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Vehicle Speed Impacts of Occasional Hazard (Playground) Warning Signs

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Final Report 2012-06

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16. Abstract (Limit: 200 words)

The main objective of this study was to estimate the speed impact of occasional hazard (playground) warning (OHPW) signs along residential streets. Three types of data were collected at each of three study sites approximately one month before and one week to one month after the installation of a pair of OHPW signs. Vehicle speed data were collected with a pneumatic tube device. Manual observations were recorded, and focused on the magnitude and location of the on-street parking and park and/or playground activities occurring at the study sites. Linear regression analysis was used to estimate the change in mean vehicle speed associated with the presence of the OHPW signs, while controlling for the effects due to activity levels on the streets and the playgrounds. At one site the OHPW sign had no discernible effect on mean vehicle speeds, while at the other two sites mean vehicle speeds decreased by 1.5 mph and 0.9 mph following installation of the OHPW signs.

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Vehicle Speed Impacts of Occasional Hazard (Playground) Warning Signs

Final Report

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Executive Summary

The main objective of this study was to estimate the vehicle speed impacts, if any, of occasional hazard (playground) warning (OHPW) signs along residential streets. A total of 13 candidate study sites in Bloomington, Minnesota, were visited and evaluated. Three of these 13 candidate study sites were selected for data collection. The sites selected were:

- Colorado Avenue South from West 94th Street to West 96th Street
- Chicago Avenue South from East 90th Street to East 92nd Street
- Columbus Avenue South from East 100th Street to East 102nd Street

Three types of data were collected at each study site approximately one month before and one week to one month after the installation of a pair of OHPW signs. Vehicle speed data were collected with a pneumatic tube device, and manual observations were recorded that focused on the magnitude and location of the on-street parking and park and/or playground activities occurring at the study sites. These data were categorized for summary and analysis purposes and results of these activities are described in this report.

Linear regression analysis was used to estimate the change in mean vehicle speed associated with the presence of the OHPW signs, while controlling for the effects due to activity levels on the streets and the playgrounds. Each individual vehicle speed was treated as a set of specified systematic influences related to activity levels or traffic controls, plus a random individual difference. The results of this regression analysis indicated that at the Colorado Avenue South study site the installation of the OHPW sign had no discernible effect on mean vehicle speeds. At the Chicago Avenue South site, however, average vehicle speeds were about 1.5 mph slower following installation of the OHPW signs, and this difference proved statistically significant. The OHPW sign installation at the Columbus Avenue South site was estimated to result in a statistically significant 0.9 mph reduction in average vehicle speed. Other regression model variables that associated with the average vehicle speed at one or more of the sites included the levels of on-street parking, park/playground activity levels in particular areas of the facility, and vehicle direction. The average vehicle speed impact estimated by the regression models, due to the OHPW signs, ranged from about zero to approximately 1.5 mph, which could imply that the impact of these signs may be site specific. In addition, an investigation also showed that average vehicle speed is highly correlated with park and/or playground activity levels. In fact, at the Chicago Avenue South study site, reductions of 10 to 15 mph appear to be associated with the more intensive uses within the park and this difference in speed appears due to the related on-street parking activity. Overall, the OHPW sign impact appears to be site specific and the result of this study could also be related to the impact of the subjects in the data collection as the complexity at the site (e.g., the amount of on-street parking park/right-of-way activities) increased.

The analyses conducted as part of this project also included a naïve mean vehicle speed comparison. The data analyzed were the vehicle speeds collected during the daylight hours of several typical weekdays when field personnel were also manually recording on-street parking and park/playground/right-of-way activities. A summary of the data revealed that the number of non-free-flow vehicle speeds collected at each site ranged from approximately 840 to 1,730, but that this range was reduced to 840 to 1,655 when vehicle speed during “unstable” on-street parking time periods were removed. The study sites considered in this research also experienced a wide range of on-street parking and park/playground/right-of-way activities. A naïve comparison of all the vehicle speeds (excluding those during “unstable” on-street parking time periods) collected before and after the installation of the OHPW signs at each study showed an overall reduction of approximately 0.1 to 3.4 mph in mean vehicle speeds. These overall differences, however, are the result of changes in all the factors (not just the OHW sign installation) that could have affected the vehicle speed within the three study areas. Some of these factors include the differences in the on-street parking and park/playground/right-of-way activities before and after the installation of the OHPW signs. Data were collected to assist in the definition of the potential impact of these factors (e.g., on-street parking), but this activity could not be completed for other factors that might also impact vehicle speed (e.g., driver type and weather).

This is the first study of the potential vehicle speed impacts of OHPW signs. It was concluded that the vehicle speed impacts attributed to these signs in this project (see above) are small, and are likely site specific. The vehicle speed results are relatively variable and this is partially due to the observed changes in the study site on-street parking and park/playground/right-of-way activities before and after the installation of the OHPW signs. It is recommended that the results of this study be used as one potential input into the sign installation decision-making process and that they be considered on a case-by-case basis. OHPW signs are installed to increase the “vigilance” of drivers to a potential hazard. The vehicle speeds used in this research project were a surrogate measure of this change in behavior, but increased “vigilance” does not always result in a measured change in vehicle speeds. Additional research is recommended to support, refute, and expand upon the results of this project. It is recommended, for example, that the originally proposed phase two of this project be completed to evaluate the “eye scanning” changes of drivers in a simulator with and without traditional and possibly enhanced OHPW signs. This type of project could address the “attention value” of these types of signs. No changes in the language related to OHPW signs in the 2009 Manual on Uniform Traffic Control Device are recommended based on the results of this one project (*1*). However, the results could be used, as appropriate, for additional guidance during the sign installation decision-making process.

Chapter 1. Introduction

Warning signs are installed along roadways to provide information to vehicle drivers about hazards that may impact their decision-making. In general, these signs are located and designed to elicit one or more driver responses (e.g., more awareness, speed reduction). They are also sometimes supplemented with advisory speed limit signs. Some hazards identified by warning signs are relatively static (e.g., the existence of a horizontal curve), whereas other warning signs are installed for hazards that may occur on a more sporadic basis. These occasional hazard warning signs can be used to raise awareness of the potential for hazards at particular locations (e.g., playground or intersection ahead) or along an entire roadway segment (e.g., deer crossing). Examples of occasional hazard warning signs include the non-standard "children-at-play" sign and the Manual on Uniform Traffic Control Devices (MUTCD) [1] compliant signs shown in Figure 1.1.

The research project described in this report focused on the potential difference in vehicle speeds before and after the installation of occasional hazard (playground) warning signs (OHPW) (W15-1) (See Figure 1.1). Vehicle speeds were measured before-and-after the installation of OHPW signs at three study sites and the level of park activities and on-street parking were noted during daylight hours. These data are summarized in this report and the results of a data analysis described.

Figure 1.1. Examples of Occasional Hazard Warning Signs

PROBLEM ADDRESSED

The impacts of residential street warning signs on vehicle speed are rarely evaluated and documented. It is typically assumed that this type of impact is very small or non-existent. It is important that any warning signs installed are respected by vehicle drivers and produce the expected response. Warning signs that do not elicit an appropriate response (e.g., vehicle speed reduction) can result in an undesirable situation. All signs that are installed also have to meet a retro-reflectivity requirement, and need to be replaced on a regular basis. Therefore, the installation of signs that are not producing their expected impact can be a costly and ineffective investment of public funds.

There is a need to evaluate the potential vehicle speed impacts of OHW signs along residential roadways. The research project described in this report included the collection and comparison of vehicle speeds before-and-after the installation of OHW signs. The data were collected during time periods with various levels of on-street parking and park activities. It was hypothesized that this type of warning sign may have a bigger impact on vehicle speeds if the hazard (i.e., park activities) was more obvious to the driver.

PROJECT SCOPE AND OBJECTIVES

The scope of this research project is limited to the collection and comparison of vehicle speeds before-and-after the installation of OHPW signs at three residential street locations in Bloomington, Minnesota. The vehicle speeds were collected through the use of a pneumatic tube device; no restriction was made to free-flow or non-free-flow vehicles. The study design was an observational before-after study, which leaves open the possibility that other influences on speed, such as activity levels in adjacent parks, were correlated with the absence or presence of the warning sign. To account for this possibility, activity levels in the adjacent parks were manually recorded by observers, allowing these effects to be quantified and accounted for. The vehicle speed data were categorized for various site-specific levels of on-street parking and park activities. As appropriate, the vehicle speeds in these categories were then statistically compared and/or modeled for the time periods before and after the installation of the OHW signs. This project did not attempt to explicitly evaluate the potential difference in vehicle speeds for activities at different locations in the park or for the number of people in the park.

Thus the primary objective of the project described in this report was to collect, compare, and evaluate the potential vehicle speed impacts of OHPW signs (W-15) installed along residential streets. Vehicle speeds were compared during similar situations before-and-after the signs were installed. If possible, sign installation guidance (e.g., possible MUTCD text), will be suggested based on the results of this research.

REPORT ORGANIZATION

There are five chapters in this project report. Chapter 1 describes the problem addressed, the scope, and the objectives of the overall research project. Chapter 2 includes a summary of literature relevant to this project. The factors that impact vehicle speed choice by drivers and the relationship between speed and roadway safety are noted. In addition, research efforts that focused on the speed and/or safety impacts of several warning signs are described. Chapter 3 describes the site selection methodology applied in this project and its results. It also includes a summary of the data collection process used during this project. Chapter 4 includes a summary, comparison, and analysis of the vehicle speed data collected at the three project study sites. The potential reasons for the outcomes presented are also noted. Finally, Chapter 5 gives conclusions and recommendations based on the results of the research project tasks described previously.

Chapter 2. Literature Summary

This chapter provides a summary of studies, documented and completed, that are relevant to this research project. Several research projects have considered the potential impacts of occasional hazard warning signs. However, none of publications found during the literature search focused on the vehicle speed impacts of the OHPW sign (See Figure 2.1).

Figure 2.1. Occasional Hazard (Playground) Warning Sign (*1*)

The text in this chapter focuses on several subjects. First, some of the factors that impact the choice of vehicle speed by drivers are presented. Then, generally accepted theories about the relationship between vehicle speed and crashes are described. The relationship between vehicle speed and pedestrian fatalities is also noted. Third, the speed and/or safety impact results from several warning sign research projects are summarized. This summary is followed by a brief synopsis of a literature review completed for the Wisconsin Department of Transportation (WisDOT) that focused on documentation related to the impacts of “Children at Play” warning signs. This sign is similar, but not the same as, the OHPW sign evaluated in this project

URBAN OR RESIDENTIAL STREET VEHICLE SPEEDS

It is generally accepted that drivers select a vehicle speed based primarily upon the roadway environment, its characteristics, and their perceived level of comfort and safety (i.e., risk). This approach to decision-making is one of the reasons the 85th percentile vehicle speed along a roadway is a primary factor in the selection of a posted speed limit. Along residential streets (the focus of this project), however, the posted speed limit is often the result of a statute rather than a speed study (i.e., the consideration of the 85th percentile speed and/or other factors). The residential roadway study sites in this project have posted or implied speed limits of 30 miles per hour (mph). The environment and characteristics of a residential street can positively or negatively impact vehicle speed, although the research in this area is limited. Some of the geometric and environmental characteristics of a roadway that have generally been shown to impact vehicle operating speeds include the following [*2, 3, and 4*]:

- Cross section (i.e., lane and/or roadway width, curbs or no curbs, etc.)
- Horizontal alignment
- Vertical alignment or grade
- Access density and design

- Land use/development and roadside characteristics (e.g., lateral restrictions)
- Parked vehicles and parking maneuvers
- Through and turning traffic volumes
- Traffic control (e.g., signing and marking)
- Other: Weather, time of day, length and purpose of trip, pedestrian activity, number of intersections, age and/or experience of driver, and vehicle

The geometric and environmental characteristics of residential streets do not always match the lower operating speeds often desired. For example, a roadway may be long, straight, and wide. From a driver's point of view this roadway may be capable of safely accommodating high speed travel. This type of perception, however, varies with the geometric and environmental characteristics of the roadway (e.g., a narrow and curvy roadway would likely result in a different vehicle speed choice outcome). In some cases, along residential roadways, one or more traffic calming devices (e.g., speed humps) are sometimes added to reduce vehicle speeds to those considered to be more acceptable. Clearly, an understanding of how roadway factors influence the selection of operating speeds by drivers is desirable for proper roadway design [*4*]. The study sites considered in this research are all residential streets. They are similar in design and roadside land uses. The level of playground or park and roadway parking activity was collected to account for the influence these activities may have on vehicle operating speeds.

SPEED AND SAFETY

Speed Variability and Crashes

Certain aspects of the relationships between speed and safety are relatively well understood. It has long been acknowledged that the severity of a crash increases with speed, and there is good evidence that the probability or likelihood of a crash for a particular vehicle also increases as the speed of that vehicle increases from the vehicle speed selected by the majority of drivers. There are some suggestions that crash risk can increase for vehicles traveling below the typical speed, but whether this effect is real, or due to methodological weaknesses, is still being debated [*3*]. Some studies have reported correlations between measures of crash experience and speed variability, but these correlations can also be explained as artifacts that occur when using aggregated crash data [4, 5].

Local residential streets, however, tend to have very low volumes and a small number of crashes. In 1998 the authors of Special Report 254, "*Managing Speed Review of Current Practice for Setting and Enforcing Speed Limits,*" were unable to find any studies that examined the relationship between the probability of a crash and vehicle speeds along residential streets [*3*]. This literature search also did not find any more recent research that filled this gap. According to the research summarized by Special Report 254, however, the highest level of non-compliance with posted speed limits occurs in urban areas and the probability of a crash along an urban arterial appears to increase for vehicles traveling "well above" the average speed but not for those at speeds lower than the average [*3*]. Another study summarized in Special Report 254 indicated that the majority (i.e., 8 of 11) of the vehicles involved in a set of intersection pedestrian crashes were traveling above the average vehicle speed or posted speed limit of the roadway [*3*].

Speed and Crash Severity

The relationship between speed and crash severity, specifically for vehicle-pedestrian incidents, is particularly relevant to the low-volume and low-speed residential street. Not surprisingly, it has long been recognized that crash severity increases with the speed of the collision [*3*]. This increase is generally a result of physics. The likelihood of a pedestrian fatality resulting from a vehicle-pedestrian collision increases with vehicle speed. The research in this subject area indicates that there is about an 85 percent chance of a pedestrian dying when the colliding vehicle is traveling 40 mph, but that this decreases to 45 percent at 30 mph and 5 percent at 20 mph [*3*, *7*, *and 8*].

The chance of a pedestrian being seriously injured is also low if the vehicle speed at collision is 15.5 mph or slower [*9*]. Slower vehicle speeds may allow a driver to see a pedestrian for a longer period of time and the vehicle can be stopped within a shorter distance [*7*]. In 2003, it was also shown that five to nine year-old males who "dart out" on to the roadway had the highest vehicle-pedestrian crash rates per 100,000 people [*7*]. In addition, in that same year about 65 percent of the vehicle-pedestrian crashes occurred at non-intersection locations (this was found to be especially true for children less than nine years old) and most child pedestrian fatalities occurred from May to July [*7*].

A study conducted at the University of Minnesota developed a simulation model of vehicle-pedestrian collisions on residential streets [9]. It proposed using the model to help identify streets where vehicle speeds or traffic volumes posed heightened risk to child pedestrians. The selection of these streets based on actual crash data is not normally possible because of the low number of collisions that occur along these roadways. A series of assumptions were made to develop the model, but it essentially represented a hypothetical situation where a driver sees a pedestrian located randomly in the front yard of a residence and running toward a collision point that was about 4.9 feet into the street [*9*]. The assumed speed for the pedestrian was chosen randomly from a distribution of running speeds for nine year-old boys, and the driver reaction and braking rates were chosen randomly from those characteristic of surprised stops [*9*]. The vehicle speeds and locations of the vehicles at the points of perception were taken from data collected in the field. It was then possible to rank a set of residential streets with respect to the probability that an inattentive child pedestrian and a vehicle would collide, and to assess how this probability would change as either traffic volume or mean speed changed.

OCCASIONAL HAZARD (PLAYGROUND) WARNING SIGN SAFETY AND/OR SPEED IMPACT RESEARCH

Several research studies have considered the effectiveness of various occasional hazard warning signs [*10*, *11*, *12*, *13*, and *14*]. None of the research documents that were found, however, focused on OHPW signs. The projects summarized below include a survey related to the effectiveness and implementation of occasional hazard warning signs and research on the speed and/or safety impacts of ice warning, wet weather, and deer crossing warning signs [*10*, *11*, *12*, *and 13*]. The results of a study that compared vehicle speeds near school and playground zones are also presented [*14*]. In addition, the content of a WisDOT literature summary focused on the effectiveness of "Children at Play" signs is described below.

Warning Sign Effectiveness and Implementation Survey Results

In 2008 the results of a survey on the effectiveness and implementation of occasional hazard warning signs were published in the *ITE Journal* [*10*]. The survey was sent online to all 50 states and two Canadian province departments of transportation (DOTs). Overall, 28 surveys (or 54 percent) were completed [*10*]. The answers provided to the survey revealed that 89 percent of the respondents believed that warning signs were "effective" or "somewhat effective" [*10*]. On the other hand, 93 percent of the respondents also had not actually evaluated their effectiveness [*10*]. Only Arkansas and Arizona had apparently attempted evaluations of occasional hazard warning signs, but these studies were not described or referenced in the *ITE Journal* article. A review of sign-related literature by the survey article authors revealed that most warning sign research did not distinguish between OHPW signs and other types of warning signs [*10*]. The research also often did not consider the potential effectiveness of traditional static warning signs and only used them as a "control" or reference for evaluating signing enhancements [*10*].

The survey also asked the DOTs about the criteria they used to determine whether there was a need for an occasional hazard warning sign [*10*]. More than one answer was allowed to this question, but over 90 percent of the respondents indicated that they used engineering judgment [*10*]. More than 60 percent also used national guidelines and 50 percent used state guidelines [*10*]. No information was provided that identified these guidelines but it is assumed that they were primarily those in the state or national *Manual on Uniform Traffic Control Devices* [*1*]. Overall, approximately 40 percent of the respondents used "best practices" for installation decisions and only 20 percent indicated that tort liability guided their decisions [*8*]. Almost all of the respondents (i.e., 96 percent) also used engineering judgment to determine the number of signs to install within an extended "hazard zone" [*10*]. However, approximately 72 percent of the respondents also used crash experience to complete this task and about 10 percent had formal guidelines to follow [*10*]. Approximately 85 percent of the respondents also indicated that they used unconventional warning signs (e.g., different designs, signs with flashing lights, and dynamic message signs) [*10*]. This result would seem to at least partially contradict the survey response that showed more than 9 of the 10 respondents believed the traditional occasional hazard warning signs were effective [*10*]. The authors of the survey article recommended that additional research on occasional hazard warning sign impacts needed to be completed [*10*].

"Ice", "Slippery when Wet", and "Deer Crossing" Warning Sign Evaluations

Very few research evaluations have focused on the effectiveness (e.g., safety or speed impacts) of traditional static occasional hazard warning signs. As noted above, the traditional static occasional hazard warning sign is often used as a "control" to investigate the impact of sign enhancements. Some examples of these enhancements include new designs and/or larger sign sizes, the addition of fluorescent yellow-green sheeting and/or flashing lights/beacons, or the addition of dynamic messages. The general assumption of past studies is that the traditional static warning sign or typical warning sign is not effective (which may or may not be true). The focus of many signing evaluation projects is their potential impact on vehicle speed, but sometimes crashes were considered. Vehicle simulators, however, have also been used in these types of evaluations. This approach allows the attention-value or eye-scanning activity of drivers (in addition to simulated vehicle speeds) to be measured for various sign designs. Desirably, evaluations of occasional hazard signs should incorporate multiple measures of effectiveness and/or take advantage of both field and simulated data.

Three examples of research studies that evaluated the potential impacts of occasional hazard occasional hazard warning signs are briefly described in the following paragraphs [*9*, *10*, *and 11*]. The first example is an occasional hazard warning sign evaluation that considered crash data with and without ice warning signs [*11*]. The researchers considered the ice-related crash frequencies and severities using three years of data in Washington State. Roadway geometrics, regional locations, and traffic flow were also considered. An analysis of the data indicated that the presence of the ice warning sign did not have a statistically significant impact on either the frequency or the severity of crashes involving ice [*11*]. The researchers indicated that this might mean the current approach to implementing these signs is ineffective, and that a new, standardized approach (that focused on crash reduction) might be needed [*11*]. In other words, the study results might have been directly related to the approach taken by the State of Washington to install this type of sign. Some of the other roadway, traffic, region/route, temporal, and crash characteristics considered in the research were found to be significantly related to ice-related crashes and could also help develop a process and mitigate this issue [*11*]. It should be noted that this was the only study found that considered the direct safety impacts of a traditional static occasional hazard warning sign.

