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THE EFFECTS OF PEDESTRIAN COUNTDOWN TIMERS ON SAFETY AND EFFICIENCY OF OPERATIONS AT SIGNALIZED INTERSECTIONS

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The Effects of Pedestrian Countdown Timers on Safety and Efficiency of Operations at Signalized Intersections

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16. Abstract

Pedestrian countdown timers are becoming common at urban and suburban intersections. The added information that pedestrian countdown timers provide to pedestrians can also be used by approaching drivers. A before-and-after case study on the effects that pedestrian countdown timers have on safety and efficiency of operations was performed at two signalized intersections in Lincoln, Nebraska. The effects on both drivers and pedestrians were analyzed. Performance measures for pedestrian analysis include pedestrian compliance and average pedestrian walking speed. Performance measures for the driver analysis include probability of stopping and speed gain of vehicles at the stop bar during the yellow phase (vehicles passing through the intersection during the yellow phase) and queue discharge headway. Data was collected using a Wide Area Detector (WAD), point detector at the stop bar and a Pan-Tilt-Zoom (PTZ) video camera. Data was collected using state-of-the-art data collection software, Wonderware, which displayed all traffic and pedestrian signal information, vehicle detections, individual vehicle speeds, vehicle distances from stop bar, and the video from the PTZ camera all on one computer screen. Statistical models were estimated to understand the effects that pedestrian countdown timers have on the performance measures. The resulting models identified statistically significant factors that affected the performance measures. Pedestrian countdown timers were found to increase pedestrian walking speed by 0.2 ft/sec, and decrease the probability of pedestrian violations. Impact of PCT on driver safety and efficiency was not found to be statistically significant at 95% level of confidence. There was however some evidence, although not statistically significant of improvement of driver safety due the presence of PCT. The trend was more pronounced at the intersection of 17th and G (smaller intersection with less visual clutter) where we observed reduction in the percentage of red light runners and some reduction of dilemma zone boundaries.
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Abstract

Pedestrian countdown timers are becoming common at urban and suburban intersections. The added information that pedestrian countdown timers provide to pedestrians can also be used by approaching drivers. A before-and-after case study on the effects that pedestrian countdown timers have on safety and efficiency of operations was performed at two signalized intersections in Lincoln, Nebraska. The effects on both drivers and pedestrians were analyzed. Performance measures for pedestrian analysis include pedestrian compliance and average pedestrian walking speed. Performance measures for the driver analysis include probability of stopping and speed gain of vehicles at the stop bar during the yellow phase (vehicles passing through the intersection during the yellow phase) and queue discharge headway. Data was collected using a Wide Area Detector (WAD), point detector at the stop bar and a Pan-Tilt-Zoom (PTZ) video camera. Data was collected using state-of-the-art data collection software, Wonderware, which displayed all traffic and pedestrian signal information, vehicle detections, individual vehicle speeds, vehicle distances from stop bar, and the video from the PTZ camera all on one computer screen.

Statistical models were estimated to understand the effects that pedestrian countdown timers have on the performance measures. The resulting models identified statistically significant factors that affected the performance measures. Pedestrian countdown timers were found to increase pedestrian walking speed by 0.2 ft/sec, and decrease the probability of pedestrian violations.

Impact of PCT on driver safety and efficiency was not found to be statistically significant at 95% level of confidence. There was however some evidence, although not statistically significant of improvement of driver safety due the presence of PCT. The trend was more pronounced at the intersection of 17th and G (smaller intersection with less visual clutter) where

we observed reduction in the percentage of red light runners and reduction of dilemma zone boundaries.

Based on this study PCT were found to be beneficial for improving both pedestrian efficiency and safety and some trends were seen of positive impacts on driver safety. The positive impacts were more pronounced for smaller intersections.

Chapter 1 Introduction

Pedestrian countdown timers are replacing traditional pedestrian signals at many signalized intersections due to the increased information they provide to both pedestrians and drivers. The effects of pedestrian countdown timers on drivers and pedestrians need to be determined in order to justify whether their benefits outweigh their costs. The effects of pedestrian countdown timers on pedestrians have been inconsistent, with some studies claiming that timers increase pedestrian compliance (1, 4, 14), whereas others report increased erratic behavior in pedestrians in the presence of countdown timers (7) and a decrease in pedestrian compliance (2, 7). In addition, drivers behave differently when pedestrian countdown timers are installed compared to when pedestrian countdown timers are not installed (8). To visualize the inconsistencies among pedestrian compliance studies, figure 1.1 shows a plot of the percent change in pedestrian violations after installation of pedestrian countdown timers, which includes findings from multiple studies. The X axis labels show number of intersection evaluated in a particular study, followed by location, followed by reference to the study.

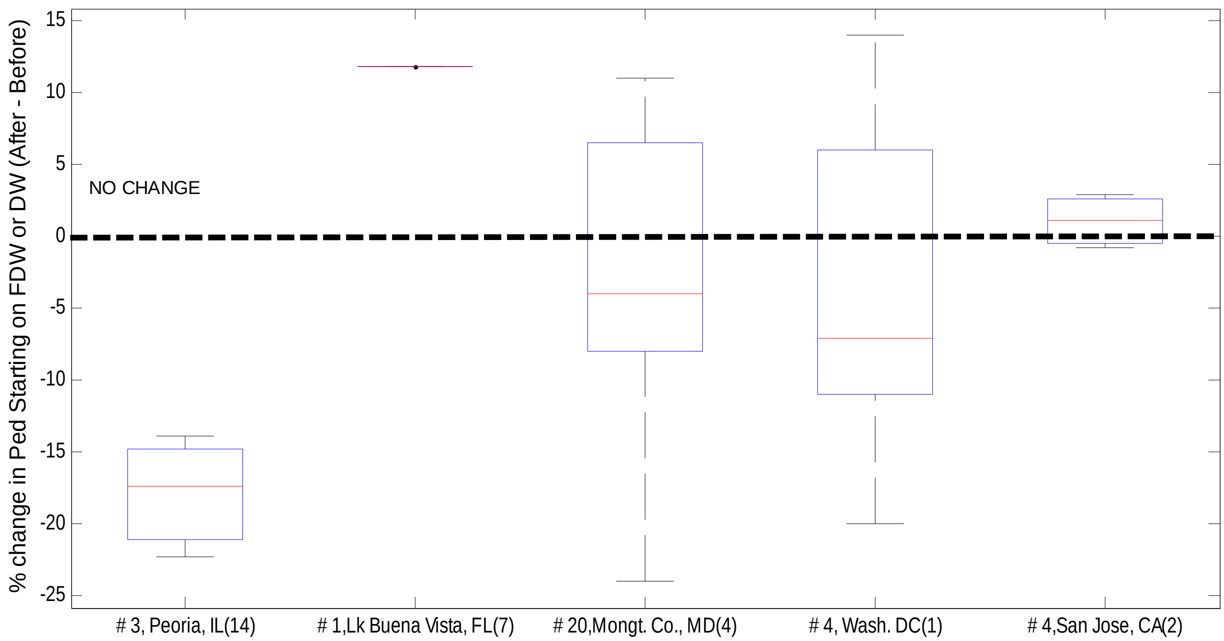


Figure 3.1 Plot of pedestrian compliance from previous studies

Three of the studies show results that are on both sides of the “no change” line meaning the results go from a negative change to a positive change. One possible reason for these conflicting results could be variability in pedestrian behavior due to regional differences. This in turn makes it necessary to investigate the effect of pedestrian countdown timers in Nebraska. In addition, contradictory results were also found at different intersections within the same city, which could be due to site-specific intersection characteristics. Another possible reason is that differences in pedestrian violations may be due to factors other than pedestrian countdown timers, such as conflicting traffic, time of day, the presence of other pedestrians, and so on. Using statistical modeling tools, the effects of pedestrian countdown timers can be uniquely identified, and tested for significance. This report presents an in-depth before-and-after analysis of driver and pedestrian behavior in the presence and absence of pedestrian countdown timers using statistical modeling tools.

A traditional pedestrian signal has a WALK phase represented by either a figure of a person walking or the word “WALK,” a flashing DON’T WALK phase represented by a flashing hand or by the flashing words “DON’T WALK,” and a steady DON’T WALK phase represented by a solid hand or the words “DON’T WALK” displayed constantly. A pedestrian countdown signal has the same three phases as a traditional pedestrian signal; however, the flashing DON’T WALK phase is represented by a flashing hand and a countdown timer that displays the amount of time left until the flashing DON’T WALK phase is over. **Error! Reference source not found.** shows a picture of a traditional pedestrian signal and a pedestrian countdown signal.

Figure 1.4 Traditional pedestrian signal (left) and pedestrian countdown signal (right)

In all pedestrian signal types, the WALK phase is displayed when pedestrians are permitted to walk in the crosswalk. The flashing DON’T WALK phase is displayed after the WALK phase and its purpose is to allow a sufficient amount of time for people who entered the crosswalk during the WALK phase to cross the intersection safely. The steady DON’T WALK phase is displayed after the flashing DON'T WALK phase. It denotes the time when it is illegal for pedestrians to be in the crosswalk because conflicting traffic has a green signal.

The objective of this research is to evaluate the effects that pedestrian countdown timers have on safety and efficiency of operations at two intersections in Nebraska. Statistical modeling tools were used to determine the effects that pedestrian countdown timers have on safety and efficiency. Table 1.1 lists the performance measures studied, the dependent variable used in each model, the coding of each dependent variable, and the hypotheses to be tested.

Table 3.1 Performance measures studied and hypotheses tested

Performance Measure Modeled	Dependent Variable	Dependent Variable Coding	Hypothesis (After Installation of PCT)
Pedestrian compliance	Pedestrian violation	0 (no violation) / 1 (violation)	Pedestrian compliance will increase
Pedestrian walking speed	Average walking speed of pedestrian, ft/sec	Decimal value of walking speed	Pedestrian walking speed will increase
Probability of Stopping	Vehicle goes or stops	0 (Go) / 1 (Stop)	Probability of stopping curve will become steeper
Speed Gain at stop bar during yellow phase	Speed Gain at the stop bar, mi/hr	Decimal value of speed Gain at stop bar	Speed gain would be positive
Queue discharge characteristics	Queue discharge headways, (sec)	Decimal value of headway of vehicles in queue, sec	Headway at the stop bar will reduce

As will the literature review presented in Chapter 2 will show, a limitation to previous research is that microscopic characteristics of both vehicles and pedestrians were not analyzed. This research is innovative because an in-depth quantitative analysis of microscopic characteristics was performed for both drivers and pedestrians before and after installation of pedestrian countdown timers. The data collected for both pedestrians and drivers will help understand the microscopic interactions among drivers and pedestrians, which led to the macroscopic results observed. The statistical modeling results provide a better understanding of driver and pedestrian decision-making at intersections with pedestrian countdown timers than has been achieved in previous research studies.

The expected benefits of this study are a better understanding of the impacts of pedestrian countdown timers on drivers and pedestrians. With two before-and-after studies at separate approaches with different characteristics such as speed limit and traffic volumes, an indication of the effects of pedestrian countdown timers on both drivers and pedestrians in Lincoln, Nebraska, can be seen. The statistical models will be useful in better understanding the underlying behavior of drivers and pedestrians and will lead to improvement in microscopic modeling tools.

Chapter 2 is composed of a thorough literature review of the effects of pedestrian countdown timers on safety and efficiency of operations at signalized intersections. Chapter 2 is divided into two sections: impacts of phase countdown timers (used outside of the U.S.) and pedestrian countdown timers. Chapter 2 also presents a result of telephonic survey conducted as a part of this project to assess the pedestrian and driver response to the pedestrian count down timers.

Chapter 3 describes the sites used for data collection. The hardware deployed for data collection is explained. Then, the error reduction techniques are described. Chapter 3 concludes with the error tolerance of the hardware components in the field.

Chapter 4 explains the data analysis of this study. The days of data collection and the number of observations used in data analysis are presented, followed by the results of this study. This report ends with Chapter 5, which contains the conclusions drawn from this research.

Chapter 2 Literature Review

Not many studies have evaluated the effects of pedestrian countdown timers on traffic operation characteristics such as dilemma zone boundaries or the velocity of vehicles during the yellow phase. Almost all literature on pedestrian countdown timers has focused on pedestrian safety, pedestrian compliance, pedestrian understanding, red light runners (RLR), and pedestrian-vehicular conflicts. However, some research has been performed on phase countdown timers—which are primarily used in Asia—to quantify the effects of phase countdown timers on traffic characteristics. Therefore, the literature review will cover research done on pedestrian countdown timers and phase countdown timers to gain a thorough understanding of the effects that both pedestrian countdown timers and phase countdown timers have on the efficiency of operations and safety at signalized intersections.

2.1 Past Literature on Pedestrian Countdown Timers

This review first addressed pedestrian countdown timers. Schattler et al. (14) performed a study in Peoria, Illinois, using a total of 13 intersections to study the effect of pedestrian countdown timers on pedestrian compliance, yellow light runners (YLR), and RLR. In the study, three intersections were studied using a before-and-after method, and 10 intersections were studied using a comparative analysis method (five intersections with pedestrian countdown timers installed and five with traditional pedestrian signals). They found that pedestrian countdown timers do not significantly increase or reduce the number of RLR and YLR.

A comparative analysis at 10 intersections also resulted in no significant differences in YLR and RLR between the intersections with pedestrian countdown timers installed and the intersections with traditional pedestrian signals. They also found that pedestrian countdown timers significantly improve pedestrian compliance over traditional pedestrian signals. The proportion of pedestrians that started walking during the walk or flashing DON'T WALK (with countdown numbers) was higher after installation of pedestrian countdown timers than with traditional pedestrian signals. At each intersection studied, the percentage of pedestrians crossing during the WALK phase (W) and flashing DON'T WALK phase (FDW) increased after the installation of pedestrian countdown timers. They performed a Z-test at 95% confidence and found that the average pedestrian violation rate over the three intersections (% Peds. Crossing on DW) significantly decreased after installation of pedestrian countdown timers.

Huang and Zegeer (7) performed a treatment and control study on five intersections: two treatment intersections had pedestrian countdown timers installed and three control intersections had traditional pedestrian signals. Three measures of effectiveness were studied: 1) pedestrian compliance with the WALK signal, 2) pedestrians who ran out of time, and 3) pedestrians who started running when the flashing DON'T WALK signal appeared. A pedestrian who complied with the WALK phase began walking in the crosswalk during the WALK phase, and did not comply by beginning to walk in the crosswalk during any other phase. They found that pedestrian compliance to the walk signal was significantly lower at intersections with pedestrian countdown timers, using the chi-squared method at the 0.005 significance level. A pedestrian who ran out of time was still walking in the crosswalk at the beginning of the DON'T WALK phase. They found an insignificant difference in the proportion of pedestrians who ran out of time. They found that pedestrian countdown timers reduce the number of pedestrians who start running when the flashing DON'T WALK appears. This is because the countdown makes pedestrians aware of how much time they have to cross the intersection before the solid DON'T WALK signal will appear; they can adjust their speed accordingly without having to assume running will be necessary to cross the intersection before the solid DON'T WALK signal. They concluded that pedestrian countdown signals are not recommended for use in the state of Florida because of the negative effect of decreasing pedestrian compliance to the WALK signal.

