIMULATOR VALIDATION STUDIES

3.2.1 Tofte, US 61

The city of Tofte is located on the north shore of US 61. Traffic calming strategies, including colored pavement, architecture treatments (i.e., planting shrubs and bushes), and lighting poles, were scheduled to be implemented in the summer of 2001. These strategies were developed in conjunction with the University of Minnesota Human Factor Research Laboratory. The traffic volume on US 61 through the City of Tofte is about 3,500 vehicles during the summer peak time. The posted speed limit is 40 mph.

3.2.2 Schroeder, US 61

The city of Schroeder is about four miles south of Tofte on US 61. The two cities have similar traffic characteristics (i.e., traffic volume, speed limit, number of lanes, etc.). A colored-pavement treatment was installed at Schroeder in the summer of 2000.

3.3 PRELIMINARY SITE VISIT

On June 12–13, 2000, the project research team consisting of Ali Kamyab, Gary Thomas, and Dennis Kroeger of CTRE visited the selected study sites. The purpose of the visit was to inspect the sites and meet with the local officials before making the final arrangements for speed data collection.

3.3.1 Twin Lakes, Mahnomen County

On the morning of June 13, 2000, the research team met with Mahnomen County Engineer Dave Heyer and Assistant County Engineer Michael Murray. They traveled to the site, which was located four miles south and 16 miles east of the City of Mahnomen on CSAH 4. The posted speed limit on the highway is 55 mph. It changes to 40 mph before entering the 30-mph speed zone at the resort area.

Because of the observed speed limit violations, in 1997 several traffic calming strategies were implemented at the site, including the following:

- rumble strips
- median and shoulder transverse stripes
- lane narrowing

A set of nine grooved rumble strips was placed perpendicular to the path of vehicles' wheels on the highway before the 40 mph speed zone (see Figure 3.1). The purpose of rumble strips is to alert motorists of an upcoming speed reduction zone by producing an audible and tactile stimulus when they are driven over.

Figure 3.1 Rumble Strips—Twin Lakes

The median was also crosshatched with varying widths and frequencies of striping (see Figure 3.2). The median is four feet in width and contains a 500-foot taper from one foot to four feet in width. The distances between the stripes decrease from 33 to 20 feet within the 500-foot taper. Transverse stripes are used to affect drivers' perceptions of their speeds. The gradually decreasing distances between the stripes create an illusion that drivers are speeding, resulting in speed reductions.

Figure 3.2 Centerline Stripes—Twin Lakes

Another speed reduction remedy, implemented at the site in 1997, was reducing the lane width to 11 feet through pavement markings and transverse stripes on the eight foot shoulders (see Figure 3.3). In general, narrower lanes demand more attention, influencing drivers to reduce their speeds.

Figure 3.3 Shoulder Stripes—Twin Lakes

Despite these treatments, an in-house traffic speed study, conducted August 12–14, 1997, indicated that the 85-percentile speeds in both directions were still higher than the posted 30-mph speed limit at the site. The data showed that the 85-percentile speeds were varying between 35 to 50 mph and 38 to 49 mph on the east and west bounds of the highway, respectively.

3.3.2 Bemidji, Beltrami County

On the afternoon of June 13, 2000, the research team met with Beltrami County Engineer Tom Kozojed. After inspecting a number of potential sites around the Bemidji Lake, a residential area on the north side of the lake on CSAH 20 was selected. The existing narrow four-foot unpaved shoulders (see Figures 3.4 and 3.5) have forced the summer time pedestrians and bicyclists to use the roadway. The residents occasionally express their concerns about the traffic safety of the area.

Figure 3.4 Unpaved Shoulders—Bemidji

Figure 3.5 Narrow Shoulders—Bemidji

3.3.3 Cities of Tofte and Schroeder, US 61

On June 14, 2000, the research team met with Rod Garver of the Minnesota Department of Transportation (Mn/DOT) in Duluth. They then visited the cities of Tofte and Schroeder. Tofte is about 80 miles north of Duluth on US 61 (see Figure 3.6). The proposed HFRL traffic calming strategies (i.e., colored pavement, landscape treatments, and lighting poles) were scheduled to be implemented in the summer of 2001 in Tofte.

Figure 3.6 Tofte, US 61

The HFRL simulator results indicated that white pavement treatments produced the greatest change in driver behavior, resulting in more moderate speeds. Data also indicated that landscape architecture treatments (i.e., planting shrubs and bushes) on the medians and road edges can produce desirable effects on drivers' choice of speeds. The study concluded that the presence of lighting poles did not contribute to traffic calming (25). The purpose of the proposed field speed study in Tofte was to assist the HFRL researchers to better assess the impact of the traffic calming strategies studied in the simulator.

On the day of our visit, the US 61 highway at Schroeder was under construction. The shoulders and median were to be paved with colored bituminous pavement (i.e., the light colored pavement evaluated by the HFRL simulator on Tofte). Entrance gates and roadside walls (see Figures 3.7 and 3.8) were also being added to urbanize the city environment.

Figure 3.7 Entrance Gate, Schroeder, US 61

Figure 3.8 Side Walls, Schroeder, US 61

4 EXPERIMENTAL DESIGN DEVELOPMENT

4.1 TRAFFIC DATA COLLECTION PROCEDURE

Traffic data were collected using two traffic data collection trailers. The trailer, shown in Figure 4.1, includes a pneumatic mast to hoist two video cameras 30 feet above the pavement's surface in order to videotape traffic operations. Videos were later reduced into traffic flow performance data through the use of image processing technology.

Figure 4.1 Traffic Data Collection Trailer

Traffic flow performance data (vehicle speed, headways, volume, etc.) were recorded before and after a speed reduction technique was in place. Using the Autoscope image processing technology, the recorded videotapes were analyzed to determine the vehicle types (i.e., passenger cars and nonpassenger cars), arrival times, and speeds of approaching vehicles.

A number of significant traffic behavior parameters were obtained through analysis of the speed data. Some of these parameters were computed directly from the data, while others were determined from a graphical representation. The analysis of the speed data included the following evaluation parameters:

- time mean speed
- speed that 85 percent of the vehicles travel (the 85th percentile speed)
- 10-mph speed interval containing the most observations (the10-mph pace)
- percentage of observations in the 10-mph pace
- standard deviation of the time speed
- percentage of observations complying with posted regulatory and advisory speed limits
- time mean speed of the highest 15 percent of speeds

Except for the mean speed and standard deviation, the balance of these parameters was determined from graphical analysis.

The speed data initially were grouped into before and after data sets for each data collection site. Furthermore, the speed data parameters were determined for passenger cars, nonpassenger cars, and all vehicles for all data sets. In order to determine whether the difference between the mean traffic speed before and after selected speed reduction treatments was statistically significant, *t*-tests were conducted at the 0.05 level of significance.

4.2 “BEFORE” CONDITION DATA COLLECTION DATES

After consultations with the involved agencies in the selected jurisdictions, CTRE scheduled on-site data collection before and after the implementation of proposed speed reduction/traffic calming strategies. The “before” condition data were collected at four selected study sites during the summer of 2000, as listed in Table 4.1. About eight hours of data were collected in each scheduled day.

Table 4.1 "Before" Condition Data Collection Schedule, Summer 2000

Date	Twin Lakes	Bemidji Lake	Tofte	Schroeder
July 9, 2000	X			
July 10, 2000	X			
July 11, 2000	X			
July 12, 2000	X			
July 13, 2000		X		
July 14, 2000		X		
July 15, 2000	X			
August 6, 2000			X	
August 7, 2000				X
August 8, 2000			X	
August 9, 2000			X	
August 10, 2000			X	
August 11, 2000				X
August 12, 2000				X

4.3 SITES

4.3.1 Twin Lakes, Mahnomen County

The speed data collection at Twin Lakes in Mahnomen County was started on Sunday, July 9, 2000, and it continued through Wednesday, July 12, 2000, for about eight hours in each day (i.e., 9:30 AM to 5:30 PM). We were told that Saturdays are the busiest days during the summer, when the new tenants move in. Thus, another eight hours of data were collected on Saturday, July 15, 2000, at this site.

On the first day of data collection, one of the data collection trailers was stationed near the posted 30-mph speed limit sign on eastbound direction of CSAH 4, and the other was placed within the area near the advisory 15-mph sign before the pedestrians crosswalk. On the remaining four days, the within-the-area trailer was moved to the other end of the highway, near the posted 30-mph speed limit sign, to capture speeds of approaching vehicles on the westbound direction of CSAH 4 (see Figure 4.2).

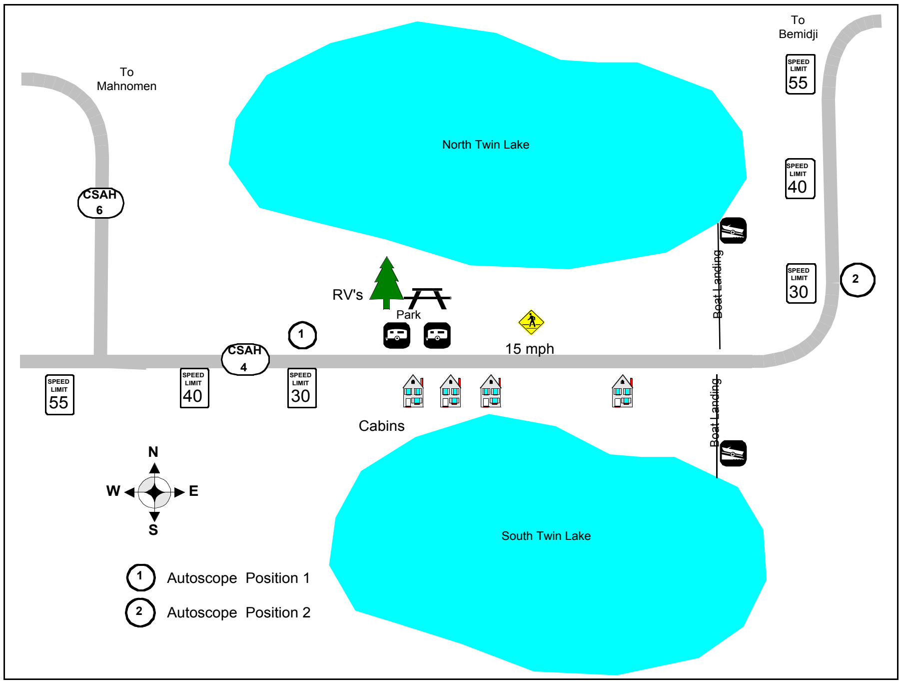

Figure 4.2 Data Collection Trailers Positions—Twin Lakes

Pictures taken during our data collection, shown in Figures 4.3 through 4.6, indicate a sample of daily traffic activities at the site. Due to a high number of cabins and recreational vehicles on both sides of the road and a low traffic volume, residents freely walk on the shoulders and cross the road (see Figures 4.3 and 4.4). Despite the fact that the site is located in a rural area, the pedestrian traffic activities at the site are very similar to the ones that are usually observed in an urban residential area. Furthermore, four young bicyclists can be seen in Figure 4.5 negotiating a curve on the wrong side of the road. There is also occasional all terrain vehicle (ATV) traffic, which usually enters the area through an adjacent trail (see Figure 4.6).

Figure 4.3 Pedestrians—Twin Lakes

Figure 4.4 Pedestrians—Twin Lakes

Figure 4.5 Bicyclists—Twin Lakes

Figure 4.6 All Terrain Vehicles—Twin Lakes

It should also be noted that while we were collecting data at this location, two members of the White Earth Tribe (Mahnomen County is within the boundaries of the White Earth Indian Reservation) approached us to express their concerns about our activities. In addition, they stated that the White Earth Tribal Council had not been contacted about the research project. Of particular concern to them was that they viewed this research as more encroachment by state and county law enforcement authorities on the Native Americans. While we are not sure that these gentlemen speak for the Tribe, it is clear that any speed reduction strategies that are implemented as a result of this study could be viewed by some members of the White Earth Tribe as more interference by civil authorities.

4.4.2 Bemidji Lake, Beltrami County

The speed data collection was conducted at the north side of the Bemidji Lake on CSAH 20 during Thursday and Friday, July 13–14, 2000, for about eight hours each day. One data collection trailer was placed on the eastbound direction of CSAH 20, 500 feet downstream of the posted 35 mph speed limit sign, while the other was stationed within the area at a distance of 1,200 feet from the first trailer (see Figure 4.7).

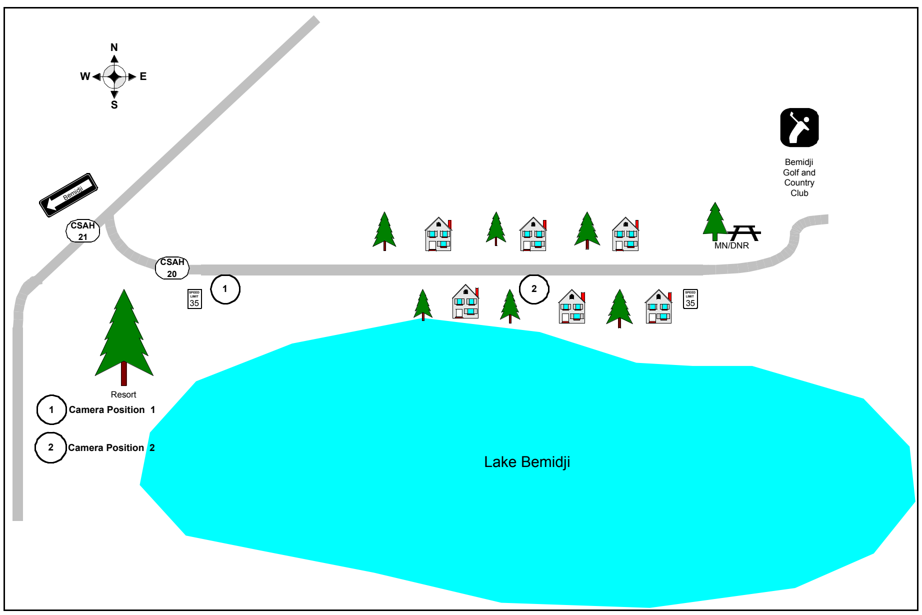

Figure 4.7 Data Collection Trailers Positions—Bemidji Lake

Lack of bike paths and paved shoulders on CSAH 20 at this site forces bicyclists to use the roadway (see Figure 4.8). The observed high number of trucks has created an unsafe situation for the bicyclists on CSAH 20 at this site (see Figure 4.9).

Figure 4.8 Bicyclists—Bemidji Lake

Figure 4.9 Trucks and Bicyclists—Bemidji Lake

4.4.3 Tofte, US 61

The speed data were collected in the city of Tofte on Sunday August 6, 2000, and Tuesday through Thursday, August 8–10, 2000, for about eight hours daily. The data collection trailers were placed approximately 700 feet downstream of the posted 40 mph speed limit signs on both north and south directions of US 61 to capture arriving vehicles' speeds (see Figure 4.10).

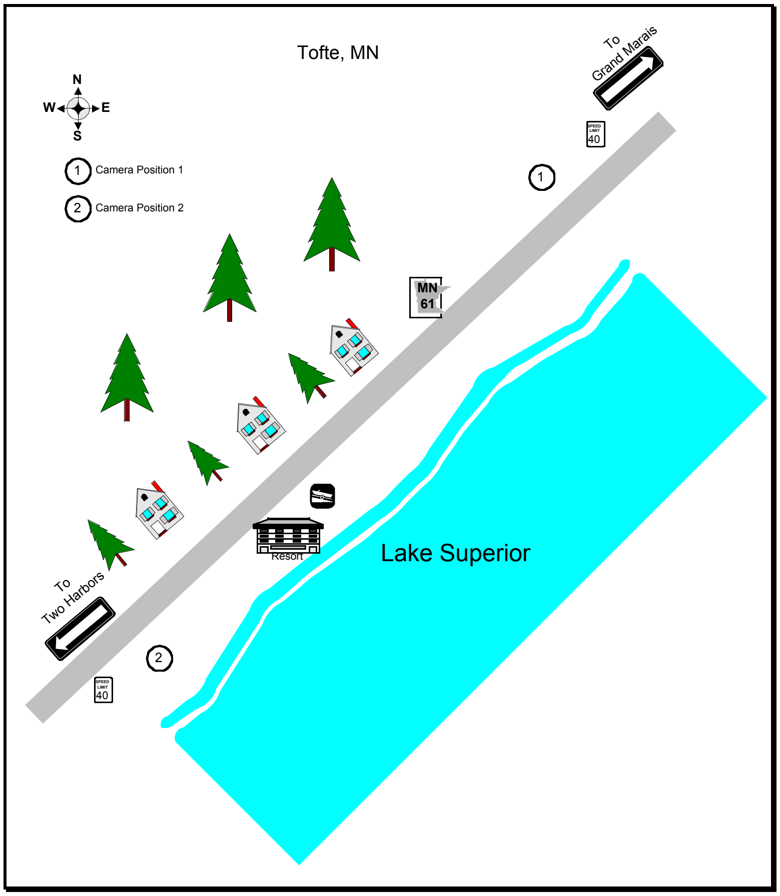

Figure 4.10 Data Collection Trailers Positions—Tofte

The US 61 through Tofte carries a high traffic volume, especially on Friday through Sunday during the summer (see Figure 4.11). The existence of two paper mills in Thunder Bay, Canada, has drawn a significant truck traffic to the area (see Figure 4.12).

Figure 4.11 Observed Traffic on Sunday Morning of August 6, 2000—Tofte

Figure 4.12 Truck Traffic—Tofte

4.4.4 Schroeder, US 61

The speed data were collected in the city of Schroeder on Monday August 7, 2000, as well as on Friday and Saturday, August 11–12, 2000 for about eight hours each day. The data collection trailers were placed approximately 350 feet downstream of the posted 40 mph speed limit signs and about 100 feet after the city entrance gates on both north and south directions of US 61 to capture approaching speeds (see Figures 4.13 and 4.14).