Many research studies that focus on warning signs evaluate the potential impacts of their enhancement. The traditional static warning sign is often the “control” with this approach and assumed to be completely ineffective. One example of a study that did not make this assumption focused on the wet weather (or “slippery when wet”) occasional hazard warning sign [*12*[. This project evaluated five wet weather warning sign designs and the “no sign” condition [*12*]. The inclusion of the latter condition allows a comparison of the data collected when no sign was installed with those collected when a traditional wet weather occasional hazard warning sign existed. Overall, vehicle speed data were collected during dry and wet conditions with and without the traditional static wet weather sign and four other sign designs (with various supplementary plaques and/or flashing lights) [*12*].

Three horizontal curve sites with the potential for skidding (based on crash data and geometrics) were considered as part of this wet weather sign project noted above [*12*]. However, the primary study site had a 20 degree curve and existing pavement skid resistance data that allowed the calculation of a critical wet weather speed [*12*]. The results at the primary study site showed that the wet weather mean free-flow speed of the highest quartile (i.e., the top 25 percent) of vehicles during the “no sign” condition was approximately the same as those with just the traditional static wet weather sign [*12*]. The mean vehicle speed for this same vehicle group during the “no-sign” condition, however, was higher than when the other four sign designs were used [*12*]. In most cases the difference appears to be less than 5 miles per hour [*12*]. In addition, the mean vehicle speed of the highest quartile of vehicles was slightly higher or about equal to the critical wet weather speed (at the point of tightest curvature) for just the “no sign” and traditional static wet weather sign [*12*]. This measure was also lower than the critical wet weather speed for the other designs. A reduction in the mean vehicle speed for the “no sign” condition during the second day of data collection was attributed to the familiar drivers on the roadway becoming more aware of the wet weather signing test [*12*]. These signs were only installed temporarily (when rain events occurred). The vehicle speed results at the other two study sites were similar to the primary site (with expected adjustments for geometrics, etc.) [*12*]. The only difference at these other sites was that the mean vehicle speeds when the traditional wet weather sign and a "slow when wet" supplementary plaque were installed did not show the reduction found at the primary site [*12*]. No explanation for this difference was provided [*12*]. Overall, the results indicate that mean vehicle speeds decrease with more conspicuous (e.g., flashing lights) signs, but it is possible that the impact is short-term and partially the result of the "novelty" of the signs [*12*].

Some occasional hazard warning sign evaluations have used vehicle simulators. For example, a project recently completed for the Minnesota Department of Transportation compared the simulated vehicle speed and eye scanning (or attention level) impacts of four deer crossing warning sign designs [*13*]. The four sign designs considered were the traditional deer crossing warning sign, the traditional sign design with a flashing light that was off and also when the light was on, and a cluster of these signs with flashing lights in operation [*13*]. These designs were presented to the subject drivers two to three times along 27 miles of simulated rural roadway [*13*]. The eye scanning and average vehicle speeds near the signs were collected or calculated for 47 drivers [*13*]. The eye scanning data was scaled and averaged for each of the 11 sign locations. Overall, the researchers concluded that the few increases in eye scanning that did occur near the signs (8 out of 517 potential opportunities) were not related to any of the sign designs [*13*]. The overall average vehicle speed near the signs was also similar (with a range of about 2.3 mph). However, the highest average speed was near the traditional sign design and the lowest near the single sign with the operating flashing light [*13*]. The difference between these two speeds was statistically significant [*13*]. In addition, the standard deviation of the vehicle speeds near the traditional sign design was the highest of the four sign designs considered [*13*]. The researchers that completed this study recommended that in the future the study design might be altered to evaluate a situation with a deer carcass on the roadside in an area with a sign and flashing lights [*13*]. It was also suggested that a sign design with light-emitting diodes (LEDs) could be evaluated [*13*].

Speed Compliance near School and Playground Zones

Many of the factors that impact the choice of vehicle speed by drivers have already been noted. Of particular interest to this project are vehicle speeds near playgrounds. Only one published study was found that appeared to be related to this issue [*14*]. In March 2009 an article on speed compliance near school and playground zones was published in the *ITE Journal* [*14*]. Other studies have focused on the impact of different traffic control devices around school zones, but this study also considered playground zones.

The province of Alberta, Canada had apparently reduced the speed limits in school and playground zones from 31.1 mph (50 kph) to 18.8 mph (30 kph) [*14*]. It was hypothesized by the author of the March 2009 article that the vehicle speeds and speed limit compliance around these two types of zones may be different [*14*]. His study tested this hypothesis with sites within 20 school and playground zones (with a speed limit of 18.8 mph (30 kph)) [*14*]. A total of 60 to 80 free-flow vehicle speeds were unobtrusively collected with a laser gun at each site [*14*]. The mean vehicle speed at all 20 sites was 20.4 mph (32.8 kph) [*14*]. Approximately 59.1 percent of the vehicles near these sites were traveling above the speed limit and about 14.2 percent were traveling greater than 24.9 mph (40 kph) [*14*]. The data also indicated that the average speed in the school and playground zones were 19.8 and 20.8 mph (31.9 and 33.4 kph), respectively [*14*]. In addition, the proportion of vehicles speeding near the playground zones was 61.5 percent, but only 53.1 percent of the vehicles were speeding near the school zones [*14*]. A similar difference or relationship for the percentage of vehicles traveling greater than 24.9 mph (40 kph) was also found (i.e., 16.5 percent in playground zones and 10.8 percent in school zones) [*14*]. The mean vehicle speeds and speed limit compliance levels at the playground and school zones considered were significantly different (based on the results of a t-test comparison) [*14*]. Overall, it should be noted that the significant differences in mean vehicle speeds were generally less than 2 mph (3.2 kph) [*14*]. The difference in the percentage of speeders, however, ranged from about 8 to 12 percent [*14*].

A comparison of the speed data from the study sites described above, of course, assumes that they are similar (except for the characteristic being compared). In fact, the school and playground zones and roadways must be similar enough that all the speed-related factors not considered by the study could be ignored. Additional documentation would need to be acquired about the study sites to determine if this assumption was correctly applied. A related concern is the potential for correlated impacts between the factors considered. Each of the location characteristics considered, and likely others, can have independent or overlapping impacts on vehicle speed and/or speed limit compliance levels. For example, it is of particular interest to determine how much of the difference in mean vehicle speeds and speed limit compliance levels between the playground and school zone sites were due to general perception of the area by the driver (i.e., playground or school zone) or, for example, the existence of a chain-link fence (and if one impacted the other). The author of the March 2009 article summarized above recommended that the speed limit reductions in the school and playground zones should continue and that chain-link fencing could be implemented as a traffic calming device [*14*].

EFFECTIVENESS OF "CHILDREN AT PLAY" SIGN SUMMARY

The "Children at Play" is one of the most requested occasional hazard warnings. It is similar to the OHPW sign, but not location-specific (i.e., it is posted in many locations). In 2007, the WisDOT published a literature summary of documents that included information about the effectiveness and/or installation of "Children at Play" signs [*15*]. The conclusions in this summary related to the impact of "Children at Play" signs generally match those used for many years based on "signing best practices" and "engineering judgment" [*15*]. However, the authors of the summary do state that "… [t]here is no evidence that special warning signs of this sort reduce driver speeds or crash rates [*15*]." They indicate that this conclusion is based on "…the unanimous conclusion of many credible sources…" and is "…supplemented by often-cited 'common sense' observations…" about these signs [*15*]. Some of these observations include the fact that the guidance provided by these signs is not clear or enforceable, that they can provide a false sense of security, and that they could expose jurisdictions to liability (if the sign installed is not compliant with the MUTCD) [*1*, *15*]. They also acknowledge that some of the arguments that are used against installing "Children at Play" signs do not necessarily apply to similar signs (e.g., "Deaf Child", "Blind Child", etc.) [*15*]. The discussion of these similar signs is very limited in the literature.

A closer review of the WisDOT summary (along with the outcome of this literature search) appears to support the idea that any "evidence" based conclusions about the "Children at Play" sign is simply based on "common sense" observations rather than research results [*15*]. The large amount of expert opinion documentation referenced in this and other summaries do not constitute research-based "evidence" that these signs do or do not reduce vehicle speed or crashes. This type of conclusion can only be made with supporting research results and it is acknowledged in the WisDOT summary (and is supported by the results of this literature review and summary) that this type of research does not appear to exist [*15*].

The WisDOT summary describes the "Children at Play" subject material from documents published by the United States Department of Transportation, Federal Highway Administration, National Cooperative Highway Research Program, and the Institute of Transportation Engineers [*15*]. They all generally discourage the use of these signs but "…none of them cites specific research demonstrating that these signs are ineffective…" [*15*]. In some cases the ineffectiveness of "Children at Play" signs is very directly stated in the referenced material and an implication is made that there have been studies to support this conclusion [*15*]. Similar information is summarized from a sample of state and local documents [*15*]. The authors of the WisDOT summary (and this literature review and summary activity), however, "…were unable to find any specific projects meeting this description [*15*]". In other words, there has been no published research completed on the potential speed and/or crash impacts of "Children at Play" OHPW signs. This does not mean that the "common sense" observations about the effectiveness of these signs are incorrect. In fact, there are many reasons to believe that any research on the effectiveness of these signs will support these long-held and documented conclusions.

SUMMARY OF FINDINGS

The relationship between roadway safety and vehicle speed is well recognized and documented. Some of the research results connected to this relationship are summarized in this chapter. The relationship between vehicle speed and the characteristics of vehicle-pedestrian crashes is also noted. In addition, several roadway factors that can impact the choice of vehicle speed by a driver are listed.

Overall, no publications were found that documented the evaluation of the potential vehicle speed impacts of OHPW signs. The results from research studies that considered the safety and/or speed impacts of other occasional hazard warning signs, however, were described in this chapter. Not surprisingly, it was found that signs with more "attention value" often had greater speed impacts than traditional static warning signs. However, many of the sign studies that were completed in the past have also used the traditional static warning sign as a "control" in order to evaluate sign improvements. This approach, unfortunately, implicitly assumes that the traditional static warning sign being improved has no impact. This chapter concluded with a summary of a literature review (completed by others) focused on the research and potential impacts of the non-compliant "Children at Play" OHPW sign. Overall, it was determined that there had been very little, if any, actual research completed about the vehicle speed and/or safety impacts of this OHPW sign. Most of the documentation about the "Children at Play" OHPW sign is based on "best practices" and "common sense".

Chapter 3. Study Site Selection Methodology and Data Collection Process

This chapter includes a summary of the study site selection methodology used in this research project. More specifically, desirable study site characteristics are identified. In addition, the existing characteristics of the candidate study sites are noted, an evaluation and comparison of the study sites completed, and the selected study sites identified. The chapter concludes with a description of the study data collection process and the data categorization completed before its summary and analysis (see the next chapter). The number of vehicle speeds contained within each data category is then documented.

As noted previously in this report, this research project was designed to determine, to the greatest extent possible, the potential impact on vehicle speeds related to the installation of OHPW signs along residential streets. Overall, it was proposed that the project would consider data from three study sites in the City of Bloomington, Minnesota. This chapter describes the approach used to select these study sites along with the data collection process applied. The data collected at the study sites are analyzed and evaluated in the next chapter.

OVERALL SITE SELECTION METHODOLOGY

The site selection methodology used in this project consisted of the following steps.

- Step 1: Collect/review City of Bloomington information (e.g., land use information, park/school locations, and sign inventory)
- Step 2: Define desirable study site characteristics (e.g., residential street design)
- Step 3: Identify candidate study sites
- Step 4: Collect candidate study site existing conditions
- Step 5: Evaluate candidate study sites
- Step 6: Select final study sites

Information related to each of these steps is described in the following paragraphs. The first objective of the study site selection process was to identify and collect the existing conditions at as many as six candidate study sites. The information provided by the City of Bloomington, along with specific candidate study site suggestions, was used for this identification. Several physical characteristics from each candidate study site were then collected and compared to those considered to be desirable from a data collection and sign installation point of view.

Collect/Review City of Bloomington Information

The first step in the study site selection process was to request information from the City of Bloomington. The project team asked for information that it believed would be relevant to the site selection process and overall project. This information was also used to familiarize the project team with the general layout and physical characteristics of the city. The documents provided by the City of Bloomington included:

- 2008 Comprehensive Plan (including land use, transportation (e.g., functional classification map), and community facilities (e.g., parks and schools) elements)
- 2008 Traffic Flow Map (including average daily traffic (ADT) volumes on major roadways)

- Website links to Parks and Recreation Department and Bloomington Athletic Association (BAA) (including a map of Parks and Recreation Facilities and the BAA facilities list)
- Inventory map of several existing OHPW signs (including some signs using the playground symbol, caution child, blind child area, kids running, deaf child area, visually impaired X-ing, and children at play or slow children at play)
- Photos of several existing OHPW signs

The information listed above was used to acquaint the project team with the roadway and land use characteristics of the City of Bloomington. The City of Bloomington is located within the Minneapolis/St. Paul metropolitan area. Its borders generally include U.S. 169, Interstate 494, and the Minnesota River. The eastern portion of the city generally has a grid system of roadways and the western portion is more curvilinear in nature. By acreage, the city is about 36 percent residential and about 32 percent public/quasi-public/conservation land. City parks appear to be spread throughout the city and scheduled recreational activities occur at many of these locations.

The warning sign photos and inventory map provided by the City of Bloomington led the project team to several important conclusions related to the study site selection. First, it appeared that occasional hazard warning signs were more prevalent in several areas within the city. Second, the sign inventory map did not always describe exactly what was actually on the warning sign. For example, a sign identified as a "Caution Child" sign on the inventory map might also include a wheelchair symbol. In addition, the warning signs that were indicated on the inventory map were sometimes non-standard signs with a symbol of a child or children running (versus the word "playground" or the standard MUTCD playground teeter-totter symbol). Lastly, it was determined that the three "Children at Play" signs on the inventory map consisted of one small yellow and black sign with a child symbol hanging on a utility pole along Stanley Avenue, and a non-standard, old, and faded red and white sign with text indicating "Caution Children at Play" along Terracewood Drive. The third "Children at Play" sign indicated on the inventory map no longer exists. These findings supported the selection of the *standard OHPW sign* (i.e., the teeter-totter symbol) as the focus of the project (See Figure 2.1). In turn, this focus helped identify some of the desirable study site characteristics for this project.

Define Desirable Study Site Characteristics

The second step in the study site selection process was the definition of desirable study site characteristics. These characteristics were identified because they assist with meeting the project objective (i.e., the evaluation of potential vehicle speed impacts related to OHPW sign along residential streets), the ability to collect vehicle speed data, and/or the need to install one or more OHPW signs in what is desirably a relatively uncluttered roadway environment. It was concluded that the following study site characteristics were beneficial to this research project:

- Surrounding land use is primarily residential (e.g., single family homes);
- Park, playground, and/or school property activity areas;
- Minimal existing warning signs and/or marked (i.e., active) pedestrian crosswalks near park, playground, and/or school property activity areas;
- Planned or scheduled park, playground, and/or school property activities;
- Asphalt roadway surface;

- Speed limit of 30 miles per hour (mph) or less (but not necessarily posted);
- One travel lane in each direction with or without parking;
- Adequate spacing between access points and/or side street(s); and,
- No nearby construction, landscaping, etc. during the data collection time period.

The project team worked with the City of Bloomington to identify candidate study sites that might meet the majority of the desirable study site characteristics identified above. None of the candidate study sites identified, however, was expected to have all of the characteristics listed above. Of course, the selection of the OHPW sign as the focus of this project also limited the number of locations that could be considered within the City of Bloomington. There needed to be park and/or playground areas where the installation of this type of sign would make sense. The OHPW sign is intended to be a caution to drivers that a roadway segment might include the "hazard" of a nearby park and/or playground activities.

Identify Candidate Study Sites and Collect Existing Conditions

The third and fourth steps in the site selection process were the identification of candidate study sites and the collection of their relevant existing characteristics. The candidate study site identification process included two approaches. First, staff from the City of Bloomington was asked to identify several candidate study sites where they would be comfortable installing OHPW signs. The only restriction placed on the suggestions by the city was that the candidate study sites be in areas that were primarily residential in their land use. Second, the information provided by the City of Bloomington (listed previously), the list of desirable characteristics, and aerial photos from the internet were used by the project team to assess another 27 potential candidate study sites. Overall, the following 13 candidate study sites were selected for site visits:

- Xerxes Avenue South from West 98th Street to West 102nd Street
- Humboldt Avenue South from West 106th Street to West 100th Street
- Rich Road from West Old Shakopee Road to Heritage Hills Drive
- Heritage Hills Drive from Rich Road to Johnson Road (and extended to crest of hill on Heritage Hills Drive by project team)
- Nesbitt Avenue South from West 94th Street to West 96th Street
- Colorado Avenue South from West 94th Street to West 96th Street
- East 92nd Street from Chicago Avenue South to 10th Avenue South
- Chicago Avenue South from East 90th Street to East 92nd Street
- Morris Avenue South between West 85th Street and Morris Circle
- East 95th Street between 1st Avenue South and 2nd Avenue South
- Emerson Avenue South between West 84½ Street and West 86th Street
- West 92nd Street between Bryant Avenue South and DuPont Avenue South
- Columbus Avenue South between East 100th Street and East 102nd Street

The first eight candidate study site locations listed above were identified by the City of Bloomington. The last five locations were a result of the project team assessment. The general locations of the 13 candidate roadway segment study sites are shown in Appendix A Figure A-1.

Site visits were completed in Fall 2009 and Winter/Spring 2010 to each of the candidate study sites identified. At each site, information that defined their existing physical conditions was collected. More specifically, data were collected or confirmed about the following characteristics:

- Road width (edge to edge) and curb/gutter width
- Number of lanes
- Lane width (if pavement marking existed)
- Speed limit (posted or statutory)
- Parking limitations (if any)
- Number of driveways and spacing
- Existence of additional warning signs
- Adjacent land uses

The data collected about these characteristics are summarized in Table 3.1. Overall, the length of the roadway segments being considered ranged from about 650 to 3,865 feet. In addition, although the pavement marking varied, all but two of the candidate study sites were two lane roadways. Only the Xerxes Avenue South candidate study site had two lanes in each direction for its entire length. The Nesbitt Avenue South candidate study site had a three lane segment (i.e., two lanes northbound and one lane southbound) for about half its length. The other half of the Nesbitt Avenue South candidate study site was a two-lane roadway with wide shoulders/bike lanes.

The pavement marking at the candidate study sites varied. Nine of the sites visited had no pavement marking. Two of the candidate study sites (i.e., Humboldt Avenue South and Nesbitt Avenue South), however, had one lane travel lane marked in each direction and an edgeline that defined a wide (approximately 8 to 10 foot) shoulder/bike lane where no parking was allowed. The four-lane Xerxes Avenue South candidate study site, on the other hand, allowed some parking during specific times along limited portions of the roadway segment of interest. One candidate study site had a centerline (i.e., Columbus Avenue South) and two (i.e., Rich Road and Heritage Hills Drive) had short segments of centerline on the approaches to stop-controlled intersections.

The overall width of the pavement surface at all 13 of the candidate study sites was typically about 32 to 33 feet or 41 feet. All the candidate study sites also had an asphalt pavement surface with a seal coat covering. The curb and gutter along the roadways, however, was generally concrete. In addition, all of the study sites had a 30 mph speed limit (although most were not posted within the candidate study site limits).

Not surprisingly, the land use along the candidate study sites was very similar. All of the roadway segments being considered had adjacent single family homes along large portions of their length. In addition they all included adjacent park, playground and/or school property with one or more baseball diamonds, soccer fields, hockey rinks, playground equipment, basketball courts, and/or tennis courts. The access density along the candidate study sites varied from approximately 32 driveways per mile at Rich Road to approximately 79 driveways per mile at Heritage Hills Drive.