Huey and Ragland (8) found that drivers behave differently based on what type of pedestrian signal is used. They tested two intersections for RLR and YLR using traditional pedestrian signals and pedestrian countdown signals. They found that with a pedestrian countdown timer installed, 67.5% of the vehicles observed at the onset of yellow went through the intersection (observed from roughly 80 ft upstream of the intersection). With a traditional pedestrian signal, 65.3% of the vehicles went through the intersection. The difference was not found to be statistically significant.

Ma et al. (11) studied the effects of pedestrian countdown timers on pedestrians in Shanghai, China. A comparative analysis was performed at two intersections: one with pedestrian countdown timers installed and one with traditional pedestrian signals. They studied pedestrian compliance in terms of pedestrians who enter the intersection during the flashing DON'T WALK phase. Two age groups were considered: younger and elder. Pedestrian countdown timers were found to increase pedestrian compliance in elder people. For younger people, the proportion of pedestrians who enter the crosswalk during the flashing DON'T WALK phase is about the same for both pedestrian countdown signals and traditional pedestrian signals.

Washburn et al. (19) performed a before-and-after study at five intersections in Gainesville, Florida, to study the effects of pedestrian countdown timers on pedestrians. They mainly studied pedestrian compliance by calculating the percentage of pedestrians entering the crosswalk during the WALK, FDW, and DW indications. In addition, they examined the compliance with the FDW indications. Percentages of pedestrians hesitating, running, or going back to the starting curb were calculated, as was the percentage of pedestrian-vehicle conflicts. Washburn et al. found that the proportion of pedestrians entering on the WALK indication increased at three of the five intersections. Correspondingly, the proportion of pedestrians entering on the DW interval decreased at the same three of the five intersections. It was found that there was no increase in the proportion of pedestrians who entered during the FDW interval. In addition, the pedestrian countdown timers had the positive effect of increasing the proportion of pedestrians exiting on the FDW interval as opposed to the DW interval. There was no trend in erratic pedestrian behavior, such as hesitating, running, or going back to the starting curb. Pedestrian-vehicle conflicts did not increase or decrease significantly. Overall, Washburn et al. found no negative effects of pedestrian countdown timers and found positive effects, including pedestrian compliance.

Eccles et al. (4) performed a before-and-after pedestrian countdown timer study of five intersections in Montgomery County, Maryland. They studied pedestrian compliance by counting the number of pedestrians who entered the crosswalk during each phase: WALK, flashing DON'T WALK, and solid DON'T WALK. Vehicle approach speeds were measured by radar from approximately 400 ft upstream of the intersection. Only vehicles that were unobstructed by other vehicles and that were recorded between 17 to 6 seconds from the onset of red were used for analysis. There was a significant decrease in mean speed at one approach; otherwise, there were no significant changes in mean speeds after the installation of pedestrian countdown timers.

For the pedestrian compliance study, Eccles et al. studied each crosswalk separately at the five intersections, for a total of 20 crosswalks. It was found that six out of 20 crosswalks had a significant increase in pedestrian compliance, which was measured as percentage of pedestrians entering the crosswalk during the WALK indication, at the 95% confidence level. It was also found that two of the 20 crosswalks had a significant decrease in pedestrian compliance. The other 12 crosswalks had insignificant results in pedestrian compliance.

Schrock and Bundy (15) studied the effects of pedestrian countdown timers on drivers in Lawrence, Kansas, in a comparative analysis of four intersections along the same corridor: two with pedestrian countdown timers installed and two with traditional pedestrian signals. Vehicle speeds were measured using LIDAR from observers located downstream of the intersection, facing oncoming traffic. Vehicles that were located in the indecision zone during the flashing DON'T WALK phase were used for data. Vehicles were categorized into one of the following categories: stopped (began decelerating at or after the beginning of the yellow phase); stopped but began decelerating early (before the beginning of the amber phase); continued steadily through the intersection; continued through the intersection but accelerated in order to do so; and continued through the intersection but ran the red light in order to do so. They found a significant decrease in drivers who accelerated in order to continue through the intersection when a pedestrian countdown timer was present. They concluded that drivers in the indecision zone drove less aggressively at intersections with pedestrian countdown timers installed.

2.2 Past Literature on Phase Countdown Timers

Phase countdown signals were also considered during the literature review. Signalized intersections are important nodal points in transportation networks, and their efficiency of operation greatly influences the performance of the entire network. Several European and Asian countries have started using phase countdown timers to provide additional information to drivers: namely, the time until the beginning of the green phase. In the U.S., engineers are still debating whether to provide phase countdown timers, but a number of pedestrian countdown timers have been installed to provide additional information to pedestrians. The presence of these timers is expected to affect both driver and pedestrian behavior. Drivers may react differently on the onset of yellow because they will have additional information on the time until the onset of yellow. This can affect both safety and efficiency of the performance of both vehicles and pedestrians at signalized intersections.

He et al. (6) performed a study of drivers' perceptions of phase countdown timers in Beijing, China. They surveyed 200 drivers about the perception of the effects that phase countdown timers have on driving behaviors and intersection safety. They found that 75% of the surveyed drivers thought that phase countdown timers could help them avoid using the emergency brake at the onset of the amber phase. All drivers were in consensus that phase countdown timers can:

- Reduce driver waiting anxiety by informing them of the time until the next phase,
- Provide a reference for drivers on when to turn off and turn on their engines in order to save fuel and help the environment, and
- Provide more information than traditional traffic signals can.

Furthermore, they found that 87.5% of surveyed drivers prefer phase countdown timers to traditional traffic signals. In addition, they found that 86.0% of drivers believed that intersections with phase countdown timers are safer than traditional traffic signal intersections. Other studies have been performed to analyze the effects that phase countdown timers have on drivers (10, 17), which mainly focus on queue discharge characteristics.

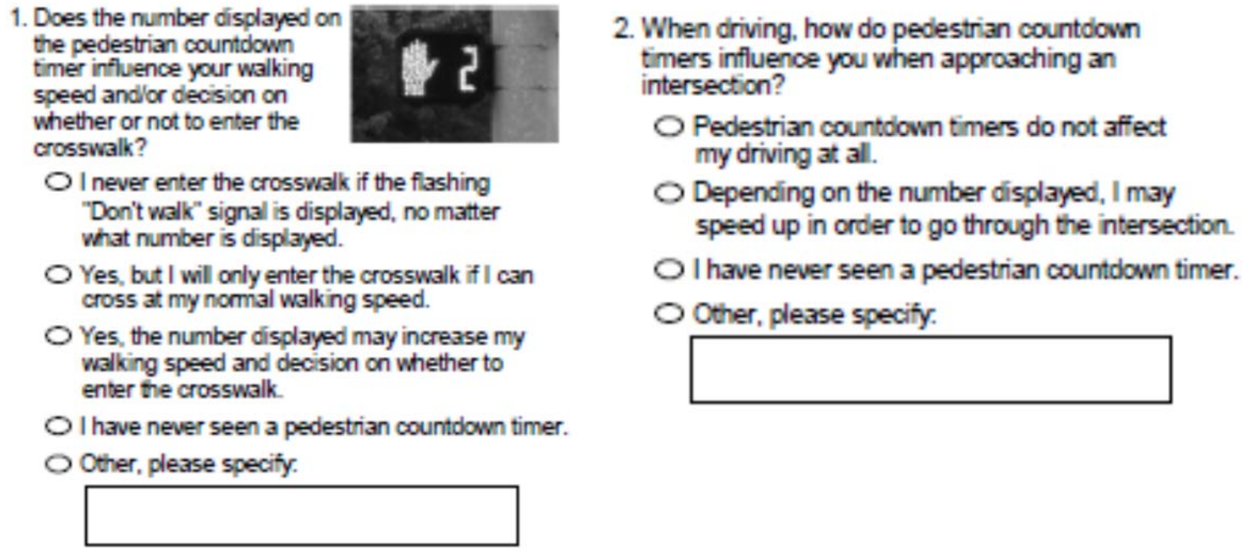
Other studies (1, 2, 9, 12, and 24) have explored the effects of pedestrian countdown timers on pedestrians and drivers with mixed results. Pedestrian countdown timers have been reported to have both positive and negative effects on drivers and pedestrians depending on the study. Therefore, it is important to study the effects of pedestrian countdown timers on both drivers and pedestrians in Lincoln in order to understand the advantages and disadvantages of pedestrian countdown timers specific to Lincoln drivers and pedestrians.

2.3 Survey for Assessing Impact of Pedestrian Countdown Timers on Nebraska Residents

The Nebraska Annual Social Indicator Survey (NASIS) conducted by Bureau of Sociological Research was used to conduct the survey of user preferences in the presence of a pedestrian countdown timer. NASIS is an omnibus survey of the quality of life in the state of Nebraska. A representative sample of approximately 2,000 Nebraskans are asked to give their opinions on topics ranging such as the environment, health, recreation, occupation, and so forth. NASIS 2010 was a paper-based mail survey in which adults (aged 19 or older) were asked to fill out an omnibus of questions. Appendix A contains a copy of NASIS 2010.

Figure 2.1 shows the questions relevant to the project included in NASIS 2010. One question asked for the pedestrian perspective on whether the number of seconds displayed on the pedestrian countdown timer influenced the pedestrian's walking speed and/or decision to enter or not enter the crosswalk. The answer options were:

a. I never enter the cross walk if the flashing DON'T WALK signal is displayed, no matter what number is displayed;
b. Yes, but I will only enter the crosswalk if I can cross at my normal speed;
c. Yes, the number displayed may increase my walking speed and decision whether to enter the crosswalk;
d. I have never seen a pedestrian countdown timer;
e. Other.



1. Does the number displayed on the pedestrian countdown timer influence your walking speed and/or decision on whether or not to enter the crosswalk?
   - ○ I never enter the crosswalk if the flashing "Don't walk" signal is displayed, no matter what number is displayed.
   - ○ Yes, but I will only enter the crosswalk if I can cross at my normal walking speed.
   - ○ Yes, the number displayed may increase my walking speed and decision on whether to enter the crosswalk.
   - ○ I have never seen a pedestrian countdown timer.
   - ○ Other, please specify:

2. When driving, how do pedestrian countdown timers influence you when approaching an intersection?
   - ○ Pedestrian countdown timers do not affect my driving at all.
   - ○ Depending on the number displayed, I may speed up in order to go through the intersection.
   - ○ I have never seen a pedestrian countdown timer.
   - ○ Other, please specify:

Figure 2.1 Relevant questions in NASIS 2010

A total of 2,032 responses were received for the pedestrian preference question. Figure 2.2 displays the distribution of responses. It can be seen that 49% (996/2,032) of the pedestrians stated that pedestrian countdown timers do impact their crossing decisions or chosen speed. Out of 2,032 responders, 568 stated that they haven't seen a PCT. If we remove these respondents, then 68% of the responders that have seen pedestrian countdown timer state that it impacts their crossing decisions and chosen speeds.

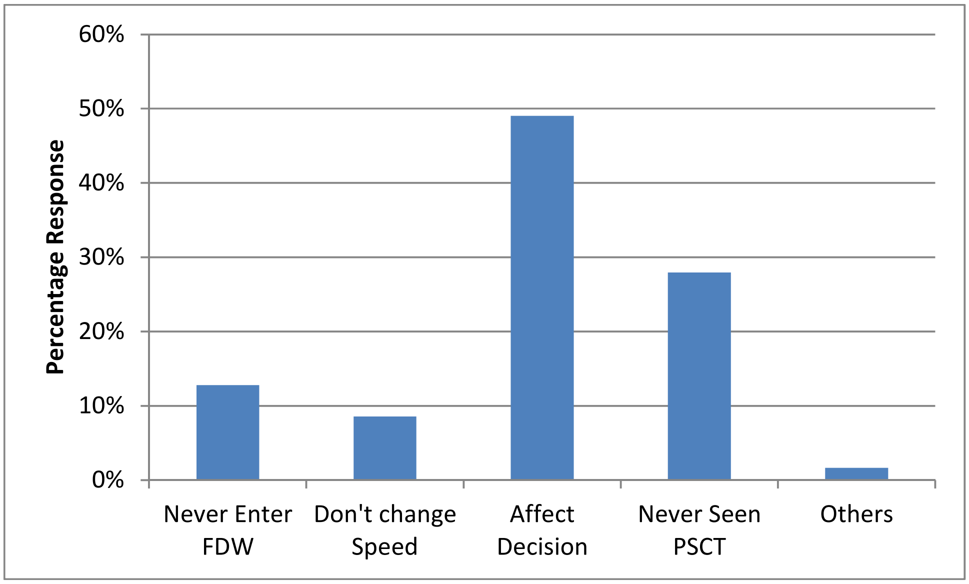


Figure 2.2 Pedestrian preferences in presence of pedestrian countdown timer

The question addressing the driver's perspective asked how pedestrian countdown timers influenced the driver when approaching and intersection. The options to choose from where:

a. Pedestrian countdown timers do not affect my driving at all;
b. Depending on the number displayed, I may speed up in order to go through the intersection;
c. I have never seen a pedestrian countdown timer;
d. Other.

A total of 2,018 responses were received for the driver preference question. Figure 2.3 displays the distribution of responses. It can be seen that 36% (722/2,018) of the drivers stated that pedestrian countdown timers do not impact their speed decisions. Out of 2,018 respondents, 702 stated that they haven't seen a PCT. If we remove these respondents, then 54% of the respondents that have seen a pedestrian countdown timer stated that PCTs do not impact their driving speed choice.

The results of survey of Nebraskan show that more than a quarter of Nebraskans have not seen a pedestrian countdown timer. For the respondents who have seen a PCT, more than half stated that the PCT affects their pedestrian crossing and speed decisions. Also, for the responders who have seen PCT, more than half claim that it doesn't affect their driving speed choice.