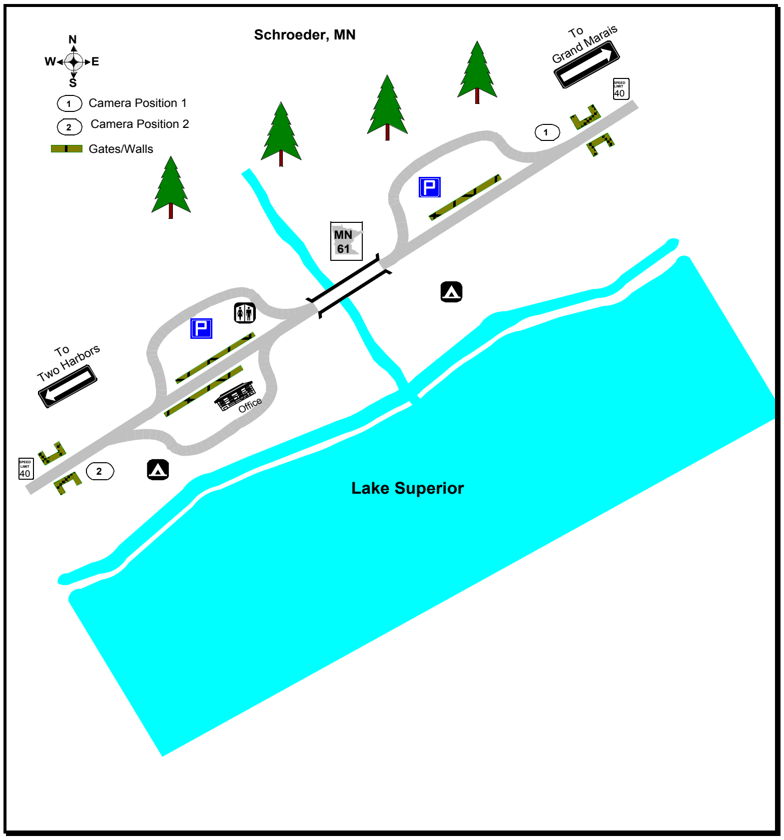

Figure 4.13 Data Collection Trailers Positions—Schroeder

Figure 4.14 Trailer's Position with Respect to the Gates and Speed Limit Sign—Schroeder

US 61 highway through the city of Schroeder had recently gone under a major construction. The two-lane highway has been widened to include a new two-way left-turn lane (see Figure 4.15). The surface of the two-way left-turn lane and shoulders were to be paved with light-colored bituminous pavement. However, due to a problem in the material mixture, the dark pavement color of the median and shoulders remained unchanged. As shown in the schematic of the site in Figure 4.13, in addition to the raised stone walls at the city entrances and roadsides, two parking lots have been added for trucks and other motorists who stop to rest and/or tour the Cross River and surrounding areas.

Figure 4.15 New Pavement and Added Two-Way Left-Turn Lane—Schroeder

During our data collection in Tofte and Schroeder, a number of speeding motorists were observed. In one occasion, a passenger car hastily had to pull onto the shoulder to prevent a potential run over by a heavy truck, which apparently could not slow down after it entered the 40-mph speed zone in the city of Tofte.

On Friday, August 11, 2000, the Minnesota State Patrol reported two separate fatal accidents on US 61. Three were dead at the scenes. According to the August 14 issue of the *Duluth News Tribune*, both accidents involved motorcycles.

5 SPEED REDUCTION TECHNIQUES

5.1 BACKGROUND

This project involved designing experiments to reduce motorist speeds entering small communities. CTRE proposed speed reduction techniques in a letter dated December 12, 2000 (see Appendix A). The project's Technical Advisory Panel met at the Minnesota Research Laboratory in Minneapolis on February 15, 2001, to agree to the proposed speed reduction experiments and identify responsibilities for installing the experiments. The summary of the meeting is included in Appendix B.

In the February 15, 2001, meeting, it was indicated that the originally planned construction schedule at Tofte is unclear and the collection of second set of "after" condition data at Schroeder would be beneficial. However, on February 23, 2001, Rod Garver of Mn/DOT, Duluth, indicated that due to issues raised by Tofte's residents, some of the roadway design factors need to be revisited. Therefore, the proposed construction did not take place during the summer of 2001, and it would be another two or three years before proposed traffic calming strategies are implemented in the town of Tofte.

To make better use of project resources, in response to our February 28, 2001, letter (see Appendices C and D), the project TAP agreed that no more data collection should be conducted at Tofte and Schroeder. Instead, "after" data conditions were collected on two occasions after implementation of the proposed speed reduction strategies (two weeks and six weeks) at locations in Twin Lakes and Bemidji Lake. Table 5.1 shows the "after" data collection dates conducted during the summer of 2001 at the two sites. This chapter reports on the traffic calming/speed reduction strategies implemented at the Twin Lakes and Bemidji sites.

Table 5.1 "After" Condition Data Collection Schedule, Summer 2001

Date	Twin Lakes	Bemidji Lake
June 23, 2001	X	
June 24, 2001	X	
June 25, 2001	X	
June 26, 2001	X	
June 27, 2001		X
June 28, 2001		X
June 29, 2001		X
August 11, 2001	X	
August 12, 2001	X	
August 13, 2001	X	
August 14, 2001	X	
August 15, 2001		X
August 16, 2001		X
August 17, 2001		X

5.2 SITES

5.2.1 Twin Lakes, Mahnomen County

The techniques deployed at the Twin Lakes consisted of removable pedestrian islands and pedestrian crossing devices (see Figures 5.1 and 5.2). These were supplied by the RubberTough Industries in Concord, New Hampshire. The combination of islands and signs created an urban effect that helped reduce motorist speed. The curbs and signs were used to concentrate pedestrian street crossings at marked crosswalks.

Figure 5.1 Rubber Curbing

Figure 5.2 Portable Pedestrian Crossing Devices

The RubberTough Industries modified the signs to meet the Minnesota state regulations by changing the wording of “yield to pedestrians in crosswalk” to “stop for pedestrians in crosswalk” on the signs. Mr. Chuck Kennedy of RubberTough had submitted a cost estimate for eight portable pedestrian crossing devices and two ten-foot rubber islands (see Figure 5.3); Mr. Heyer in turn requested additional funds for the curbs and signs from the Research Implementation Committee of the LRRB, which met on March 21, 2001.

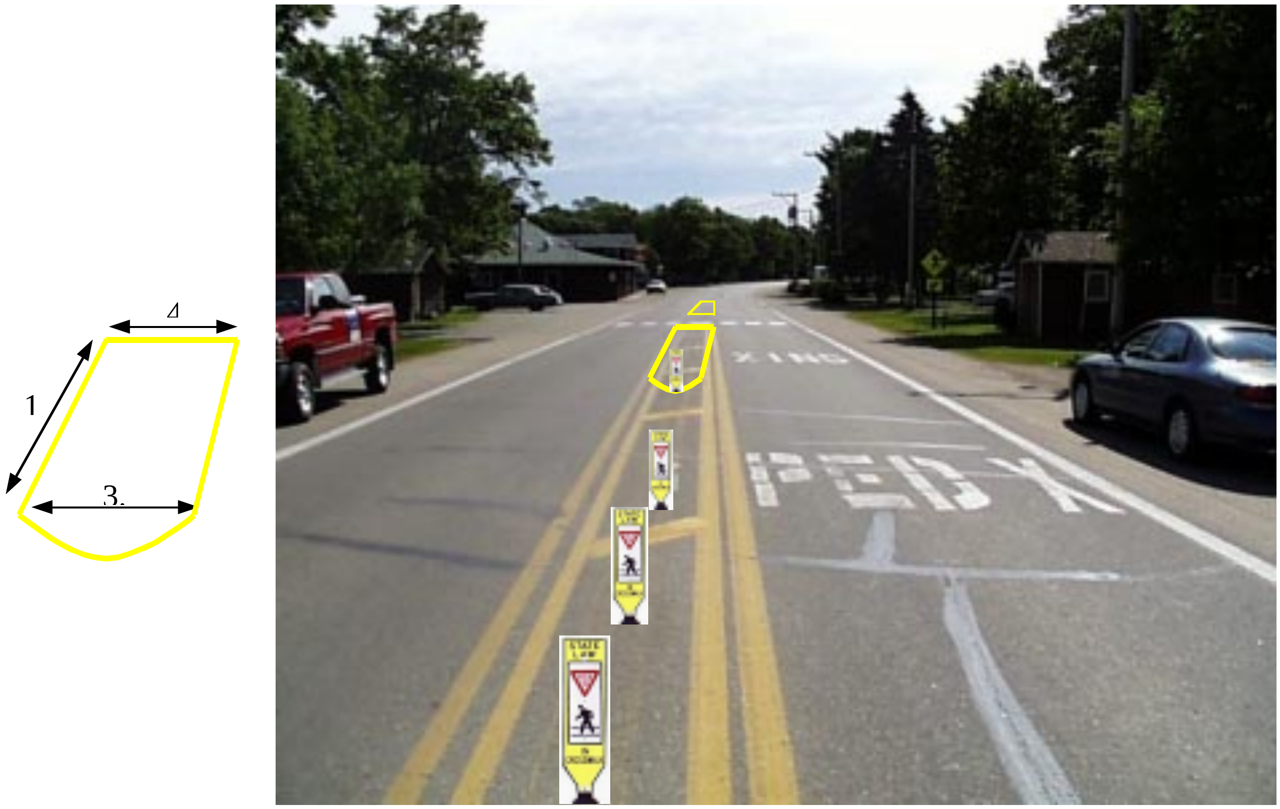

Figure 5.3 Proposed Layout at the Twin Lakes

Following implementation of the portable curbs and signs, CTRE collected 2–3 days of speed data on two occasions. One set of data was collected about two weeks after installation and one set about six weeks after installation. Two data collection occasions following the implementation of the proposed speed reduction strategies at the Twin Lakes site provided a better understanding of the short-term and long-term effects of the engaged speed reduction strategies.

5.2.2 Bemidji Lake, Beltrami County

One dynamic variable message sign sending a single-word message (SLOW) to motorists traveling over the speed limit was installed at the Bemidji Lake site. The installation of the sign was planned to be coupled with initial police enforcement to convey the idea that speeds are being observed. Enforcement was to be reduced to normal levels, relying on the dynamic sign to give the illusion of enforcement. However, no enforcement was provided.

ADDCO, a St. Paul-based manufacturer of the dynamic variable message sign (see Figure 5.4), loaned one to Minnesota DOT for the project free of charge for two months. The Beltrami County highway department provided assistance in installing the sign on a metal frame and running power to the sign. Following installation, as in Twin Lakes, CTRE collected 2–3 days of speed data on two occasions to study the short-term and long-term impacts of the sign.

Figure 5.4 Dynamic Variable Message Sign

CTRE sent a representative to the two sites during the week of June 10, 2001, to observe the installation procedures.

6 DATA COLLECTION AND ANALYSIS

Data collection consisted of two cycles. Speed data were collected at the four selected study sites, under the existing conditions (i.e., “before” conditions), during the months of July and August of 2000. The “after” condition data collection was conducted during the summer of 2001 after the selected speed reduction strategies were implemented at the Twin Lakes and Bemidji Lake sites. This chapter presents the resulted speed parameters and their statistical analyses.

Using CTRE’s two traffic data collection trailers, the traffic flow performance data (vehicle speed, headways, volume, etc.) were recorded in “before” and “after” conditions at the selected study sites. Using the Autoscope image processing technology, the recorded videotapes were analyzed to determine the vehicle types (i.e., passenger cars and non-passenger cars), arrival times, and speeds of approaching vehicles. A number of significant parameters (see Chapter 4) were obtained through the analysis of the speed data. Some of the parameters were computed directly from the data while others were determined from a graphical analysis of the speed data.

6.1 “BEFORE” DATA CONDITION

The "before" speed data parameters were determined for all vehicles, passenger cars, and nonpassenger cars for each direction in selected sites. Table 6.1 shows data collection duration at each site. Approximately eight hours of data were collected in each day. Thus, depending on the number of days and traffic volume, different data points were collected at each site. However, having defined the free flowing vehicles as those with headways greater than or equal to five seconds, about half of the data points were eliminated in the final analysis (see Table 6.1). It is believed that only free flowing vehicles provide a valid sampling for vehicle speed. Following vehicles are obviously traveling the same speed as the lead vehicles; thus including them would skew the speed data.

Table 6.1 also includes the observed truck percentage per direction in each site. The table shows a high number of trucks observed on US 61 through Tofte and Schroeder as well as on the westbound direction of Minnesota County State Aid Highway (CSAH) 20 on the north side of Bemidji Lake.

Table 6.1 Collected Data Points—"Before" Condition

Site	Truck Population (%)		Data Collection Duration (day)	Data Points (numbers)		Discarded Data Points (%)	
	EB or NB	WB or SB		EB or NB	WB or SB	EB or NB	WB or SB
Twin Lakes	5.8	5.7	5	2,000	1,500	30	25
Bemidji Lake	9.6	14.2	2	2,500	3,000	30	50
Tofte	12.5	23.6	4	8,000	6,000	50	40
Schroeder	15.6	18.2	3	6,000	5,000	50	45

6.2 "AFTER" DATA CONDITION

The "after" condition speed data were collected at the Mahnomen and Bemidji sites in two occasions in June and August of 2001. The purpose of the two "after" condition data collections was to examine short-term and long-term effects of the deployed treatments in reducing speeds.

As shown in Figures 6.1 through 6.3, four signs, spaced at 100 feet, were lagged down on the centerline of CSAH 4 on each direction in Twin Lakes. The signs meet the Minnesota state regulations, that is, wording "STATE LAW, STOP FOR PEDESTRIANS IN CROSSWALK." The islands and signs were used to concentrate pedestrian street crossings at marked crosswalks.

Figure 6.1 Pedestrian Island and Sign—Mahnomen

Figure 6.2 Pedestrian Crossing Devices—Mahnomen

Figure 6.3 Another View of the Island and Signs—Mahnomen

A dynamic variable message sign, sending a single-word message SLOW to motorists traveling over the speed limit (i.e., 35 mph), was installed at the Bemidji site (see Figures 6.4 and 6.5). The sign was mounted on the westbound direction of CSAH 20 about 600 feet downstream of the posted regulatory speed limit sign.

Figure 6.4 Dynamic Variable Message Sign—Bemidji

Figure 6.5 Another View of the Sign—Bemidji

Traffic data were collected at the Mahnomen and Bemidji sites on the indicated dates listed in Table 6.2. Similar to the "before" condition, only free flowing vehicles (i.e., vehicles with headways greater than or equal to five seconds) were considered in the final analysis. Table 6.3 shows that about quarter of the data points were eliminated.

Table 6.2 Data Collection Dates

Site	Date		
	Before	After-1	After-2
Twin Lakes EB	July 9–12, 15, 2000	June 23–26, 2001	—
Twin Lakes WB			August 11–14, 2001
Bemidji Lake EB	July 13–14, 2000	—	—
Bemidji Lake WB		June 28–30, 2001	August 16–18, 2001

Table 6.3 Collected Data Points—Two "After" Occasions

Site	Truck Population (%)		Data Collection Duration (day)	Data Points (numbers)		Discarded Data Points (%)	
	EB	WB		EB	WB	EB	WB
Twin Lakes 1	5.9	4.1	4	900	1,000	25	21
Twin Lakes 2	—	4.3	4	—	1,600	—	15
Bemidji Lake 1	—	3.5	3	—	2,000	—	29
Bemidji Lake 2	—	2.3	3	—	3,000	—	25

The first "after" data were recorded on both directions of CSAH 4 in Twin Lakes. The second "after" data were, however, collected only on the westbound direction CSAH 4 due to the similarities of the east and west bounds' speed parameters determined in the first "after" condition (see speed parameters in Tables 6.6 and 6.7). Since the dynamic variable message sign installed on the westbound direction of CSAH 20 in Bemidji, the two "after" data collections were only conducted on the westbound direction.

6.3 RESULTS

For graphical analysis, each data set was first grouped into intervals of two miles per hour (mph). For example, vehicles traveling from 40 mph to 42 mph were grouped together. Frequencies of vehicles traveling in each two-mph group were then obtained and used to calculate the cumulative percentage of vehicles traveling at each interval. Plots of the cumulative percentages for each of the three data sets (all vehicles, passenger cars, and nonpassenger cars) in each direction are shown in Figures E.1 through E.24 in Appendix E for the “before” condition. The “after” condition plots of the cumulative percentages are shown in Figures F.1 through F.15 in Appendix F. Most figures exhibit the expected S-shaped curves. However, due to a small number of nonpassenger car data points, some plots do not show a smooth S-shaped curve (see, e.g., nonpassenger car plots of Twin Lakes and Bemidji Lake in Figures E.3 and E.9). Also, shown in each plot are dashed lines for the lower and upper boundary of the 10-mph pace, and the 85th percentile speed. The values estimated through both graphical and numerical analysis are shown in tables for each site throughout this chapter.

Statistical comparisons were carried out to ascertain whether the differences of mean speeds and speed compliance rates, obtained in the “before” and “after” conditions, are statistically significant. Tukey’s *t*-test was utilized to determine significance of differences in the mean speeds at the 95 percent confidence level. The null and the alternative hypotheses were as follows:

> H_o: The mean speeds are the same in the “before” and “after” conditions.
>
> H_a : The mean speeds are different in the “before” and “after” conditions.

The decision rules were as follows:

> If $| t^* | \leq t\,(1 - 0.05/2;\, n - 1)$, conclude H_o, i.e., mean speeds are the same.
>
> If $| t^* | > t\,(1 - 0.05/2;\, n - 1)$, conclude H_a, i.e., mean speeds change.