Table 3.1. Candidate Study Site Existing Conditions

Candidate Study Site	Length (Feet)	Number of Lanes	Roadway Surface Width (Feet)	Curb Width (Feet)	Travel Lane Width (Feet)**	Existing Warning Signs?	Pavement Marking	Speed Limit (mph)	Parking Allowed	Driveway Density (Per Mile)
Xerxes Avenue South (West 98th Street to West 102nd Street)	2,591	4	41	2	11	No	Centerline& Lane Lines	Not Posted	Limited	67.2
	Adjacent land uses: Eastside – Single family homes; Westside – Minnehaha Academy (a private school), Bloomington Covenant Church, Brookside Park (including playground equipment, soccer fields, baseball diamond, hockey rink, tennis courts, etc.), and single family homes									
Humboldt Avenue South (West 106th Street to West 100th Street)	3,866	2	40	2	12	Pedestrian Crossing and Deer Crossing Signs	Centerline& Edge Line	30	None	62.8
	Adjacent land uses: Eastside – Single family homes, Oak Grove Elementary/Middle School (with playground equipment) and a hockey rink; Westside – Central Park (only forest visible from roadway) and single family homes									
Rich Road (West Old Shakopee Road to Heritage Hills Drive)	1,310	2	33	2	N/A	Playground Signs for Park	Centerline on Stop-Controlled Approach	Not Posted	Both Sides	32.2
	Adjacent land uses: Eastside – Front of South Glen Park (including baseball diamond, playground equipment, soccer field, tennis courts, and hockey rink), and one single family home; Westside – Single and multi- family homes									
Heritage Hills Drive (Rich Road to the crest of the hill)	869	2	33	2	N/A	Stop Ahead Sign for Four-Way Stop at Rich Road	Centerline on Stop-Controlled Approach	Not Posted	Both Sides	79.0
	Adjacent land uses: Eastside – Side of South Glen Park (including baseball diamond, playground equipment, soccer field, tennis courts, and hockey rink), and single family homes; Westside – Single family homes and forest land									

Table 3.1. Candidate Study Site Existing Conditions (continued)

Candidate Study Site	Length (Feet)	Number of Lanes	Roadway Surface Width (Feet)	Curb Width (Feet)	Travel Lane Width (Feet)**	Existing Warning Signs?	Pavement Marking	Speed Limit (mph)	Parking Allowed	Driveway Density (Per Mile)
Nesbitt Avenue South (West 94th Street to West 96th Street)	1,274	2 or 3*	41	2	9-12	Three Pedestrian Crossing Signs	Centerline & Edge Line	30	None	53.9
	Adjacent land uses: Eastside – Single family homes and Saint Edwards Church; Westside – Single family homes and the front of Ridgeview Elementary School									
Colorado Avenue South (West 94th Street to West 96th Street)	1,305	2	33	2	N/A	T-Intersection Sign for West 94th Street	None	Not Posted	None	52.6
	Adjacent land uses: Eastside – Ridgeview Park, the back of Ridgeview Elementary School (including baseball diamonds, soccer field, tennis courts, hockey rink, and playground equipment), and single family homes; Westside – Single family homes									
East 92ndStreet (Chicago Avenue South to 10th Avenue South)	648	2	33	2	N/A	Split-Intersection Sign for 10th Avenue South	None	Not Posted	Both Sides	65.2
	Adjacent land uses: Southside – Single family homes; Northside – Open fields, four baseball diamonds, and Saint Bonaventure Catholic Community (i.e., church, school, social hall, office and friary)									
Chicago Avenue South (East 90th Street to East 92nd Street)	1,286	2	33	2	N/A	No	None	Not Posted	Both Sides	65.7
	Adjacent land uses: Eastside – Saint Bonaventure Catholic Community (i.e., church, school, social hall, office and friary), four baseball diamonds, and open fields; Westside – Single family homes									

Table 3.1. Candidate Study Site Existing Conditions (continued)

Candidate Study Site	Length (Feet)	Number of Lanes	Roadway Surface Width (Feet)	Curb Width (Feet)	Travel Lane Width (Feet)**	Existing Warning Signs?	Pavement Marking	Speed Limit (mph)	Parking Allowed	Driveway Density (Per Mile)
Morris Avenue South (West 85th Street to Morris Circle)	577	2	32	2	N/A	None	None	Not Posted	Yes	45.79
	Adjacent land uses: Eastside – Single family homes; Westside – Poplar Bridge school (including baseball fields, soccer field, playground equipment, hockey rink, tennis courts, basketball courts, and park building).									
East 95th Street (1st Avenue South to 2nd Avenue South)	647	2	32	2	N/A	None	None	Not Posted	No parking 7AM-4PM	48.96
	Adjacent land uses: Northside – Single family homes; Southside – Maplewood Park (including baseball fields, playground equipment, park building, basketball court, etc.)									
Emerson Avenue South (West 84-1/2th Street to West 86th Street)	961	2	32	2	N/A	None	None	Not Posted	Yes	65.97
	Adjacent land uses: Eastside – Bryant Park (including baseball field, hockey rink, playground equipment, basketball court, softball fields, parking lot, open space, and tennis courts); Westside – Single family homes.									
West 92nd Street (Bryant Avenue South to DuPont Avenue South)	655	2	32	2	NA	None	None	Not Posted	Some No Parking Areas	48.37
	Adjacent land uses: Northside – Single family homes; Southside – Vanderbie Park (including softball field, baseball field, tennis courts, and playground equipment).									
Columbus Avenue South (East 100th Street to East 102nd Street)	1,290	2	32	2	NA	Cross Road Symbol Warning Sign Approaching 100th Street E.	Centerline on approach to Inter-Section	30	Two Short No Parking Zones	73.67
	Adjacent land uses: Eastside – Single family homes; Westside – Columbus Playlot (including several softball fields, playground equipment, and basketball court) and single family homes									

*One lane in each direction for about half the segment and three lanes (two northbound lanes and one southbound) for the other half of the segment.
**N/A = not applicable (e.g., no parking lane and/or centerline markings). Travel lane widths may also vary

Evaluate Candidate Study Sites

The fifth step in the site selection process was a critical evaluation of the candidate study sites. A description of the candidate study sites along with the results of this evaluation are described below. Each description includes a conclusion about the feasibility of each candidate as a final data collection study site. These conclusions are based on a comparison of the desirable study site characteristics with those that exist at the candidate study sites.

- Xerxes Avenue South (West 98th Street to West 102nd Street) – This candidate study site is a four-lane undivided roadway with some parking. A two-lane roadway was desired for this project. However, there was a plan for this roadway to receive a new seal coat and be marked for two lanes (with wide shoulders/bike lanes) in 2010. The current cross section and plans for construction eliminated this candidate study site from further consideration.
- Humboldt Avenue South (West 106th Street to West 100th Street) – This candidate study site has a variety of land use characteristics. Central Park abuts the roadway, but only with forested land (versus activity areas). Across the roadway from the forest land is an elementary/middle school complex that includes playground equipment (the front of the school is actually facing West 104th Street, a side street to Humboldt Avenue South). The remainder of the land use along the candidate study site (particularly north of West 104th Street) is residential. There are two pairs of existing warning signs near the school. A pedestrian crosswalk (across Humboldt Avenue South) is supplemented with pedestrian warning signs, and there is a pair of deer crossing warning signs nearby. The existence of the other warning signs in the area near the school/playground eliminated this candidate study site from further consideration. It was concluded that the addition of another pair of warning signs along this roadway segment was inappropriate.
- Rich Road (West Old Shakopee Road to Heritage Hills Drive) – This candidate study site is adjacent to South Glen Park. The entrance to the parking lot for South Glen Park is on Rich Road. The other land uses along the roadway segment include single and multi-family homes. Two OHPW signs already exist along Rich Road near South Glen Park. The existence of these signs eliminated this candidate study site from further consideration.
- Heritage Hills Drive (Rich Road to the crest of the hill on Heritage Hills Drive) – This candidate study site is adjacent to another side of South Glen Park (see Rich Road description above). The roadway segment considered here consists of a downgrade that provides drivers a viewpoint of a portion of South Glen Park (e.g., the parking lot and baseball diamond). The land uses along this roadway segment consists of the park and single family homes. Two disadvantages of this site include the fact that it is on a hill and only part of South Glen Park can be seen from the driver's perspective. In addition, at the bottom of the hill there is a horizontal curve and a stop ahead warning sign that is a notification of the four-way stop-controlled intersection of Rich Road and Heritage Hills Drive. In Fall 2009 the City of Bloomington, after additional site investigation, determined that it could not be install a OHPW sign along this segment roadway. This site, therefore, was eliminated from further consideration.

- Nesbitt Avenue South (West 94th Street to West 96th Street) – This candidate study site has pavement markings (for about half its length) that define one travel lane and a wide shoulder/bike lane in each direction. Along the other half of the roadway segment length, however, there are two marked lanes in the northbound direction. The width of the roadway is approximately 40 feet. The roadway alignment is located in front of Ridgeview Elementary School and is crossed by a mid-block pedestrian crosswalk, which is staffed by students at the end of the school day. The crosswalk that is posted with pedestrian warning signs and a similar warning sign is located in advance of the crosswalk at the intersection of Nesbitt Avenue South and West 94th Street. The playground equipment and activity areas connected to Ridgeview Elementary School and/or Ridgeview Park are primarily behind the school building. The existing warning signs, mid-block crosswalk, change in the number of lanes, and the fact that most of the playground equipment and park activity areas are behind the school eliminated this candidate study site from further consideration.
- Colorado Avenue South (West 94th Street to West 96th Street) – This candidate study site is parallel to and one block west of the Nesbitt Avenue South site described above. Both sides of the roadway have single family home properties and Ridgeview Park is to the east of the candidate study site. This park includes three baseball diamonds, a soccer field, tennis courts, and a hockey rink. Adjacent to the park is Ridgeview Elementary School and its playground equipment. The portion of the candidate roadway segment study site that is adjacent to the park, however, is also approximately split in half by a "T-intersection" with Dakota Road. At the time of the site visit there was no parking allowed along this candidate study site. Based on the characteristics described of this candidate study site it was concluded that the implementation of OHPW signs was feasible and that it was suitable for this project.
- East 92nd Street (Chicago Avenue South to 10th Avenue South) – This candidate study site was the shortest roadway segment suggested by the City of Bloomington. It is two blocks long (approximately 650 feet). There are baseball diamonds to the north of the roadway segment and residential homes to the south. Elliot Avenue South forms a "T-intersection" with East 92nd Street at about the midpoint of the candidate study site segment. In addition, the 10th Avenue South intersection with East 92nd Street is "split" and is posted with a warning sign. During the site visit it was also noted that East 92nd Street was closed for construction several blocks to the east of the suggested study site. The shorter length of the study site, combined with the fact that it was further divided by a side street, and the potential for construction-related impacts eliminated this candidate study site from further consideration.
- Chicago Avenue South (East 90th Street to East 92nd Street) – This candidate study site intersects with the East 92nd Street site described above. The Chicago Avenue South candidate study site, however, is twice as long as the East 92nd Street candidate study site and it is not split by a side street intersection. This candidate study site is adjacent to baseball diamonds and open fields behind the Saint Bonaventure Church Community (which includes a church and what appears to be an elementary school or pre-school). Based on the characteristics of this candidate study site it was concluded that the implementation of OHPW signs was feasible and that it was suitable for this project.

- Morris Avenue South (West 85th Street to Morris Circle) – This candidate site is a two lane roadway adjacent to a baseball field in Poplar Bridge Park. The roadway segment being considered is about 575 feet long and terminates at the northern border of the park and at a stop sign-controlled intersection with West 85th Street. The land use surrounding the Poplar Bridge Park is single family homes and a school. The estimated average annual daily traffic (AADT) on Morris Avenue South was 300 vehicles per day (vpd) during 2008 (the most recent data available). Unfortunately, sidewalk construction was scheduled in 2010 along Morris Avenue South, and for this reason this site was eliminated from further consideration.
- East 95th Street (1st Avenue South to 2nd Avenue South) – This candidate site is a two lane roadway adjacent to Maplewood Park. This park includes baseball diamonds, a basketball court, and playground equipment. The East 95th Street roadway segment is approximately 650 feet long and is the only through roadway adjacent to the park. Single family homes surround the park, and a high school is nearby. The 2008 AADT on East 95th Street was estimated to be 1,200 vpd. All of the roadways that surround Maplewood Park, including East 95th Street, have time-based parking restrictions (e.g., no parking from 7 AM to 4 PM). Unfortunately, East 95th Street also has an all-way stop-controlled intersection with Stevens Avenue South, and this intersection is located at approximately the mid-point of the park and roadway segment being considered. The existence of this stop-controlled intersection eliminated this site from further consideration.
- Emerson Avenue South (West 84-1/2th Street to West 86th Street) – This candidate site is a two lane roadway adjacent to Bryant Park. Bryant Park is a large facility surrounded by several roadways. The activity areas in the park are dispersed and are sometimes at a significant distance from some of the surrounding roadways. It was determined that two of the roadways adjacent to the park allow vehicle drivers the ability to observe some of the activities within the facility. The Emerson Avenue South roadway segment (estimated AADT of 500 vpd in 2009) is west of the park and adjacent to one of its parking lots and a lake/open area. One of the baseball fields and the hockey rink are also visible to vehicle drivers. The other activity areas in the park (e.g., two other baseball diamonds, tennis courts, etc.), on the other hand, are closer to the east side of the park and Bryant Avenue South. Overall, because of the roadway and park characteristics, it was concluded that candidate study site on Emerson Avenue South should be eliminated from further consideration.
- West 92nd Street (Bryant Avenue South to Dupont Avenue South) – This candidate site is a two lane roadway adjacent to Vanderbie Park. No parking signs are interspersed along the roadway segment but parking appears to be allowed at particular locations. Single family homes are north and east of the park, but industrial and commercial properties are south and west, respectively. The park includes playground equipment, baseball fields, and tennis courts. Unfortunately, there is an all-way stop controlled intersection along West 92nd Street at DuPont Avenue South. This intersection is next to the baseball field in Vanderbie Park and the field is in a valley or depression below the roadway surface. The ability of a vehicle driver to see activities in this area is limited. These two characteristics were used to eliminate any further consideration of this site.

- Columbus Avenue South (East 100th Street to East 102nd Street) – This candidate site is a two lane roadway adjacent to the Columbus Playlot. Single family homes surround the playlot. Parking is allowed on both sides of the roadway except within two small segments next to the playlot that define the sidewalks that are used to enter the facility. The speed limit along Columbus Avenue South is posted at 30 mph and the roadway segment being considered terminates to the south at a stop-controlled intersection with East 102nd Street. There is a cross road symbol warning sign on the northbound approach to East 100th Street and this uncontrolled intersection represents the north terminus of the roadway segment being considered. The playlot location is about the same distance from each of these intersections. The estimated 2009 AADT for Columbus Avenue South is 500 vpd (2009). Overall, it was determined that the Columbus Avenue South roadway segment had many of the data collection site characteristics desirable for this project. It was selected as a study site for data collection. It was later discovered, however, that Portland Avenue South (three blocks or about 1,000 feet to the west) was being resurfaced during the "before" sign installation data collection activities but not during the "after" period. This resurfacing was not occurring during the "after" sign installation data collection activities. It was impossible to determine if this situation had an impact on the vehicle speed choice of those drivers using the Columbus Avenue South study site. The potential impact however, is acknowledged in the next two chapters.

SUMMARY OF SELECTED STUDY SITES

Three of the 13 candidate study sites described above were selected for data collection. The sites selected were the following:

- Colorado Avenue South from West 94th Street to West 96th Street
- Chicago Avenue South from East 90th Street to East 92nd Street
- Columbus Avenue South from East 100th Street to East 102nd Street

Vehicle speed data were collected at each of these three sites before and after the installation of a pair of OHPW signs. A vehicle speed data collection device was placed next to the park and/or playground adjacent to the roadway segments listed, and during daylight hours the magnitude and general location of the on-street parking and activities within the park and/or playground were also manually recorded. In addition, the number of parked cars within pre-defined sections of the three study site roadway segments was also documented. The park and/or playground areas and the roadway segment sections defined for the data collection at each study site are shown in Appendix A, Figures A-2 to A-4. More information about the data collection process used at these locations and the categorization of the vehicle speeds collected is described below.

OVERALL DATA COLLECTION PROCESS

The data collection process applied for this research project was relatively simple and straightforward. Three categories of data were collected at each of the three selected study sites. These data described vehicle speeds, on-street parking, and park and/or playground activities. The processes used to collect these types of data and their categorization is described below. A summary of the number of vehicle speeds in each category is then provided.

Vehicle Speed Data Collection

The vehicle speeds at each study site were collected using a JAMAR Technologies, Incorporated TRAX Apollyon™ automatic pneumatic tube traffic data collection device. This device was placed on the roadway approximately one month before and one week to one month after the installation of the OHPW signs. The device collected the speed, classification, and direction of each vehicle that activated its pneumatics. In addition, the date and time of the data collection for each vehicle were also recorded. The vehicle speed, direction, and time stamp were the only data used in this project. It should also be noted, however, that the vehicle speed data analyzed in this project were not "free-flow" speeds. "Free-flow" vehicle speeds occur when the driver is capable of choosing a vehicle speed without regard to other vehicles on the roadway. The vehicle speed data collected during this project were not categorized to allow a "free flow" speed analysis.

A pneumatic vehicle speed data collection devices was placed at a roadway location within the limits of each study site. They were installed adjacent to the park and/or playground of interest at a location the project team knew would be between the proposed OHPW signs. The general locations of the data collection devices, with respect to the park and/or playground areas at each study site, are shown in Appendix A Figures A-2 to A-4. The approximate distance from the device to the proposed location of each OHPW sign at each site are indicated below:

- Colorado Avenue South: 265 feet from the north sign and 554 feet from the south sign
- Chicago Avenue South: 526 feet from the north sign and 172 feet from the south sign
- Columbus Avenue South: 205 feet from the north sign and 276 feet from the south sign

The specific locations of the data collection device between the OHPW signs was also based on the need to secure and lock the counters to a permanent or semi-permanent fixture, the ability of drivers to see the activities occurring within the park/playground at the data collection point, and the avoidance of intersection and/or driveways along the roadway segment. Overall, the vehicle speed data collection devices were typically placed on the roadway for four to five days approximately one month before and one week to one month after the installation of the warning signs.

It is also important to note that the vehicle speed data collected during this research project were treated to several quality checks. Firstly, the project team removed the first and last hour of the data collected. This action was taken to minimize the potential impacts on the data due to the activities connected to the installation and removal of the data collection devices. Second, in some cases the data collection device could not interpret the vehicle activations correctly. These data, typically indicated by a vehicle speed of zero, were removed from the database.

On-Street Parking Activity Data Collection

On-street parking activity data were also collected at each study site. During daylight hours (e.g., 7:00 AM to 7:00 PM, 8:00 PM or 8:30 PM, depending on the time of the year) field personnel were inconspicuously positioned to observe the number, direction, and general location of parked vehicles along the study site roadway. Changes to the number of parked vehicles within the study site were then approximated by keeping a record of the time when one or more vehicles either exited or entered the parking lane along the roadway segment study site. The general location of the parked vehicles was also noted by assigning them to a particular section or zone within the study site roadway segment. The boundaries of the roadway segment sections or zones at each study site are shown in Appendix A Figures A-3 and A-4. It should be noted that no parking was allowed at the Colorado Avenue South study site (See Appendix A Figure A-2). In addition, of particular interest to this project are the parked vehicle orientation and related activities within the roadway section which includes the vehicle speed data collection device. The impact on vehicle speeds along a roadway due to on-street parallel parking and/or parked vehicles can be significant. The on-street parking activity categories used to summarize and analyze the potential impacts of this variable on vehicle speeds before and after the installation of the OHPW signs are described in the next section of this chapter.

Park/Playground Activity Data Collection

Park and/or playground activity data were also collected at each study site. These types of activities varied from study site to study site and also temporally within each park and/or playground. During the daylight hours (e.g., 7:00 AM to 7:00 PM, 8:00 PM or 8:30 PM, depending on the time of the year) the same field personnel as those noted above documented the number and general location(s) of the people within the park and/or playground. Changes to these activities were approximated by recording the general time when one or more people entered or left the park and/or playground. Not surprisingly, the overall number of people active within a park and/or playground (along with amount of entering and exiting foot traffic) during particular portions of a day sometimes required generalizations by the field personnel. The general location of the activities recorded within each park and/or playground was noted as occurring within one of the study site areas shown in Appendix A Figures A-2 to A-4 of the appendix. The boundaries of these areas were either defined by a particular activity (e.g., baseball) or by the fact that they were general green space in which any number of activities could occur. At each study site field personnel could also indicate whether an activity occurred throughout the entire park or playground (e.g., mowers) or just within the roadway right-of-way (e.g., walkers and bikers).

POST-DATA COLLECTION CATEGORIZATION

In the next chapter the vehicle speeds collected at each study site are summarized and analyzed. Some additional data categorization was needed before these summaries and analyses could be completed. First, it was concluded that only the vehicle speed data collected while field personnel were present (i.e., during daylight hours) should be included in the data summary and analysis (see the next chapter). This decision reduced some of the potential impacts lighting may have on the choice of vehicle speed. Each of the vehicle speeds collected, based on its time stamp, was then assigned to an appropriate on-street parking and park and/or playground activity category. The on-street parking categories defined for this research project included the following groups:

- No Parking – no parked vehicles within the entire roadway study site segment
- Stable Low Impact Parking – one or more parked vehicles within the roadway study site segment, but no “tunnel” effect (e.g., at least one parked car on both sides of the

roadway) within the roadway section or zone that contains the vehicle speed data collection device (See Appendix A Figures A-2 to A-4)

- Stable High Impact Parking – one or more parked within the roadway study site segment that produces the "tunnel" effect (e.g., a least one parked car on both sides of the roadway) within the roadway section or zone that contains the vehicle speed data collection device (See Appendix A Figures A-2 to A-4)
- Unstable – period of unpredictable parking and/or parking-related activities (e.g., pedestrians in street, large number of U-turns, loading/unloading of passengers, vehicles waiting for parking spaces) that typically occurs just before and after a major park and/or playground event (e.g., a baseball game)

Overall, the categories listed above focus on whether the "tunnel" effect occurs near the vehicle speed data collection device. It was assumed that this type of effect can occur when one or more vehicles park on the opposite sides of the roadway near the device. The beginning and end of these unstable time periods were chosen subjectively by the field personnel. However, they are also time periods when the vehicle speeds collected by the pneumatic tube device were also clearly impacted by a wide range of factors for which data were not collected during this research project. Any vehicle speeds collected by the pneumatic tube device during these time periods are somewhat questionable and should be viewed and analyzed cautiously. The more activities that occur at study site can increase the number of unstable times that needed to be identified by the field personnel. The subjectivity of this exercise could impact the robustness and comparability of the data in this category from study site to study site. The vehicle speeds within all but the unstable on-street parking category were used in the data summary described in the next chapter. The regression analysis considered the vehicle speed data included in all of the on-street parking categories. No additional categorization, except as noted above, was done that focused solely on the number of vehicles parked within the study site.