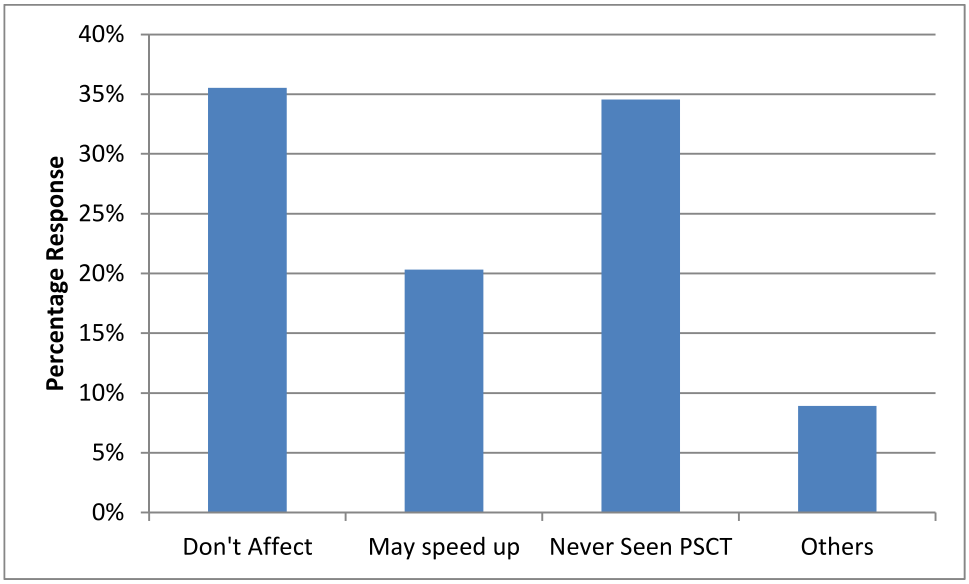


Figure 2.3 Driver preferences in presence of pedestrian countdown timer

Chapter 3 Data Collection

After a thorough literature review, a detailed research plan and methodology were presented to the Nebraska Department of Roads Traffic Advisory Committee (TAC) on June 4, 2009. The TAC, consisting of professionals from the Nebraska Department of Roads and the City of Lincoln Public Works Department, chose two intersections at which to perform the study in Lincoln, Nebraska: the intersection of S. 17th St. and G St. and the intersection of N. 27th St. and Cornhusker Highway. It was determined that the best approaches to perform the study were the northbound approach at 17th St. and G St., and the eastbound approach at 27th St. and Cornhusker Highway. At both of these locations, the pedestrian countdown timers can easily be seen by oncoming traffic at distances over 500 ft. Other technical constraints, met at both intersections selected, needed for this study were:

- Presence of pedestrian signal recall to ensure that the countdown is displayed at every cycle.
- Presence of space in the traffic cabinet to accommodate the instrumentation for data collection purposes.
- Availability of exterior hardware component storage including mast arms (no span wires) to hold the WADs and light poles to hold the PTZ cameras.

Table 3.1 lists the intersection width at the two intersection approaches used to perform this study.

Table 3.1 Intersection width

Intersection	Approach	Intersection Width (ft)
17th and G	NB	95
27th and Cornhusker	EB	160

Due to an inability to obtain accurate pedestrian walking speeds at 27th and Cornhusker, explained in detail later, pedestrian data was only reduced at the intersection of 17th St and G St. Exact measurements of the four crosswalks were measured at S. 17th and G St.

Table **4**.2 lists the length and width of each crosswalk at the intersection of 17th and G. Figure 5.1 shows the intersection of 17th and G with the crosswalk dimensions shown.

Table 4.2 Crosswalk dimensions at 17th and G

Leg	North	South	East	West
Length, ft	41.32	42.04	41.23	39.78
Width, ft	12.33	13.33	10.25	11.92

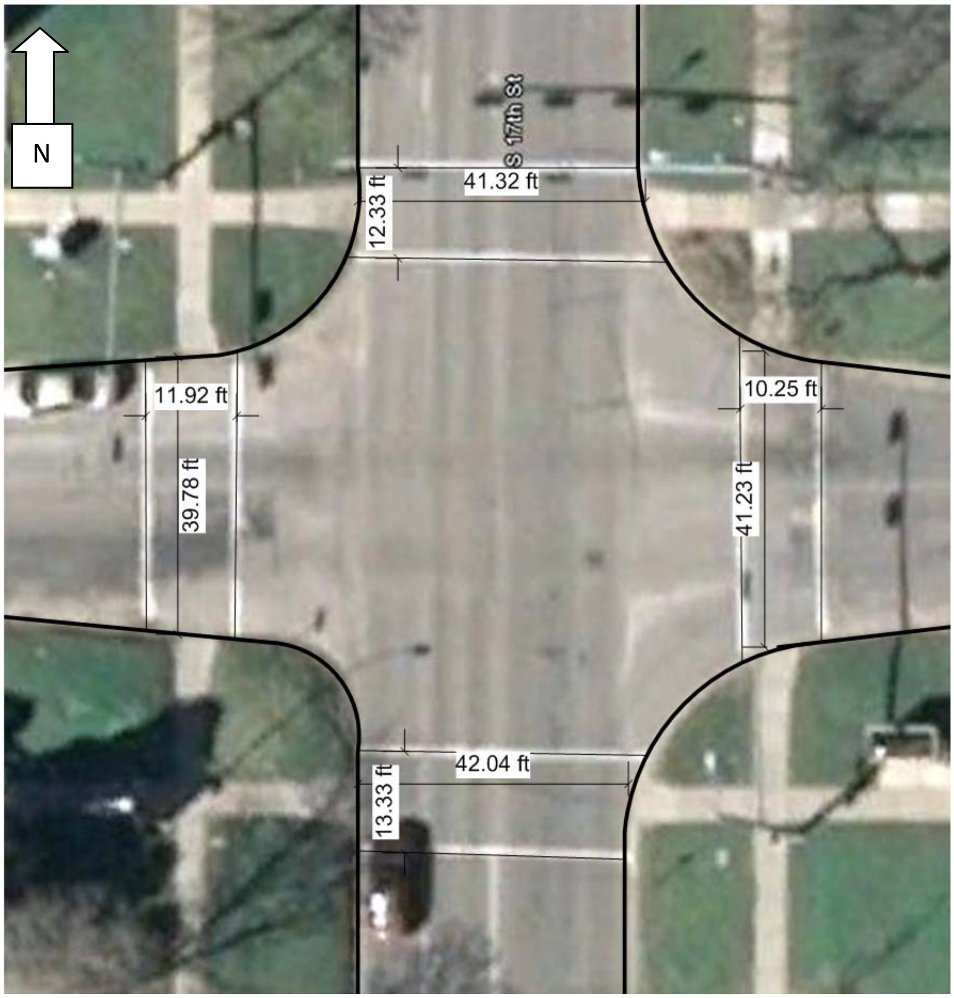


Figure 5.1 17th and G crosswalk dimensions

In order to satisfy the performance measures of the project, many hardware components were installed in the field. For all pedestrian performance measures, a PTZ camera was needed. A wide area detector (WAD) was needed to collect data needed for probability of stopping curves and the speed at the stop bar of vehicles during the yellow phase. MOXA I/O devices, explained later, were used to collect the traffic and pedestrian signal phase information.

For wide area detection, the Wavetronix SmartSensor Advance was used. The Wavetronix SmartSensor Advance has a detection range of 500 ft, and it was installed on the traffic signal mast arm at both locations. Figure 3.2 shows the detection area of the Wavetronix SmartSensor Advance.

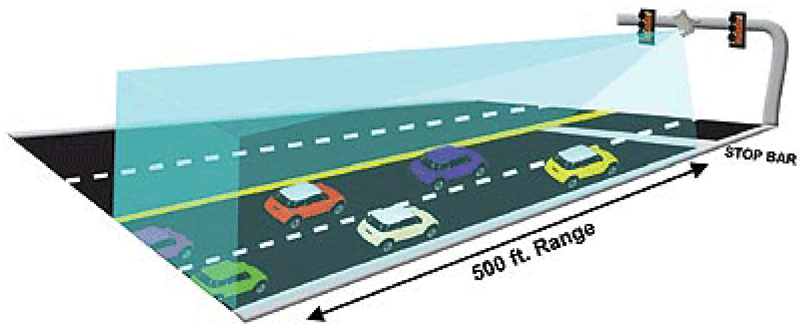


Figure 3.2 Wavetronix SmartSensor Advance
(http://www.wavetronix.com/products/smartsensor/200)

The Wavetronix sensor has the ability to track individual vehicles and display their locations and speeds instantaneously. In addition, all vehicular location and speed information is stored in a database for future retrieval. By pairing up the Wavetronix information and the video captured by the PTZ camera, the instantaneous speed of each vehicle in the video was displayed.

The Sensys Wireless Vehicle Detection System was used for the stop bar detectors. This system has three components: flush-mount wireless sensors, an access point, and contact closure cards. The access point relays the stop bar detector information to the contact closure card. Figure 3.3 shows the relative locations of each hardware component in the field. Appendix B shows the actual dimensions between hardware components installed at both intersections.

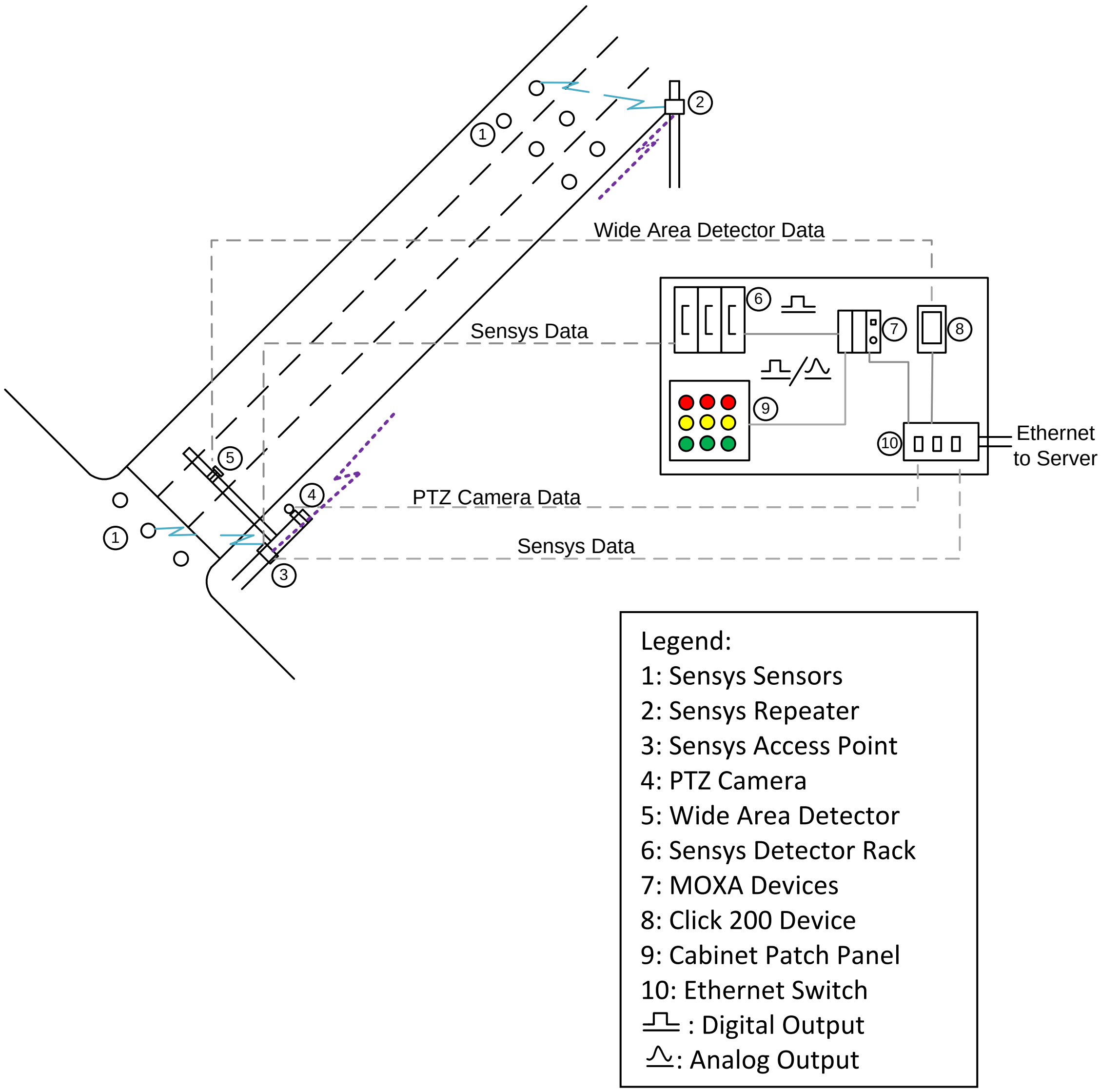


Figure 3.3 Hardware in the field

Pictures of 17th and G as well as 27th and Cornhusker were taken after installation of the hardware in the field. Figure 3.4 shows a picture of the northbound approach at 17th and G. Figure 3.5 shows a picture of the PTZ camera at 17th and G. It is located on the northwest corner of 17th and G.

Figure 3.4 Northbound approach at 17th and G

Figure 3.5 PTZ camera at 17th and G

Figure shows a picture of the eastbound approach at 27^{th} and Cornhusker. Figure 3.7 shows a picture of the PTZ camera installed at the 27^{th} and Cornhusker intersection: it is the lowest camera installed on the pole.

Figure 3.6 Eastbound approach at 27th and Cornhusker

Figure 3.7 PTZ camera at 27th and Cornhusker

MOXA Input/Output and Ethernet network adapter were used to get the contact closures from stop bar detectors and signal phases. The I/O box had 16 digital I/O channels, which took information from the traffic signals and Sensys sensors, and connected to the Ethernet Network Adapter. The Ethernet Network Adapter connected to the City of Lincoln network. The information was accessed from the City of Lincoln Public Works Department Engineering Services office, where a server computer collected all data.

To view the information collected in the field in real-time, the software Wonderware was used. Wonderware has the ability to take MOXA information and display it on a computer screen with the live video from the PTZ camera. Wonderware Intouch Tags were created and assigned to each individual MOXA channel. Table 3.3 lists the MOXA channel, Intouch Tag, and corresponding field data used at 17th St. and G St. Similarly, field data from 27th St. and Cornhusker Highway were assigned Intouch Tags from MOXA channels.

Table 3.3 Wonderware Intouch Tags at 17th St. and G St.

MOXA Channel	Intouch Tag	Field Data
0	10001	Phase 2 (17th) Red
1	10002	Phase 2 (17th) Yellow
2	10003	Phase 2 (17th) Green
3	10004	Phase 2 (17th) Pedestrian Flashing DON'T WALK
4	10005	Phase 2 (17th) Pedestrian Walk
5	10006	Phase 4 (G) Pedestrian Flashing DON'T WALK
6	10007	Phase 4 (G) Pedestrian Walk
7	10008	Sensys 300A
8	10009	Sensys 30C4
9	10010	Sensys A9A9
10	10011	Sensys 3063
11	10012	Sensys 30CD
12	10013	Sensys A9BF
13	10014	Sensys 3094
14	10015	Sensys 30F8
15	10016	Sensys AA17

An example screen shot of Wonderware, Wavetronix, and a flow chart of information is presented in figure 3.8. Wonderware can show the video from the PTZ camera, display which detectors are sending pulses, display the timestamp, and display all phase information for both traffic signals and pedestrian signals. In addition, Wonderware stores all information in a Historian that can be sorted and reduced. Data from a certain time and date can be extracted easily and further analyzed. The computer screen can be recorded at a 15-frames-per-second resolution.