As for speed compliance rates, the normal approximation to the binomial distribution was used to determine whether the changes in the rates were statistically significant (a binomial distribution is commonly used to represent situations consisting of repeated trails, *n*, in which each trial is independent and has a probability of success, *p*). In this study, there are samples of *n* observations and percents of vehicles (*p*), which complied with the posted speed limit during the “before” and “after” conditions. On the westbound direction at the Mahnomen site, for example, only 30 percent (p) of 1,237 observed vehicles (n) stayed within the speed limit during the data collection in the "before" condition (see Table 6.11). After mounting the pedestrian signs and islands, 58 percent of 1,113 vehicles and 51 percent of 1,392 vehicles obeyed the posted speed limit during the first and second data collection occasions on the same direction, respectively.

By entering the total observed traffic volumes and speed compliance proportions into Equation 6.1, a t-statistic was determined for each direction and vehicle type.

$$t = \frac{p_b - p_a}{\sqrt{p_0 q_0 \left(\frac{1}{n_b} + \frac{1}{n_a} \right)}} \tag{6.1}$$

where

$$p_0 = \frac{p_b n_b + p_a n_a}{n_b + n_a}$$

$q_0 = 1 - p_0$

n_a and n_b are the total number of vehicles observed after and before the treatments, respectively

p_a and p_b are the percent of vehicles observed after and before the treatments, respectively

Statistical analyses of mean speeds and speed compliance rates for each study site are presented in this chapter. A t-statistic of ±1.96 or higher indicates statistical significance at the 95 percent confidence level.

6.3.1 Twin Lakes, Mahnomen County

"Before" Data Condition

The mean speeds of vehicles observed on CSAH 4 at Twin Lakes were generally higher than the posted 30 mph speed limit (see Tables 6.4 and 6.5). The data show that about 42 percent of vehicles on eastbound and 30 percent on westbound directions obeyed the posted speed limit. Furthermore, the 85th percentile speeds on eastbound and westbound directions were between 12 mph and 15 mph over the posted speed limit, respectively. The 85th percentile speeds of nonpassenger cars are recorded as 54 mph and 52 mph for the eastbound and westbound, respectively. It is noted that only 24 percent of nonpassenger cars complied with the posted speed limit on westbound direction, which is seven percent lower than the passenger car percentage in the same direction.

Table 6.4 Twin Lakes Eastbound (30 mph Posted Speed Limit)—Before

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	32.7	42	26–36	42	10.04	42	49.3
Passenger cars	32.5	42	26–36	42	9.65	42	48.3
Nonpass. cars	35.2	54	26–36	41	14.89	44	65.5

Table 6.5 Twin Lakes Westbound (30 mph Posted Speed Limit)—Before

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	35.0	45	30–40	40	10.56	30	50.1
Passenger cars	34.8	45	32–42	40	10.35	31	49.7
Nonpass. cars	37.4	52	30–40	41	12.65	24	58.8

“After” Data Condition

The observed mean speeds at Twin Lakes were about the posted speed limit, which is 30 mph (see Tables 6.6 through 6.8). The data show that the 85th percentile speeds were still about 8 mph over the posted speed limit. They are, however, 7 mph less than the ones observed during the “before” condition (i.e., 45 mph). Furthermore, the number of vehicles in the 10-mph pace increased by about eight percent as the pace speed intervals decreased after the pedestrian signs and islands were mounted on the centerline. In other words, more vehicles traversed the roadway within the posted speed limit after the treatment deployment.

Table 6.6 Twin Lakes Eastbound (30 mph Posted Speed Limit)—After-1

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	29.3	38	22–32	48	8.33	59	43.1
Passenger cars	29.3	37	22–32	49	8.05	59	42.1
Nonpass. cars	28.8	44	16–26	48	12.10	65	55.2

Table 6.7 Twin Lakes Westbound (30 mph Posted Speed Limit)—After-1

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	29.5	37	22–32	48	8.17	58	42.5
Passenger cars	29.5	37	22–32	48	8.09	58	42.4
Nonpass. cars	28.8	39	24–34	48	9.86	65	46.0

Table 6.8 Twin Lakes Westbound (30 mph Posted Speed Limit)—After-2

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	30.6	38	22–32	48	7.81	51	43.1
Passenger cars	30.7	38	22–32	48	7.70	51	42.8
Nonpass. cars	29.5	37	18–28	43	9.86	57	47.0

Figure 6.6 shows that the speed compliance increased over 15 and 25 percent on the eastbound and westbound directions, respectively. Although, the speed limit obedience on the westbound direction somewhat decreased during the second “after” data collection, it was still significantly higher than the “before” condition. In other words, the long-term effect of deployed treatments in improving speed compliance was somewhat less than the short-term effect, but still 20 percent more effective than the existing (no-treatment) condition observed last year. By most measures this is a significant increase in speed compliance and an important finding in the ongoing research on speed reduction measures.

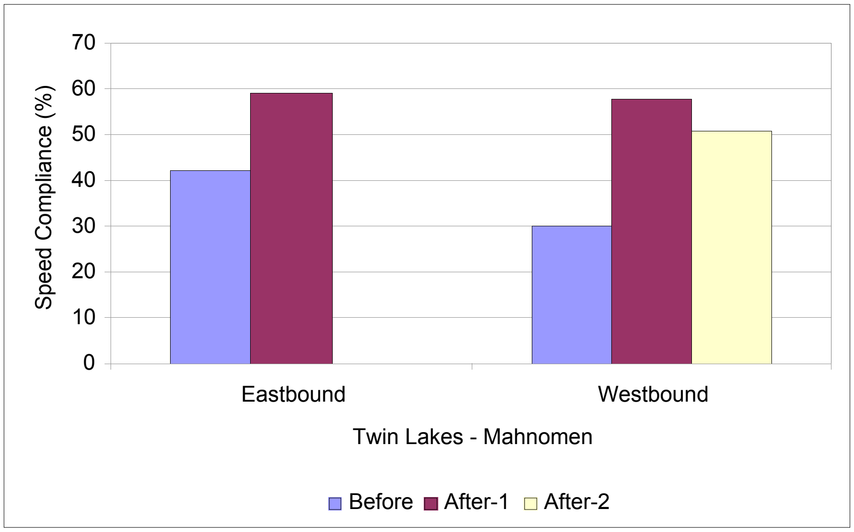

Figure 6.6 "All-Vehicle" Speed Compliance Changes in Twin Lakes—Mahnomen

Before-and-After Data Comparison

As shown in Tables 6.9 through 6.14, the differences between the mean speeds and speed compliance rates recorded before and after the treatment deployment were found to be statistically significant on both directions of CSAH 4. Therefore, the hypothesis that the deployed treatment improves the mean speed and speed compliance rate is accepted. In other words, the employed traffic calming strategies were effective in improving traffic safety in short-term and long-term applications.

Table 6.9 Passenger Cars—Twin Lakes Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1152	34.8	—	—	31	—	—
After-1	1067	29.5	13.49	Yes	58	-12.80	Yes
After-2	1331	30.7	11.05	Yes	51	-10.01	Yes

Table 6.10 Nonpassenger Cars—Twin Lakes Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	71	37.4	—	—	24	—	—
After-1	46	28.8	4.11	Yes	65	-4.42	Yes
After-2	60	29.5	4.01	Yes	57	-3.84	Yes

Table 6.11 All Vehicles—Twin Lakes Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1237	35	—	—	30	—	—
After-1	1113	29.5	14.20	Yes	58	-13.68	Yes
After-2	1392	30.6	11.02	Yes	51	-10.85	Yes

Table 6.12 Passenger Cars—Twin Lakes Eastbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1289	32.5	—	—	42	—	—
After-1	827	29.3	8.25	Yes	59	-7.63	Yes

Table 6.13 Nonpassenger Cars—Twin Lakes Eastbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	80	35.2	—	—	44	—	—
After-1	52	28.8	2.71	Yes	65	-2.36	Yes

Table 6.14 All Vehicles—Twin Lakes Eastbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1370	32.7	—	—	42	—	—
After-1	879	29.3	8.71	Yes	59	-7.87	Yes

6.3.2 Bemidji Lake, Beltrami County

"Before" Data Condition

As shown in Tables 6.15 and 6.16, the mean and 85th percentile of westbound nonpassenger vehicles are higher than passenger cars' speeds on both directions of CSAH 20 on the north side of Bemidji Lake. The posted speed limit at this location is 35 mph, where only 40 percent of all vehicles observed the posted speed limit.

Table 6.15 Bemidji Lake Eastbound (35 mph Posted Speed Limit)—Before

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	37.2	43	30-40	62	7.18	40	47.6
Passenger cars	37.2	43	30-40	62	7.00	38	47.1
Nonpass. cars	37.7	43	30-40	60	8.72	47	52.3

Table 6.16   Bemidji Lake Westbound (35 mph Posted Speed Limit)—Before

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	36.0	43	30-40	52	9.52	40	49.4
Passenger cars	35.4	43	30-40	53	9.25	42	48.6
Nonpass. cars	40.4	47	30-40	43	9.98	32	58.1

"After" Data Condition

Both "after" data collection occasions were conducted on the westbound direction of CSAH 20 in Bemidji. As shown in Figure 6.7, almost no changes are observed in the mean speed after the dynamic variable message sign was mounted at the site. The figure shows that the sign was effective to increase the speed compliance by about 10 percent in short term. Its impact in improving the speed compliance, however, faded after six weeks into the sign operation (i.e., long term).

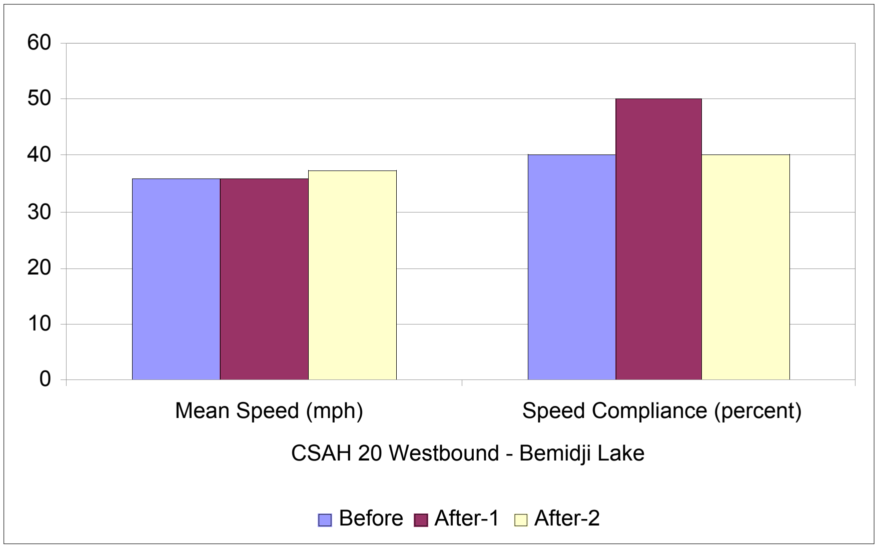

Figure 6.7 "All-Vehicle" Mean Speed and Speed Compliance Changes in Bemidji

As can be seen in Tables 6.17 and 6.18, the 85th percentile and pace interval speeds show no sign of changes in the "before" and "after" conditions. The number of vehicles in the 10-mph pace did not change in the first "after" condition. It, however, increased by about 10 percent during the second "after" data collection.

Table 6.17 Bemidji Lake Westbound (35 mph Posted Speed Limit)—After-1

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	35.9	44	30–40	51	9.29	50	50.6
Passenger cars	35.8	44	30–40	51	9.23	50	50.5
Nonpass. cars	40.0	50	30–40	48	9.63	37	57.4

Table 6.18 Bemidji Lake Westbound (35 mph Posted Speed Limit)—After-2

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	37.3	43	32–42	62	6.55	40	47.7
Passenger cars	37.3	43	32–42	62	6.52	40	47.6
Nonpass. cars	36.9	43	32–42	64	8.04	40	52.8

Before-and-After Data Comparison

Tables 6.19 through 6.21 show results of the statistical analysis conducted on the mean speeds and speed compliance percentages recorded before and after the sign placement. The comparison of the “before” and first “after” data indicates no significant changes in the mean speeds observed in these two conditions. The comparison of the “before” and second “after” data, however, indicates significant increases in the mean speeds of “passenger cars” and “all vehicles” in the long term. The similar comparison for the “nonpassenger cars” shows significant decrease in their mean speeds.

Table 6.19 Passenger Cars—Bemidji Lake Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1255	35.4	—	—	42	—	—
After-1	1707	35.8	-1.16	No	50	-4.31	Yes
After-2	2214	37.3	-6.43	Yes	40	1.14	No

Table 6.20 Nonpassenger Cars—Bemidji Lake Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	209	40.4	—	—	32	—	—
After-1	62	40.0	0.29	No	37	-0.74	No
After-2	53	36.9	2.69	Yes	40	-1.11	No

Table 6.21 All Vehicles—Bemidji Lake Westbound

	Observed Traffic	Mean Speed (mph)	*t*-statistic	Significant (95%)	Speed Compliance (%)	*t*-statistic	Significant (95%)
Before	1468	36	—	—	40	—	—
After-1	1786	35.9	0.30	No	50	-5.70	Yes
After-2	2268	37.3	-4.51	Yes	40	0	Unchanged

Moreover, no statistically significant differences were observed in the speed compliance rates of “nonpassenger cars.” The increases in compliance rates for “passenger cars” and “all vehicles” were, however, significant in the first “after” data condition. The rates decreased insignificantly for “passenger cars” and remained unchanged for “all vehicles” during the second “after” data collection period.

The primary reasons for the dynamic variable message sign’s inefficiency in encouraging motorists to comply with the posted speed limit are the sign's single-word message (i.e., SLOW), location, and most importantly, lack of enforcement. Because of the area’s power source limitation, the sign was posted at the end of a horizontal curve (pointed by an arrow in Figure 6.8) providing a limited exposure to the approaching motorists.

Figure 6.8 Dynamic Variable Message Sign Location on CSAH 20 in Bemidji

The single-word message by itself was not informative enough to adequately encourage drivers to slow down. It is suggested that messages like “SLOW DOWN, YOU ARE SPEEDING” or “YOUR SPEED IS … , SLOW DOWN” would had been more effective in controlling speed.

The preliminary work plan, approved by the project technical advisory panel (see Task 5 report), called for the installation of the sign to be coupled with initial police enforcement to convey the idea that speeds are being observed. Enforcement could then be reduced to normal levels, relying on the dynamic sign to give the illusion of enforcement. No enforcement was, however, provided during each of "after" data collection occasion.

6.3.3 Tofte, US 61

"Before" Data Condition

Tables 6.22 and 6.23 show that the recorded mean speeds at the Tofte site are close to the posted 40 mph speed limit. The 85th percentile speeds, however, are between 6 mph and 12 mph higher than the posted speed limit for passenger cars and nonpassenger cars on southbound and northbound directions, respectively. It is noted that on both south and north bound directions only 40 percent of non-passenger vehicles complied with the posted speed limit.

Table 6.22 Tofte Northbound (40 mph Posted Speed Limit)

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	40.0	47	36–46	45	8.85	53	53.9
Passenger cars	39.6	47	36–46	44	8.77	55	53.7
Nonpass. cars	42.8	52	36–46	48	8.94	40	57.0

Table 6.23 Tofte Southbound (40 mph Posted Speed Limit)

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	39.8	47	36–46	56	7.63	50	51.4
Passenger cars	39.4	46	36–46	57	7.35	53	50.7
Nonpass. cars	41.3	49	36–46	52	8.29	40	52.9

6.3.4 Schroeder, US 61

"Before" Data Condition

As shown in Table 6.24, during the three days of data collection at the Schroeder site, only 16 percent of northbound vehicles complied with the posted 40-mph speed limit. This percentage is higher for the southbound vehicles (see Table 6.25). The 85th percentile speeds are about 10 mph or more over the posted speed limit on both directions.

Table 6.24 Schroeder Northbound (40 mph Posted Speed Limit)

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	47.1	54	40–50	56	7.24	16	58.5
Passenger cars	47.1	54	40–50	56	7.23	16	58.6
Nonpass. cars	47.3	55	40–50	55	7.33	16	59.2

Table 6.25 Schroeder Southbound (40 mph Posted Speed Limit)

Vehicle	Mean Speed	85th Percentile	10-mph Pace	Percent in Pace	Standard Deviation	% Comply w/ Speed Limit	Mean of Highest 15%
All vehicles	42.8	50	36–46	59	6.71	36	58.9
Passenger cars	42.7	50	36–46	59	6.66	36	52.8
Nonpass. cars	43.4	50	36–46	59	6.91	33	55.0

7 CONCLUSIONS

The collected speed data indicate that less than 50 percent of vehicles complied with the posted speed limits at the selected study sites under the existing conditions. The 85th percentile speed, which sometimes referred to as the critical speed, is traditionally used as a guide in establishing reasonable speed limits. However, as the data shows, the observed 85th percentile speeds were generally higher than the posted speed limits in all four sites. Thus, either the current speed limits should be changed or some types of speed reduction techniques had to be implemented to ensure a safer environment for the pedestrians and drivers at the selected sites.

The city of Schroeder has recently invested in some speed reduction strategies. The US 61 highway through the city of Schroeder had recently gone under a major construction. The two-lane highway has been widened to include a new two-way left-turn lane. The surface of the two-way left-turn lane and shoulders were to be paved with light colored bituminous pavement. However, due to a problem in the material mixture, the dark pavement color of the median and shoulders remained unchanged. Furthermore, entrance gates and roadside walls were also added to urbanize the city environment. The collected speed data, however, indicate that the implemented strategies have been somewhat ineffective in encouraging drivers to slow down.