The park and/or playground data collected in the field as part of this project were categorized by the area within which it was located (See Appendix A, Figures A.2 to A.4). Some activities were also categorized as occurring within the entire park and/or playground or just within the roadway right-of-way of the study sites (e.g., walkers and bicyclists). Overall, it was assumed that any walkers and bicyclists within the study site roadway right-of-way were there for one minute. This assumption was necessary because the specific time of entry and exit of every walker and bicyclist was not recorded by the field personnel. It was also needed to assign relevant vehicle speed data to this type of activity. The start and end times of other activities in the park and/or playground, on the other hand, were typically noted by field personnel. The number of people involved in the park and/or playground activities were collected, but not used in the categorization of the data. This information was applied during the regression analysis described in the next chapter.

SUMMARY OF FINDINGS

This chapter summarized the site selection and data collection processes used in this research project. The site selection process consisted of six steps and completion of each step was described. A total of 13 candidate study sites were visited and their general location is shown in Appendix A Figure A-1. Three of these study sites were selected for data collection. The study sites selected are located along Colorado Avenue South, Chicago Avenue South, and Columbus

Avenue South in the City of Bloomington, Minnesota (See Appendix A Figures A-1 to A-4). Three types of data were collected at each study site approximately one month before and one week to one month after the installation of a pair of OHPW signs. Vehicle speed data were collected with a pneumatic tube device and manual observations were used to record on-street parking and park and/or playground activities occurring within the study site. Some of these data have been categorized for summary and analysis purposes (see Chapter 4) and are described in this chapter.

The number of vehicle speeds collected during the time periods defined by the on-street parking and park and/or playground activity categories described previously are shown in Tables 3.2 to 3.4. One of the more important characteristics to note in these data summary tables includes the fact that more than one activity can occur when a vehicle speed is collected. In other words, the sum of the activity and "no activity" vehicle speeds do not equal the total number of vehicle speeds collected. At the Colorado Avenue South study site, however, there were 838 and 846 vehicle speeds collected while the field personnel were present before and after the OHPW sign were installed, respectively. About 51 and 62 percent of these vehicle speeds, before and after the OHPW sign installation, respectively, occurred with no activity in the park/playground. The number of vehicle speeds collected during when one or more of the activities are occurring also generally decreased. This pattern could be a result of many factors, including weather, scheduled use of the playground/park by the school or city, and time of the year the data was collected. Of course, all the data were collected when there was no on-street parking because this activity was not allowed at the study site.

The Chicago Avenue South study site had 973 and 1,088 vehicle speeds collected while field personnel were present before and after the OHPW signs were installed, respectively. It appears that the vast majority of the vehicle speeds, both before and after the installation of the OHPW signs, were collected when park/playground activities were occurring and/or the on-street parking was categorized as "stable high impact" or "unstable". Only about 47 and 37 percent of the vehicle speeds were collected before and after the OHPW sign installation, respectively, when no park or playground activities were occurring. Before the OHPW sign installation, however, approximately 66 percent of these "no activity" vehicle speeds occurred with "stable low impact" on-street. After the OHPW sign installation this decreased to about 24 percent of the "no activity" vehicle speeds. Overall, the number of vehicle speeds during "stable high impact" and "unstable" on-street parking has dramatically increased and those collected with "stable low impact" on-street parking has generally decreased. Again, there are any number of potential reasons these data patterns could have occurred.

Finally, at the Columbus Avenue South study site there were 1,730 and 1,047 vehicle speeds collected while field personnel were present before and after the OHPW signs were installed, respectively. It is believed that the difference experienced in the overall number of vehicle speeds collected was due to the resurfacing occurring several blocks to the west on a parallel route. Although the roadway being resurfaced was still open it was operating in a restricted manner. It is assumed that drivers were using the Columbus Avenue South study site as an unofficial detour to avoid the resurfacing. During the "after" data collection time period the resurfacing was not occurring. Approximately 53 and 60 percent of the vehicle speeds at the Columbus Avenue South study site were collected before and after the OHPW sign installation, respectively, when no park or playground activities were occurring. Before and after the OHPW sign installation, however, approximately 85 and 83 percent of these "no activity" vehicle speeds occurred with "stable low impact" on-street. The number of vehicle speeds collected while particular activities were occurring, however, seemed somewhat more variable than experienced at the other two study sites.

A more detailed summary and analysis of the vehicle speeds generally summarized in Tables 3.2 to 3.4 are described in the next chapter.

Table 3.2. Colorado Avenue South – Number of Vehicle Speeds by On-Street Parking and Park and/or Playground Activity Database Category[1]

	Before Sign Installation				After Sign Installation			
Park and/or Playground Activity Category[2]	**No Parking**	**Stable Low Impact Parking**	**Stable High Impact Parking**	**Unstable Parking**	**No Parking**	**Stable Low Impact Parking**	**Stable High Impact Parking**	**Unstable Parking**
No Activity	430	0	0	0	525	0	0	0
BB1	0	0	0	0	1	0	0	0
BB2	43	0	0	0	34	0	0	0
BB3	1	0	0	0	6	0	0	0
Soccer	17	0	0	0	21	0	0	0
Tennis	57	0	0	0	10	0	0	0
NBA	11	0	0	0	8	0	0	0
NHL	0	0	0	0	10	0	0	0
NFL	39	0	0	0	0	0	0	0
PG	40	0	0	0	69	0	0	0
REC	175	0	0	0	162	0	0	0
South	42	0	0	0	30	0	0	0
ROW	178	0	0	0	115	0	0	0
All	26	0	0	0	2	0	0	0

[1]More than one activity can occur when a vehicle speed is collected. Parking categories are defined previously in this chapter. The total number of vehicle speeds collected before and after the sign installation was 838 and 846, respectively.
[2]See Appendix A Figure A-2 for location of park and/or playground activity category.

Table 3.3. Chicago Avenue South – Number of Vehicle Speeds by On-Street Parking and Park and/or Playground Activity Database Category[1]

	Before Sign Installation				After Sign Installation			
Park and/or Playground Activity Category[2]	No Parking	Stable Low Impact Parking	Stable High Impact Parking	Unstable Parking	No Parking	Stable Low Impact Parking	Stable High Impact Parking	Unstable Parking
No Activity	153	302	0	0	309	96	0	0
B	1	19	143	38	0	0	273	100
C	0	58	279	120	3	38	477	127
D	0	6	252	84	4	0	217	71
E	0	14	260	93	1	12	431	127
F	0	6	159	59	0	4	412	120
All	3	0	0	0	2	0	0	0
ROW	7	16	20	7	21	1	15	0

[1]More than one activity can occur when a vehicle speed is collected. Parking categories are defined previously in this chapter. The total number of vehicle speeds collected was 973 and 1,088 before and after the sign installation, respectively.
[2]See Appendix A Figure A-3 for location of park and/or playground activity category.

Table 3.4. Columbus Avenue South – Number of Vehicle Speeds by On-Street Parking and Park and/or Playground Activity Database Category[1]

	Before Sign Installation				After Sign Installation			
Park and/or Playground Activity Category[2]	No Parking	Stable Low Impact	Stable High Impact	Unstable	No Parking	Stable Low Impact	Stable High Impact	Unstable
No Activity	0	780	134	0	0	520	108	0
B1	0	49	71	37	0	12	162	13
B2	0	25	140	49	0	8	0	0
PIC	0	20	27	0	0	31	29	3
PG	0	354	271	75	0	63	218	17
NBA	0	40	0	0	0	2	0	0
Trail	0	8	1	0	0	2	0	0
All	0	0	0	0	0	34	0	0
ROW	0	54	9	0	0	15	42	2

[1]More than one activity can occur when a vehicle speed is collected. Parking categories are defined previously in this chapter. The total number of vehicle speeds collected before and after the sign installation was 1,730 and 1,047, respectively.
[2]See Appendix A Figure A-4 for location of park and/or playground activity category.

Chapter 4. Estimated Effects of Occasional Hazard (Playground) Warning Signs

PROBLEM OVERVIEW

As indicated in Chapter 1, a primary objective of this study is to estimate the mean change in vehicle speeds following installation of OHPW signs. The selected study design was an observational before-after design, where vehicle speeds were first measured during a period without the OHPW signs and then in a roughly comparable period with the OHPW signs present. Because this was an observational study rather than a true controlled experiment, the possibility remains that the effect of the OHPW signs could be confounded when other important influences (e.g. activities in the associated parks) also differed in the before versus after periods. These influences cannot be controlled experimentally, and our goal is to account for them statistically. To do this, their influences on mean speed are estimated and then subtracted from the original speed measurements, using linear regression analysis.

OUTLINE OF THE LINEAR REGRESSION APPROACH

The basic idea behind this application of linear regression is to treat each individual vehicle speed as resulting from a set of specified systematic influences related to activity levels or traffic controls, plus a random individual difference. To illustrate, imagine a road segment adjoining a playground where, in the absence of activity in the playground and where no OHPW sign is present, on average drivers travel at 25 mph. When there is activity in the playground, drivers reduce their speed by 2 mph. Suppose also that the effect of the OHPW sign is to reduce speeds by 3 mph. Then a simple regression model capturing these ideas would be

$$y_i = 25 - 2*A_i - 3*B_i + e_i \qquad (4.1)$$

where

y_i = speed of driver number i traversing the road segment
A_i = 1, if playground activity was present when driver i traversed the road
0, if playground activity was not present when driver i traversed the road
B_i = 1, if OHPW sign was present when driver i traversed the road
0, if OHPW sign was not present when driver i traversed the road
e_i = random effect reflecting driver i's individual deviation from average behavior

If we know the base mean speed (25 mph) and the coefficients reflecting the deviations from mean speed associated with the activity and OHPW sign (-3 mph and -2 mph, respectively), equation (4.1) could be used to predict what the mean speed would be at this location for different combinations of presence or absence of activity and the OHPW sign. For example, when neither playground activity nor a OHPW sign is present the predicted speed would simply be 25 mph, while if both playground activity and a OHPW sign are present the predicted speed would be 20 mph. The value of this model in controlling for possible confounding can also be illustrated. Suppose that, in a before/after study of a OHPW sign, no playground activity was present during the before period. During the after period, playground activity was consistently present. However, this systematic difference in activity was not recorded. Because the effect of the OHPW sign is confounded with that of activity, it would appear that the OHPW sign reduced speeds by 5 mph, instead of the true value of 3 mph.

Most often, we will not know values for base mean speed and coefficients beforehand, but must estimate these from a sample of individual vehicle speeds, y_i, i=1,..n, together with observations of the values for A_i and B_i associated with each sample vehicle's traversal. Let β_0 ,β_1, β_2 denote the now unknown base speed and coefficients. One common method for solving this estimation problem is to first form a sum of squares function

$$SS = [y_1-(\beta_0+\beta_1A_1+\beta_2B_1)]^2+[y_2-(\beta_0+\beta_1A_2+\beta_2B_2)]^2+\ldots+[y_n-(\beta_0+\beta_1A_n+\beta_2B_n)]^2 \qquad (4.2)$$

reflecting the degree to which the regression model predicts the observed speeds, and then selecting as estimates of β_0 ,β_1, β_2 those values that minimize the sum of squares. The resulting estimates are called ordinary least-squares (OLS) estimates. In addition to their intuitive plausibility, OLS estimates have two properties that make them attractive for applied work *[16]*.

First, given reasonably general conditions for how the random deviations e_i are distributed over the population of drivers, OLS estimates are what statistician's term consistent: as the sample size gets arbitrarily large, the probability an estimate deviates from the (unknown) true value becomes negligibly small. Second, for large sample sizes, the sampling distribution of the OLS estimates can be approximated with a normal distribution. This means that confidence intervals for the regression coefficients, or tests of hypotheses about the coefficients, can be constructed using relatively elementary statistics. Note that it is not necessary that the random deviations e_i follow a normal distribution for this approximation result to hold. Rather, this is an example of a Central Limit Theorem, where the distribution of an average converges to a normal distribution as the number of components in the average becomes large.

Generally, we will be interested in considering more than two predictor variables in our regression model, and may want these predictors to take on values other than 0 or 1. A general form for a linear regression model can be expressed as

$$y_i = \Sigma_j \beta_j x_{ij} + e_i \qquad (4.3)$$

where

- y_i = speed of driver number i traversing the road segment
- x_{ij} = value of measured feature j corresponding to the traversal of driver i
- β_j = coefficient reflecting the influence of predictor j on mean speed
- e_i = random error reflecting driver i's individual deviation from average

As indicated in Chapter 3, the vehicle speeds y_i were measured using portable pneumatic tube equipment, while values for relevant predictors were recorded by observers stationed unobtrusively in the playgrounds. The predictor variables divide into two groups, those that were common to two or more sites, and those that were specific to the individual sites. Table 4.1 summarizes the set of common predictors.

Table 4.1. Speed Predictors Common to More than One Site

Variable	Meaning	Values	Description
NP	No Parking	1 = No Parking occurring 0 = Parking observed	No cars on the street adjacent to the tubes
SLP	Stable Low Parking	Number of vehicles in street	Cars parked on roadway, but no bottleneck (i.e. cars parked on both sides)
SHP	Stable High Parking	Number of vehicles in street	Bottleneck condition where cars are parked on opposite side of street adjacent to tubes
UNS	Unstable	Number of vehicles in street	Condition with pedestrians in roadway, u-turns, slow parking and pulling out, characteristic of periods immediately before and after scheduled activities
NO DATA		1=No Data, 0=Data	No data collected, usually due to data collector being on break
NO ACT	No Activity	1=No Activity, 0=Activity	No activity in park was recorded during single vehicular trip
ROW	Right of Way	Number of peds/bicycles in ROW	Accounts for pedestrian/bicyclist activity on sidewalks or in street
ALL		Number of people traversing entire park	Activity that spreads to all areas of the park; typically lawn mowers fall into this category
BA	Before/After code	0 = before OHPW sign , 1 = after OHPW sign	
Dir	Direction of veh.	0= SB, 1 = NB	

Before proceeding to the analyses for the three study sites, a caution about interpreting the regression results is in order. For observational data such as that collected in this study, the fitted regression models give useful summaries of how model variables are associated, and can be used to predict the speed of a vehicle traversing that particular site, under conditions similar to those operating when the data were collected. Because it may be possible that other, unobserved, factors may also have been affecting vehicle speeds, the regression models should not be used to predict speeds at other sites, or even at these study sites at times other than those when the data were collected.

ANALYSES FOR COLORADO AVENUE SOUTH STUDY SITE

The before/after study at the Colorado Avenue site was conducted during Fall 2009. (See Chapter 3 for a description of the study site). The before sign installation vehicle speed data were collected from approximately 10:45 AM on Tuesday, September 29, 2009 to 8:35 AM on Saturday, October 3, 2009. Field personnel were present to collect on-street parking and park/playground/right-of-way activity information from 12:15 PM on Tuesday, September 29, 2009 until 7:00 PM on Friday, October 2, 2009. Only those vehicle speeds collected while the field personnel were present are used in this analysis. No on-street parking was allowed along this portion of Colorado Avenue South when these data were collected, and the park is immediately adjacent to an elementary school playground. Activities in both these areas occurred throughout the day. Activity data were collected until 7:00 PM each day.

A pair of OHPW signs were installed at the study site on Tuesday, October 27, 2009 and the after sign installation vehicle speed, on-street parking, and playground/park/right-of-way activity data collection was completed the following week (to avoid the impending start of winter). Vehicle speed data for this portion of the study were collected from approximately 10:30 AM on Tuesday, November 3, 2009 to approximately 9:10 AM on Saturday, November 7, 2009. However, on-street parking and park/playground/right-of-way activity data were collected from 11:00 AM on Tuesday, November 3, 2009 to 7:00 PM on Friday, November 6, 2009. Activity data were, again, collected until approximately 7:00 PM each day during the "after" time period. In addition to general predictors listed in Table 4.1, activity levels at different locations within the park and schoolyard were also collected, as listed in Table 4.2. Table 4.3 presents some summary measures for the predictor variables measured at the Colorado Avenue South site.

Table 4.2. Activity Level Variables Measured at Colorado Avenue Site

Variable	Meaning	Values	Location
BB1	Baseball Field 1	Number of people in BB1	See Figure A-2
BB2	Baseball Field 2	Number of people in BB2	"
BB3	Baseball Field 3	Number of people in BB3	"
SOC	Soccer Field	Number of people in soccer field	"
TEN	Tennis Courts	Number of people in tennis courts	"
NBA	Basketball Courts	Number of people in basketball courts	"
NHL	Hockey Rink	Number of people in hockey rink	"
NFL	Football Field	Number of people in football field	"
PG	Playground	Number of people in playground	"
REC	Recess Area	Number of people in recess area	"
SOUTH	Open field on south side of park	Number of people in south park	"

Table 4.3. Summary Measures for Predictors at Colorado Avenue South

Variable	Mean	Median	St. Dev.	Minimum	Maximum
BB1	0.00059	0	0.02437	0	1
BB2	0.4757	0	2.5707	0	30
BB3	0.01425	0	0.25056	0	5
SOC	0.0683	0	0.5628	0	15
TEN	0.1116	0	0.747	0	10
NBA	0.1253	0	1.4046	0	20
NHL	0.0261	0	0.3814	0	10
NFL	0.3581	0	2.4301	0	18
PG	0.4418	0	1.9024	0	16
REC	4.251	0	10.493	0	70
SOUTH	0.4935	0	2.5361	0	26
ROW	0.3554	0	1.1111	0	9
ALL	0.3376	0	2.71	0	26
NP	1	1	0	1	1

Regression Analysis Results

For both the before and after periods, data preparation and reduction began by downloading the individual speeds, together with their time and date stamps, into a spreadsheet with each individual speed taking up one row. Additional columns were created, one for each of the observed predictor variables. The project's research assistants then entered the appropriate values for each predictor and each speed from the observers' field data sheets. The before and after spreadsheets were loaded into the statistical analysis software Minitab, with the before period columns stacked above the corresponding after period columns. An additional column was constructed with the value of 0 assigned to before period speeds, and 1 for those speeds observed during the after period. Speeds corresponding to the "No Data" periods were coded as missing. Minitab's data analysis features were then used to summarize the data and develop the linear regression models. Figure 4.1 shows a sequential plot of Colorado site speeds, while Figure 4.2 is a histogram displaying the frequency distribution of the Colorado site speeds.