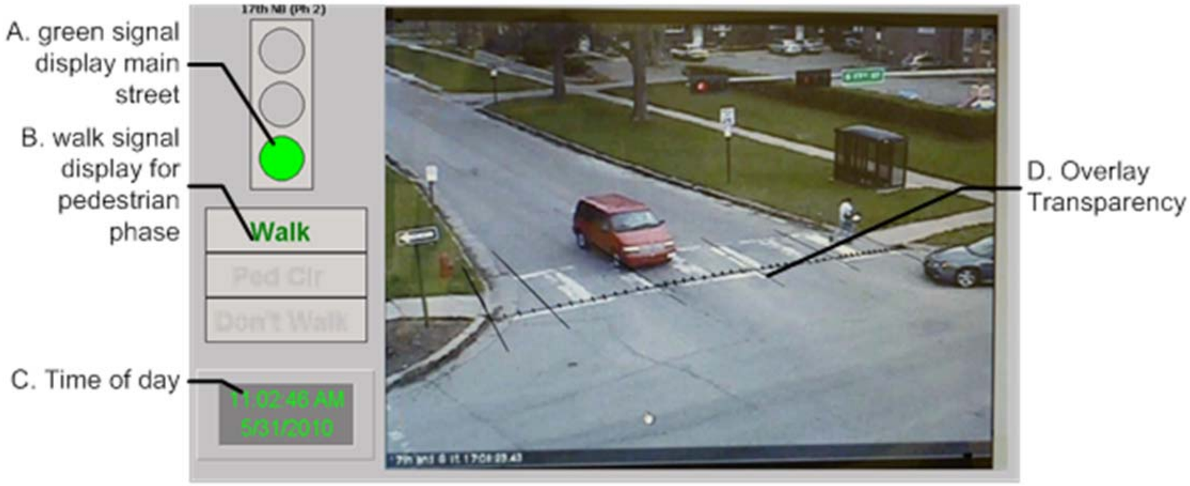


Figure 3.8 Example screenshot of Wonderware for 17th and G

Information from the Wonderware Historian can be accessed from Microsoft Excel by obtaining data using a Microsoft Query and typing in a Structured Query Language (SQL) command. An example Wonderware Historian data set is shown in table 3.4. In this table, a value of 0 represents a time when the pedestrian phase was not flashing DON'T WALK. A value of 1 means that the pedestrian signal phase was flashing DON'T WALK. The example data presented in table 3.4 shows one pedestrian signal cycle on July 9, 2010. During this cycle, the flashing DON'T WALK phase began at 12:01:46 a.m., and ended at 12:01:56 a.m.

Table 3.4 Example Wonderware Historian data

Tag Name	Date and Time	Value
17th_FDW	2010-07-09 00:00:56.217	0
17th_FDW	2010-07-09 00:01:46.197	1
17th_FDW	2010-07-09 00:01:56.190	0

The software MATLAB was used to plot vehicle speed and distance obtained from the WAD. The plot was positioned next to the Wonderware screen, so that each vehicle could be seen as it was being plotted. MATLAB stored all vehicle speed and distances from the stop bar in files that can be accessed for data reduction purposes such as dilemma zone boundaries. Figure shows a screenshot of the MATLAB plots next to the Wonderware screen.

Figure 3.9 Wonderware and MATLAB screenshot

To assess the amount of error incurred while collecting and reducing data, many techniques were employed. First, it was important to know exactly the time difference between the video that was displayed on screen and the time the video was taken in the field. The video camera's maximum response time (delay) was 2.9 ms. Figure shows a graph of the response time over a 24-hour period for the Axis video camera used at S 17th St.

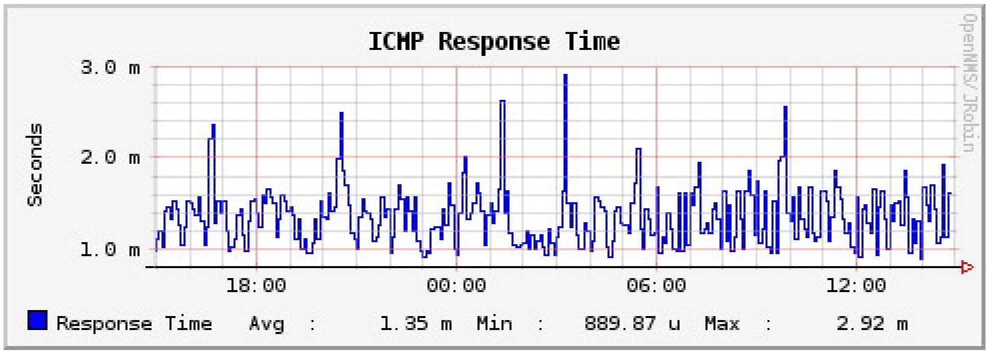


Figure 3.10 Axis video camera 24 hour response time

The same procedure was used for the MOXA device at S. 17th St. The MOXA device relays all signal phase, pedestrian phase, and underground sensor information. The maximum ping time was slightly higher for the MOXA device, at 11.3 ms; however, the average ping time was 1.3 ms. Figure shows a graph of the response time over a 24-hour period for the MOXA device used at S. 17th St.

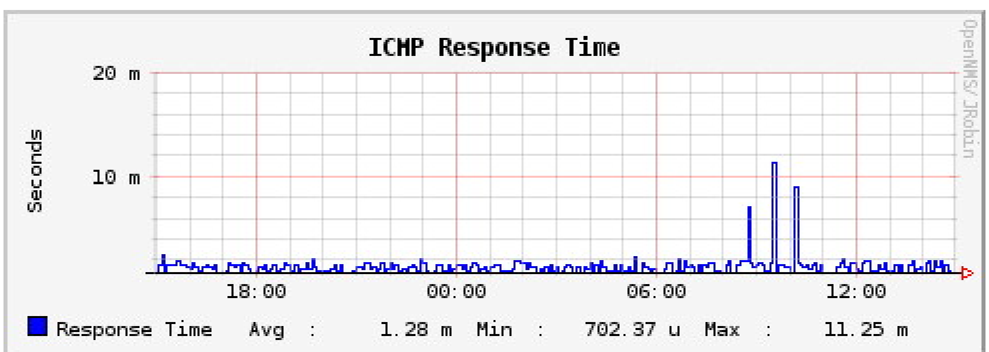


Figure 3.11 MOXA Device 24 hour response time

When reducing the pedestrian data, it was necessary to be consistent in recording when a pedestrian arrived at a certain location. This was especially important when calculating pedestrian walking speeds. The video data was accurate to about 0.1 sec because it recorded data at 15 frames per second and displayed data to the nearest hundredth of a second. Data was recorded to the nearest 0.01 sec, but walking speed results were calculated to the nearest 0.1 ft/sec to reflect the highest accuracy possible.

Pedestrian arrival times were determined by the time when a pedestrian's first foot crossed a line drawn on a transparency, which was attached to the computer screen, at 10 ft increments at 17th and G. This helped determine when pedestrians reached the locations, and in turn it helped calculate pedestrian walking speed with more accuracy. Between each 10-ft line, smaller dashes were drawn, indicating 1 ft. Figure 3.12 shows a picture of the transparency used for pedestrian data reduction.

Figure 3.12 Pedestrian walking speed data reduction

It was found that at 27th St. and Cornhusker Highway, the pedestrian arrival times could not be accurately determined. The video camera was positioned over 150 ft away from pedestrians at a difficult angle to verify exactly when pedestrians arrived at certain locations, including the beginning and end of the crosswalk. Calculations of pedestrian walking speed would have been inaccurate. Pedestrian violations were difficult to determine due to the uncertainty of when the pedestrian entered and exited the crosswalk. Therefore, due to inaccuracy in data collected at 27th and Cornhusker, the effects of pedestrian countdown timers were analyzed using data from 17th St. and G St.

The accuracy of the Wide Area Detector (WAD) was crucial in this project. The accuracy of the WAD was tested using a vehicle equipped with a GPS unit capable of capturing data at a 100-Hz rate was used. The vehicle was driven with the GPS unit inside, capturing time, location, speed, and other data every 1/100 sec. At the same time, the WAD was collecting data. The WAD collects individual vehicle data at rates determined by site characteristics. The WAD collects and stores vehicle ID, range (in 5 ft increments), and speed data. A graph showing speed versus distance from stop bar of the particular vehicle was created from the data captured: one line with GPS data, one line with WAD data, and one line with forecast GPS data. The forecast GPS data line was created in order to compare the two lines at specific distances. Figure 3.13 shows an example of a speed vs. distance graph.

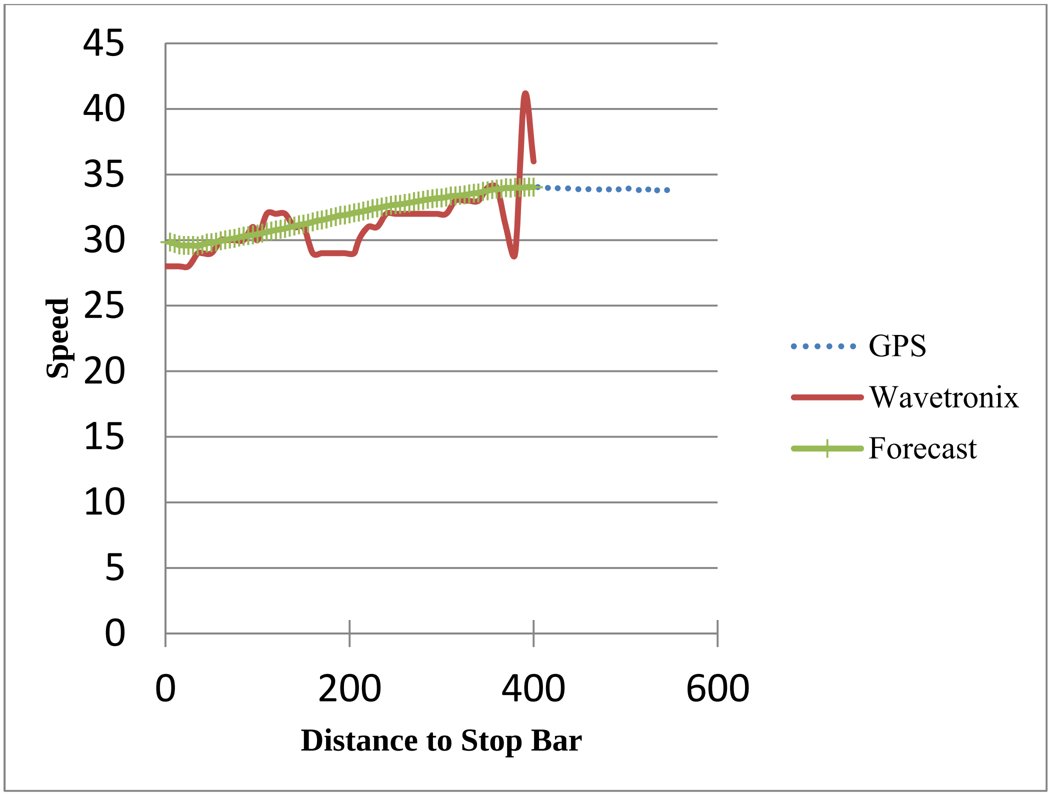


Figure 3.13 Example speed vs. distance plot for a single GPS run

Data obtained from the GPS were interpolated to obtain readings corresponding to WAD observations. The error in speed (mi/hr), equal to the difference in speed between the GPS data and WAD data, was calculated for every data point collected by the WAD. A probe vehicle made nine data collection runs at each intersection. The relative frequency plot of the error in speed at 17th St. and G St. is shown in figure 3.14.

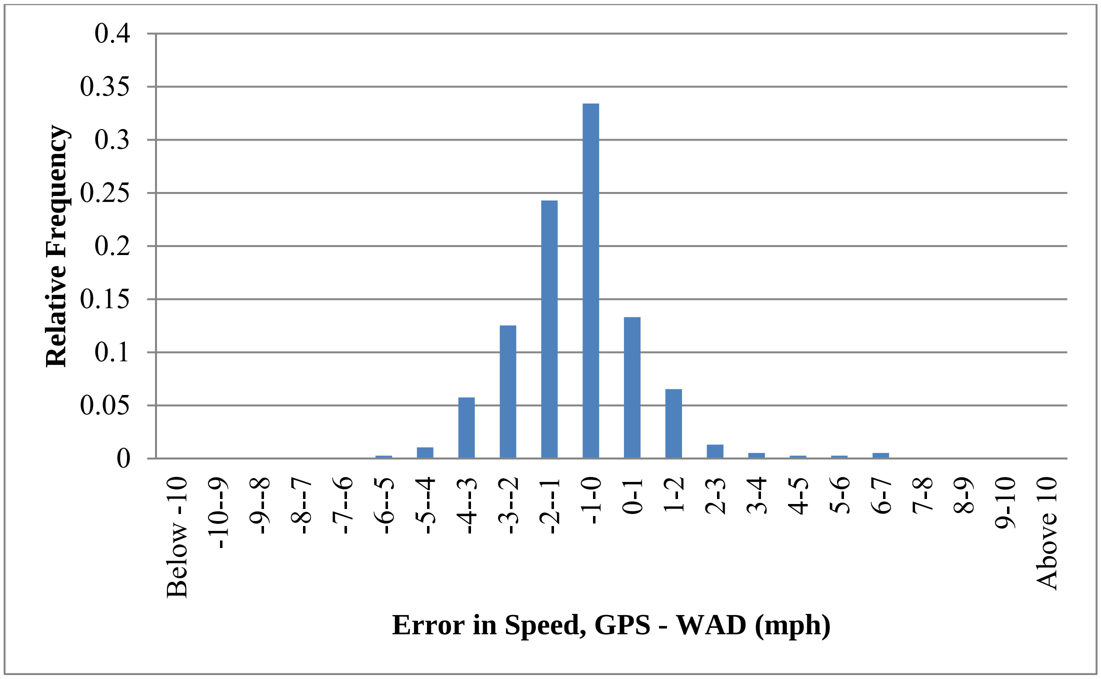


Figure 3.14 Overall relative frequency of error for all GPS runs at 17th and G

As mentioned previously, the error in speed between the GPS data and the WAD data was calculated for each data point collected by the WAD. The combined data from all data collection runs were used to find the mean value of error. The mean value of error in speed for all GPS runs at 17th and G St. was -0.83 mi/hr. Similar results were found at 27th and Cornhusker Highway, in that the mean value of error in speed for all GPS runs at 27th and Cornhusker Highway was -0.91 mi/hr. To further reduce potential error, only the lead vehicles were considered in instances of multiple vehicles approaching the intersection at the onset of yellow.

Chapter 4 Data Analysis

At 17th St. and G St., vehicle data was collected at the northbound approach, and pedestrian data was collected at the east crosswalk (parallel to 17th St). At 27th and Cornhusker Highway, vehicle data was collected at the eastbound approach. For both intersections, data was collected from April 2010 - May 2011. A thorough data reduction process was used to eliminate possible erroneous data. All data was visually inspected before being reduced and only data during fair weather days (no precipitation) was used. In addition, no data collected during December 2010 - February 2011 was used due to extreme cold temperatures experienced, and ice/snow on roadways. The daily high temperature was used as an independent variable in the statistical models. Studies have shown that probability of stopping curves, developed from probit models, stabilize using a small sample size of approximately 150 observations (18, 25). In this study, over 400 data points were collected at each location before and after installation, which is a sufficient amount of data based on previous research findings (18, 25). Tables 4.1 and 4.2 list the number of days of data collection, and number of observations used in the data analysis of this study for both intersections, before and after installation of pedestrian countdown timers, respectively.