Moreover, the University of Minnesota Human Factors Research Lab has completed a traffic calming study in that city of Tofte in which a driving simulator was used to study the impact of light poles, pavement coloring, and planting on drivers' behavior. Traffic calming strategies were to be built in the summer of 2001. After the deployment of the proposed designs, the Center for Transportation Research and Education planned to conduct another speed study in Tofte during the summer of 2001 or 2002 to validate the simulator results. However, due to issues raised by residents, no traffic calming strategies are planned to be implemented in Tofte for the next few years.

The research study shows that the traffic calming strategy deployed in Mahnomen was effective to significantly reduce the mean speed and improve speed limit compliance rate both in short term and long term. According to local officials, several residents noted an obvious reduction in the speed and were pleased with the outcomes. The “after” data in Mahnomen show that the observed 85th percentile speeds were still higher than the posted speed limit. Increasing the current posted speed limit is not advisable; thus, other speed reduction treatments in conjunction with the current ones should also be used to enhance pedestrian safety.

Despite proven effectiveness elsewhere, the deployed speed reduction treatment in Bemidji failed to lower the speed at the study site. The sign’s single-word message and its location as well as lack of initial enforcement were the primary reasons for such failure. The motorists’ disregard of the implemented treatment was evident as the sign was intentionally run over, damaging the sign. According to a witness account, sometime between the first and second “after” data collection periods, a pickup truck quickly backed up, hit the sign, and left the scene. A number of beer bottles and cans were also found under the sign, which was a clear indication of sign vandalism.

REFERENCES

1. Britt, J.W., A.B. Bergman, and J. Moffat. Law Enforcement, Pedestrian Safety, and Driver Compliance with Crosswalk Laws: Evaluation of a Four-Year Campaign in Seattle. *Transportation Research Record 1485*, July 1995, pp. 160–167.

2. Hall, J.W. Pedestrian Accidents on Rural Highways. *Transportation Research Record 904,* 1983, pp. 46–50.

3. Mueller, B.A., P.H. Frederick, P. Rivera, and A.B. Bergman. Urban-Rural Location and the Risk of Dying in a Pedestrian-Vehicle Collision. *The Journal of Trauma*, Vol. 28, No. 1, 1988, pp. 91–94.

4. Stutts, J.C., W.W. Hunter, and W.E. Pein. Pedestrian-Vehicle Crash Types: An Update. *Transportation Research Record 1538*, 1996, pp. 68–74.

5. Choueiri, E.M., R. Lamm, G.M. Choueiri, and B.M. Choueiri. Pedestrian Accidents: A 15-Year Survey from the United States and Western Europe. *Institute of Transportation Engineers Journal*, July 1993, pp. 36–42.

6. Sarkar, S., A.A.J. Nederveen, and A. Pols. Renewed Commitment to Traffic Calming for Pedestrian Safety. *Transportation Research Record 1578*, 1997, pp. 11–19.

7. Snyder, M., and R.L. Knoblauch. *Pedestrian Safety—The Identification of Precipitating Factors and Possible Countermeasures.* Contract No. FH-11-7312. Operations Research, Inc., 1971.

8. Retting, R.A. Traffic Engineering Approaches to Improving Pedestrian Safety. *Transportation Quarterly*, Vol. 53, No. 2, 1999, pp. 87–98.

9. Calvert, E.C., and E.M. Wilson. Incremental Safety Improvements for Unpaved Rural Roads. *Transportation Research Record 1652,* May 1999, pp. 118–125.

10. Ribbens, H. Pedestrian Facilities in South Africa: Research and Practice. *Transportation Research Record 1538*, 1996, pp. 10–18.

11. Cynecki, M.J., J.W. Sparks, and J.L. Grote. Rumble Strips and Pedestrian Safety. *Institute of Transportation Engineers Journal*, Aug. 1993, pp. 18–24.

12. *Fatality Facts 1997—Pedestrians.* Insurance Institute for Highway Safety.

13. *Causative Factors and Countermeasures for Rural and Suburban Pedestrian Accidents: Accident Data Collection and Analysis.* National Highway Traffic Safety Administration, Mar. 1977.

14. Jensen, S.U. Pedestrian Safety in Denmark. *Transportation Research Record 1674*, 1999, pp. 61–69.

15. Thompson, S.J., and S. Heydon. Improving Pedestrian Conspicuity by the Use of a Promontory. *Traffic Engineering and Control*, Vol. 32, No. 7–8, July-Aug. 1991, pp. 370–371.

16. Knoblauch, R.L., B.H. Tustin, S.A. Smith, and M.T. Pietrucha. *Investigation of Exposure Based Pedestrian Accident Areas: Crosswalks, Sidewalks, Local Streets, and Major Arterials.* FHWA-RD-87-038. U.S. Department of Transportation, Washington, D.C., 1987.

17. Clark, K.L., J.E. Hummer, and N. Dutt. Field Evaluation of Fluorescent Strong Yellow-Green Pedestrian Warning Signs. *Transportation Research Record 1538*, Nov. 1996, pp. 39–46.

18. Sparks, J.W., and M.J. Cynecki. Pedestrian Warning Flashers in an Urban Environment: Do They Help? *Institute of Transportation Engineers Journal*, Jan. 1990, pp. 32–36.

19. Burritt, B.E., R.C. Buchanan, and E.I. Kalivoda. School Zone Flashers—Do They Really Slow Traffic? *Institute of Transportation Engineers Journal*, Jan. 1990, pp. 29–31.

20. Glennon, J.C. Accident Effects of Centerline Markings on Low-Volume Rural Roads. *Transportation Research Record 1027*, 1985, pp. 7–13.

21. Hunter, W., J. Stutts, W. Pein, and C. Cox. *Pedestrian and Bicycle Crash Types of the Early 1990s.* Publication FHWA-RD-95-163. Federal Highway Administration, U.S. Department of Transportation, June 1996.

22. McMahon, P.J., C. Duncan, J.R. Stewart, C.V. Zegeer, and A.J. Khattak. Analysis of Factors Contributing to "Walking Along Roadway" Crashes. *Transportation Research Record 1674*, 1999, pp. 41–47.

23. Maze, T.H., A. Kamyab, and S. Schrock. *Evaluation of Work Zone Speed Reduction Measures.* Center for Transportation Research and Education, Iowa State University, Ames, Iowa, Apr. 2000.

24. Maze, T.H., A. Kamyab, and C. Poole. *Midwest States Smart Work Zone Deployment Initiative, Technology Evaluations—Year One*. Center for Transportation Research and Education, Iowa State University, Ames, Iowa, May 2000.

25. Scanllen, S. and Carmody, J. *Investigating the Effects of Roadway Design on Driver Behavior: Applications for Minnesota Highway Design*. Minnesota Department of Transportation, St. Paul, Minn., Feb. 1999.

APPENDIX A

PROPOSED SPEED REDUCTION TECHNIQUES
(DECEMBER 12, 2000)

December 12, 2000

Bill Bunde, Administrative Liaison
Minnesota DOT
Office of Research and Strategic Services (ORSS)
Mail Stop 330, 1st Floor North
395 John Ireland Blvd
St. Paul, MN 55155

Re: MN/DOT Agreement No. 74995
Work Order No. 2
"Methods to Reduce Traffic Speed in High Pedestrian Areas (HPA)"
Proposed Speed Reduction Plans for Summer 2001

Dear Bill,

Per our telephone conversation, I have enclosed product information for the identified speed reduction strategies that the Center for Transportation Research and Education is proposing to be evaluated in summer of 2001 at the Mahnomen and Bemiji study sites. The following are the proposed speed reduction plans for Mahnomen and Bemiji sites:

Twin Lakes—Mahnomen County
The traffic calming techniques proposed for the Mahnomen site consist of a removable pedestrian island and pedestrian crossing devices. Having observed a high number of pedestrians crossing the roadway, these techniques tend to add a touch of urbanization to the area. The pedestrian island can easily be installed near the designated pedestrian crossing. Several pedestrian crossing devices will be placed on the centerline before and after the island. The total cost for the proposed traffic calming techniques is estimated as $2,000.

Bemidji Lake—Beltrami County
A dynamic variable message sign is the primary speed reduction technique proposed to be evaluated in the Bemiji site. This radar-equipped sign will be triggered, displaying a recorded message, as a speeding vehicle approaches. To heighten the speed reduction at the area, local law enforcement will be frequently used at first. The engagement of the police enforcement will decline as the impact of the display is established throughout the area. The dynamic sign will be provided free of charge for the research purposes. Cooperation of local law enforcement would also be required.

We would like to schedule a meeting with the technical advisory panel, local officials, and law enforcement personnel on the last of week of January 2001 to review the proposed plans and coordinate efforts. Please provide me with the contact information of the interested parties at your convenience. If you have any further questions, please feel free to contact me at 515-294-4303 or kmb@iastate.edu.

Sincerely,

Ali Kamyab

cc: Gary Thomas
Steve Andrle

Brief Descriptions of the Proposed Speed Reduction Techniques

Rubber Curbing

Rubber curbing is used to construct pedestrian islands and traffic circles in the roadway to urbanize an area causing vehicles to slow down. The curbing material is made of recycled scrap tires. It costs $7.50 for a foot section that is 5.75 inches wide and 6.0 inches high. The curbing can be applied for temporary use by applying either spikes, or lag screws, or a combination of both. It is suggested that one of the methods is used for every foot applied. The curbing can also be applied permanently by applying an epoxy, however it is unlikely a permanent application would be desired. Inside the island would be filled with either dirt or bricks, depending on desired look. The rubber curbing and the next technique, pedestrian crossing device, are manufactured by Rubber Tough Industries.

Pedestrian Crossing Device

Pedestrian crossing devices are placed on a roadway centerline at high pedestrian areas. The cost for each crossing device varies from $75 to $100, depending on the desired reflection and type. The portable base plate needed for each device is an additional $110.

Dynamic Variable Message Sign

A dynamic variable message sign can be either post mounted or placed on a trailer. The sign is equipped with radar to determine the speed of approaching vehicles and consequently displays input messages. For example, a driver who complies with the posted speed limit will receive a "Thanks" message. The sign, however, displays a "You are speeding" message to a speeding vehicle. The variable message sign will be customized and provided by ADDCO.

APPENDIX B

SUMMARY OF THE PROJECT TECHNICAL ADVISORY PANEL MEETING (FEBRUARY 15, 2001)

Local Road Research Board Investigation 756
Methods to Reduce Traffic Speed in High Pedestrian Areas

Summary of Meeting
10:30 AM February 15, 2001
Mn/DOT Material Research Laboratory

Study Committee—Present
William Bunde, Minnesota DOT
David Heyer, Mahnomen County Engineer
Kathleen Harder, University of Minnesota

Study Committee—Not Present
Tom Kozojed, Beltrami County
Rod Garver, Minnesota DOT
David Robley, Douglas County Engineer

CTRE Team—Present
Ali Kamyab, Principal Investigator
Steve Andrle, Director

Background

This project involves designing experiments to reduce motorist speeds entering small communities. Four test locations are being investigated: Minnesota County State Aid High (CSAH) 4 through Twin Lakes in Mahnomen County; Minnesota CSAH 20 in Beltrami County, north of Bemidji Lake; The Town of Tofte and the Town of Schroeder on US 61. Data on current speeds at each location were collected in the summer of 2000. CTRE proposed speed reduction techniques in a letter dated December 12, 2000. The purpose of this meeting is to agree to the speed reduction experiments and identify responsibilities for installing the experiments. The decisions made at the meeting with respect to each site are summarized below.

Twin Lakes, Mahnomen County

The techniques proposed for this site consist of removable pedestrian islands and pedestrian crossing devices (signs). The combination of islands and signs will create an urban effect that should help reduce motorist speed. Mr. Heyer also noted that the curbs and signs can be used to concentrate pedestrian street crossings at marked crosswalks.

The committee agreed that this strategy should be pursued in Twin Lakes. Mr. Heyer noted that the signs should say “stop for pedestrians in crosswalk,” not “yield to pedestrians in crosswalk.” It was agreed that signs would say “stop,” not “yield.” Mr. Heyer also noted that the proposed signs are not *Manual on Uniform Traffic Control Devices* (MUTCD) compliant. He agreed to see if there is any problem using the proposed signs and report back to Mr. Bunde and Mr. Kamyab.

Mr. Andrle noted that the county sheriff, tribal police, merchants, and citizens should be notified about the project. Mr. Heyer will provide guidance on this matter. CTRE offered to attend an information meeting if necessary and prepare a news release.

It was agreed that CTRE will sketch a design showing the location of the portable curb islands and signs, and will refine a cost estimate for rubber curbing and signs. Mr. Heyer will provide a suitable plan drawing of the street. Mr. Heyer will request funds for the curbs and signs from the Research Implementation Committee of the LRRB. Subsequent to the meeting, we learned from David Johnson of Minnesota DOT that E-mail approval will be requested. This will help keep the project on schedule. Mahnomen County will be responsible for installing the portable curbs and signs. The County will also install standard "stop for Pedestrians in Crosswalk" signs at both approaches to Twin Lakes.

Following implementation of the portable curbs and signs, CTRE will collect 2-3 days of speed data on one occasion. It would be desirable to collect data on two occasions following installation, but the project is only budgeted for one "before" and one "after" data collection effort.

Bemidji Lake

The plan for Bemidji Lake is to install one dynamic variable message sign that will send a single-word message to motorists traveling over the speed limit. The installation of the sign should be coupled with initial police enforcement to convey the idea that speeds are being observed. Enforcement should then be reduced to normal levels, relying on the dynamic sign to give the illusion of enforcement. The committee agreed with the concept and agreed that the sign should display a single word. The general feeling is that the sign should display "slow" for the speeding vehicles.

ADDCO, a St. Paul-based manufacturer of the dynamic variable message sign, will loan one to Minnesota DOT for the project. The Beltrami County highway department will install the sign on a metal frame and run power to the sign. CTRE staff is checking with Tom Kozojed in Beltrami county for final approval. As in Twin Lakes, this project should be coordinated with local law enforcement and other officials and the public should be notified. Tom Kozojed will be responsible for local coordination.

Following installation, CTRE will collect 2-3 days of speed data on one occasion. As in Twin Lakes, two "after" condition data collection efforts would be desirable, but the project is only budgeted for one.

Tofte

Data were collected in the summer of 2000, documenting the "before" condition. Roadway improvements intended to reduce motorist's speed were originally planned for the summer of 2001, but the construction schedule is unclear. Mr. Kamyab will check with Rod Garver of Minnesota DOT to confirm the schedule. CTRE will collect "after" condition data at Tofte in either the summer of 2001, if the project is completed by then, or in the summer of 2002. If the data collection must wait until 2002, a no-cost time extension to the project will be necessary.

Schroeder
CTRE collected "after" condition data in Schroeder in the summer of 2000. Improvements had already been implemented before this project started. The committee feels that it would be beneficial to have a second set of "after" condition data at Schroeder, because the first data were collected shortly after construction. CTRE will collect data again at Schroeder on the same trip used to collect "after" condition data at Tofte.

Summary of Action Items

1. CTRE will prepare a sketch of the recommended installation at Twin Lakes and prepare a material cost estimate. Mr. Heyer will provide a suitable plan drawing of the street for use as a base.

2. Mr. Heyer will check to see if there is any problem using signs that are not in the MUTCD.

3. Mr. Heyer will submit a funding request via E-mail to the Research Implementation Committee of the LRRB. As soon as the request is approved, Mr.Heyer will order the materials for installation in the May or June 2001.

4. Mr. Heyer will inform local authorities and the public in Mahnomen County about the project, requesting assistance from CTRE as needed.

5. CTRE will contact Mr. Kozojed in Beltrami County for final approval of the dynamic variable message sign proposal. If approved, CTRE will contact ADDCO to initiate obtaining a loaned sign. Beltrami County will install the sign and run power to the site.

6. CTRE will contact Mr. Garver regarding the construction schedule in Tofte. The data collection in Tofte and Schroeder will be scheduled accordingly.

Staff Notes

- Chuck Kennedy from RubberTough indicated that the Pedestrian Crossing Devices can be customized according to the Minnesota state law ("stop" instead of "yield"). Mr. Kennedy will send CTRE a cost sheet for ten devices and Rubber Curbs as soon as we provide him with a site plan drawing.

- Mr. Kozojed was informed about the possibility of requesting funds from the Research Implementation Committee of the LRRB for potential expenses associated with the installation and maintenance of the dynamic variable message sign. Regarding his final approval of the proposed sign, in his voice message, Mr. Kozojed indicated that his crew will install and maintain the sign and he will coordinate the project with local law enforcement and other officials.

- Brian Nicholson from ADDCO indicated that his company will provide additional Bricks if needed for longer messages. It should be noted that for a single word "SLOW!!" with a letter size of 11.3 inches, three Bricks would be sufficient.

APPENDIX C

AMENDMENT TO THE FEBRUARY 15, 2001, PROJECT PANEL MEETING (FEBRUARY 28, 2001)

Date: February 28, 2001

To: Technical Advisory Panel - LRRB Investigation 756

From: Ali Kamyab, CTRE

Re: MN/DOT Agreement No. 74995
Work Order No. 2
"Methods to Reduce Traffic Speed in High Pedestrian Areas (HPA)"
Minutes of the panel meeting on February 15, 2001—"Amendment"

Rod Garver of Mn/DOT, Duluth, indicates that due to issues raised by Tofte's residents, some of the roadway design factors need to be revisited. Therefore, the proposed construction will not take place this summer, and it might be another two or three years before proposed traffic calming strategies are implemented in the Town of Tofte. Given this fact, the research team recommends that Tofte be dropped from the study at this point.