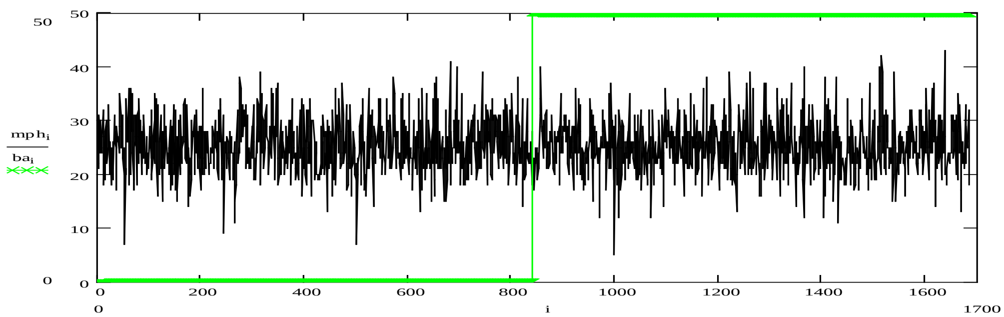

Figure 4.1. Sequential Plot of Speed Measurements from Colorado Site ('After' Period Begins at Position = 839)

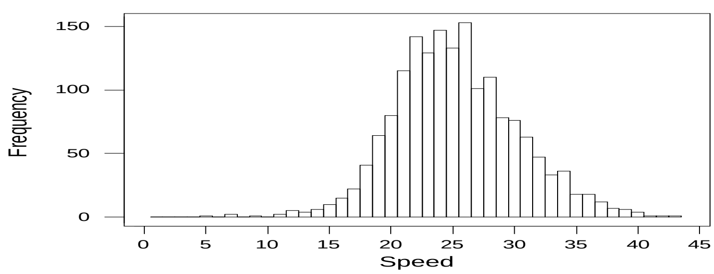

Figure 4.2. Histogram of Speed Measurements from Colorado Site, Before and After Data Combined

Using all available variables as predictors, an initial regression model was fit using Minitab's linear regression routine, and the results of this fitting are displayed in Table 4.4. Note that at the Colorado Avenue site (the initial study site), values for the variables NP, SLP, SHP, and UNS, reflecting parking activity in street, were not used; parking was not permitted. The 'Predictor' column in Table 4.4 gives the name of the predictor variable, with 'Constant' standing for the overall average. The 'Coef' column gives the estimated regression coefficient while the 'SE Coef' column gives the standard error of estimates for the coefficients. The 'T' column displays Student's T statistics testing the hypotheses that the corresponding coefficients equal zero, i.e. that the predictor makes no significant contribution to model's ability to predict speeds. The 'P' column gives the p-value for the test. For example, the predictor 'Dir' which contained the value 0 for southbound vehicles and 1 for northbound vehicles, had an estimated coefficient on -1.83, indicating that northbound vehicles traveled, on average about 1.8 mph slower than the southbound vehicles. Regarding the hypothesis of no difference between northbound and southbound traffic, the probability that this effect was due to chance is less than 1 in 1000, indicating that this difference was reliably present in the data. On the other hand, the estimated coefficient predictor BB1, reflecting activity in baseball field 1, was 1.765. When the true value of this coefficient is 0 one could expect an estimate this large over 70% of the time so this coefficient is not significantly different from zero. Using a liberal significance level of about 20%, only the constant term and the predictors Dir, Rec, and BB2 appear to have significant associations with the vehicle speeds. A restricted model with these predictors plus the before-after code BA was then estimated, and the results of this are displayed in Table 4.5.

Table 4.4. Regression Results Using All Predictors: Colorado Site

```
The regression equation is
Speed = 26.0 - 1.83 Dir + 1.77 BB1 + 0.103 BB2 - 0.126 BB3
           + 0.115 SOC - 0.145 TEN - 0.0586 NBA - 0.149 NHL + 0.0171 NFL
           + 0.0512 PG + 0.0159 REC - 0.0276 SOUTH - 0.066 ROW - 0.076 BA

1680 cases used 4 cases contain missing values
```

Predictor	Coef	SE Coef	T	P
Constant	25.9919	0.2130	122.01	0.000
Dir	-1.8344	0.2424	-7.57	0.000
BB1	1.765	4.905	0.36	0.719
BB2	0.10279	0.06390	1.61	0.108
BB3	-0.1262	0.4800	-0.26	0.793
SOC	0.1150	0.2139	0.54	0.591
TEN	-0.1450	0.1650	-0.88	0.380
NBA	-0.05857	0.08935	-0.66	0.512
NHL	-0.1488	0.3190	-0.47	0.641
NFL	0.01708	0.05042	0.34	0.735
PG	0.05123	0.06422	0.80	0.425
REC	0.01593	0.01281	1.24	0.214
SOUTH	-0.02759	0.06501	-0.42	0.671
ROW	-0.0660	0.1100	-0.60	0.548
BA	-0.0756	0.2469	-0.31	0.760

```
S = 4.896       R-Sq = 3.8%      R-Sq(adj) = 3.0%
```

In Table 4.5 the estimated constant term, 25.99 mph, corresponds to a base mean speed, for southbound vehicles, before the OHPW sign was installed, and when there was no activity at BB2 or REC. Northbound vehicles were on average about 1.8 mph slower than southbound vehicles, while activity at BB2 and REC were associated with small increases in mean speed. The coefficient associated with the predictor BA, reflecting a difference in mean speed after installation of the OHPW sign, was -0.0759. A test of the hypothesis that the true value was equal to zero yielded a T statistic of -0.32 and p-vale of 0.75. Thus at this site the installation of the OHPW sign had no discernible effect on mean vehicle speeds.

Table 4.5. Final Regression Model with 'Significant' Predictors Only: Colorado Site

```
The regression equation is
Speed = 26.0 - 1.83 Dir + 0.0883 BB2 + 0.0122 REC
           - 0.076 BA
```

Predictor	Coef	SE Coef	T	P
Constant	25.9913	0.2034	127.79	0.000
Dir	-1.8344	0.2403	-7.64	0.000
BB2	0.08832	0.04809	1.84	0.066
REC	0.01223	0.01176	1.04	0.299
BA	**-0.0759**	**0.2385**	**-0.32**	**0.750**

```
S = 4.883       R-Sq = 3.7%      R-Sq (adj) = 3.5%
```

ANALYSES FOR CHICAGO AVENUE SOUTH STUDY SITE

At the Chicago Avenue South study site, the before sign installation vehicle speed data were collected from approximately 9:00 AM Monday, May 17, 2010 to approximately 9:00 AM on Friday, May 21, 2010. On-street parking and park and/or right-of-way activity data were collected from 7:00 AM on Tuesday, May 18, 2010 to 8:30 PM on Thursday, May 20, 2010. In general, most but not all of the on-street parking and park and/or right-of-way activity at this study site occurred in the evening. It was possible to have as many as four baseball games or practices occurring at the same time at this study site, or multiple games or practices on the same baseball diamond at different times during one evening.

A pair of OHPW signs were installed at this study site on Wednesday, June 16, 2010 and the after sign installation data collection was completed approximately a month later. Specifically, the “after” vehicle speed data were collected from approximately 11:30 AM on Monday, July 19, 2010 to approximately 12:15 PM on Friday, July 23, 2010. The on-street parking and park/right-of-way activity data were collected by field personnel from approximately 7:00 AM on Tuesday, July 20, 2010 to 8:30 PM on Thursday, July 22, 2010. Each day the data were collected from 7:00 AM to 8:00 AM until approximately 8:30 PM. Only the vehicle speed data collected while the field personnel were present at the study site are used in this research.

The data collection and reduction procedures used for the Chicago Avenue South study site were similar to those previously described for the Colorado Avenue South site. However, data for the variables NP, SLP, SHP, and UNS, reflecting various levels of on-street parking activity were also available. The magnitude of the activity levels within five different areas of the adjacent park were also recorded, as indicated in Table 4.6, while Table 4.7 summarizes the predictor variables measured at the Chicago Avenue South site.

Table 4.6. Park Activity Level Variables Measured at Chicago Avenue South Study Site

Variable	Meaning	Values	Location
B	Zone B of park	Number of people in Zone B	see Figure A-3
C	Zone C of park	Number of people in Zone C	“
D	Zone D of park	Number of people in Zone D	“
E	Zone E of park	Number of people in Zone E	“
F	Zone F of park	Number of people in Zone F	“

Table 4.7. Summary Measures for Predictors at Chicago Avenue South

Variable	Mean	Median	St.Dev.	Minimum	Maximum
B	2.246	0	5.304	0	28
C	19.918	6	22.802	0	70
D	4.543	0	10.315	0	45
E	15.877	0	20.736	0	55
F	8.928	0	14.432	0	60
ROW	0.06065	0	0.31578	0	4
NP	0.24309	0	0.42905	0	1
SLP	0.5124	0	1.3125	0	17
SHP	14.321	0	21.333	0	73
UNS	5.213	0	15.139	0	73

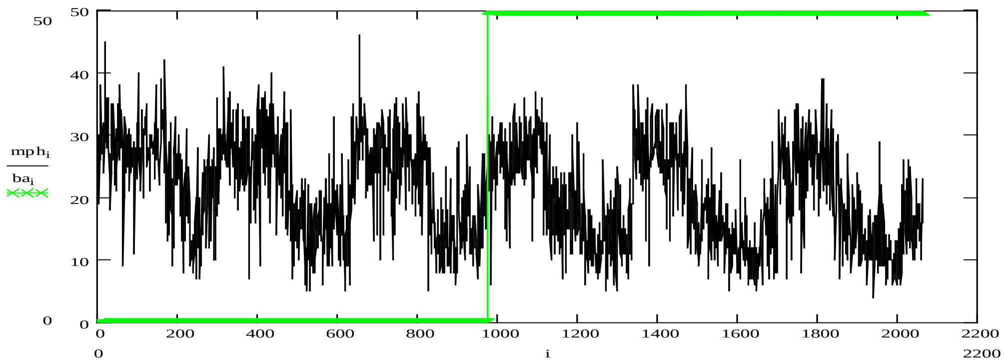

Figure 4.3. Sequential Plot of Vehicle Speed Measurements from the Chicago Avenue South Study Site ('After' Period Begins at Position = 974)

Figure 4.3 shows a sequential plot of observed speeds at the Chicago Avenue South study site, while Figure 4.4 displays the frequency distribution for these speeds, with before and after data combined. The sequential plot in Figure 4.3 shows an interesting cyclical pattern for the speeds, roughly corresponding to periods of high versus low activity in the adjacent park and the associated parking activity in the street. This pattern is reinforced by the histogram in Figure 4.4, which suggests that the speeds are generated by a mixture of two different, underlying distributions.

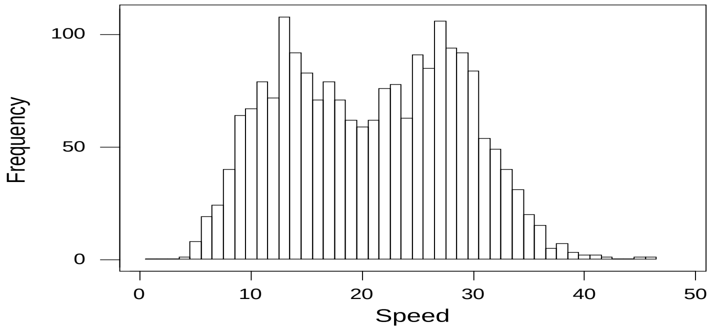

Figure 4.4. Histogram of Speed Measurements from Chicago Avenue South Study Site, Before and After Data Combined

Regression Analysis Results

As for the Colorado Avenue site, an initial regression model was fit using all available predictors, and the results of this are shown in Table 4.8. Predictors whose contribution was deemed non-significant were then removed and the regression model re-estimated. These results are shown in Table 4.9.

Table 4.8. Initial Regression Model with All Predictors: Chicago Avenue South Study Site

```
The regression equation is
Speed = 25.0 + 0.0987 B - 0.121 C - 0.0754 D + 0.0051 E + 0.0421 F
           - 1.53 BA - 0.773 ROW + 2.78 NP + 0.098 SLP - 0.0965 SHP
           - 0.145 UNS + 0.239 Dir
```

Predictor	Coef	SE Coef	T	P
Constant	25.0056	0.3157	79.21	0.000
B	0.09866	0.03399	2.90	0.004
C	-0.12081	0.01761	-6.86	0.000
D	-0.07542	0.01679	-4.49	0.000
E	0.00505	0.01622	0.31	0.755
F	0.04207	0.01457	2.89	0.004
BA	-1.5253	0.2961	-5.15	0.000
ROW	-0.7730	0.3914	-1.97	0.048
NP	2.7778	0.4024	6.90	0.000
SLP	0.0975	0.1170	0.83	0.405
SHP	-0.09645	0.02576	-3.74	0.000
UNS	-0.14499	0.02631	-5.51	0.000
Dir	0.2389	0.2460	0.97	0.332

S = 5.575 R-Sq = 51.1% R-Sq (adj) = 50.8%

Table 4.9. Final Regression Model: 'Significant' Predictors Only: Chicago Avenue South Study Site

```
The regression equation is
Speed = 25.3 - 1.53 BA + 0.106 B - 0.118 C - 0.0774 D + 0.0443 F- 0.786 ROW + 2.64 NP
- 0.0997 SHP - 0.149 UNS
```

Predictor	Coef	SE Coef	T	P
Constant	25.2730	0.2330	108.46	0.000
BA	**-1.5314**	**0.2925**	**-5.24**	**0.000**
B	0.10600	0.03307	3.21	0.001
C	-0.11798	0.01726	-6.84	0.000
D	-0.07745	0.01574	-4.92	0.000
F	0.04428	0.01438	3.08	0.002
ROW	-0.7857	0.3909	-2.01	0.045
NP	2.6386	0.3544	7.45	0.000
SHP	-0.09966	0.02095	-4.76	0.000
UNS	-0.14871	0.02224	-6.69	0.000

```
S = 5.574       R-Sq = 51.0%     R-Sq(adj) = 50.8%
```

The base mean speed on Chicago Avenue South was about 25.3 mph, and when no parking was present on Chicago Avenue speeds were on average about 2.6 mph higher. Activity in the right of way (ROW), stable high parking (SHP), and unstable (UNS) conditions were all associated with reductions in average speeds. More importantly, speeds were, on average, about 1.5 mph slower after the OHPW signs were installed, and this difference is highly statistically significant. Whether or not this reduction has practical significance, however, is less clear.

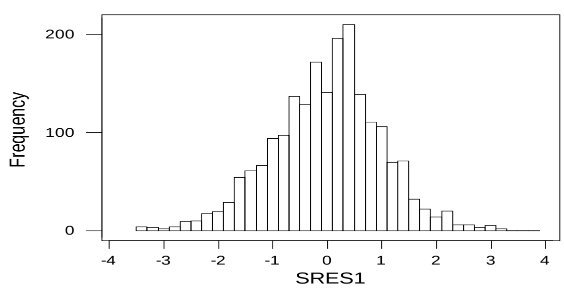

Figure 4.5. Histogram for Final Regression Model's Residuals: Chicago Avenue South Study Site

Figure 4.5 shows a frequency distribution of the regression residuals from the final model, obtained by first using the fitted regression model to predict each observed speed and then subtracting this predicted speed from the corresponding observed speed. The residuals can be interpreted as estimates of the random individual terms e_i, and can be used to investigate whether the bimodal nature of the speeds is due to systematic differences captured by the regression model or due to inherent differences in the driver population. The unimodal shape of the histogram in Figure 4.5 indicates that the bimodal pattern observed in the original speed data is primarily due to differences in activity levels captured by the regression model.

ANALYSES FOR COLUMBUS AVENUE SOUTH STUDY SITE

The before OHPW sign installation vehicle speed data were collected at the Columbus Avenue South study site from approximately 10:05 AM Monday, May 24, 2010 to approximately 10:10 AM on Friday, May 28, 2010. On-street parking and park/right-of-way activity data were collected from 7:00 AM on Tuesday, May 25, 2010 to 8:30 PM on Thursday, May 27, 2010. This site generally experienced some on-street parking, or park and/or right-of-way activity throughout the day, but these activities peaked during the evening hours. Depending on the weekday, one or two baseball games or practices could occur in the park and multiple games or practices could occur on the same baseball diamond at different times during one evening.

A pair of OHPW signs were installed at this study site on Wednesday, June 16, 2010 and the after sign installation data collection was completed approximately one month later, from approximately 8:00 AM on Monday, July 12, 2010 to approximately 12:00 PM on Friday, July 16, 2010. The on-street parking and park/right-of-way activity data were collected by field personnel from approximately 8:00 AM on Tuesday, July 13, 2010 to 8:30 PM on Thursday, July 15, 2010. Each day these data were collected from 7:00 AM to 8:00 AM until approximately 8:30 PM. It should be noted again that the only vehicle speed data used in this research were those collected while the field personnel were present at the study site. Table 4.10 lists the activity variables measured at the Colorado Avenue South site, while Table 4.11 summarizes that site's predictor variables.

Table 4.10. Activity Level Variables Observed at Columbus Avenue South Study Site.

Variables	Meaning	Values	Location
B1	Baseball Field 1	Number of people in BB1	See Figure A-4
B2	Baseball Field 2	Number of people in BB2	"
PIC	Picnic Area	Number of people in picnic area	"
PG	Playground	Number of people in playground	"
NBA	Basketball Court	Number of people in basketball court	"
TRAIL	Trail traversing west/east through park	Number of people on trail	"

Table 4.11. Summary Measures for Predictors at Columbus Avenue South

Variable	Mean	Median	St. Dev.	Minimum	Maximum
B1	2.54	0	8.834	0	60
B2	2.563	0	10.19	0	50
PIC	0.0778	0	0.5118	0	13
PG	1.7198	0	2.9905	0	17
NBA	0.03025	0	0.26939	0	4
TRAIL	0.00648	0	0.11369	0	3
ROW	0.07346	0	0.37818	0	5
SLP	2.5621	3	2.3724	0	15
SHP	3.517	0	8.025	0	44
UNS	0.7195	0	4.1413	0	37

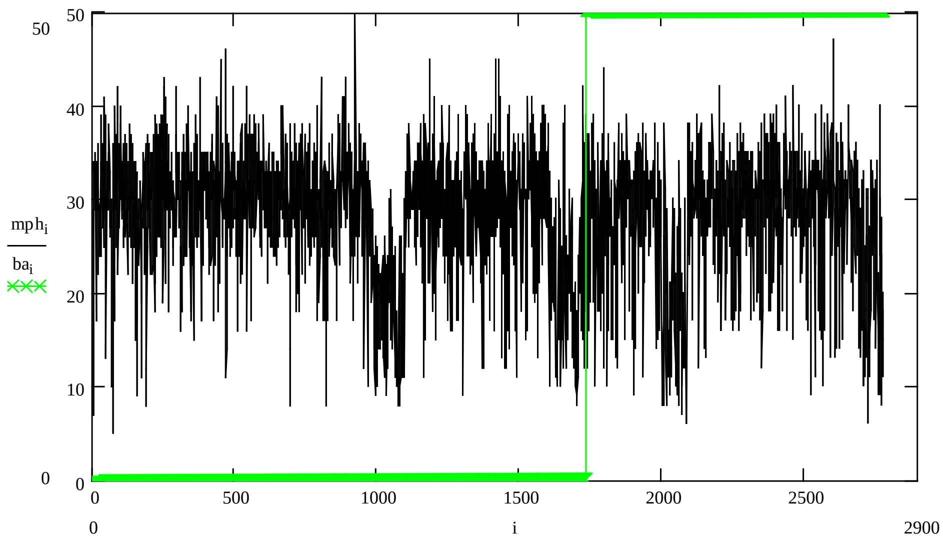

Figure 4.6. Sequential Plot of Vehicle Speed Measurements: Columbus Avenue South Study Site. 'After' Period Begins at Index=1731

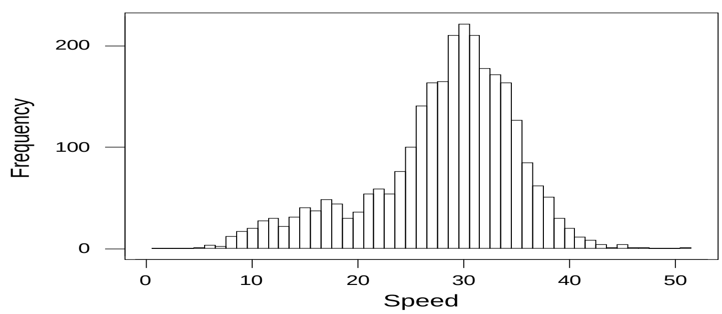

Figure 4.7. Histogram of Vehicle Speed Measurements: Columbus Avenue South Study Site. Before and After Data Combined

Regression Analysis Results

Figure 4.6 shows a sequential plot of the individual vehicle speeds observed at the Columbus Avenue South study site, while Figure 4.7 shows the frequency distribution of the combined vehicle speeds collected before and after installation of OHPW signs. Overall, the vehicle speed pattern at the Columbus Avenue South study site seems to be intermediate between the essentially homogeneous situation seen on Colorado Avenue and the clearly cyclical pattern seen on Chicago Avenue South study site. Table 4.12 shows results from fitting a linear regression model with all available predictors, while Table 4.13 shows results from fitting a reduced model containing only statistically significant predictors.