Table 4.1 Data collection and number of observations used before installation of PCT

Intersection	Number of Days Data Collected	Number of Pedestrian Observations	Number of Driver Observations for probability of stopping
S. 17th St. and G St.	49	954	429
27th St. and Cornhusker Highway	14	-	525

Table 4.2 Data collection and number of observations used after installation of PCT

Intersection	Number of Days Data Collected	Number of Pedestrian Observations	Number of Driver Observations for probability of stopping
S 17th St and G St	35	500	422
27th St and Cornhusker Highway	14	-	482

4.1 Analysis of Pedestrian Violations

A pedestrian is non-compliant to a pedestrian signal when he or she is inside the crosswalk during the solid DON'T WALK (DW) phase. There are two ways to achieve non-compliance: by entering the crosswalk during the solid DON'T WALK (DW) phase and by being inside the crosswalk when the phase changes from Flashing DON'T WALK (FDW) to DW. According to Jim Davidsaver of the City of Lincoln Police Department (personal communication, August 17, 2010), in the City of Lincoln, it is not a violation for a pedestrian to enter an intersection during the FDW phase as long as that pedestrian exits the intersection before the DW phase begins.

Figure 4.1 shows the percentage of violations before and after installation of the PCT, where a violation in this study was defined as the presence of a pedestrian in crosswalk during the DW phase. Overall, 83% violations were observed before PCT installation which reduced to 68% after installation of the PCT. From a simple comparison, it can be concluded that presence of PCT led to a reduction in violations. However, this simple comparison ignores any effects that other factors may have on violations. Therefore, a probit model was estimated for probability of violations.

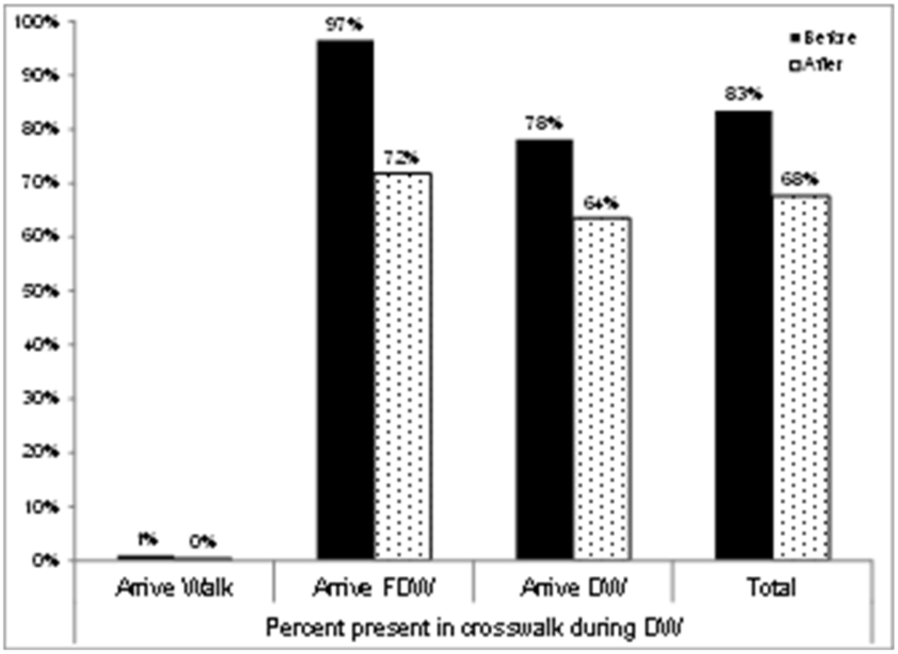


Figure 4.1 Pedestrian compliance results

Pedestrians can be either compliant or not compliant to the pedestrian signal. This can be modeled using a probit model corresponding to the probability of a pedestrian violating a pedestrian signal. The probit model is a binary choice model that takes the form:

$$Pr(Y = 1 / X) = \Phi(X'\beta),$$

Where:

Pr(Y =1 | X) is the probability that the dependent variable is equal to 1 given the independent variable X.

This can be calculated using the CDF of the standard normal distribution function, $\Phi(X'\beta)$, where β is estimated parameters using maximum likelihood. In the pedestrian compliance model, the dependent variable tested was the probability of a violation.

List of independent variables used in pedestrian models is shown in Table 4.3.

Table 4.3 List of variables collected for evaluating impact on pedestrian behavior

Variable Abbreviation	Description
Speed	Pedestrian speed while traversing the intersection
DW_viol	Dummy variable, takes a value of 1 if a pedestrian was in the cross walk during DW phase, else remains 0
FDWStart	Start time of FDW phase
DWStart	Start time of DW phase
ArrTime	Arrival time of pedestrian
Gst_last	Total traffic volume on G St. for two cycles prior to pedestrian crossing
Gst_now	Total traffic volume on G St. for cycle during which the pedestrian crossed
Gst_next	Total traffic volume on G St. for two cycles after the pedestrian crossing
Gst_total	Cumulative traffic volume on G St. for all 5 cycles
17_last	Total traffic volume on 17^{th} St. right turn for two cycles prior to pedestrian crossing
17_now	Total traffic volume on 17^{th} St. right turn for cycle during which the pedestrian crossing
17_next	Total traffic volume on 17^{th} St. right turn for two cycles after the pedestrian crossing
17_total	Cumulative traffic volume on 17^{th} St. right turn for all the 5 cycles
Car_G	Dummy variable, takes a value of 1 if there is a car waiting on G St., else remains 0
Ped_Pres	Dummy variable, takes a value of 1 if there is another pedestrian present in the crosswalk, else remains 0
Arr_W	Dummy variable, takes a value of 1 if pedestrian arrives during Walk phase, else remains 0
Arr_DW	Dummy variable, takes a value of 1 if pedestrian arrives during DW phase, else remains 0
Arr_FDW	Dummy variable, takes a value of 1 if pedestrian arrives during FDW phase, else remains 0
North2South	Dummy variable, takes a value of 1 if pedestrian goes from North to South, else remains 0
Morn_Rush	Dummy variable, takes a value of 1 if time of arrival is between 6 AM – 8 AM, else remains 0
Variable Abbreviation	**Description**
Evening	Dummy variable, takes a value of 1 if time of arrival is between 6 PM – 8 PM, else remains 0
Pres_PCT	Dummy variable, takes a value of 1 for pedestrian observations after PCT installation, else remains 0

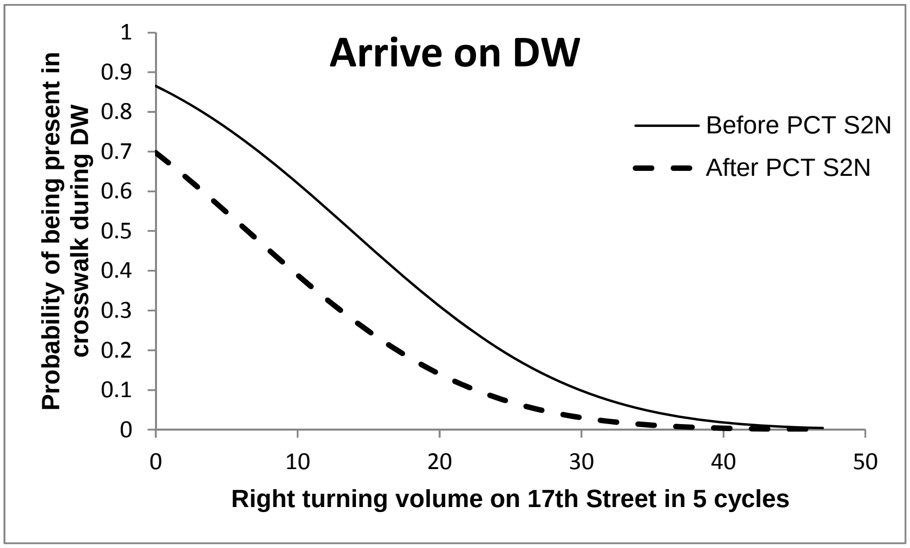
NLOGIT software (Econometric Software Inc., version 4.0) was used to estimate a linear regression model using two considerations: F-test /chi-square test should be significant (an indicator of model significance) and any variable with little or no statistical significance should not be part of the model specification. Table 4.4 presents the final probit model estimated using the above criteria. A t-statistic of 1.96 shows statistical significance at the 95% confidence level.

Table 4.4 Pedestrian compliance model results

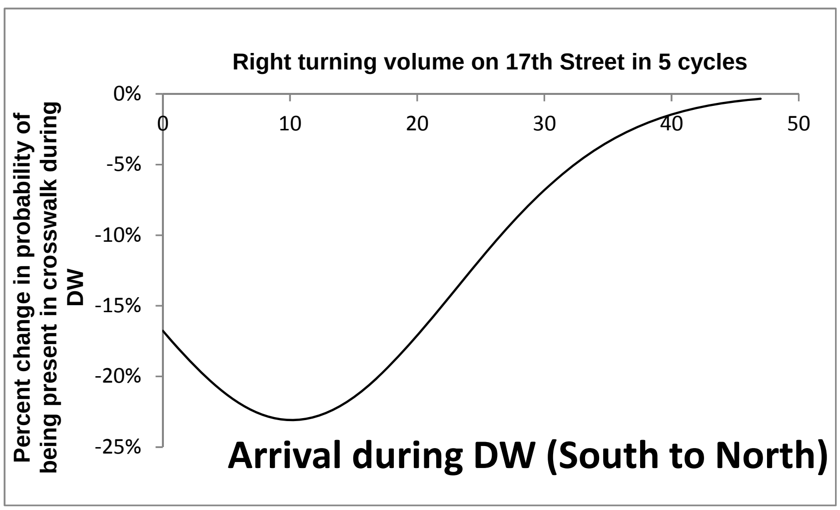
Probit Model			
Number of observations: 1,356			
Restricted Log Likelihood: -796.6 Log Likelihood: -265.1			
McFadden Pseudo $R^2 = 0.67$			
Sensitivity: Actual violations correctly predicted = 97.6%			
Specificity: Actual compliance correctly predicted = 89.8%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	1.1	6.2	Probability of violation can be calculated using the constant term for conditions not covered in any of the dummy variables
17_total	-0.1	-2.6	Increase in right turn traffic on 17th St. conflicting with pedestrian movement reduces the probability of violation
Arr_W	-3.3	-18.0	Arrival of pedestrian during Walk phase reduces the probability of violation
Arr_FDW	0.5	3.5	Arrival of pedestrian during FDW phase increases the probability of violation
North2South	0.3	2.5	Probability of violation for pedestrians traversing from north to south is higher. A possible reason is that these pedestrians can see right-turning traffic from 17th St., which is a one-way street from south to north.
Pres_PCT	-0.6	-4.3	Presence of countdown timer decreases the probability of violation

The model results show several factors affecting the probability of pedestrian violations. Conflicting right-turning traffic for 5 cycles on 17th St. was found to decrease pedestrians' tendency for violations. Figure 4.2 (a) shows the probability of stopping for pedestrians versus 17th street right turn traffic volumes for 5 cycles for pedestrian arriving during DW phase and traversing from South to North direction. The probability of violation reduces as the conflicting right-turning traffic volume increases. Figure 4.2 (b) shows the percent change in violation before and after installation of PCT versus conflicting right-turning traffic volume plot. It can be seen that the percent change in violation starts from the range of -15 to 20 percent but gradually starts decreasing as the conflicting right-turning traffic volume increases. This implies that if the observations were made only during the rush hours with high right-turning traffic, it is possible that the analyst may not see any significant change in the probability of violation.

The model results also show that arrival of pedestrians during the Walk phase is associated with lower violation probability but arrival during the FDW phase is associated with greater violation probability. Probability of violation for pedestrians traversing from north to south was greater; a possible reason for this finding is that these pedestrians can see right-turning traffic from the 17th St., which is a one-way street from south to north. Finally, the model results show that installation of the PCTs is associated with lower probability of pedestrian violations, thus confirming the first hypothesis that installation of PCTs increases pedestrian compliance at the intersection.



a) Before and after plots of the probability of being present in crosswalk during DW, given the arrival is during DW for pedestrians traversing from South to North



b) Percent change in probability of being present in crosswalk during DW, given the arrival is during DW (After-Before) for pedestrians traversing from South to North

Figure 4.2 Example before and after plots of the probability of being present in the crosswalk during DW phase

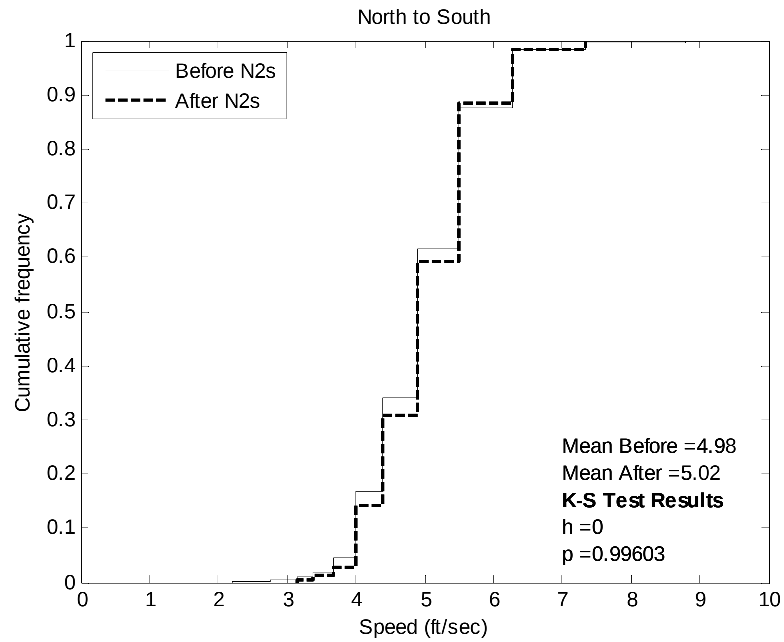
4.2 Analysis of Pedestrian Walking Speeds

Pedestrian speeds (ft/s) before and after installation of the PCT were tested using the Kolmogorov-Smirnov (K-S) test. This is a non-parametric test meaning that it makes no assumption on the underlying probability distributions of variables; it quantifies a distance between the empirical distributions of two samples to determine if two datasets differ significantly. The null distribution of this statistic is calculated under the hypothesis that the samples are drawn from the same distribution; the alternate hypothesis is that they are drawn from different distributions.

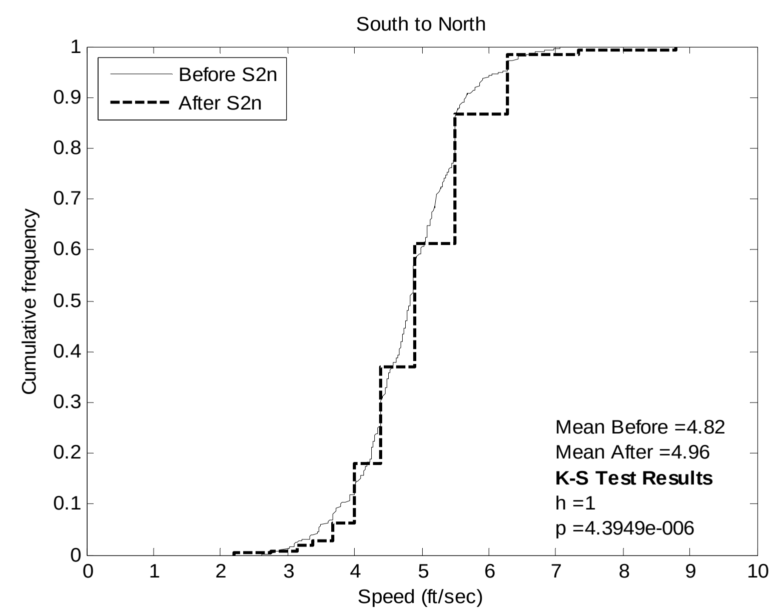
Figure 4.3 compares the empirical cumulative density function (CDF) of speed of the pedestrians traversing from north to south (a) and south to north (b). The continuous line shows pedestrian speed prior to the installation of PCT and while the dashed line represents pedestrian speeds after installation of PCT. The K-S test was conducted for each direction to test whether the cumulative distribution function (CDF) of pedestrian speeds for before and after installation are statistically significantly different from each other. Text providing statistical information about each CDF is also shown in Figure 4.3. The mean speeds before and after PCT installation are displayed.