If you agree to this, it makes the data collection at Schroeder less cost-effective, because CTRE budgeted the data collection in pairs to minimize cost. In our February 15th meeting, it was mentioned that a second set of "after" condition data at Schroeder would be beneficial, since the first "after" data, conducted in August 2000, was shortly after the completion of construction. While it is desirable to collect a second set of "after" condition data at Schroeder, it would make better use of project resources to concentrate on Twin Lakes and Bemidji.

The research team at CTRE recommends reallocating data collection resources to Twin Lakes and Bemidji because these are shaping up as well-designed experiments. The benefits of conducting these experiments can be enhanced by testing the long-term (e.g., 6 weeks) speed-reducing effects of the proposed experiments as well as the short term effects (e.g., two weeks). The research team recommends conducting two "after" condition data collections at the sites in Twin Lakes and Bemidji Lake this summer. One set of data would be collected about two weeks after installation and one set about six weeks after installation. Two data collection occasions following the implementation of the proposed speed reduction strategies at these locations will provide a better understanding of the short term and long term effects of the proposed speed reduction strategies.

Please let me know via E-mail (kmb@iastate.edu) which of the following data collection plans should be scheduled:

1. Stick with the plan agreed to at the February 15th meeting, which calls for collecting "after" condition data at each of four sites. Data collection at Schroeder and Tofte will be conducted after the construction at Tofte is completed. (*This option requires a two or three-year no-cost time extension to the project.*)

2. Collect "after" condition data on two occasions after implementation (two weeks and six weeks) at locations in Twin Lakes and Bemidji Lake. Cancel further data collection at Tofte and Schroeder. (*Research team's recommendation*)

3. Collect "after" condition data on two occasions at Twin Lakes and Bemidji Lake as proposed in option 2. Also, collect data in Schroeder in the summer of 2001 as planned but drop Tofte. *(This plan is more expensive than the proposal, because it entails five "after" condition data collection activities instead of four as proposed. Also, the CTRE data collection team in Schroeder cannot collect data at two locations in one trip. We may need to request a budget adjustment for this option.)*

cc: Bill Bunde
David Heyer
Tom Kozojed
Kathleen Harder
Rod Garver
David Robley
Steve Andrle
Gary Thomas

APPENDIX D

COMMITTEE MEMBERS' RESPONSES TO THE FEBRUARY 28, 2001, MEMO

From: "**Dave Heyer**" **<**Dave.Heyer@co.mahnomen.mn.us>
Subject: LRRB Inv 756 - Data Collection
To: kmb@iastate.edu
Cc: bill.bunde@dot.state.mn.us, tom.kozed@dot.state.mn.us,
dave.robley@mail.co.douglas.mn.us
Date: Tue, 6 Mar 2001 10:48:39 -0600

I agree that due to the recent delays in the construction at Tofte, Tofte be dropped from the study.

I support your Plan No. 2 - Collect "after" condition data on two occasions after implementation (two weeks and six weeks) at the Twin Lakes and Lake Bemidji locations. Cancel further data collection at Tofte and Schroeder.

From: "**Dave Robley**" <dave.robley@mail.co.douglas.mn.us>
To: <kmb@iastate.edu>, <Dave.Heyer@co.mahnomen.mn.us>
Cc: <bill.bunde@dot.state.mn.us>, <tom.kozed@dot.state.mn.us>
Subject: Re: LRRB Inv 756 - Data Collection
Date: Tue, 6 Mar 2001 14:08:57 -0600

Even though I have not been able to attend the meetings, I read the information received this last week and would agree with Dave Heyer's comments below.

From: "**Rod Garver**" <rod.garver@dot.state.mn.us>
Date: Thu, 08 Mar 2001 15:39:02 -0600
To: <kmb@iastate.edu>
Subject: Data Collection

Ali,
I would agree with your assessment as stated in your letter of 28 Feb 01. Option 2 would make the most sense at this time.

From: "**William Bunde**" <bill.bunde@dot.state.mn.us>
Date: Fri, 09 Mar 2001 09:07:01 -0600
To: "<Ali Kamyab" <kmb@iastate.edu>
Subject: Data collection

Ali, because of the administrative responsibilities of my position, I will refrain from selecting a preference for data collection plans. (#2 does seem to be the most reasonable choice).