Table 4.12. Initial Regression Model with All Predictors: Columbus Avenue South Study Site

```
The regression equation is
Speed = 30.8 - 1.41 Dir - 0.0617 B1 + 0.0078 B2 - 0.484 PIC
           - 0.218 PG - 0.642 NBA + 0.76 TRAIL - 0.891 BA - 0.405 ROW
           + 0.0211 SLP - 0.236 SHP - 0.465 UNS
```

Predictor	Coef	SE Coef	T	P
Constant	30.7673	0.2894	106.33	0.000
Dir	-1.4110	0.2309	-6.11	0.000
B1	-0.06170	0.02445	-2.52	0.012
B2	0.00779	0.02604	0.30	0.765
PIC	-0.4838	0.2269	-2.13	0.033
PG	-0.21830	0.04901	-4.45	0.000
NBA	-0.6417	0.4290	-1.50	0.135
TRAIL	0.757	1.010	0.75	0.454
BA	-0.8909	0.2640	-3.37	0.001
ROW	-0.4055	0.3082	-1.32	0.188
SLP	0.02106	0.06526	0.32	0.747
SHP	-0.23641	0.04532	-5.22	0.000
UNS	-0.46546	0.05023	-9.27	0.000

```
S = 6.042       R-Sq = 24.7%     R-Sq(adj) = 24.4%
```

Table 4.13. Final Regression Model: 'Significant' Predictors Only, Columbus Avenue South Study Site

```
The regression equation is
Speed = 30.8 - 0.904 BA - 0.0655 B1 - 0.490 PIC - 0.219 PG - 0.632 NBA
           - 0.421 ROW - 0.230 SHP - 0.459 UNS - 1.41 Dir
```

Predictor	Coef	SE Coef	T	P
Constant	30.8362	0.2038	151.32	0.000
BA	**-0.9043**	**0.2512**	**-3.60**	**0.000**
B1	-0.06550	0.01805	-3.63	0.000
PIC	-0.4898	0.2266	-2.16	0.031
PG	-0.21863	0.04895	-4.47	0.000
NBA	-0.6318	0.4276	-1.48	0.140
ROW	-0.4212	0.3072	-1.37	0.170
SHP	-0.23013	0.02067	-11.13	0.000
UNS	-0.45913	0.03352	-13.70	0.000
Dir	-1.4111	0.2306	-6.12	0.000

```
S = 6.040       R-Sq = 24.7%     R-Sq(adj) = 24.5%
```

The results in Table 4.13 indicate that, on this street, the base mean speed was about 30.8 mph, with northbound vehicles traveling on average about 1.4 mph slower. Increased activity levels were generally associated with reductions in mean speed, while the speeds were on average about 0.9 mph slower after installation of the OHPW sign. This reduction was statistically significant. However, as with the Chicago Avenue South study site, it is less clear whether or not this difference has practical significance.

Finally, it may be of interest to look at what appears to be one important influence on speeds. Figure 4.3 indicated a cyclical pattern in the vehicle speeds at the Chicago Avenue South, and Figure 4.8 shows a similar plot of corresponding predicted vehicle speeds. These predicted mean speeds were computed using the regression model presented in Table 4.9.

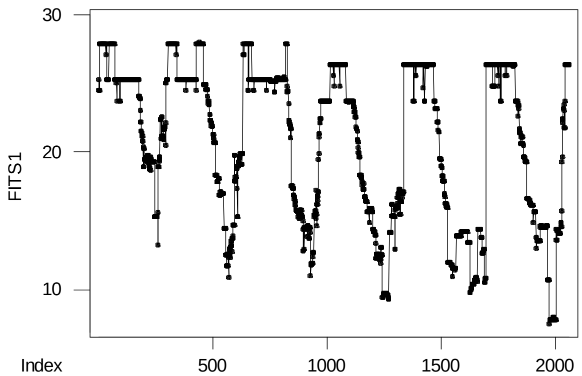

Figure 4.8. Time-Series Plot of Predicted Speeds, using Final Regression Model ('After' Period Begins at time=974)

Figure 4.8 shows the 1.5 mph reduction in speed following the installation of the OHPW signs at the Chicago Avenue study site. But, the figure also shows reductions of 10 to15 mph associated with the more intensive activities in the park. This variation in speed appears to be primarily due to the on-street parking activity related to these activities. Figure 4.9 is a boxplot of the vehicle speeds collected at the Chicago Avenue South study site with and without on-street parking activity. This boxplot shows that the range of vehicle speeds appears be similar in with and without on-street parking conditions, but that when on-street parking is present the median vehicle speed is about 9 mph lower than when there are no vehicles parked along the study site roadway. Also, when the on-street parking is present, 75 percent of the vehicle speeds are below about 25 mph and 25 percent below 12 to 13 mph.

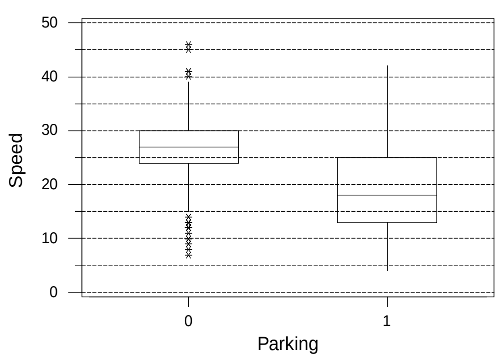

Figure 4.9. Boxplot Summarizing the Distribution of Vehicle Speeds without On-Street Parking (=0) and with On-Street Parking (=1) at the Chicago Avenue South Study Site

SUMMARY OF FINDINGS

This chapter summarized and analyzed the vehicle speed, on-street parking, and park/playground/ right-of-way activity data collected at the three study sites selected for this research project. The time periods of the data collection activities were described and it is important to note that data was collected at one study site in the fall (i.e., October and November) and the activities at the other two were completed in the spring and summer (i.e., May and July). Different time periods for the data collection can result in different levels of park/playground/right-of-way activities and their associated on-street parking. The vehicle speed data collected before and after the OHPW sign installation at the three study sites were summarized for various combinations of on-street parking and park/playground/right-of-way activities. The overall difference in the average vehicle speeds before and after the installation of the OHPW signs ranged 0.1 to 3.4 mph. These difference, however, are the result of the various factors that could potentially impact the choice of vehicle speeds by driver within the study site. Some of these factors, in addition to the OHPW signs, include the magnitude and/or location of the on-street parking and the activities are occurring in the park/playground/right-of-way. The potential impacts of these factors on the average vehicle speed within each study site were explored through a regression analysis. The estimated average vehicle speed impact defined by the regression analyses ranged from zero to 1.5 mph. The models also found that vehicle direction, activities in one or more areas within the parks/playground/right-of-way, and stable high impact and unstable parking situations influence the magnitude of the differences in average vehicle speed calculated at each study site. There are, of course, also a number of factors that could impact these vehicle speed results for which data could not be collected. These factors include, but are not limited to, weather, driver type and purpose, and the proportion of vehicle type in the traffic flow. The inability to measure and/or control for these factors is the reason more than one type of data analysis was completed as part of this project, but was also not unexpected when an observational study design was selected.

Chapter 5. Conclusions and Recommendations

The main objective of this study was to estimate the impact, if any, that the placement of OHPW signs might have on vehicle speeds. Three residential streets in Bloomington, Minnesota, were selected as study sites for a before-and-after study. Data were collected at each study site for at least three typical weekdays approximately one month before the installation of a pair of OHPW signs, and similar data were collected for three relatively comparable weekdays one week to one month after the installation. Individual vehicle speeds were measured and recorded using portable pneumatic tube equipment, and the magnitude and location of on-street parking and the activities in the park/playground/right-of-way were recorded manually by field personnel. Linear regression analysis was used to control for factors that could have affected the vehicle speeds at the study sites and could have been correlated with the absence or presence of the OHPW signs. Additional summary statistics and comparisons were then computed and are presented in Appendix B. The tasks completed as part of this study lead to the following conclusions and recommendations.

CONCLUSIONS

- OHPW signs are generally installed to raise the awareness of drivers to a hazard. These hazards can occur at specific locations or along a roadway segment. Hazards are “occasional” when they occur at varying times and/or locations. Examples of OHPW sign s include intersection ahead, playground, and deer crossing signs. The non-compliant “Children at Play” is also a OHPW sign.
- Very little research has been completed that evaluates the potential speed impact of traditional OHPW signs. In fact, no studies were found that focused on the vehicle speed impacts of the OHPW sign. Most of the OHPW sign studies that have been completed also assume the traditional OHPW sign is ineffective. This assumption may or may not be true. One analysis of ice warning signs concluded that their presence did not appear to impact the frequency or severity ice-related crashes. Other OHPW sign studies found that warning signs with more “attention value” (e.g., those with flashing lights, etc.) had greater vehicle speed impacts than traditional signs.
- The study sites considered in this research project had a relatively wide range of park/playground and/or right-of-way activities and on-street parking. These attributes were also different before and after the installation of the OHPW signs. This project collected descriptive data on these activities along with vehicle speeds. The changes in study site characteristics were likely the result of when the data were collected (e.g., there is more park/playground activity in summer than fall, etc.) and the physical attributes and traffic control at the study sites (i.e., what type of activities are allowed in the playground/park, does the roadway right-of-way have sidewalks, and is on-street parking available or allowed). Overall, the Colorado Avenue South study site had no on-street parking allowed and had lower levels of park/playground and right-of-way activity in comparison to the other two study sites. The Columbus Avenue South study site appeared to have intermediate levels of both on-street parking and park and/or right-of-way activities, and the Chicago Avenue South study site had that greatest amount of park activities and relatively high levels of on-street parking (particularly in the evening).

- Overall, a basic naïve comparison showed that the non-free-flow mean vehicle speeds after the installation of the OHPW signs was 0.1 to 3.4 mph smaller than the mean vehicle speed before the installation of the OHPW signs. These differences, however, are the result of a wide range of changes in the study site characteristics at all three locations (see above). Data were collected on many of these characteristics (e.g., vehicle direction, vehicle speed, park/playground/right-of-way activities, and on-street parking) and used in this research. However, there are also a number of factors that can impact vehicle speeds for which data could not be collected or analyzed (e.g., driver type, vehicle type, weather, etc.). This fact is inherent in observational study designs.
- A linear regression analysis approach was used to more specifically define the potential vehicle speed impacts related to the installation of OHPW signs and other factors at each study site. The results of these analyses indicated that the installation of the OHPW signs at the three study sites was associated with a reduction in non-free-flow mean vehicle speeds of 0, 0.9, and 1.5 mph, respectively. The mean vehicle speed differences attributed to the OHPW signs at two of the study was statistically significant at two of the study sites. Other significant predictors in the linear regression models were related to vehicle direction, various levels of on-street parking, and a range of park/playground and/or right-of-way activities at each study site. The vehicle speed impacts appear to be site specific and also related to the complexity of the data collection involved (e.g., the amount of on-street parking and park/playground/right-of-way activities).
- Some of the variability in the vehicle speed impact results from this project is likely due to the differences in study site characteristics and also the relative subjectivity of the on-street parking categorization completed by various field personnel.

RECOMMENDATIONS

- The results of this study should be used with caution. The practical significance of the change in mean vehicle speed that the study attributes to the installation of the OHPW signs should be considered on a case by case basis. The results found in this research project appear to be site specific and their applicability is limited to sites with similar characteristics. The results documented in this report should be used as one more input to the sign installation decision-making process.
- Along with the recommendation above it should be recognized that the objective of this type of warning sign is to raise the "attention" or "awareness" of the driver to a particular hazard. Vehicle speeds were used in this project as a surrogate measure for this type of change in behavior. Unfortunately, in some cases an increase in "awareness" may not be matched with a decrease in vehicle speed. Additional eye scanning could result without a change in mean vehicle speeds. The potential that these signs increase the "vigilance" of a driver should also be considered during the sign installation decision-making process.
- The OHPW sign is installed at specific location (i.e., a park) that has the appearance of an observable "hazard" location when activities do occur. It can be hypothesized that that warning signs with a less specific message or location-based installation guidance may have less of an impact on mean vehicle speeds than what was

discovered in this research. The “Children at Play” and deer crossing warning signs are two examples of these type of signs.

- No change is currently recommended to the language in the 2009 MUTCD based on the range of vehicle speed results produced by this research project. Engineering judgment should still be applied when considering the installation of these types of signs and the results of this research should be considered one factor in the decision-making process.
- It is recommended that additional research be completed that focuses on the potential vehicle speed impacts and “attention” value of traditional OHPW signs. The installation of signs that produce the impacts expected is an economically efficient approach and should improve traffic control communication with the traveling public. More specifically it is recommended that additional analysis be completed on the potential vehicle speed impacts related to the layout of parks (and the proximity to the roadway of their associated activities). More study sites with and without OHPW signs could also be evaluated to support or refute the results of this study. It is also suggested that the installation of OHPW signs on higher speed roadways, with more unfamiliar drivers, may produce different results and may be of interest to study. Finally, a second phase of this study was initially proposed and it is recommended that it be completed. Phase two of this project would include a vehicle speed and eye scanning evaluation of drivers and their reaction to traditional and enhanced OHPW signs in a simulator.

References

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Appendix A. Maps and Photographs of Study Sites

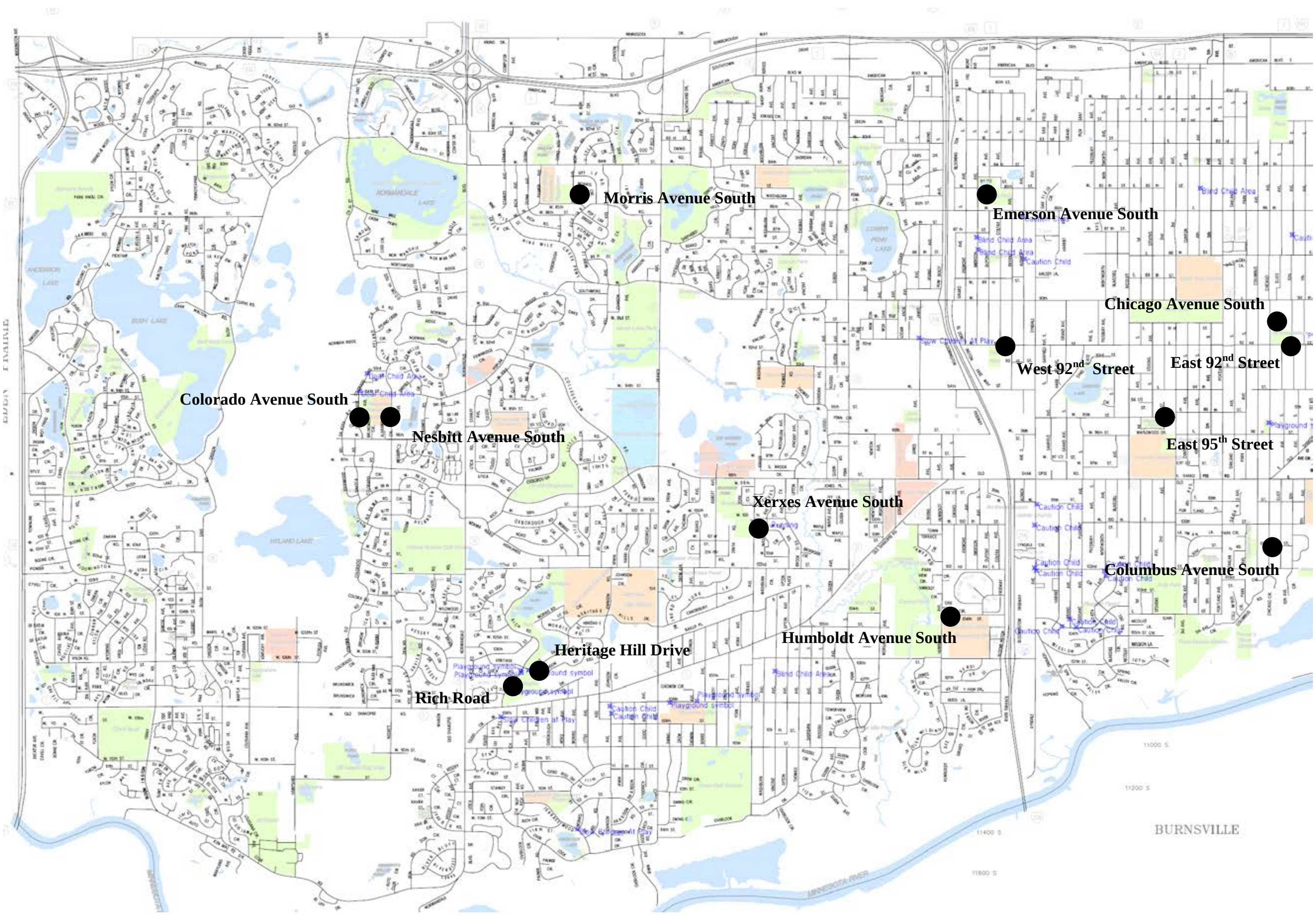

Figure A.1. City of Bloomington Candidate Study Site Locations (Map Provided by the City of Bloomington, MN, August 10, 2009)

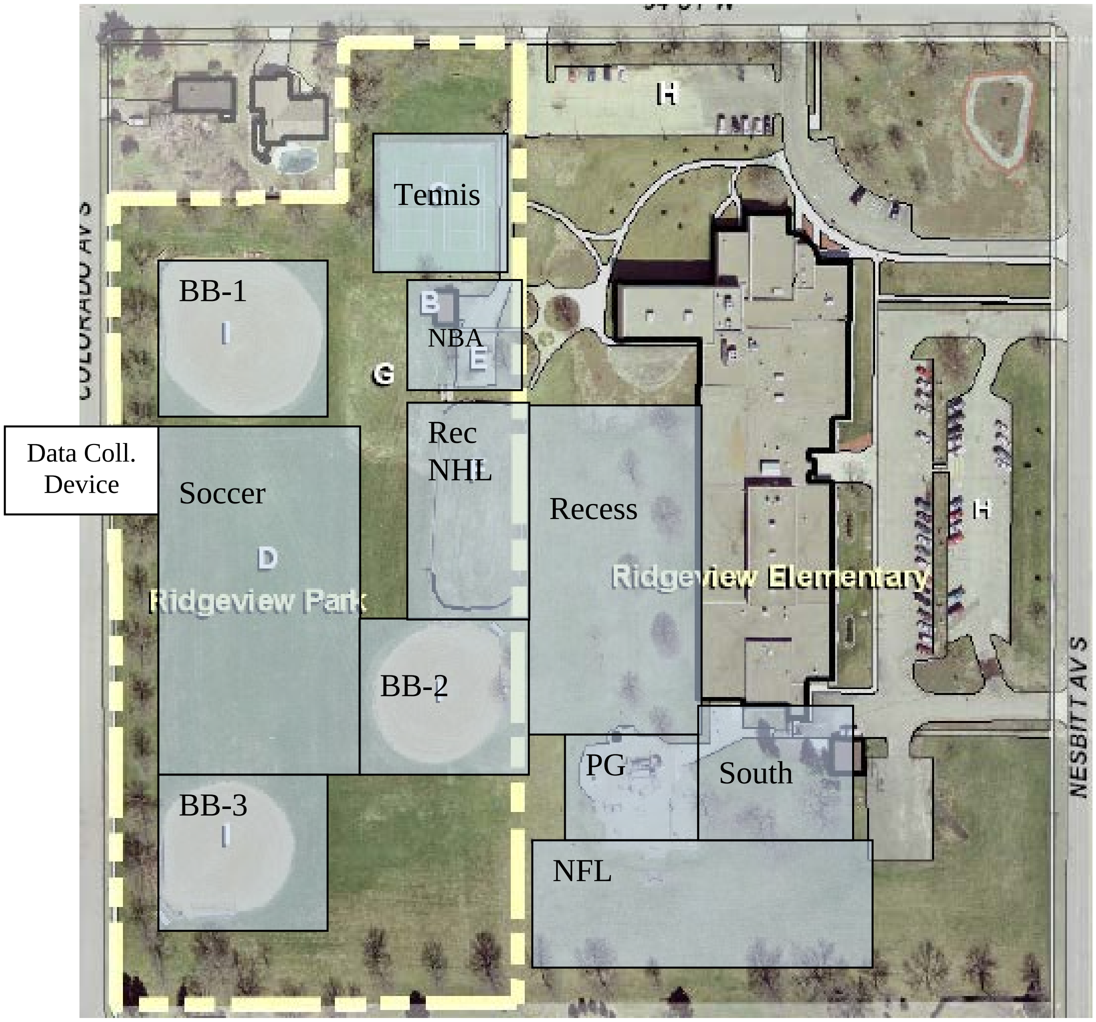

Figure A.2. Colorado Avenue South Study Site Layout [17]