The K-S test results for the null hypothesis that the cumulative distributions of speeds for before and after PCT are not different from each other are shown in Figure 4.3. 'H=0' implies that the null hypothesis cannot be rejected at 95% confidence level. 'H=1' implies the data provide enough evidence to reject the null hypothesis in favor of the alternate hypothesis. The speeds for pedestrians travelling from north to south were found to be not statistically significantly different before and after the installation of. However, the speeds of pedestrians travelling from south to north were found statistically significantly different from each other

PCT. To investigate further, regression analysis was conducted on the dataset to account for factors that may affect pedestrians' speeds.



a) Kolmogorov Smirnov test results for pedestrian speed (ft/s) traversing from North to South



b) Kolmogorov Smirnov test results for pedestrian speed (ft/s) traversing from South to North

Figure 4.3 Empirical CDF for pedestrian walking speeds at 17 St. and G St. intersection, Lincoln, NE

Linear regression was used to model the pedestrian walking speed. The simple linear regression model is as follows (20):

$$Y_i = \beta_0 + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + ... + \beta_j \cdot X_j + ... + \beta_n \cdot X_n + \varepsilon_i ,$$

where:

Y_i = Estimated value of dependent variable during observation i,

β = Estimated coefficient of independent variable,

n = number of independent variables,

X = Value of independent variable j during observation i, and

ε = Disturbance term, normally distributed with mean = 0 and variance = σ^2

Ordinary least squares regression was used to minimize the disturbance. Table 4.5 lists the results of the pedestrian walking speed model. The criteria and variables used in linear regression model estimation were similar to that used in estimation of the probit model.

The estimated model shows that presence of cars on G St. (the street pedestrians are crossing) results in faster walking speed, pedestrians' arrival on the FDW phase causes faster walking speed, and faster pedestrian walk speeds during the morning rush hour (6–8 am). The model shows pedestrians' walk speeds decreased during the evening hours (6–8 pm). Importantly, the model shows that walk speeds increased after installation of the PCT, confirming the second hypothesis that installation of PCTs increases the walking speed of pedestrians. Pedestrians' direction of travel was not found statistically significant and hence excluded from the model specification. It should be noted that the increase in speed although statistically significant is very small (0.2 ft/s).

Table 4.5 Pedestrian walking speed regression model

Linear Regression			
Number of observations: 1,356			
Mean = 4.9 ft/s Std dev = 0.8 ft/s			
Adjusted $R^2 = 0.05$ Model test F[5, 1350] (prob) = 15.49 (.0000)			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	4.72	147.4	This is the base speed of the pedestrians that are not qualified by any one of the dummy variables below
Car_G	0.15	2.5	Presence of a car on G St. increases the speed of the pedestrian
Arr_FDW	0.29	4.3	Pedestrians arriving on FDW walk at a faster speed
Morn_Rush	0.38	4.2	Pedestrians during morning rush hour walk faster
Evening	-0.18	-2.7	Pedestrians during evening hours walk slower
Pres_PCT	0.17	3.5	Presence of countdown timer increases the speed

4.3 Analysis of Driver Probability of Stopping at Onset of Yellow

When a driver approaches an intersection, the driver is forced to make a decision on whether to go through the intersection or come to a stop at the onset of yellow. A probit model, a type of binary discrete choice statistical model, can model the driver's decision. According to Sheffi and Mahmassani (18), the sample size required for estimating dilemma zone boundaries is significantly reduced when using a probit model to model the driver's decision. The result of the probit model is a probability of stopping curve that gives the probability of a driver choosing to stop at the intersection given the vehicle's distance from the stop bar at the onset of yellow at a certain speed. Using the probability of stopping curve, dilemma zone boundaries can be determined. According to Zegeer (21), the dilemma zone is a range of distances from the stop bar, beginning at a distance where 10% of vehicles stop and ending at a distance where 90% of vehicles stop, where drivers are forced to make a decision to either stop or go through the intersection at the onset of yellow. The length of the dilemma zone is calculated as the difference between the dilemma zone boundaries.

Following the methodology developed by Sheffi and Mahmassani (18), Sharma (16), and Burnett (3), a probit model was developed to determine the probability of stopping of a single vehicle approaching an intersection. The dependent variable was a dummy variable corresponding to either the vehicle proceeding through the intersection (0) or the vehicle coming to a stop (1). Example independent variables included in the model were:

- High temperature, °F (Integer)
- Day of week (Dummy)
- Time of day (Dummy)
- Time to stop bar assuming the vehicle traveled at a constant speed equal to the speed it was going at the onset of yellow (Decimal)
- 15 min. volume of traffic on 17th St. (Integer)
- Presence of a pedestrian waiting to cross 17th St. (Dummy)
- Lane (Dummy)
- Presence of pedestrian countdown timers (Dummy)

A complete list of variables is listed in Appendix A. Three separate probit models were developed, one before installation, one after installation, and one with all data combined from before and after installation of pedestrian countdown timers.

The probit models for probability of stopping at S. 17th St. and G St. before and after installation of PCT are presented in tables 4.6 and 4.7 respectively.

Table 4.6 Probit model before installation of PCT at S. 17th St. and G St.

Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 429			
Restricted Log Likelihood: -292.1 Log Likelihood: -97.74			
McFadden Pseudo $R^2 = 0.67$			
Sensitivity: Actual Stops correctly predicted = 83.4%			
Specificity: Actual Go correctly predicted = 93.5%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-4.01	-10.9	
Time	1.14	10.6	Probability of stopping increases with time to the stopbar

Table 4.7 Probit model after installation of PCT at S. 17th St. and G St.

Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 422			
Restricted Log Likelihood: -292.5 Log Likelihood: -63.2			
McFadden Pseudo $R^2 = 0.78$			
Sensitivity: Actual Stops correctly predicted = 95.2%			
Specificity: Actual Go correctly predicted = 92.5%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-5.03	-10.9	
Time	1.43	10.6	Probability of stopping increases with time to the stopbar

Developed by using the probit models presented in tables 4.6 and 4.7, figure 4.4 shows the probability of stopping curves before and after installation of pedestrian countdown timers at S 17^{th} St and G St.

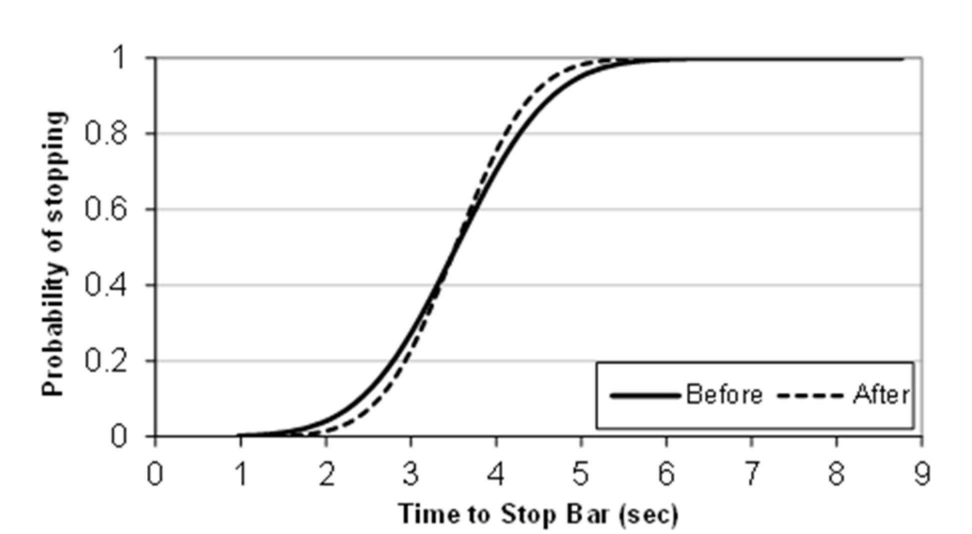


Figure 4.4 Probability of stopping at S. 17th St. and G St.

It can be seen in figure 4.4 that the probability of stopping curve became steeper after installation of pedestrian countdown timers. The steeper curve results in shifted dilemma zone boundaries. Table 4.8 shows the dilemma zone boundaries before and after installation of pedestrian countdown timers at S. 17th St. and G St.

Table 4.8 Dilemma zone boundaries at S. 17th St. and G St.

	Time from the stopbar (sec)		
	Begin Dilemma Zone	End Dilemma Zone	Length of Dilemma Zone (sec)
Before	2.4	4.7	2.3
After	2.6	4.4	1.8

The dilemma zone is shortened after installation of pedestrian countdown timers at S. 17th St. and G St. by 0.5 sec. This shows a reduction in variance in decision making on the onset of yellow, which is a desirable result for improvement of safety. In addition, at S. 17th St. and G

St., the number of red light runners reduced after installation of pedestrian countdown timers. Before installation, 10 vehicles out of 429 vehicles (2.3%) ran the red light. After installation, only 3 vehicles out of 422 vehicles (0.7%) ran the red light. This also supports the argument that installation of PCT shows positive impact on driver safety.

A third probit model was developed that contained all data, to determine if the presence of pedestrian countdown timers statistically significantly affects the probability of stopping curve. Table 4.9 lists the results of the combined model.

Table 4.9 Probit model of combined data at S. 17th St. and G St.

Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 851			
Restricted Log Likelihood: -586.9 Log Likelihood: -160.95			
McFadden Pseudo $R^2 = 0.72$			
Sensitivity: Actual Stops correctly predicted = 89.7%			
Specificity: Actual Go correctly predicted = 93.1%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-4.01	-10.9	
Time	1.14	10.6	
PCT_Pres	-1.02	-1.57	Not Significant at 95% level of confidence
PCT_Time	0.29	1.59	Not Significant at 95% level of confidence

The impact of pedestrian count down timer was not found to be statistically significant at 95% level of confidence. Thus there is not enough evidence for 17th and G street to reject the null hypothesis that PCT have a statistically significant impact on probability of stopping on the onset of yellow with 95% level of confidence. It should be noted that the difference is significant at

88% percent level of confidence implying that there is some evidence that the presence of countdown timer helps in shrinking the dilemma zone boundaries at 17&G.

The probit models for probability of stopping at 27th St. and Cornhusker Highway are presented in tables 4.10 and 4.11.

Table 4.10 Probit model before installation of PCT at 27th St. and Cornhusker Highway

Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 525			
Restricted Log Likelihood: -341.9 Log Likelihood: -154.3			
McFadden Pseudo $R^2 = 0.55$			
Sensitivity: Actual Stops correctly predicted = 80.2%			
Specificity: Actual Go correctly predicted = 91.7%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-4.06	-12.6	
Time	1.00	12.4	Probability of stopping increases with time to the stopbar

Table 4.11 Probit model after installation of PCT at 27th St. and Cornhusker Highway

Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 482			
Restricted Log Likelihood: -302.7 Log Likelihood: -141.7			
McFadden Pseudo $R^2 = 0.53$			
Sensitivity: Actual Stops correctly predicted = 76.8 %			
Specificity: Actual Go correctly predicted = 92.1 %			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-4.28	-12.1	
Time	1.03	11.8	Probability of stopping increases with time to the stopbar

Developed by using the probit models presented in tables 4.1 and 4.2, figure 4.5 shows the probability of stopping curves before and after installation of pedestrian countdown timers at 27th St and Cornhusker Highway. Table 4.12 shows the dilemma zone boundaries before and after installation of pedestrian countdown timers at 27th St and Cornhusker Highway

.

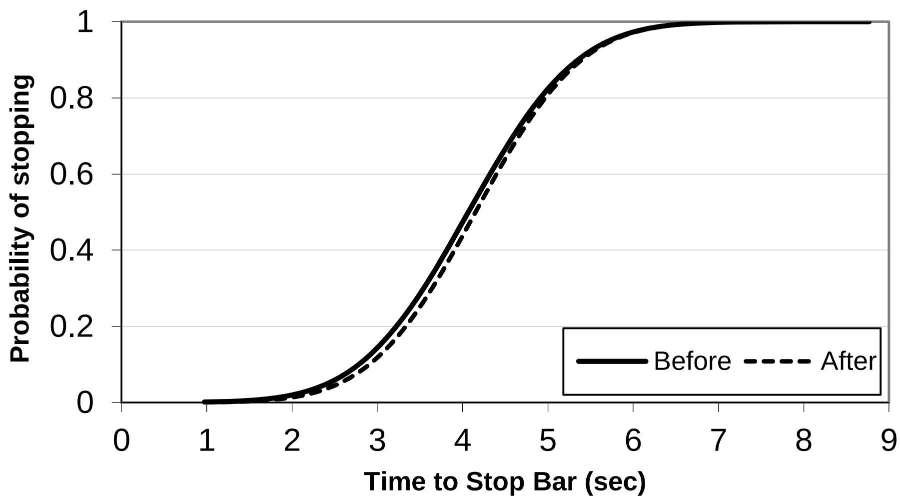


Figure 4.5 Probability of stopping at 27th St. and Cornhusker Highway

As can be seen from Figure 4.5 there is not much of a difference between before and after installation. One of the reasons could be the difference between the size of the intersections. 27 & Cornhusker being a bigger intersection provide lot of clutter for the people to notice pedestrian count down timer and its presence doesn't seem to affect the stopping behavior of the drivers. Table 4.12 shows the dilemma zone boundaries before and after installation of pedestrian countdown timers at S. 27th St. and Cornhusker highway. The change in dilemma zone boundary is negligible.

Table 4.12 Dilemma zone boundaries at 27th St. and Cornhusker Highway

	Distance from Stop Bar (ft)		
	Begin Dilemma Zone	End Dilemma Zone	Length of Dilemma Zone (sec)
Before	2.8	5.4	2.6
After	2.9	5.4	2.5

At 27th St. and Cornhusker Highway, approximately the same number of vehicles ran the red light before and after installation. Before installation, 7 vehicles out of 525 vehicles (1.3%) ran the red light, and after installation, 8 vehicles out of 482 vehicles (1.6%) ran the red light. To test the statistical significance of the shift in probability of stopping curve due to installation of PCT, an overall probit model was developed, and is presented in table 4.13.