APPENDIX E

“BEFORE” CONDITION CUMULATIVE PERCENTAGE PLOTS

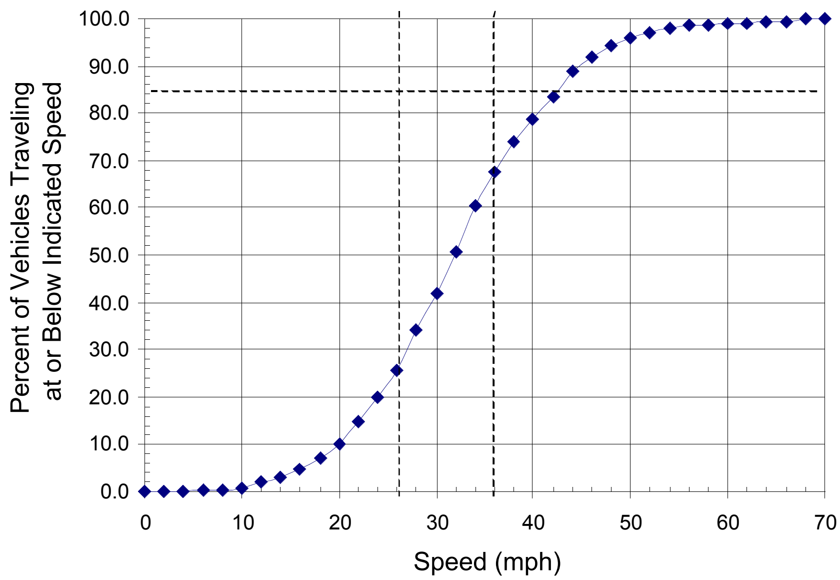

Figure E.1 Twin Lakes—All Vehicles—Eastbound

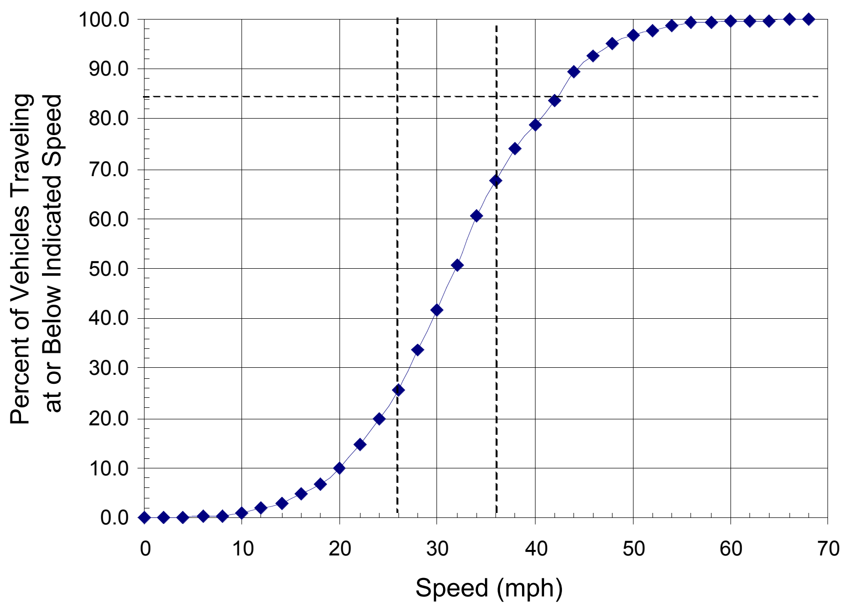

Figure E.2 Twin Lakes—Passenger Cars—Eastbound

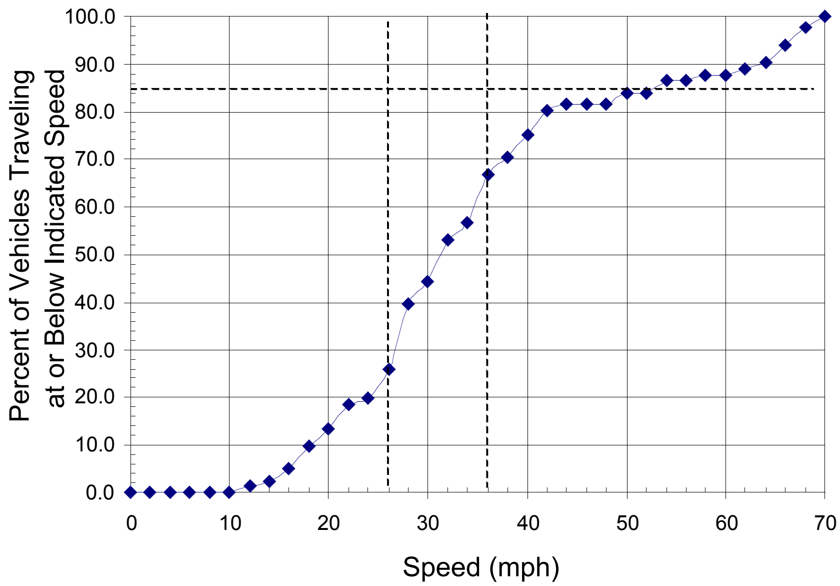

Figure E.3 Twin Lakes—Nonpassenger Cars—Eastbound

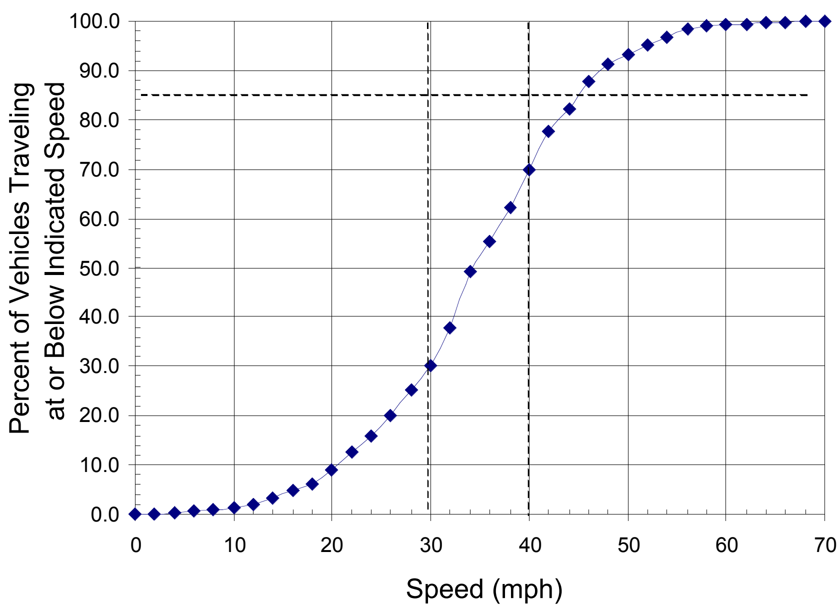

Figure E.4 Twin Lakes—All Vehicles—Westbound

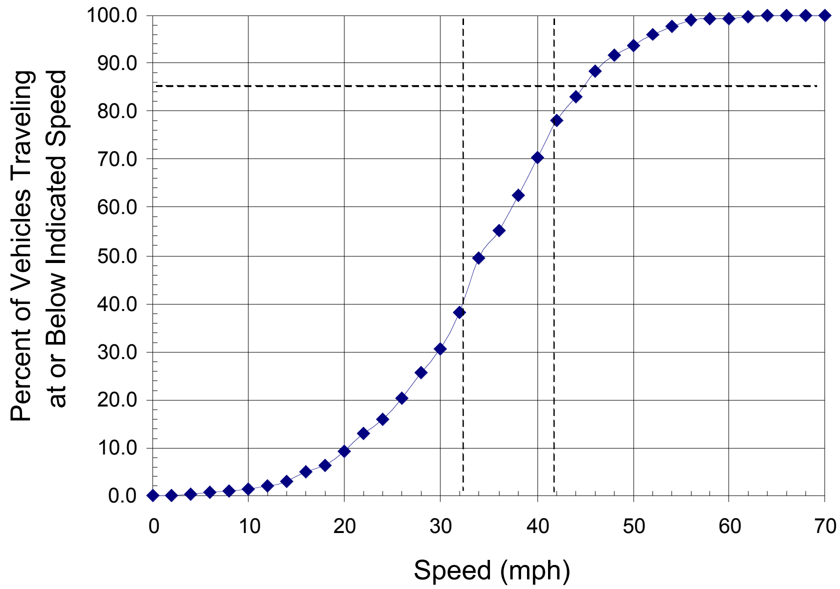

Figure E.5 Twin Lakes—Passenger Cars —Westbound

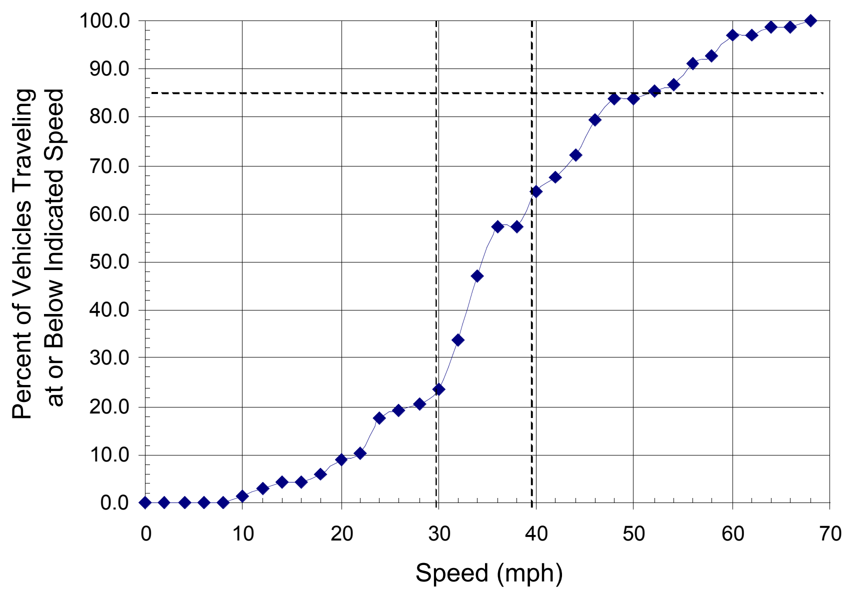

Figure E.6 Twin Lakes—Nonpassenger Cars—Westbound

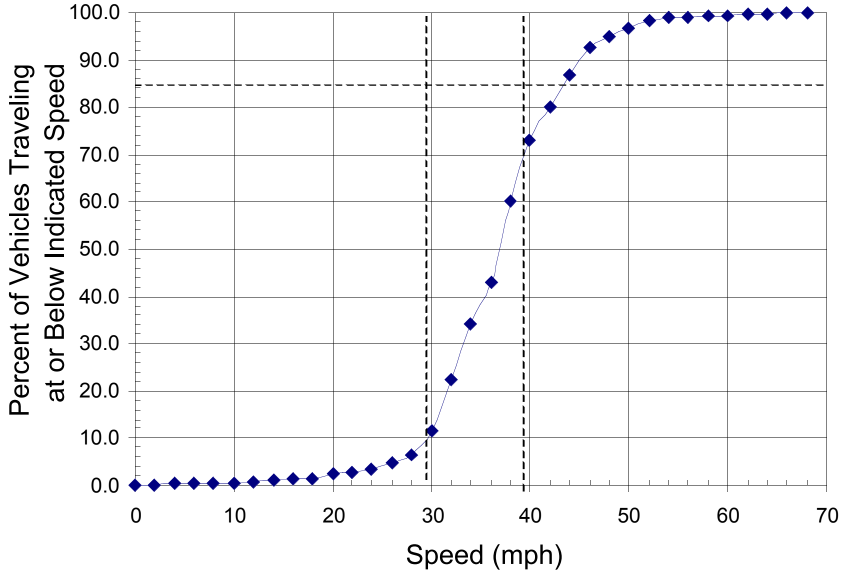

Figure E.7 Bemidji Lake—All Vehicles—Eastbound

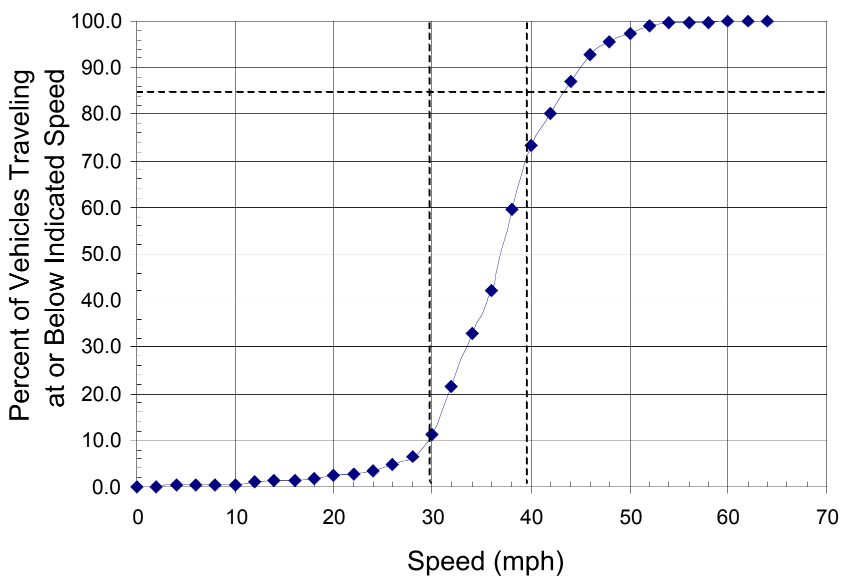

Figure E.8 Bemidji Lake—Passenger Cars—Eastbound

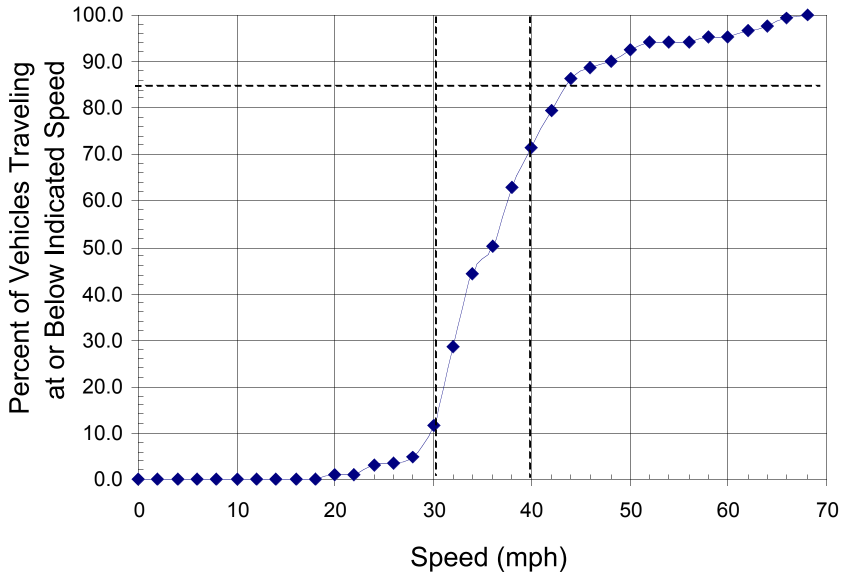

Figure E.9 Bemidji Lake—Nonpassenger Cars—Eastbound

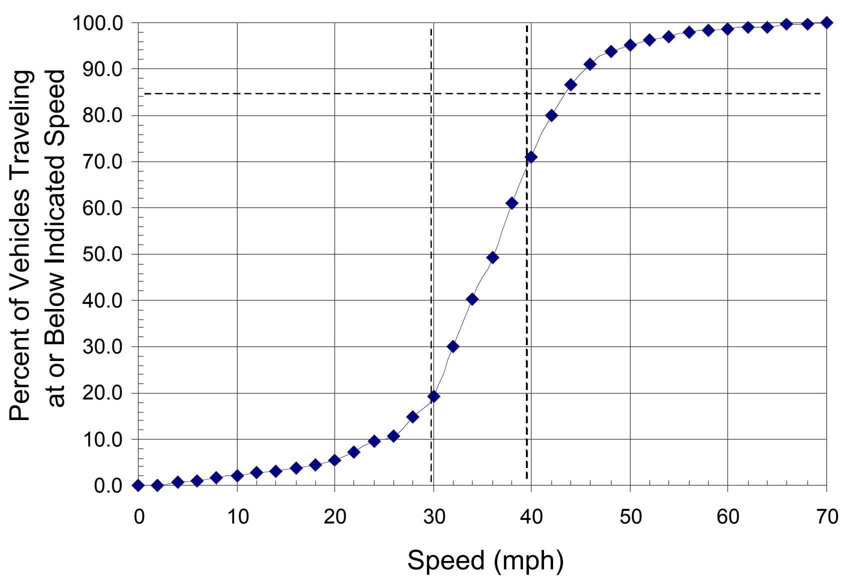

Figure E.10 Bemidji Lake—All vehicles—Westbound

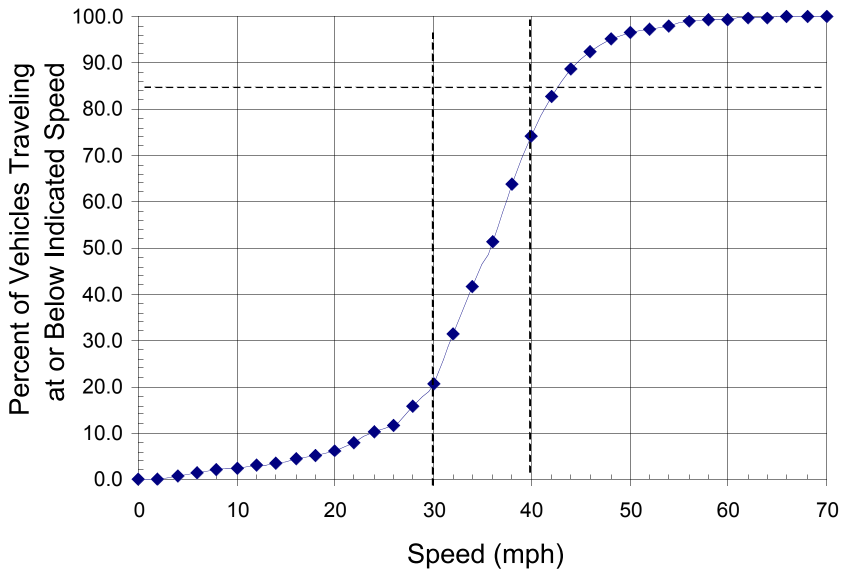

Figure E.11 Bemidji Lake—Passenger Cars—Westbound

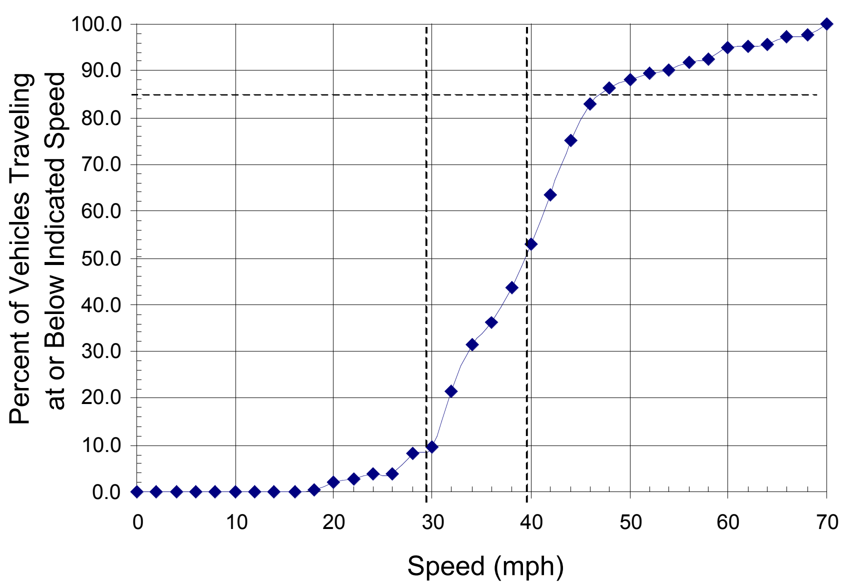

Figure E.12 Bemidji Lake—Nonpassenger Cars—Westbound

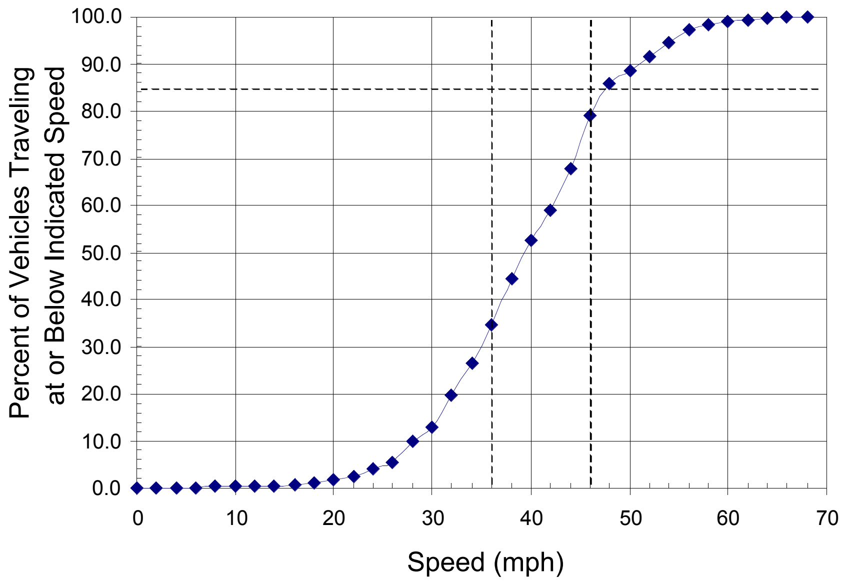

Figure E.13 Tofte—All Vehicles—Northbound