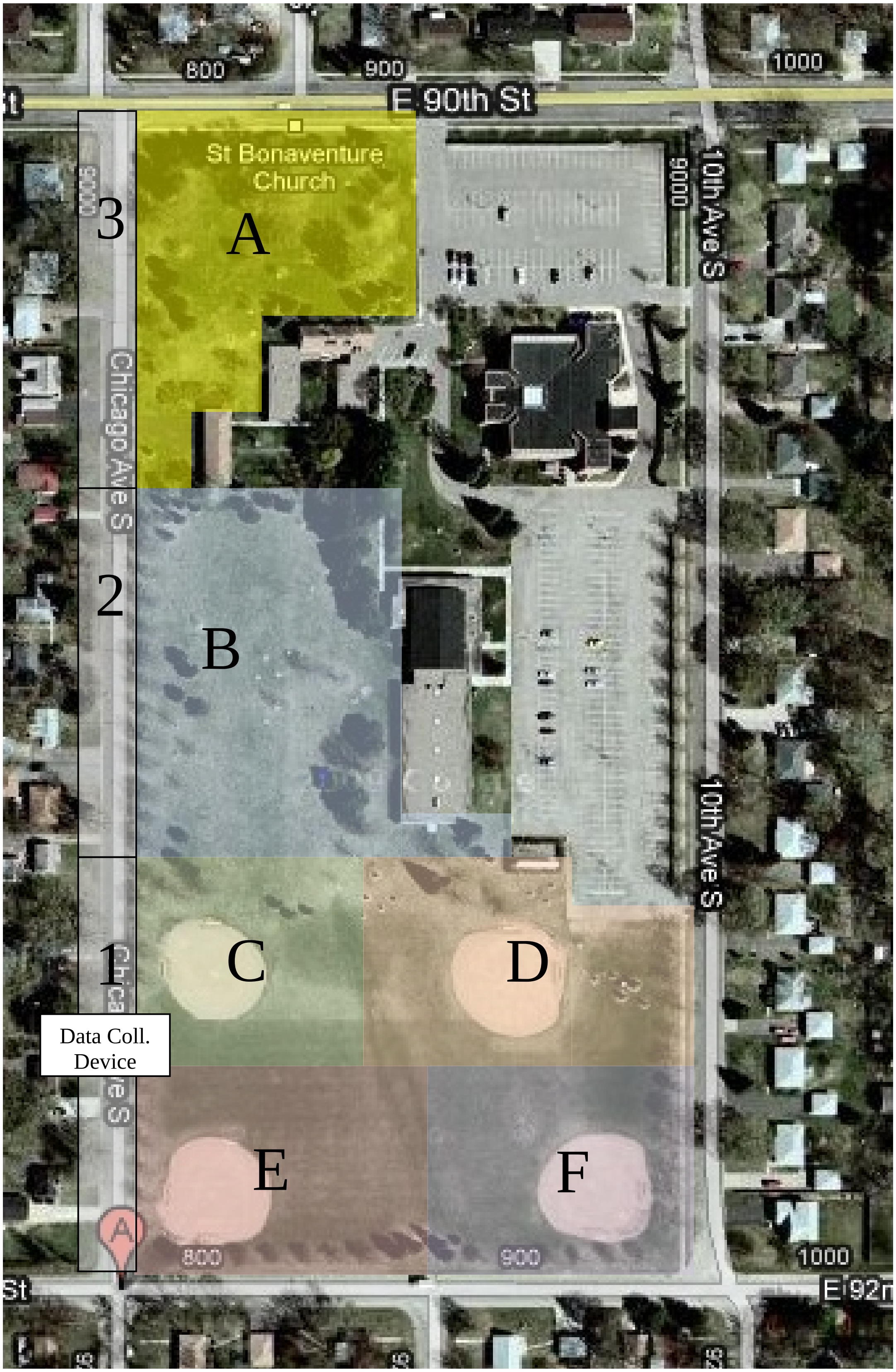

Figure A.3. Chicago Avenue South Study Site Layout [18]

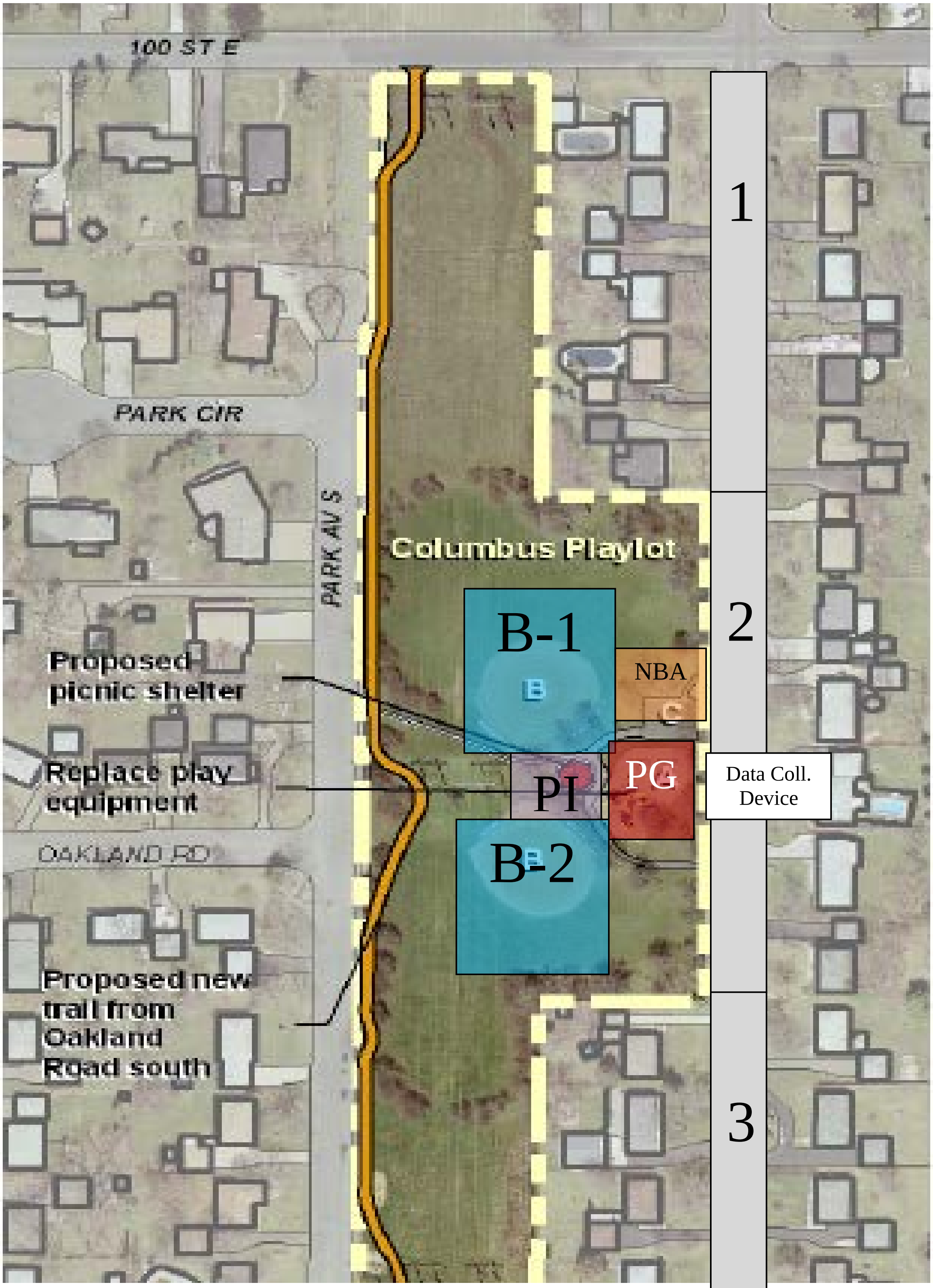

Figure A.4. Columbus Avenue South Study Site Layout [19]

Appendix B. Additional Analyses by Dr. Keith Knapp

In this Appendix, the vehicle speed data collected in the field are analyzed. Descriptive statistics of the vehicle speed data collected at each location are categorized, summarized, and more closely examined. First, summary and descriptive statistics are provided for the vehicle speeds collected during the entire data collection time period at each study site and during time periods with various combinations of on-street parking (i.e., none, stable low impact, and stable high impact) and park/playground and/or right-of-way activities. These descriptive statistics are provided for similar combinations before and after the installation of the OHPW signs at each study site. A naïve statistical comparison of the before-and-after average vehicle speeds for each combination is then completed and the results of these comparisons described. These naïve comparisons, however, are general in nature and can only partially define some of the reasons for the differences in mean vehicle speeds that may have been calculated.

As previously noted, the data collected at this study site (and the others) were summarized and analyzed using two methods. In this Appendix, a summary of the vehicle speed data from each study was completed and a naïve statistical comparison of the before-and-after OHPW sign installation mean vehicle speeds calculated for various combinations of on-street parking and park/playground activities applied. These naïve comparisons did not take into account many of the factors that may have produced the mean vehicle speed differences that were calculated (See Page 31 for more information about confounding factors). In Chapter 4, a linear regression analysis was applied and the potential mean vehicle speed impacts of the playground sign installation and other study site characteristics were more closely evaluated. This approach was used to more specifically differentiate the potential vehicle speed impacts of the OHPW sign from the potential impact of other study site factors. The results of both approaches are described below.

Colorado Avenue South Study Site

Summary statistics for the Colorado Avenue South data are provided in Tables B.1 and B.2. A total of 838 and 846 vehicle speeds, respectively, were collected before and after the OHPW signs were installed. Approximately 51 and 62 percent (n = 430 and 525) of the vehicle speeds before and after the OHPW sign installation, respectively, were collected when there was no activity within the park/playground and/or right-of-way. On the other hand, approximately 49 and 38 percent (n = 408 and 321) of the vehicle speeds (before and after the OHPW sign installation, respectively) were collected when children and/or adults were active within the study site in some manner. No on-street parking was allowed on Colorado Avenue South during the time period this data collection was completed.

Tables B.1 and B.2 include the number, minimum, maximum, mean, standard deviation, and 85th percentile vehicle speed summary statistics for the data collected before and after the OHPW sign installation at Colorado Avenue South. These statistics are provided for the overall vehicle speed database and also for those collected when park/playground/right-of-way activities were and were not occurring. The overall mean vehicle speed calculated for the before and after time periods were 25.3 miles per hour (mph) and 25.2 mph (a reduction of 0.1 mph), respectively. The 85th percentile speed during the before and after time periods, on the other hand, were 30.2 and 29.7 mph (a reduction of 0.5 mph), respectively. The variability in the vehicle speed data is shown by overall standard deviations that range from 4.9 to 5.0 mph. These three descriptive statistics for the time periods with and without parking/playground/right-of-way activities were similar to those noted above and ranged from 25.2 to 25.4 mph, 30.1 to 30.2 mph, and 5.0 to 5.1 mph, respectively, in the before time period, and 25.0 to 25.5 mph, 29.3 to 30.3 mph, and 4.7 to 5.2 mph, respectively, in the after time period.

Table B.3 contains the mean vehicle speed differences calculated for various situations before and after the installation of the OHPW signs. The results from a naïve statistical analysis of these differences are also shown. The information in Table B.3 (along with the general summary statistics in Tables B.1 and B.2) was used to complete an initial investigation of some of the factors that may have resulted in any changes to the mean vehicle speeds at the study site. First, the difference in the mean vehicle speeds within the before and after time periods with and without park/playground/right-of-way activities were compared (See Table B.3). These comparisons were completed to more closely consider the potential impact the activities in the park/playground/right-of-way may have on mean vehicle speeds. However, no statistically significant difference was found in the mean vehicle speeds before and after the OHPW sign installation. In fact, the difference in the mean vehicle speeds was no larger than 0.5 mph and the mean vehicle speeds calculated during the time periods without park/playground/right-of-way activities were unexpectedly lower than those collected when activities were occurring. The reason for this particular result is unknown. Similar statistical results were also found when the mean vehicle speeds from before and after the sign installation were compared. No statistical difference in the mean vehicle speeds was discovered overall or for the time periods with and without park/playground/right-of-way activities. Therefore, at this particular study site the park/playground/right-of-way activities and the OHPW signs appear to have had little, if any, impact on vehicle speeds.

Table B.1. Bidirectional Colorado Avenue South Vehicle Speed Descriptive Statistics – Before OHPW Sign Installation

Vehicle Speed Statistic	Overall	With Activities[1]	Without Activities[1]
Number	838	408 (49%)	430 (51%)
Minimum (mph)	7	7	7
Maximum (mph)	41	39	41
Mean (mph)	25.3	25.4	25.2
Standard Deviation (mph)	5.0	5.1	5.0
85^{th} Percentile (mph)	30.2	30.2	30.1

[1]Park, playground, and/or right-of-way activities are defined in Chapter 3.

Table B.2. Bidirectional Colorado Avenue South Vehicle Speed Descriptive Statistics – After OHPW Sign Installation

Vehicle Speed Statistic	Overall	With Activities[1]	Without Activities[1]
Number	846	321 (38%)	525 (62%)
Minimum (mph)	5	12	5
Maximum (mph)	43	42	43
Mean (mph)	25.2	25.5	25.0
Standard Deviation (mph)	4.9	5.2	4.7
85^{th} Percentile (mph)	29.7	30.3	29.3

[1]Park, playground, and/or right-of-way activities are defined in Chapter 3.

Table B.3. Select Naïve Mean Vehicle Speed Comparisons: Colorado Avenue South

Comparison	Difference in Mean Vehicle Speeds (mph)	Statistically Significant?[1]
Before OHPW Sign Time Period		
With and Without Park, Playground, and/or Right-of-way Activities[2]	-0.2	No
After OHPW Sign Time Period		
With and Without Park, Playground, and/or Right-of-way Activities[2]	-0.5	No
Before to After OHPW Sign Time Periods		
Overall[3]	-0.1	No
With Park, Playground, and/or Right-of-way Activities[3]	+0.1	No
Without Park, Playground, and/or Right-of-way Activities[3]	-0.2	No

[1]A standard T-test was completed to determine the statistical significance of the difference (to a 95^{th} percentile level of confidence) between the mean vehicle speeds calculated. The vehicle speed data was assumed to be normally distributed for the application of this test.
[2]Difference = mean vehicle speed without minus mean vehicle speed with park, playground, and/or right-of-way activities during the time period indicated (from Tables 4.5 and 4.6).

[3]Difference = mean vehicle speed during the after time period minus mean vehicle speed during the before time period (from Tables 4.5 and 4.6)

Chicago Avenue South Study Site

Vehicle speed summary statistics for the data collected at the Chicago Avenue South study site are provided in Table B.4. These statistics, however, exclude those vehicle speeds collected during the time periods of "unstable" on-street parking conditions. The vehicle speed data collected during these time periods are influenced by a wide range of activities for which data could not be collected. Overall, a total of 842 and 961 vehicle speeds, respectively, were collected before and after the OHPW signs were installed at this site. Approximately 54 and 42 percent (n = 455 and 405) of these vehicle speeds, before and after the OHPW sign installation, respectively, were collected when there was no activity within the park or right-of-way. These "no activity" data were collected when there was either no on-street parking or stable low impact on-street parking within the study site. More specifically, approximately 34 and 76 percent (n = 153 and 309) of the vehicle speeds collected before and after the warning sign installation, respectively, were recorded when no on-street parking was observed. The remainder of vehicle speeds (i.e., 66 and 24 percent (n = 302 and 96)) were acquired during stable low impact on-street parking time periods. Clearly, a larger proportion of the vehicle speeds collected after the OHPW sign installation had no parking on the street when there were no activities occurring within the park and/or right-of-way. Overall, on average, approximately 2 vehicles were parked on the street during the stable low impact parking time periods before the OHPW sign installation and only one vehicle after the sign installation.

The vehicle speed data collected at the Chicago Avenue South study site when park and/or right-of-way activities were occurring are also summarized in Table B.4. Approximately 46 and 58 percent (n = 387 and 556) of the vehicle speeds collected before and after the OHPW sign installation, respectively, were recorded when activities were occurring within the park or right-of-way. These data were also collected when there was either no, stable low impact, or stable high impact on-street parking at the study site. Specifically, approximately 3 and 5 percent (n = 11 and 28) of the vehicle speed data were collected before and after the warning sign installation, respectively, when no on-street parking existed. Note, however, that no additional summary statistics are shown in Table B.4 for these particular data categories because of their small size (they also were not compared to other data categories, see Table B.5). The remaining vehicle speeds collected during park and/or right-of-way activities were influenced by stable low impact on-street parking (i.e., 23 and 7 percent (n = 88 and 39) before and after the OHPW sign installation, respectively) or stable high impact on-street parking (i.e., 74 and 88 percent (n = 288 and 489) before and after the OHPW sign installation, respectively). Of course, no summary statistics or comparison results are shown in Tables B.4 or B.5 for the dataset with 39 vehicle speeds, but it is clear that the proportion of vehicle speeds collected during stable high impact on-street parking time periods increased after the OHPW signs were installed. Overall, there was an average of about 3 and 5 vehicles parked on the street, before and after the OHPW signs were installed, respectively, during the stable low impact on-street parking time periods when park/right-of-way activities were occurring (See Table B.4). This result is greater than the average number of parked vehicles during stable low impact on-street parked vehicle time periods when no park/right-of-way activities are occurring (see above). The average number of parked cars on the street during stable high impact on-street parking time periods, on the other hand, was about 29 and 43 before and after the OHPW sign installation, respectively (See Table B.4).

Table B.4 also includes the number, minimum, maximum, mean, standard deviation, and 85th percentile vehicle speed summary statistics for the data collected before and after the OHPW sign installation at Chicago Avenue South. The average number of vehicles parked on the street is also recorded. These statistics are provided for the overall vehicle speed database and various combinations of on-street parking and park and/or right-of-way activities.

Table B.4. Bidirectional Chicago Avenue South Vehicle Speed Descriptive Statistics[1]

Vehicle Speed Statistics							
	Number	**Minimum (mph)**	**Maximum (mph)**	**Mean (mph)**	**Standard Deviation (mph)**	**85th Percentile (mph)**	**Average Number of On-Street Parked Vehicles**
Before OHPW Sign Installation							
Overall	842	5	46	23.7	7.5	30.4	10.9
With Activities[2]	387 (46%)	5	37	19.1	7.1	26.7	22.3
No On-Street Parking	11 (3%)	INS	INS	INS	INS	INS	INS
SLP On-Street Parking[3]	88 (23%)	5	37	24.6	6.4	30.0	2.8
SHP On-Street Parking[3]	288 (74%)	5	36	17.1	6.2	23.6	29.1
Without Activities[2]	455 (54%)	7	46	27.6	5.3	32.0	1.1
No On-Street Parking	153 (34%)	9	46	28.7	5.3	32.7	0.0
SLP On-Street Parking[3]	302 (66%)	7	42	27.0	5.3	31.6	1.7
With No On-Street Parking	164 (19%)	9	46	28.6	5.3	32.6	0.0
With On-Street Parking	678 (81%)	5	42	22.5	7.5	29.6	13.5
SLP On-Street Parking[3]	390 (58%)	5	42	26.5	5.6	31.3	1.9
SHP On-Street Parking[3]	288 (42%)	5	36	17.1	6.2	23.6	29.1
After OHPW Sign Installation							
Overall	961	4	39	20.3	7.6	28.5	22.3
With Activities[2]	556 (58%)	4	32	15.9	5.5	21.4	38.4
No On-Street Parking	28 (5%)	INS	INS	INS	INS	INS	INS
SLP On-Street Parking[3]	39 (7%)	INS	INS	INS	INS	INS	INS
SHP On-Street Parking[3]	489 (88%)	4	32	15.1	5.0	19.9	43.2
Without Activities[2]	405 (42%)	6	39	26.3	5.6	31.4	0.2
No On-Street Parking	309 (76%)	7	39	26.2	5.7	31.3	0.0
SLP On-Street Parking[3]	96 (24%)	6	38	26.6	5.6	31.6	1.0
With No On-Street Parking[3]	337 (35%)	7	39	25.9	5.7	31.2	0.0
With On-Street Parking[3]	624 (65%)	4	38	17.2	6.6	24.5	34.4
SLP On-Street Parking[3]	135 (22%)	6	38	24.9	6.2	30.8	2.2
SHP On-Street Parking[3]	489 (78%)	4	32	15.1	5.0	19.9	43.2

[1]All descriptive statistics exclude vehicle speeds collected during unstable time periods. The definition of an unstable time period is provided in Chapter 3. INS = insufficient data for individual basic comparison purposes, but data included in larger data categories.
[2]Park, playground, and/or right-of-way activities are defined in Chapter 3.
[3]SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for the definition of these terms

Table B.5. Select Naïve Mean Vehicle Speed Comparisons: Chicago Avenue South

Comparison	Difference in Mean Vehicle Speeds (mph) and Parked Vehicles	Statistically Significant?[1]
Before OHPW Sign Time Period		
Overall With and Without Park and/or Right-of-way Activities[2]	+8.5 (Avg. Number of Parked Vehicles = -21.2)	Yes
SLP On-Street Parking With and Without Park and/or Right-of-way Activities[2]	+2.4 (Avg. Number of Parked Vehicles = -1.1)	Yes
All No On-Street Parking and All On-Street Parking[3]	-6.1 (Avg. Number of Parked Vehicles = +13.5)	Yes
SLP and SHP On-Street Parking[3]	-9.4 (Avg. Number of Parked Vehicles = +27.2)	Yes
After OHPW Sign Time Period		
Overall With and Without Park and/or Right-of-way Activities[2]	+10.4 (Avg. Number of Parked Vehicles = -38.2)	Yes
All No On-Street Parking and All On-Street Parking[3]	-8.7 (Avg. Number of Parked Vehicles = +34.4)	Yes
SLP and SHP On-Street Parking[3]	-9.8 (Avg. Number of Parked Vehicles = +41.0)	Yes
Before to After OHPW Sign Time Periods[4]		
Overall	-3.4 (Avg. Number of Parked Vehicles = +11.4)	Yes
Overall With Park and/or Right-of-way Activities	-3.2 (Avg. Number of Parked Vehicles = +16.1)	Yes
Overall Without Park and/or Right-of-way Activities[4]	-1.3 (Avg. Number of Parked Vehicles = -0.9)	Yes
No On-Street Parking Without Park and/or Right-of-way Activities	-2.5 (Avg. Number of Parked Vehicles = 0.0)	Yes
SLP On-Street Parking Without Park and/or Right-of-way Activities	-0.4 (Avg. Number of Parked Vehicles = -0.7)	No
SHP On-Street Parking With Park and/or Right-of-way Activities	-2.0 (Avg. Number of Parked Vehicles = +14.1)	Yes
Overall With No On-Street Parking	-2.7 (Avg. Number of Parked Vehicles = 0.0)	Yes
Overall With On-Street Parking	-5.3 (Avg. Number of Parked Vehicles = +20.9)	Yes
Overall With SLP On-Street Parking	-1.6 (Avg. Number of Parked Vehicles = +0.3)	Yes
Overall With SHP On-Street Parking	-2.0 (Avg. Number of Parked Vehicles = +14.1)	Yes

[1]A standard T-test was completed to determine the statistical significance of the difference (to a 95th percentile level of confidence) between mean vehicle speeds calculated. The vehicle speed data was assumed to be normally distributed for the application of this test.
[2]Difference = mean vehicle speed or vehicles without minus mean vehicle speed or vehicles with park, playground, and/or right-of-way activities during the time periods indicated (from Table 4.11). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.
[3]Difference = mean vehicle speed with SHP, all on-street parking, or vehicles minus mean vehicle speed with SLP, no on-street parking, or vehicles during the time periods indicated (from Table 4.11). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.
[4]Difference = mean vehicle speed or vehicles during the after time period minus mean vehicle speed or vehicles during the before time period (from Table 4.11). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.