Table 4.13 Probit model of combined data at 27th St. and Cornhusker Highway

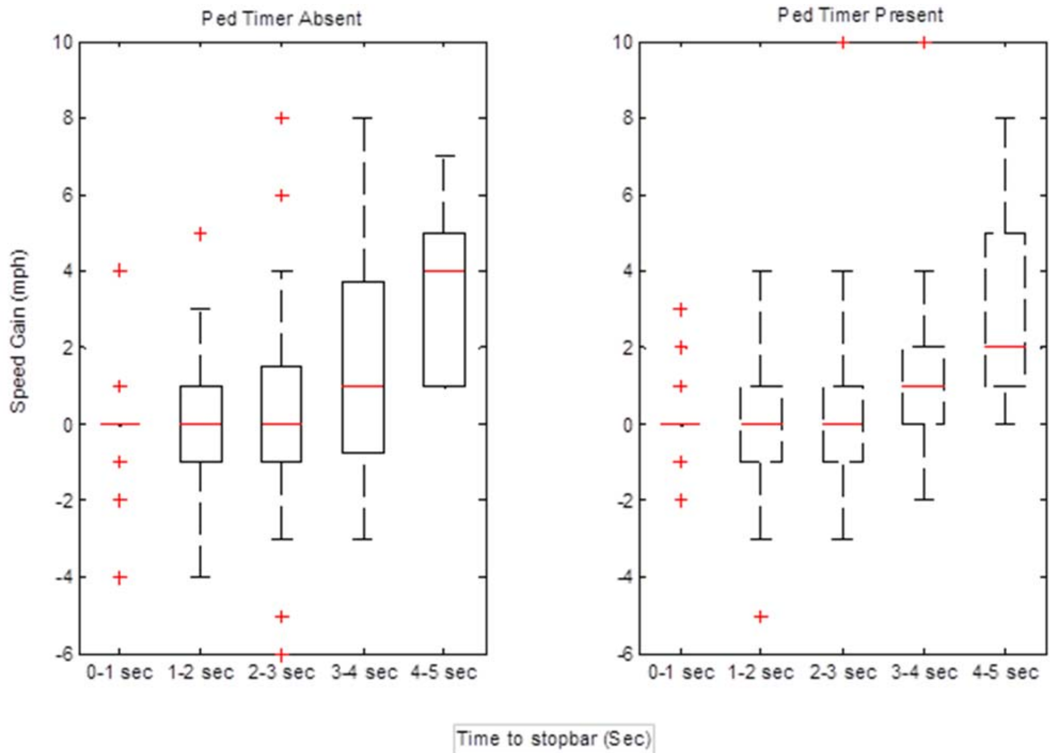
Probit Model Dependent Variable: Vehicles Goes or Stops (Goes = 0 / Stops = 1)			
Number of observations: 1007			
Restricted Log Likelihood: -645.3 Log Likelihood: -296.1			
McFadden Pseudo $R^2 = 0.54$			
Sensitivity: Actual Stops correctly predicted = 78.7%			
Specificity: Actual Go correctly predicted = 91.8%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-4.06	-12.6	
Time	1.00	12.5	
PCT_Pres	-0.22	-0.45	Not Significant at 95% level of confidence
PCT_Time	0.03	0.27	Not Significant at 95% level of confidence

The impact of pedestrian count down timer was not found to be statistically significant at 95% level of confidence. Thus there is not enough evidence for 27th and Cornhusker Highway to reject the null hypothesis that PCT have a statistically significant impact on probability of stopping on the onset of yellow with 95% level of confidence.

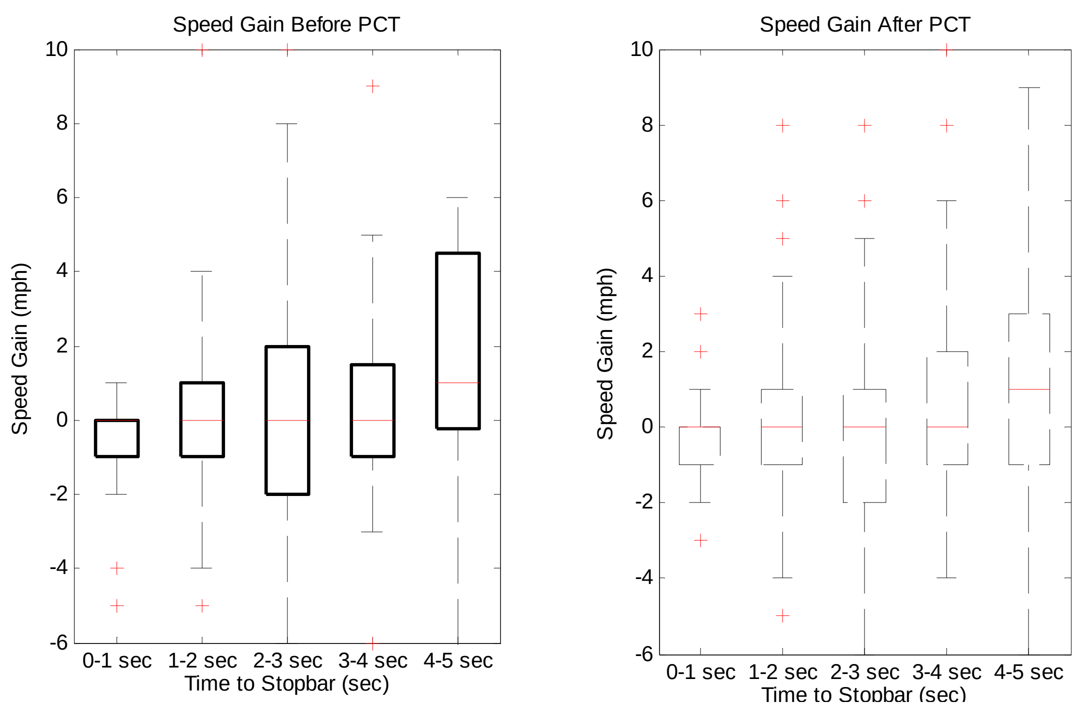
4.4 Analysis of Driver Speed Gain between Speed at the Onset of Yellow and Speed at the Stopbar

To see the effects that pedestrian countdown timers have on vehicle speeds, the speed gain at the stop bar of vehicles during the yellow phase was studied. All vehicles that passed through the intersection during the yellow phase were included. Figure 4.6 shows the plot of speed gain at the stop bar relative to the speed of the vehicles deciding to go at the onset of yellow. Figure 4.6 a presents the boxplot for 17 & G street. It can be seen as the vehicles are further and further away from the stop bar they tend to speed up to go on the onset of yellow. Same trend is noticed in Figure 4.6 b plotting the speed gain for 27th and Cornhusker highway. As can be seen from the figure 4.6, the presence or absence of countdown timer doesn't seem to substantially affect the speed gain distribution.

The statistical significance of the change is assessed by developing linear regression model for speed gain for both the sites. The dependent variable in the model was the difference in speed of the vehicle as it crosses the stop bar from its speed on the onset of yellow. A positive value of speed gain would imply that vehicles tend to speed up to cross the stop bar after the signal phase indication turns yellow. The independent variables were the same as the probability of stopping probit model, with the addition of the vehicle's speed at the onset of yellow (see Appendix A for a complete list of independent variables). One overall model was used to determine if pedestrian countdown timers have an effect on speed at the stop bar of vehicles



a) Speed gain before and after installation of PCT at 17th and G street



b) Speed gain before and after installation of PCT at 27th and Cornhusker street

Figure 4.6 Speed gain at the stop bar from the speed at onset of yellow

Table 4.14 Speed at stop bar of vehicles during yellow phase model at S. 17th St. and G St.

Linear Regression			
Number of observations: 460			
Mean = 0.35 mph Std dev = 2 mph			
Adjusted R^2 = 0.11 F-stat = 28.2 F-test = Significant at 99%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	0.19	-1.88	
TTS_3T	0.51	7.35	
Pres_PCT	-0.21	-1.19	NOT SIGNIFICANT
Linear Regression with only significant variables			
Number of observations: 460			
Mean = 0.35 mph Std dev = 2 mph			
Adjusted R^2 = 0.11 F-stat = 54.9 F-test = Significant at 99%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	0.09	0.933	
Time to Stop Bar	0.52	7.41	Speed gain is higher for vehicle further upstream of stopbar

Table 4.15 Speed at stop bar of vehicles during yellow phase model at 27th and Cornhusker Highway

Linear Regression			
Number of observations: 642			
Mean = 0.09 mph Std dev = 4.3 mph			
Adjusted R^2 = 0.03 F-stat = 10.3 F-test = Significant at 99%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-0.16	-0.61	
Time to stop bar (> 3sec)	0.4	4.36	
Pres_PCT	-0.45	-1.32	NOT SIGNIFICANT
Linear Regression with only significant variables			
Number of observations: 642			
Mean = 0.09 mph Std dev = 4.3 mph			
Adjusted R^2 = 0.03 F-stat = 54.9 F-test = Significant at 99%			
Variable Name	**Estimated Coefficient**	**t-stat**	**Comments**
Constant	-0.4	-1.92	
Time to stop bar (> 3sec)	0.4	4.35	Speed gain is higher for vehicle further upstream of stopbar

during the yellow phase at each intersection. Table 4.14 and Table 4.15 lists the results of the vehicle speed gain at stop bar for 17th & G Street and 27th and Cornhusker highway respectively.

From Table 4.14 and table 4.15 it can be noticed that the impact of PCT is not statistically significant on the speed gain at 95% level of confidence. Although, the sign of change is negative for both the intersection implying there is some evidence that speed gain might be reduced by the presence of PCT.

4.5 Analysis of Queue Discharge Headways at 27th and Cornhusker

Analysis of queue discharge headway was conducted at 27th and Cornhusker. Data for 372 queued vehicles before the installation of PCT was compared against the data 399 queued vehicles after the installation of PCT during evening peak hours.

Figure 4.7 presents a boxplot of queue position versus headway before and after installation of PCT. Based on the boxplot the headways for vehicles at queue location 2, 3, 4, 5, 6 are very similar. The dispersion of headway for the first vehicle in the queue increases after installation of PCT with some addition of relatively smaller headways.

K-S test was used to test the statistical significance in the change of overall queue discharge headways and the queue discharge headways of the first vehicle. Figure 4.8 compares the empirical cumulative density function (CDF) of queue discharge headway overall (a) and for the first vehicle (b). The continuous line shows queue discharge headway prior to the installation of PCT and while the dashed line represents pedestrian speeds after installation of PCT. The K-S test was conducted for both overall and first vehicle queue discharge headway whether the cumulative distribution function (CDF) of those for before and after installation are statistically significantly different from each other.

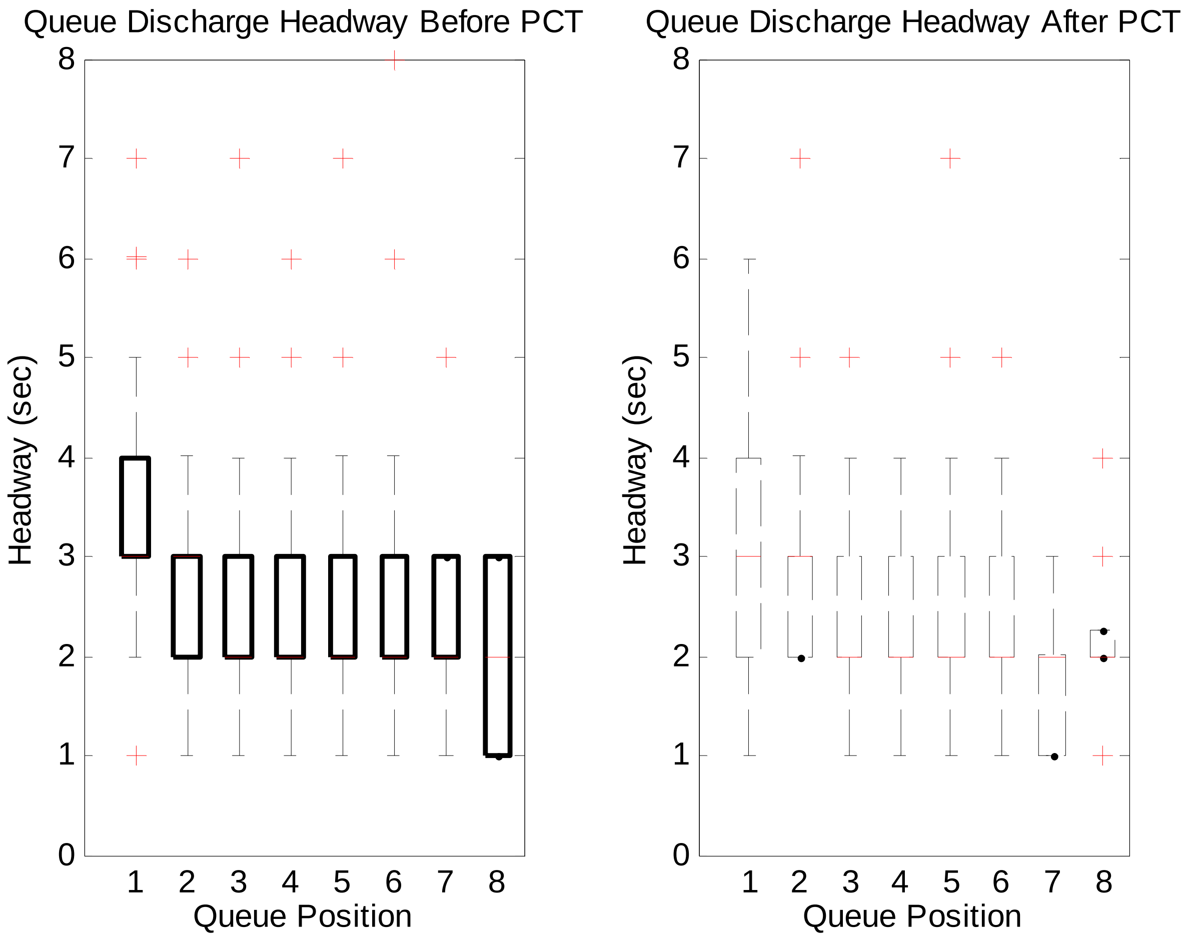
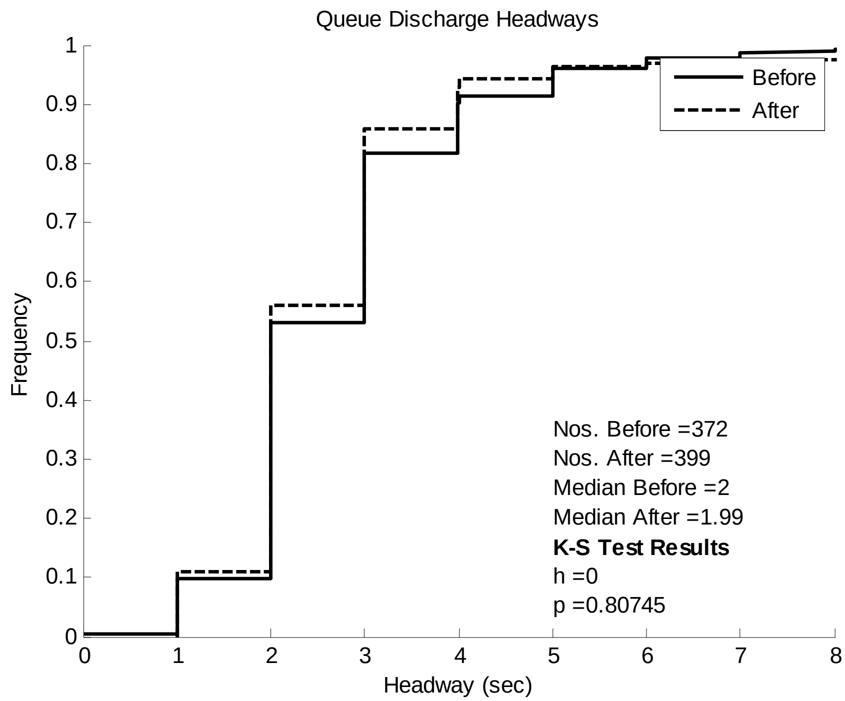