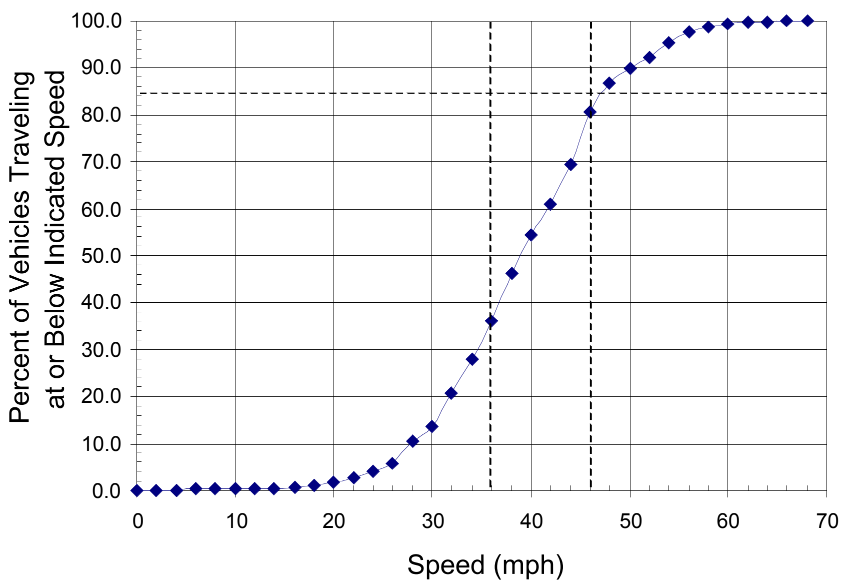

Figure E.14 Tofte—Passenger Cars—Northbound

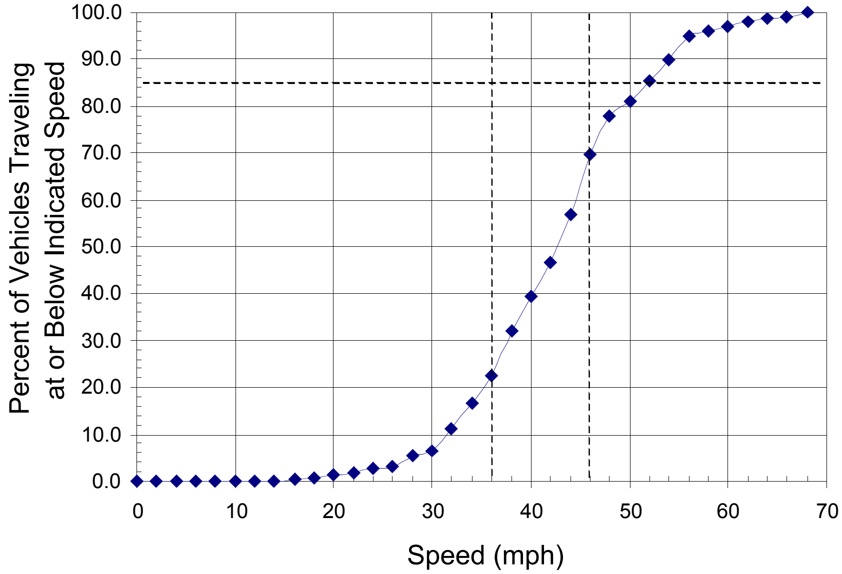

Figure E.15 Tofte—Nonpassenger Cars—Northbound

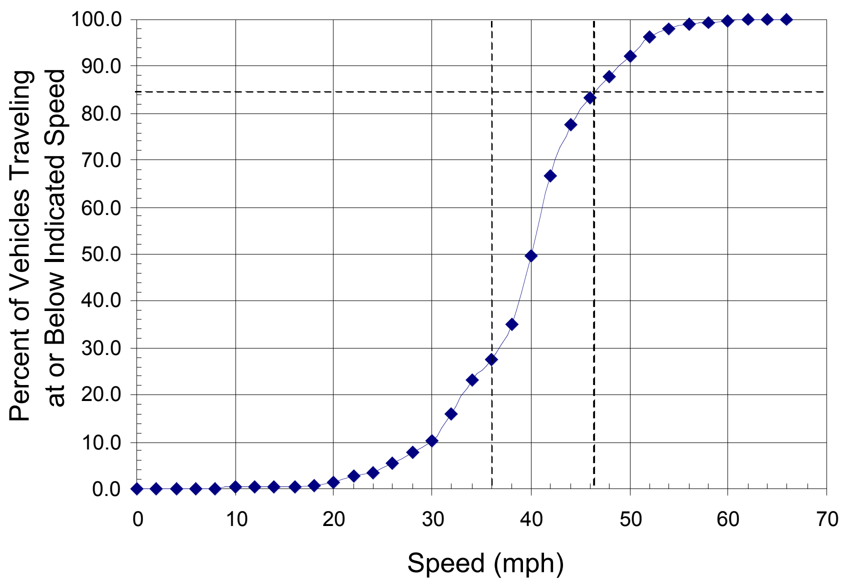

Figure E.16 Tofte—All Vehicles—Southbound

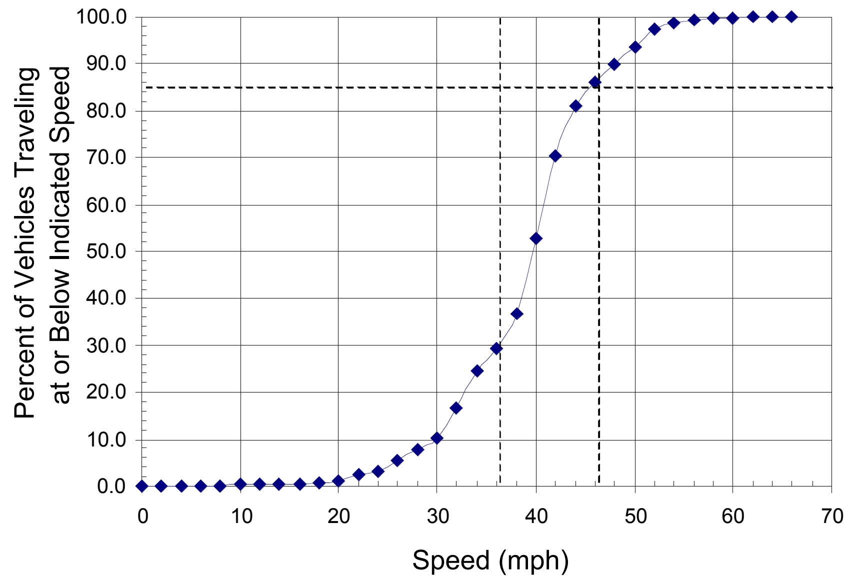

Figure E.17 Tofte—Passenger Cars —Southbound

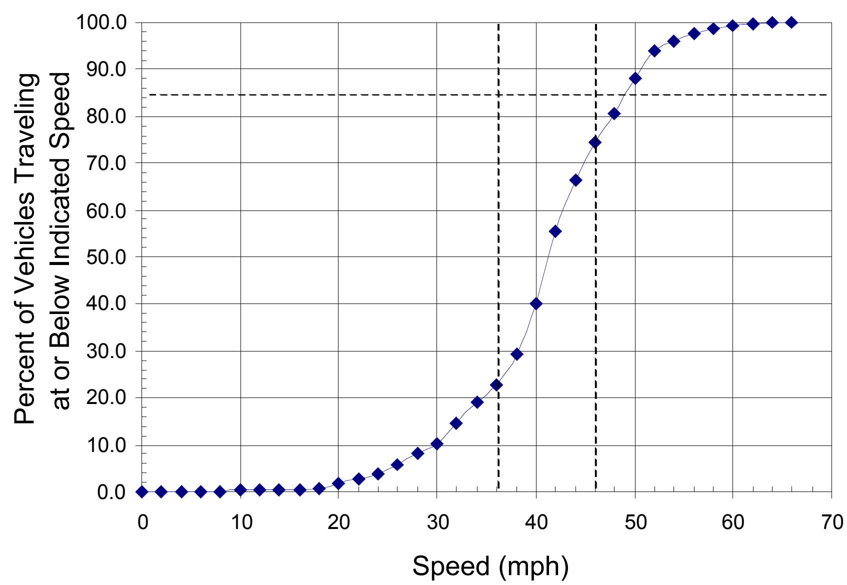

Figure E.18 Tofte—Nonpassenger Cars—Southbound

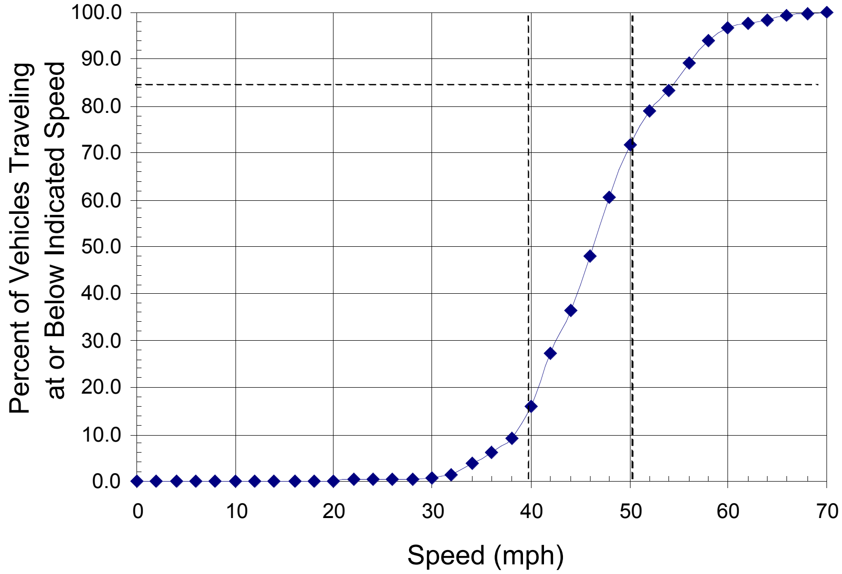

Figure E.19 Schroeder—All Vehicles—Northbound

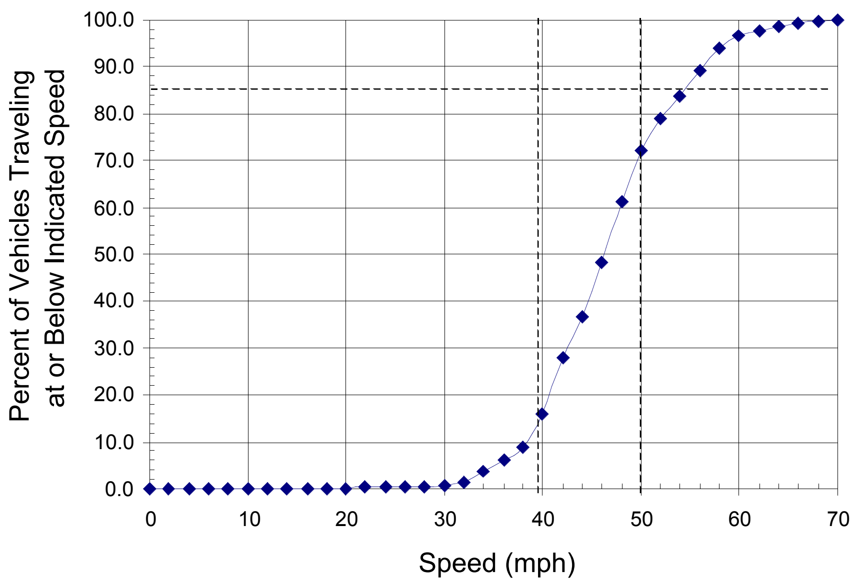

Figure E.20 Schroeder—Passenger Cars—Northbound

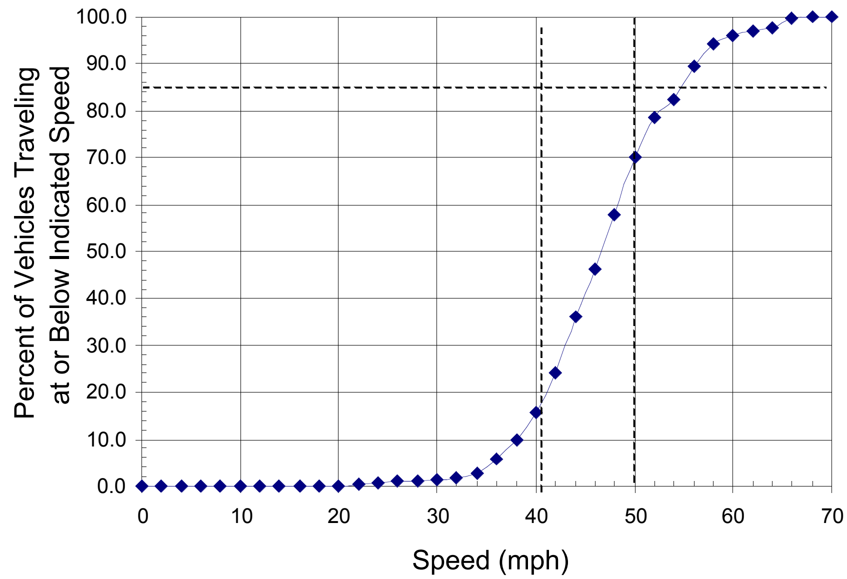

Figure E.21 Schroeder—Nonpassenger Cars—Northbound

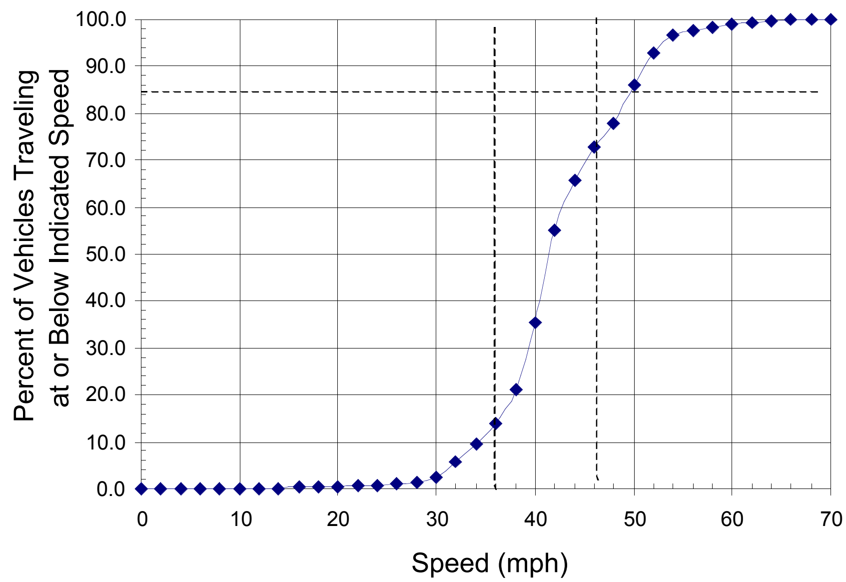

Figure E.22 Schroeder—All Vehicles—Southbound

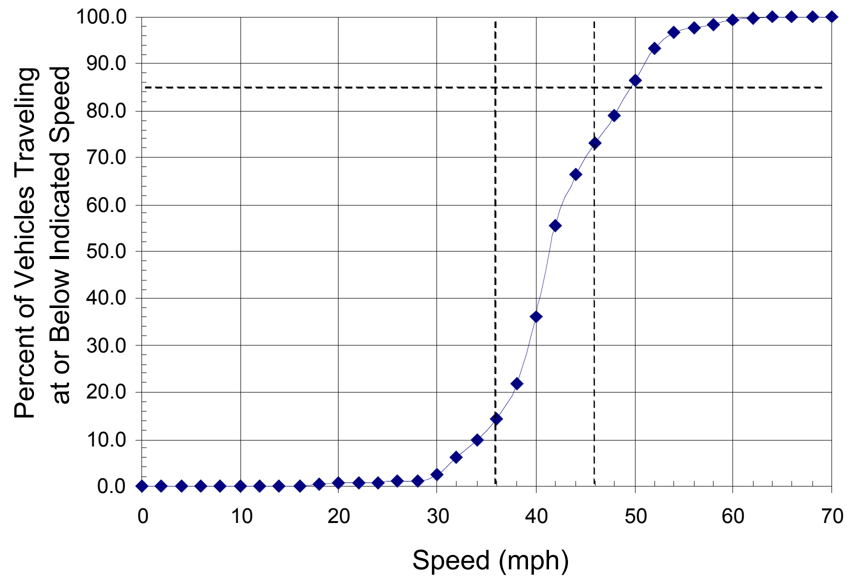

Figure E.23 Schroeder—Passenger Cars—Southbound

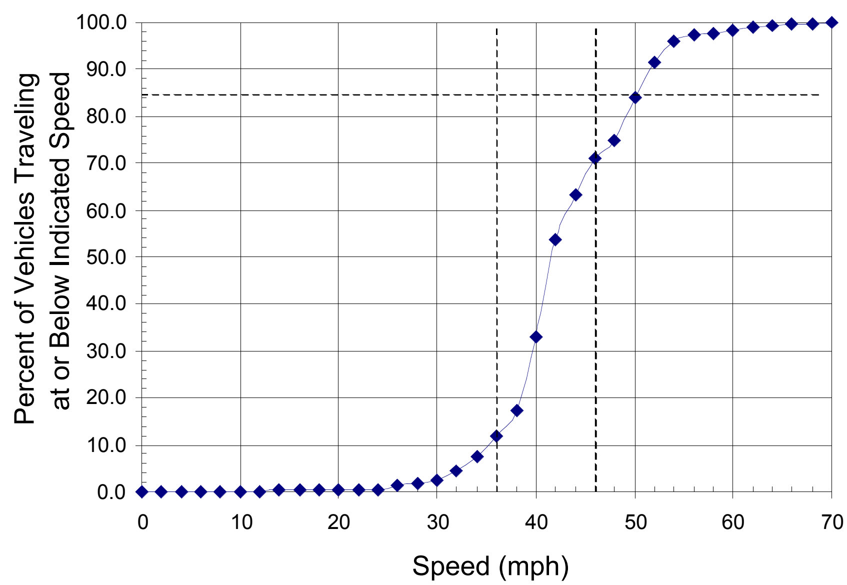

Figure E.24 Schroeder—Nonpassenger Cars—Southbound

APPENDIX F

"AFTER" CONDITION CUMULATIVE PERCENTAGE PLOTS

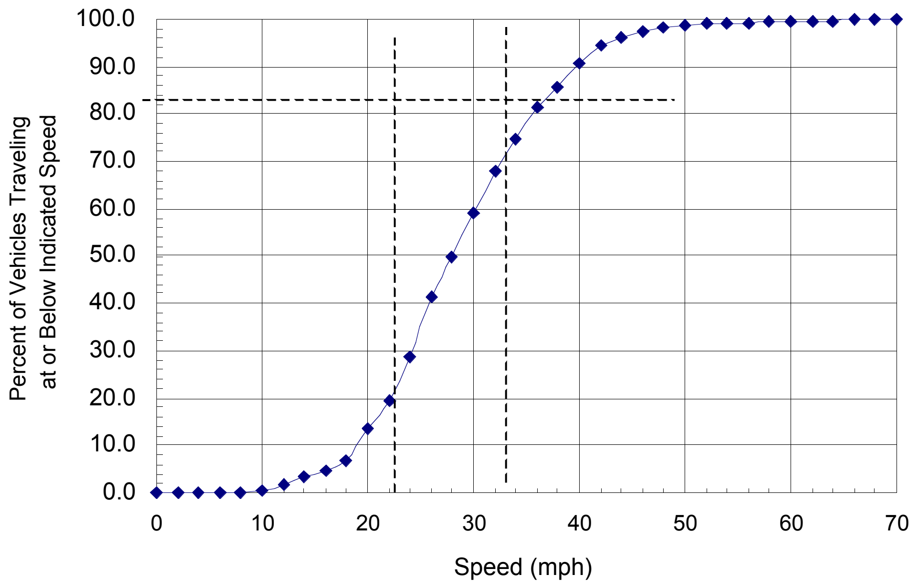

Figure F.1 Twin Lakes—All Vehicles—Eastbound—After-1

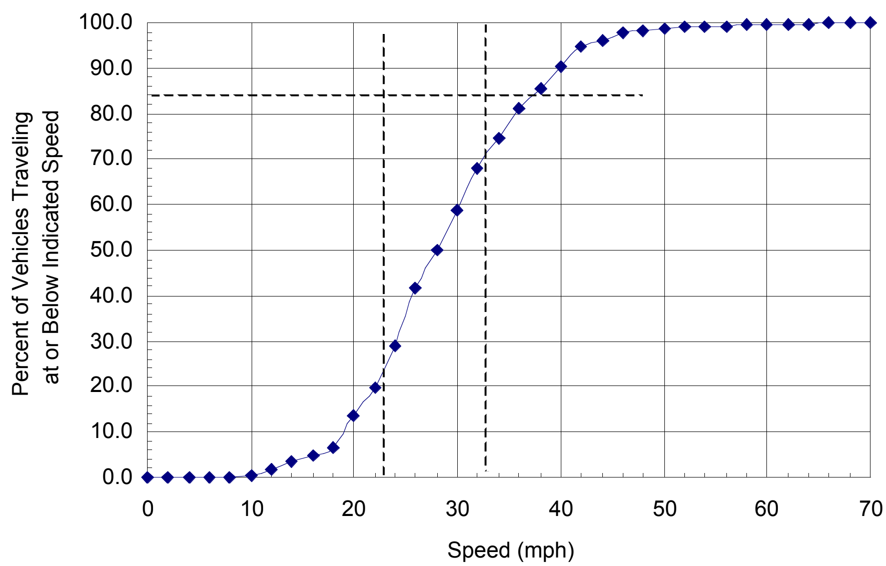

Figure F.2 Twin Lakes—Passenger Cars—Eastbound—After-1

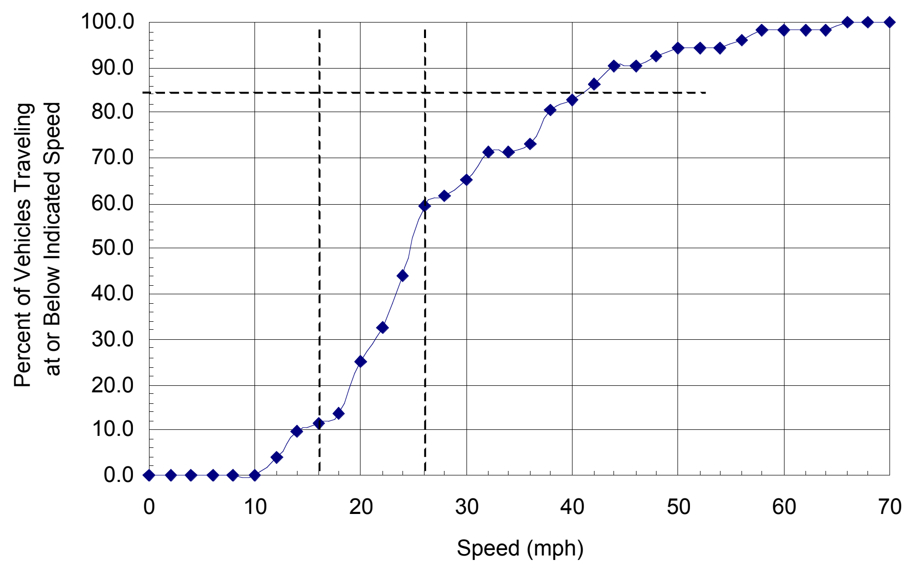