Overall, the mean vehicle speed calculated for the before and after time periods, respectively, were 23.7 mph and 20.3 mph (a reduction of 3.4 mph). However, it is important to note that this difference represents the combined impact of the OHPW sign installation and the differences in on-street parking, park and/or right-of-way activities, and all of the other factors at the study site that may have impacted the vehicle speed choice of the drivers (e.g., weather, vehicle type, directional split, driver characteristics, etc.). The overall 85th percentile vehicle speeds calculated for the before and after time periods, on the other hand, were 30.4 and 28.5 mph (a reduction of 1.9 mph), respectively. In addition, the variability of the vehicle speeds collected during the before and after time periods is indicated by the standard deviations of 7.5 and 7.6 mph (See Table B.4). Overall, the average number of parked vehicles on the street before and after the OHPW signs was approximately 11 and 22, respectively. It is clear there is a large amount of vehicle speed variability and on-street parking at the Chicago Avenue South study site. The overall vehicle speed standard deviations and average number of vehicles parked on the street at the Chicago Avenue South study are greater than the other two study sites. Similar descriptive statistics (along with the average number of vehicles parked on the street within the study site) are presented in Table B.4 for various sub-category park and/or right-of-way activities, and on-street parking combinations.

Table B.5 contains the results from a series of mean vehicle speed comparisons for the data collected before and after the installation of the OHPW signs at the Chicago Avenue South study site. The results from a naïve statistical analysis of these differences are also shown. The information in Table B.5 (along with the general summary statistics in Table B.4) was used to complete an initial investigation of some of the factors that may have resulted in any changes to the mean vehicle speeds at the study site. The magnitude of and the differences in various mean vehicle speeds, along with the average number of on-street parked vehicles before and after the OHPW sign installation (See Tables B.4 and B.5) were used to evaluate what might have produced the 3.4 mph overall mean vehicle speed reduction calculated for Chicago Avenue South study site.

The differences in the average mean vehicle speeds and the average number of on-street parked vehicles for several time periods with similar warning sign and park and/or right-of-way activity status were compared (but only for those database categories with 50 or more vehicle speeds) as part of this research project. For example, the mean vehicle speed and average number of vehicles parked on the street that were calculated for the stable low and stable high impact parking time periods (with park and/or right-of-way activities) before the OHPW sign installation were compared. The mean vehicle speed impact per on-street parked vehicle calculated from these comparisons ranged from approximately +0.4 to -1.0 mph/vehicle. The average overall potential mean vehicle speed reduction per on-street parked vehicle, however, was about 0.3 mph. Therefore, it could be speculated that the average overall increase of 11.4 vehicles parked on the street after the installation of the OHPW signs (See Table B.5) may be responsible for the entire 3.4 mph mean vehicle speed reduction shown in Tables B.4 and B.5. It is more likely, however, that the impact of the on-street parking on mean vehicle speed is lower than the calculated average. In general, the range in the mean vehicle speed impact per on-street parked vehicle is an indication of the variability in the data being used in this research and it also shows that on-street parking is only one of many factors (only a few for which data were collected) that could have an impact on vehicle speed choice. In addition, the relative subjectivity used in the identification of the on-street parking (particularly stable low impact, stable high impact, and unstable) time periods by field personnel may have a greater impact on the results at Chicago Avenue South. This study site appeared to have a greater amount of on-street parking than the other two study sites.

An approach similar to that described above was also used to investigate the potential mean vehicle speed impact of activities in the park and/or right-of-way. The overall difference in mean vehicle speeds for the time periods with and without park and/or right-of-way activities before and after the OHPW sign installation indicate a reduction of 8.5 and 10.4 mph, respectively, when park/right-of-way activities occur. The average impact due to the difference in the number of on-street parked vehicles during these time periods (based on the above calculations), however, may account for as much as 6.4 and 11.5 mph of these differences, respectively. The latter result, being larger than overall 10.4 mph difference, shows the high level of variability that exists in the data. In general, these results imply that the potential reduction in mean vehicle speed due to activities in the park or right-of-way may range from 0.0 to 2.1 mph. Similar comparisons were also attempted for time periods with no, stable low impact, and stable high impact parking, but only one comparison (i.e., stable low impact parking with and without activities before the OHPW sign installation) was possible due to the size of the datasets. The result of this comparison did not change the potential range of mean vehicle speed impacts noted above. This overall range of results again shows the variability in the data and data categories being used in this research. It also supports the conclusion that there are many factors that might impact the choice of vehicle speed. The small differences in the observed mean vehicle speeds calculated for Chicago Avenue South study site make this variability in data an important consideration in the evaluation of the data.

Columbus Avenue South Study Site

A total of 1,655 and 1,028 vehicle speeds (excluding those collected during time periods with unstable on-street parking) were collected at the Columbus Avenue South study site before and after, respectively, the OHPW sign installation (See Table B.6). The vehicle speed data collected during these unstable on-street parking time periods are influenced by a wide range of activities for which data could not be collected. It was also concluded, after a discussion with a neighborhood resident and city staff that one of the primary reasons for the overall difference in the number of vehicle speeds collected in the before and after time period was the roadway resurfacing project that occurred along a parallel route approximately three blocks west of the study site. This resurfacing was ongoing during the "before" data collection time period, but was completed before the "after" period. A potential difference in the type of drivers (and their primary objectives) before and after the installation of the OHPW signs at this study site should be considered when its vehicle speeds are evaluated. Unfortunately, no data were collected about the type of drivers using the study sites during this research project.

Vehicle speed summary statistics for the Columbus Avenue South study site are provided in Table B.6. Approximately 55 and 61 percent (n = 914 and 628) of the vehicle speeds, before and after the OHPW sign installation, respectively, were collected when there was no activity within the park and/or right-of-way. However, all of these data were collected when there was either stable low impact or stable high impact on-street parking at the study site (See Chapter 3 for a definition of these on-street parking terms and a description of the study site). More specifically, approximately 85 and 83 percent (n = 780 and 520) of the vehicle speeds collected before and after the OHPW sign installation, respectively, were recorded when stable low impact on-street parking was observed. The remainder of vehicle speeds (i.e., 15 and 17 percent (n = 134 and 108)), were acquired during stable high impact on-street parking time periods. Overall, on average, approximately 3 and 5 vehicles were parked on the street during the stable low and high impact parking time periods, respectively, before the OHPW signs were installed. Approximately 5 and 7 vehicles were parked on the street during similarly defined stable low and high impact parking time periods after the OHPW sign installation (See Table B.6).

The vehicle speed data collected at the Columbus Avenue South study site during time periods with park and/or right-of-way activities are also summarized in Table B.6. Not surprisingly, the on-street parking characteristics when these data were collected are different than those described above. Approximately 45 and 39 percent (n = 741 and 400) of the vehicle speeds collected before and after the OHPW sign installation, respectively, were recorded when activities were occurring within the park and/or right-of-way. These data were also collected when some type of on-street parking (i.e., stable low impact or stable high impact) existed at the study site (See Chapter 3 for a definition of these on-street parking terms and a description of the study site). About 61 and 32 percent (n = 451 and 127) of the vehicle speeds collected before and after the warning sign installation, respectively, were recorded when stable low impact on-street parking was observed. The remaining vehicle speeds (i.e., 39 and 68 percent (n = 290 and 273)), however, were acquired when stable high impact on-street parking conditions existed. Clearly, the proportion of vehicle speeds collected with stable high impact on-street parking increased dramatically between the before and after OHPW sign installation time periods. Subsequently, the vehicle speed data collected during the stable low impact on-street parking time periods has decreased. Overall, there was an average of 4 vehicles parked on the street during the stable low impact on-street parking time periods (when park/right-of-way activities were also occurring) both before and after the OHPW signs were installed (See Table B.6). This result is similar to the average number of on-street parked vehicles when no park/right-of-way activities were occurring (see above). The average number of vehicles parked on the street during stable high impact parking time periods, on the other hand, were 16 and 14, respectively, before and after the warning sign installation (See Table B.6). These averages are two to three times greater than those calculated for the high impact parking time periods when no activities were observed in the park/right-of-way.

Table B.6 includes the number, minimum, maximum, mean, standard deviation, and 85th percentile vehicle speed summary statistics for the data collected before and after the OHPW sign installation at Columbus Avenue South. The average number of vehicles parked on the street is also recorded. These statistics are provided for the overall vehicle speed database and for various combinations of on-street parking and park and/or right-of-way activities.

Overall, the mean vehicle speed calculated for the before and after time periods, respectively, were 28.9 mph and 27.8 mph (a reduction of 1.1 mph). However, it is important to note that this difference represents the combined impact of the OHPW sign installation and the differences in on-street parking, park and/or right-of-way activities, and all of the other factors at the study site that may have impacted the vehicle speed choice of the drivers (e.g., weather, vehicle type, directional split, driver characteristics, etc.). The overall 85th percentile vehicle speeds calculated for the before and after time periods, on the other hand, were 34.2 and 33.7 mph (a reduction of 0.5 mph), respectively. In addition, the variability of the vehicle speeds collected during the before and after time periods is shown by standard deviations of 6.3 and 7.0 mph (See Table B.6). Overall, the average number of vehicles parked on the street is 6 to 7 in the time periods before and after the installation of the OHPW signs. The variability in the vehicle speeds at this study site appears to be relatively high, but the average overall number of vehicle parked on the street is relatively stable. Similar descriptive statistics (along with the average number of vehicles parked on the street within the study site) are also presented in Table B.6 for various sub-category park and/or right-of-way activities and on-street parking combinations.

Table B.7 contains the results from a series of mean vehicle speed comparisons for the data collected before and after the installation of the OHPW signs at the Columbus Avenue South study site. The results from a naïve statistical analysis of these differences are also shown. The information in Table B.7 (along with the general summary statistics in Table B.6) was used to complete an initial investigation of some of the factors that may have resulted in any changes to the mean vehicle speeds at the study site. The magnitude of and the differences in various mean vehicle speeds, along with the average number of parked vehicles before and after the playground sign installation (See Tables B.6 and B.7), were used to evaluate what might have produced the 1.1 mph overall mean vehicle speed reduction calculated for the Columbus Avenue South study site.

The differences in the average mean vehicle speeds and the average number of on-street parked vehicles for those time periods with similar warning sign and park and/or right-of-way activity status were compared for this research project. For example, the mean vehicle speed and average number of vehicles parked on the street that were calculated for the stable low and stable high impact on-street parking time periods (without any park/right-of-way activities) before the OHPW sign installation were compared. The mean vehicle speed impact per on-street parked vehicle calculated from these comparisons ranged from approximately +0.06 to -0.5 mph/vehicle. The average overall mean vehicle speed reduction per on-street parked vehicle, however, was about 0.4 mph. Therefore, it could be speculated that the overall average increase of 1.5 vehicles parked on the street after the installation of the OHPW signs (See Table B.7) may represent as much as 0.6 mph of the overall 1.1 mph mean vehicle speed reduction shown in Tables B.6 and B.7. It should be noted, however, that the range in mean vehicle speed impact per on-street parked vehicle is an indication of the variability in the data being used in this research and it also shows that on-street parking is only one of many factors (only a few for which data were collected) that could have an impact on vehicle speed choice. These other factors are not considered in this general comparison.

An approach similar to that described above was also used to investigate the potential mean vehicle speed impact of activities in the park and/or right-of-way. The overall mean vehicle speeds for the time periods with and without park and/or right-of-way activities before the OHPW sign installation indicate a reduction of 2.6 mph when park/right-of-way activities occur. A 3.3 mph reduction was calculated from a similar comparison of the overall mean vehicle speeds after the playground sign installation. The average impact due to the difference in the number of on-street parked vehicles during these time periods (based on the calculations above), however, may account for as much as 2.1 and 2.3 mph of these differences, respectively. In general, these results imply that the potential reduction in mean vehicle speed due to activities in the park and/or right-of-way may be as much as 0.5 to 1.0 mph. However, a similar comparison was also made for the same descriptive statistics during the stable low impact and stable high impact on-street parking data categories. The results of these other comparisons indicated that the park and/or right-of-way mean vehicle speed impacts could range from +0.08 to -1.4 mph (with an average of about -0.7 mph). This range of results again shows the variability in the data being used in this research and the many factors that might impact the choice of vehicle speed. For example, additional analysis also showed that just the activities within the right-of-way could impact the calculated mean vehicle speeds for some of the data categories in Table 4.16 by +0.2 to -0.6 mph. The small differences in the observed mean vehicle speeds calculated for Columbus Avenue South study site make this variability in the data an important consideration in the evaluation of the data.

Table B.6. Bidirectional Columbus Avenue South Vehicle Speed Descriptive Statistics[1]

	Vehicle Speed Statistics						
	Number (Percentage)	Minimum (mph)	Maximum (mph)	Mean (mph)	Standard Deviation (mph)	85th Percentile (mph)	Average Number of On-Street Parked Vehicles
Before Playground Sign Installation							
Overall	1,655	5	51	28.9	6.3	34.2	5.7
With Activities[2]	741 (45%)	8	51	27.5	6.8	33.5	8.7
SLP Parking[3]	451 (61%)	8	51	29.2	5.8	34.0	4.0
SHP Parking[3]	290 (39%)	8	46	24.8	7.3	31.8	15.9
Without Activities[2]	914 (55%)	5	45	30.1	5.6	34.7	3.4
SLP Parking[3]	780 (85%)	5	45	30.1	5.7	34.8	3.1
SHP Parking[3]	134 (15%)	14	43	30.2	5.3	34.5	4.9
With SLP On-Street Parking[3]	1,231	5	51	29.8	5.8	34.5	3.4
With SHP On-Street Parking[3]	424	8	46	26.5	7.2	33.2	12.4
After OHPW Sign Installation							
Overall	1,028	6	47	27.8	7.0	33.7	7.2
With Activities[2]	400 (39%)	6	44	25.8	7.9	32.8	10.7
SLP Parking[3]	127 (32%)	12	44	29.2	6.5	34.6	4.3
SHP Parking[3]	273 (68%)	6	40	24.2	8.0	32.1	13.8
Without Activities[2]	628 (61%)	9	47	29.1	6.0	34.3	4.9
SLP Parking[3]	520 (83%)	10	47	29.2	5.9	34.3	4.5
SHP Parking[3]	108 (17%)	9	39	28.4	6.4	34.3	6.9
With SLP On-Street Parking[3]	647	10	47	29.2	6.0	34.3	4.5
With SHP On-Street Parking[3]	381	6	40	25.4	7.8	32.6	11.8

[1]All descriptive statistics exclude vehicle speeds collected during unstable time periods. The definition of an unstable time period is provided in Chapter 3.
[2]Park, playground, and/or right-of-way activities are defined in Chapter 3.
[3]On-street parking existed when all (i.e., 100 percent) of the vehicle speed data were collected at this site. SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for the definition of these terms

Table B.7. Select Mean Vehicle Speed Comparisons – Columbus Avenue South

Comparison	Difference in Mean Vehicle Speeds (mph) and Parked Vehicles	Statistically Significant?[1]
Before Time Period		
Overall With and Without Park and/or Right-of-way Activities[2]	+2.6 (Avg. Number of Parked Vehicles = -5.3)	Yes
SLP On-Street Parking With and Without Park and/or Right-of-way Activities[2]	+0.9 (Avg. Number of Parked Vehicles = -0.9)	Yes
SHP On-Street Parking With and Without Park and/or Right-of-way Activities[2]	+5.4 (Avg. Number of Parked Vehicles = -11.0)	Yes
SLP and SHP On-Street Parking[3]	-3.3 (Avg. Number of Parked Vehicles = +9.0)	Yes
After Time Period		
Overall With and Without Park and/or Right-of-way Activities[2]	+3.3 (Avg. Number of Parked Vehicles = -5.8)	Yes
SLP On-Street Parking With and Without Park and/or Right-of-way Activities[2]	0.0 (Avg. Number of Parked Vehicles = +0.2)	No
SHP On-Street Parking With and Without Park and/or Right-of-way Activities[2]	+4.2 (Avg. Number of Parked Vehicles = -6.9)	Yes
SLP and SHP On-Street Parking[3]	-3.8 (Avg. Number of Parked Vehicles = +7.3)	Yes
Before to After Time Periods[4]		
Overall	-1.1 (Avg. Number of Parked Vehicles = +1.5)	Yes
Overall With Park and/or Right-of-way Activities	-1.7 (Avg. Number of Parked Vehicles = +2.0)	Yes
Overall Without Park and/or Right-of-way Activities	-1.0 (Avg. Number of Parked Vehicles = +1.5)	Yes
SLP On-Street Parking With Park and/or Right-of-way Activities	0.0 (Avg. Number of Parked Vehicles = +0.3)	No
SLP On-Street Parking Without Park and/or Right-of-way Activities	-0.9 (Avg. Number of Parked Vehicles = +1.4)	Yes
SHP On-Street Parking With Park and/or Right-of-way Activities	-0.6 (Avg. Number of Parked Vehicles = -2.1)	No
SHP On-Street Parking Without Park and/or Right-of-way Activities	-1.8 (Avg. Number of Parked Vehicles = +2.0)	Yes
Overall With SLP On-Street Parking	-0.6 (Avg. Number of Parked Vehicles = +1.1)	No
Overall With SHP On-Street Parking	-1.1 (Avg. Number of Parked Vehicles = -0.6)	Yes

[1]A standard T-test was completed to determine the statistical significance of the difference (to a 95th percentile level of confidence) between mean vehicle speeds calculated. The vehicle speed data was assumed to be normally distributed for the application of this test.
[2]Difference = mean vehicle speed or vehicle without minus mean vehicle speed or vehicles with park, playground, and/or right-of-way activities during the time periods indicated (from Table 4.16). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.
[3]Difference = mean vehicle speed or vehicles with SHP parking minus mean vehicle speed or vehicles with SLP parking during the time periods indicated (from Table 4.16). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.
[4]Difference = mean vehicle speed or vehicles during the after time period minus mean vehicle speed or vehicles during the before time period (from Table 4.16). SLP = stable low impact parking and SHP = stable high impact parking. See Chapter 3 for more details.

Summary

This Appendix summarized and analyzed the vehicle speed, on-street parking, and park/playground/ right-of-way activity data collected at the three study sites selected for this research project. The time periods of the data collection activities were described and it is important to note that data was collected at one study site in the fall (i.e., October and November) and the activities at the other two were completed in the spring and summer (i.e., May and July). Different time periods for the data collection can result in different levels of park/playground/right-of-way activities and their associated on-street parking. The vehicle speed data collected before and after the OHPW sign installation at the three study sites were summarized for various combinations of on-street parking and park/playground/right-of-way activities. The overall difference in the average vehicle speeds before and after the installation of the OHPW signs ranged 0.1 to 3.4 mph. These difference, however, are the result of the various factors that could potentially impact the choice of vehicle speeds by drivers within the study site. Some of these factors, in addition to the OHPW signs, include the magnitude and/or location of the on-street parking and the activities are occurring in the park/playground/right-of-way. There are, of course, also a number of factors that could impact these vehicle speed results for which data could not be collected. These factors include, but are not limited to, weather, driver type and purpose, and the proportion of vehicle type in the traffic flow. The inability to measure and/or control for these factors is the reason more than one type of data analysis was completed as part of this project, but was also not unexpected when an observational study design was selected.