Figure F.3 Twin Lakes—Nonpassenger Cars—Eastbound—After-1

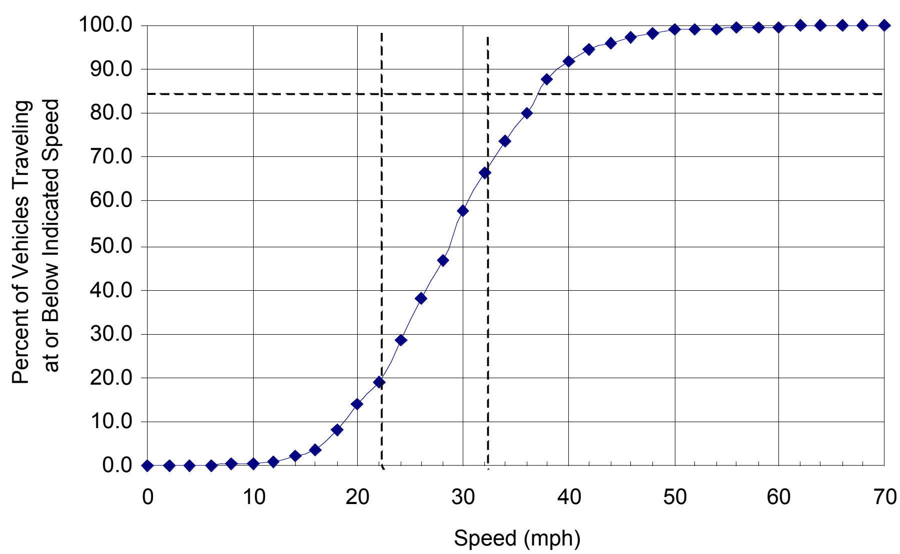

Figure F.4 Twin Lakes—All Vehicles—Westbound—After-1

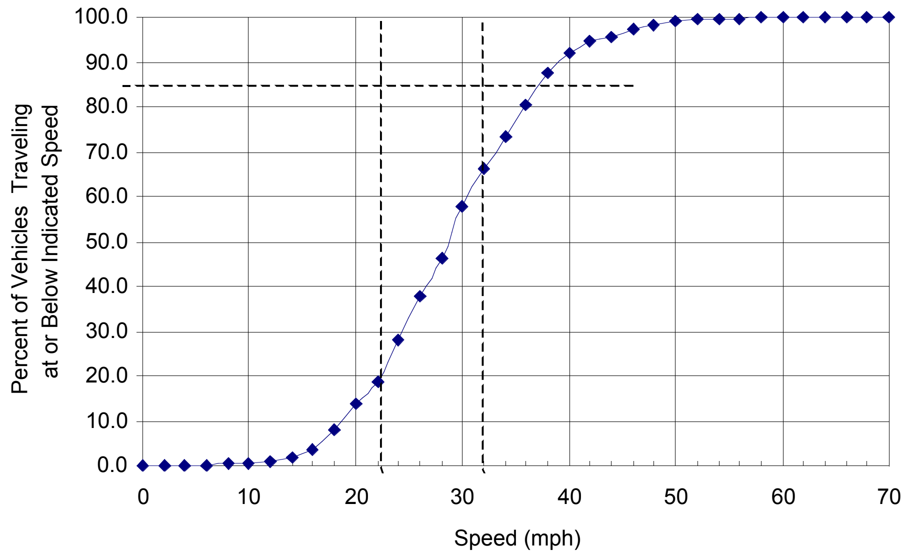

Figure F.5 Twin Lakes—Passenger Cars—Westbound—After-1

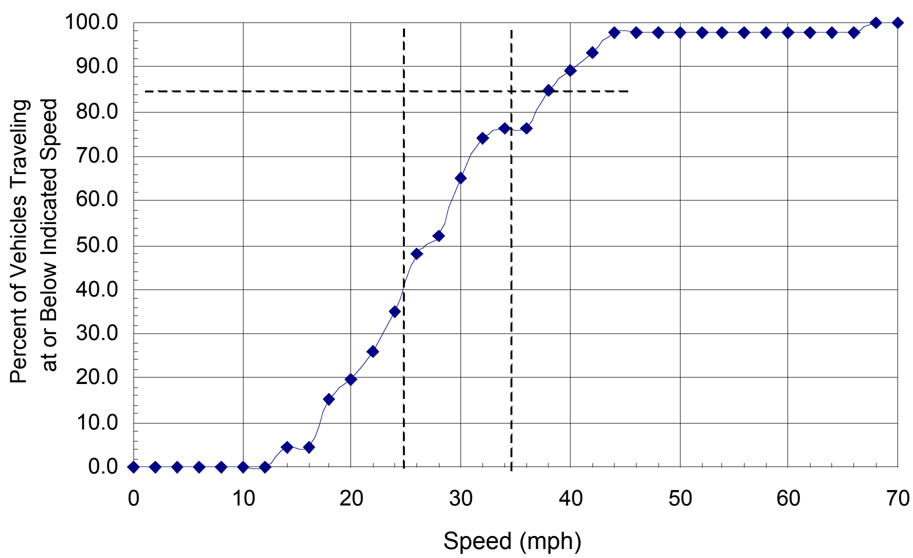

Figure F.6 Twin Lakes—Nonpassenger Cars—Westbound—After-1

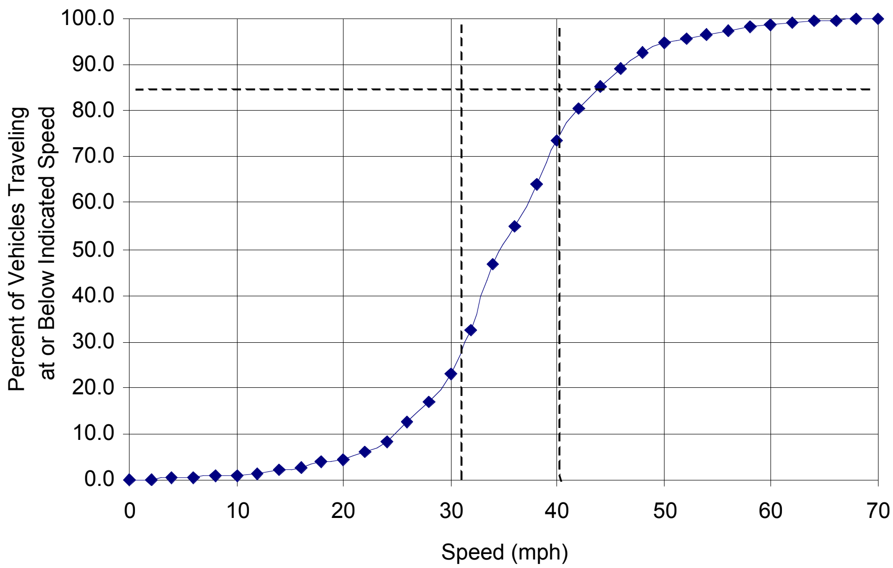

Figure F.7 Bemidji Lake—All Vehicles—Westbound—After-1

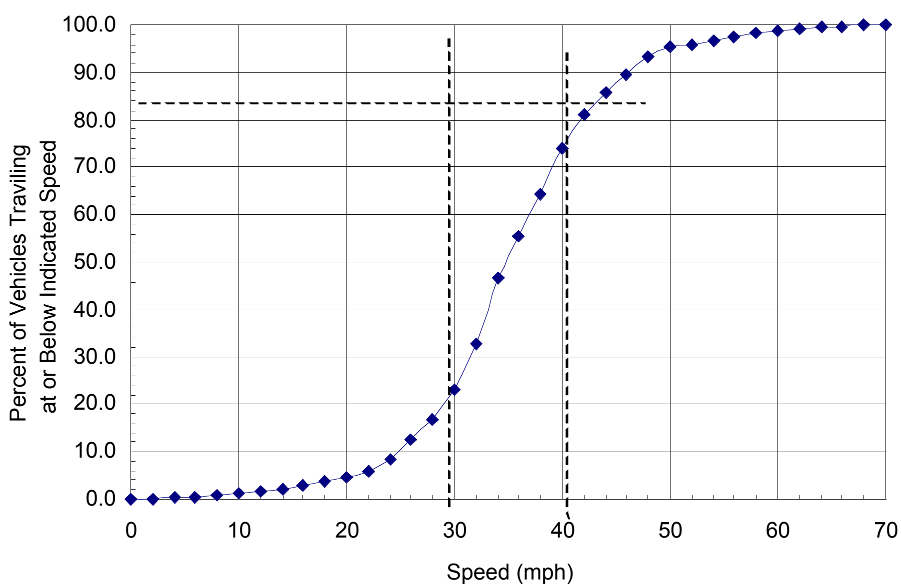

Figure F.8 Bemidji Lake—Passenger Cars—Westbound—After-1

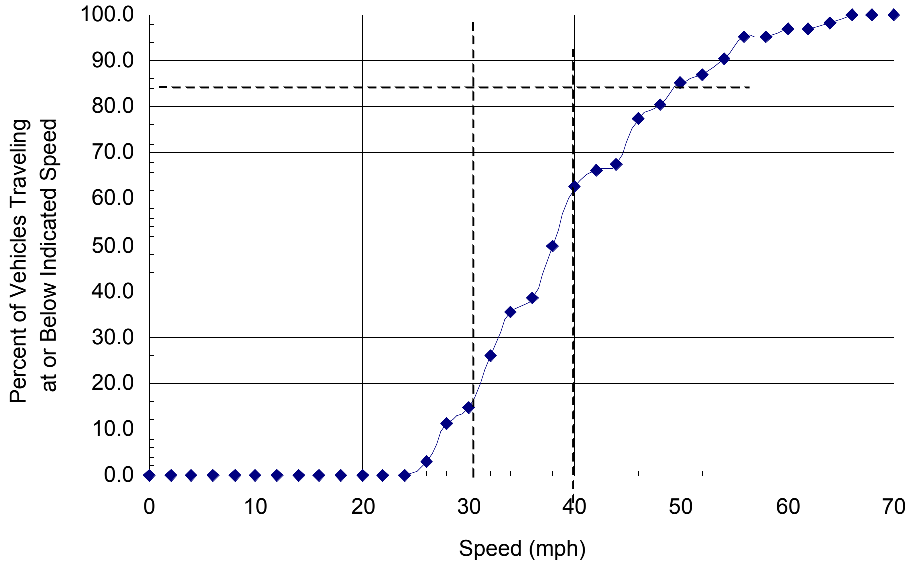

Figure F.9 Bemidji Lake—Nonpassenger Cars—Westbound—After-1

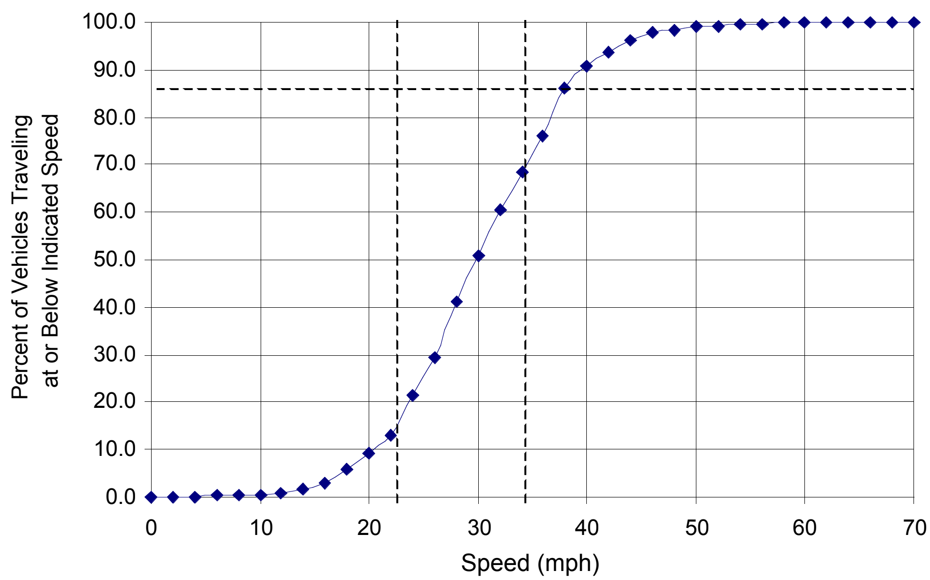

Figure F.10 Twin Lakes—All Vehicles—Westbound—After-2

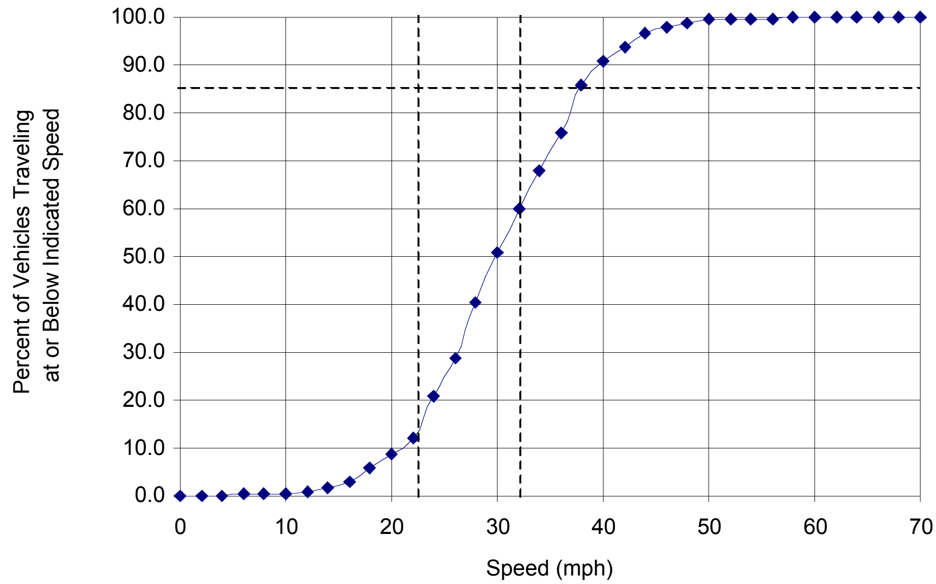

Figure F.11 Twin Lakes—Passenger Cars—Westbound—After-2

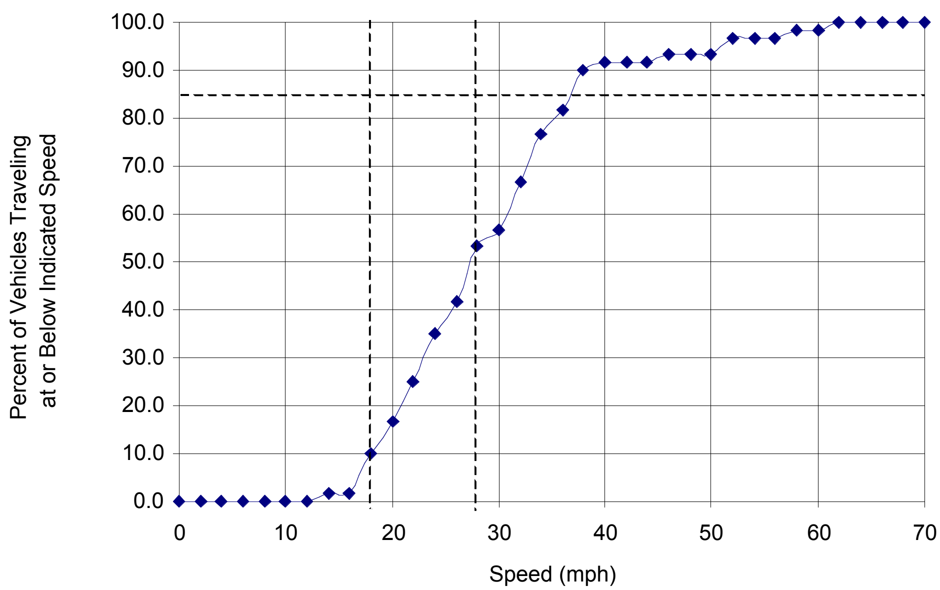

Figure F.12 Twin Lakes—Nonpassenger Cars—Westbound—After-2

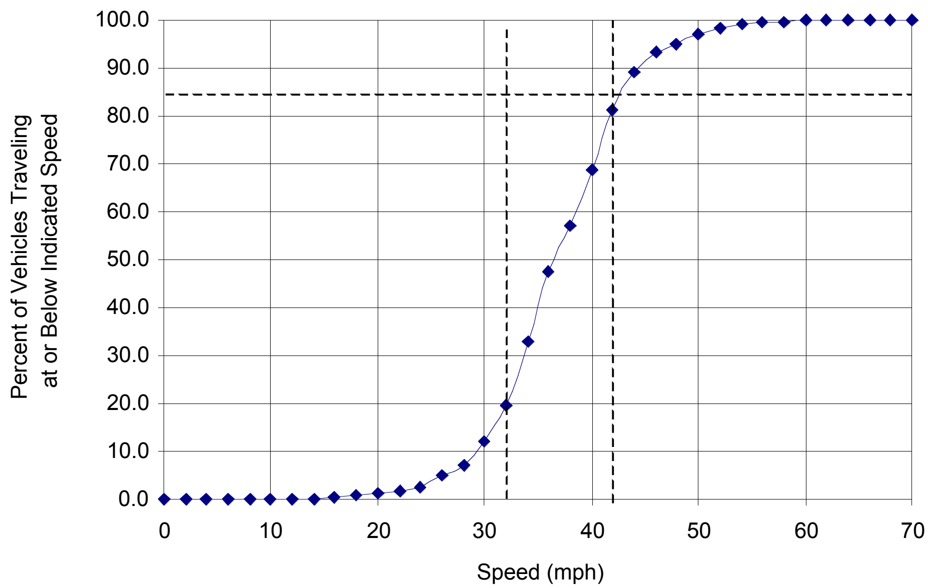

Figure F.13 Bemidji Lake—All Vehicles—Westbound—After-2

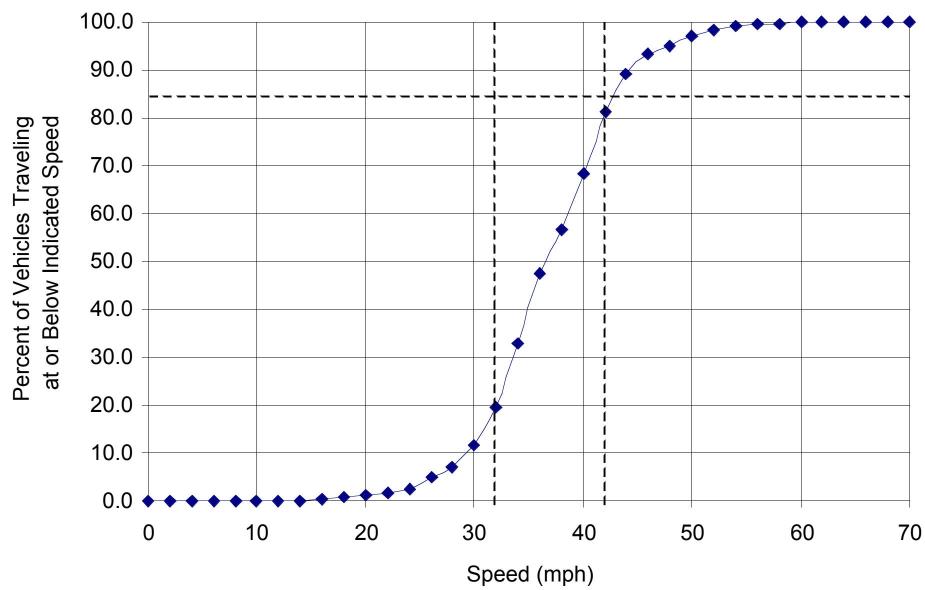

Figure F.14 Bemidji Lake—Passenger Cars—Westbound—After-2

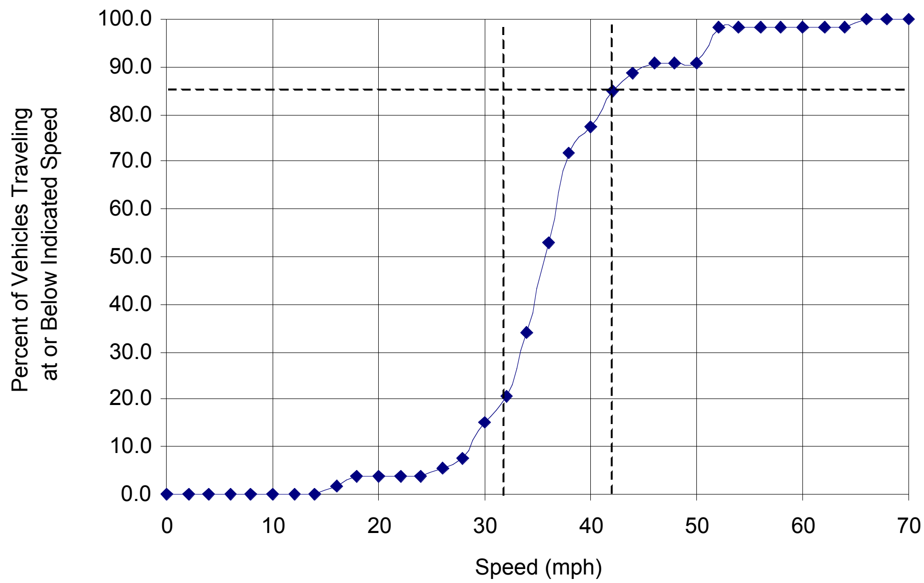

Figure F.15 Bemidji Lake—Nonpassenger Cars—Westbound—After-2