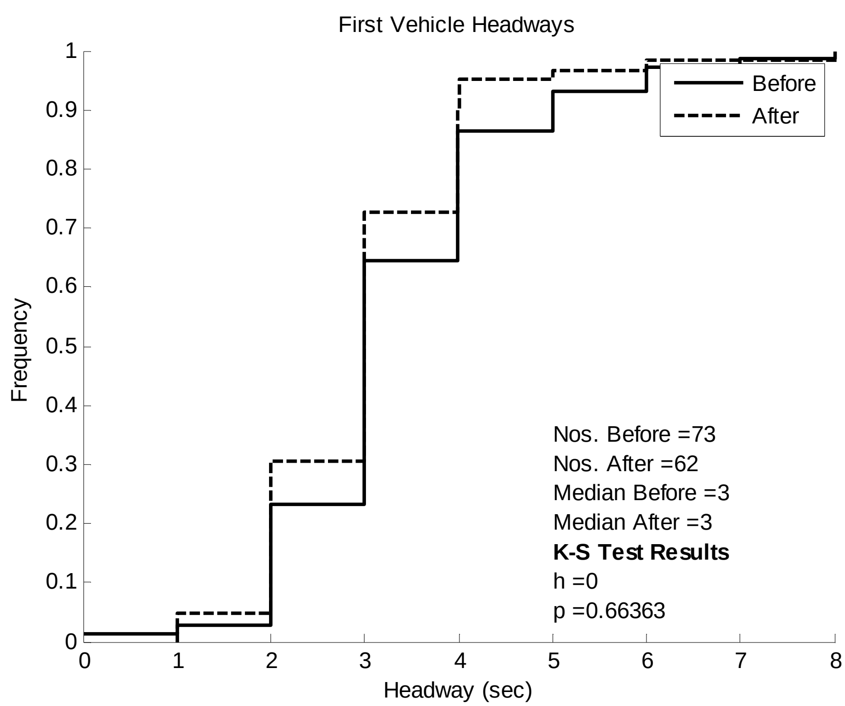
Figure 4.7 Boxplot of queue discharge headways at 27th and Cornhusker

Text providing statistical information about each CDF is also shown in Figure 4.3. The mean median headways before and after PCT installation are displayed.

The K-S test results for the null hypothesis that the cumulative distributions of overall headways and first vehicle for before and after PCT are not different from each other are shown in Figure 4.3. ‘H=0’ implies that the null hypothesis cannot be rejected at 95% confidence level. ‘H=1’ implies the data provide enough evidence to reject the null hypothesis in favor of the alternate hypothesis.



a) Overall queue discharge headway



b) Queue discharge headway for the first vehicle

Figure 4.8 Empirical cumulative distribution function for queue discharge headways

At S. 17th St. and G St., pedestrian countdown timers statistically significantly (at 95% level of confidence) increased pedestrian walking speed by 0.2 ft/sec and pedestrian countdown timers also statistically significantly increased the pedestrian compliance. The study did not find enough evidence to reject the null hypothesis about probability of stopping, speed gain or queue discharge headway at 95% level of confidence at either site. There was however some evidence, although not statistically significant of improvement of driver safety due the presence of PCT. The trend was more pronounced at the intersection of 17th and G where we observed reduction in the percentage of red light runners and reduction of dilemma zone boundaries.

Table 4.16 summarizes the final results for all the hypotheses tested at each site.

Table 4.16 Effects of pedestrian countdown timers on safety and efficiency of operations

Performance Measure	**Effect of Pedestrian Countdown Timers**	**Significant at 17th and G (95% Confidence)**	**Significant at 27th and Cornhusker (95% Confidence)**	**Physical Amount of Effect**
Pedestrian Compliance	Increase in pedestrian compliance	Yes	Not Tested	Depends on Conflicting volume
Pedestrian Walking Speed	Increase in pedestrian walking speed	Yes	Not Tested	0.2 ft/sec
Probability of Stopping	Steeper probability of stopping curve	No (Significant at 88% confidence)	No	NA
Speed Gain at Stop Bar of Vehicles during Yellow Phase	Decreased speed gain at stop bar of vehicles during yellow phase	No	No	NA
Queue Discharge Headway	Reduction of headway specially for the first vehicle in the queue	No	Not Tested	NA

Chapter 5 Conclusions

Past studies show somewhat conflicting results related to the effectiveness of PCTs. The study reported in this research utilized data collected at a study site in Lincoln, NE to evaluate the impacts PCT while controlling for microscopic factors that affect pedestrian walk speed and tendency for violations. The two hypotheses tested were: installation of a PCT increases the walking speed of pedestrians and that installation of a PCT increases pedestrian compliance at the intersection. The study specifically accounted for several factors such as, 5 minute conflicting traffic volumes (through and right turning traffic), time of day, presence of cars waiting on conflicting approach, presence of another pedestrian in cross walk, arrival on Walk, FDW or DW, direction of crossing etc.

Based on the results of this study, it is concluded that installation of PCTs at signalized intersections contributes to faster pedestrian walking speed in the crosswalk and increased pedestrian compliance.

Impact of PCT on driver safety and efficiency was not found to be statistically significant at 95% level of confidence. There was however some evidence, although not statistically significant (at 95%) , of improvement of driver safety due the presence of PCT. The trend was more pronounced at the intersection of 17th and G where we observed reduction in the percentage of red light runners and reduction of dilemma zone boundaries.

Based on this study PCT were found to be beneficial for improving both pedestrian efficiency and safety and some trends were seen of positive impacts on driver safety. The positive impacts were more pronounced for smaller intersections.

However, the results are based on data collected at two intersections in NE; additional intersections in diverse geographic settings with a variety of pedestrian and traffic characteristics need to be studied for more generalized conclusions.

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Appendix A

Copy of NASIS 2010 Survey

NASIS 2010

Nebraska Annual Social Indicators Survey

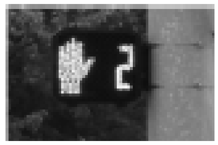
We need your help to learn about how Nebraskans' think, feel, and live. Your responses will help shape Nebraska program and policy development now and into the future.

In order to make this study more scientific, we ask that this survey be completed by the adult (age 19 or older) in your household who most recently celebrated a birthday.

University of Nebraska Lincoln

2010

1. Does the number displayed on the pedestrian countdown timer influence your walking speed and/or decision on whether or not to enter the crosswalk?



   - ○ I never enter the crosswalk if the flashing "Don't walk" signal is displayed, no matter what number is displayed.
   - ○ Yes, but I will only enter the crosswalk if I can cross at my normal walking speed.
   - ○ Yes, the number displayed may increase my walking speed and decision on whether to enter the crosswalk.
   - ○ I have never seen a pedestrian countdown timer.
   - ○ Other, please specify:

2. When driving, how do pedestrian countdown timers influence you when approaching an intersection?
   - ○ Pedestrian countdown timers do not affect my driving at all.
   - ○ Depending on the number displayed, I may speed up in order to go through the intersection.
   - ○ I have never seen a pedestrian countdown timer.
   - ○ Other, please specify:

3. What type of vehicle do you usually drive?
   - ○ Car, van, or truck
   - ○ Bus
   - ○ Single-unit truck or semi-truck
   - ○ Other, please specify:

4. Do you recycle?
   - ○ Yes
   - ○ No

5. Do you strongly agree, agree, neither agree nor disagree, disagree, or stongly disagree with the following statement?
   The more time a child spends in nature the less likely she or he is to be obese (seriously overweight).
   - ○ Strongly agree
   - ○ Agree
   - ○ Neither agree nor disagree
   - ○ Disagree
   - ○ Strongly disagree

6. How fearful are you of terrorism?
   - ○ Very fearful
   - ○ Fearful
   - ○ Somewhat fearful
   - ○ Not at all fearful

7. Please indicate if you strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with each of these statements.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I enjoy playing in or watching soccer matches.	○	○	○	○	○
b. I would encourage my children to play youth soccer.	○	○	○	○	○
c. Compared to sports like football and baseball, soccer is "un-American."	○	○	○	○	○

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Now we have some questions about nursing homes and assisted living facilities.

8. Based on what you know or have heard, how would you evaluate the overall quality of care in nursing homes?
   - ◯ Very high quality
   - ◯ Moderately high quality
   - ◯ Moderately low quality
   - ◯ Very low quality

9. If a loved one became chronically ill or disabled, how willing would you be to have that person cared for in a nursing home?
   - ◯ Very willing
   - ◯ Somewhat willing
   - ◯ Somewhat unwilling
   - ◯ Very unwilling

10. Now we have a series of statements about nursing homes. Please indicate how much you agree or disagree with each statement.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. The nursing home in your local community provides higher quality care than those in other parts of the country.	◯	◯	◯	◯	◯
b. If I ever need 24-hour nursing care, I would rather receive care by trained staff in a nursing home than to be dependent upon family members to take care of me.	◯	◯	◯	◯	◯
c. Nursing homes are usually treated fairly by newspaper and television reports.	◯	◯	◯	◯	◯
d. Once a person enters a nursing home, he or she is there for life.	◯	◯	◯	◯	◯
e. Patients lose many of their rights, such as the right to vote or to make choices, when they move into the nursing home.	◯	◯	◯	◯	◯

11. Do you think that the care provided in nursing homes today is better than, worse than, or about the same as it was 5 years ago?
   - ◯ Better than
   - ◯ About the same as
   - ◯ Worse than

12. How familiar are you with assisted living facilities?
   - ◯ Very familiar
   - ◯ Somewhat familiar
   - ◯ Not too familiar
   - ◯ I've never heard of assisted living facilities.

13. Compared to nursing home residents, would you say most people living in assisted living facilities are healthier, about the same as, or sicker than nursing home residents?
   - ◯ Healthier than
   - ◯ About the same as
   - ◯ Sicker than

14. Based on what you know or have heard, how would you evaluate the overall quality of assisted living facilities?
   - ◯ Very high quality
   - ◯ Moderately high quality
   - ◯ Moderately low quality
   - ◯ Very low quality

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ASIS responses inform
ommunity and state program
nd policy development.

15. How involved are people who live in assisted living facilities in their community? Would you say they are very involved, somewhat involved, not too involved, or not at all involved in the community in which they live?
   - ○ Very involved
   - ○ Somewhat involved
   - ○ Not too involved
   - ○ Not at all involved

16. Based on what you know or have heard, would you be very willing, somewhat willing, somewhat unwilling, or very unwilling to have a loved one cared for in an assisted living facility?
   - ○ Very willing
   - ○ Somewhat willing
   - ○ Somewhat unwilling
   - ○ Very unwilling

17. Please indicate if you strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with each of these statements.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. Sending American manufacturing jobs to other countries harms the U.S. economy.	○	○	○	○	○
b. International laws undermine America's ability to protect its national interests.	○	○	○	○	○
c. American culture is strengthened by the values and traditions that new immigrants bring here.	○	○	○	○	○

18. What is the highest degree you have attained?
   - ○ No diploma
   - ○ High School Diploma/GED
   - ○ Some college, but no degree
   - ○ Technical/Associate/Junior College (2 yr, LPN)
   - ○ Bachelor's Degree (4 yr, BA, BS, RN)
   - ○ Graduate Degree (Masters, PhD, Law, Medicine)

19. Please indicate the category that describes your total family income in the last 12 months.
   - ○ Under $5,000
   - ○ $5,000 - $9,999
   - ○ $10,000 - $14,999
   - ○ $15,000 - $19,999
   - ○ $20,000 - $24,999
   - ○ $25,000 - $29,999
   - ○ $30,000 - $39,999
   - ○ $40,000 - $49,999
   - ○ $50,000 - $59,999
   - ○ $60,000 - $74,999
   - ○ $75,000 - $99,999
   - ○ $100,000 or more

20. Do you typically work full-time, part-time, go to school, keep house, or something else? *Please check all that apply.*
   - ☐ Working a full time job (35 hours or more)
   - ☐ Working a part time job(s)
   - ☐ Unemployed, laid off, looking for work
   - ☐ Retired
   - ☐ In school
   - ☐ Keeping house
   - ☐ Disabled
   - ☐ Other, please specify: ____________

   Go to question 23 →

21. How satisfied are you with your job?
   - ○ Very satisfied
   - ○ Satisfied
   - ○ Neither satisfied nor dissatisfied
   - ○ Dissatisfied
   - ○ Very dissatisfied

22. During the average week, how many hours do you usually work, NOT including the time you travel to and from work? *Please write total hours worked including any second jobs.*

   ☐☐ average total hours per week

5391645182

23. What is your current marital or relationship status?
   - ◯ Married
   - ◯ Married, living apart
   - ◯ Not married but living with partner (cohabiting)
   - ◯ Never married
   - ◯ Divorced
   - ◯ Widowed
   - ◯ Separated

   (Never married, Divorced, Widowed, Separated) → **Go to question 25**

24. Does your spouse or partner typically work full-time, part-time, go to school, keep house, or something else?
   Please check all that apply.
   - ☐ Working a full time job (35 hours or more)
   - ☐ Working a part time job(s)
   - ☐ With a job, but not at work (due to illness, vacation, strike)
   - ☐ Unemployed, laid off, looking for work
   - ☐ Retired
   - ☐ In school
   - ☐ Keeping house
   - ☐ Disabled
   - ☐ Other, please specify: ____________

25. The following statements concern your family's financial situation. For each statement, please indicate how much you agree or disagree.

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
a. My family has enough money to afford the kind of home we need.	◯	◯	◯	◯	◯
b. We have enough money to afford the kind of clothing we need.	◯	◯	◯	◯	◯
c. We have enough money to afford the kind of food we need.	◯	◯	◯	◯	◯
d. We have enough money to afford the kind of medical care we need.	◯	◯	◯	◯	◯

26. During the past 12 months, how much difficulty have you had paying your bills?
   - ◯ A great deal of difficulty
   - ◯ Quite a bit of difficulty
   - ◯ Some difficulty
   - ◯ A little difficulty
   - ◯ No difficulty at all

27. Think again over the past 12 months. Generally, at the end of each month did you end up with:
   - ◯ More than enough money left
   - ◯ Some money left over
   - ◯ Just enough to make ends meet
   - ◯ Almost enough to make ends meet
   - ◯ Not enough to make ends meet

28. Overall, how satisfied are you with your current financial situation?
   - ◯ Very satisfied
   - ◯ Satisfied
   - ◯ Neither satisfied nor dissatisfied
   - ◯ Dissatisfied
   - ◯ Very dissatisfied

29. What about your financial prospects? Do you feel that you are better off this year than you were two years ago at this time, about the same, or worse off?
   - ◯ Better
   - ◯ Same
   - ◯ Worse

Results from NASIS have been used in the state legislature.

30. Were you born in Nebraska, another state, or a foreign country?
   - ○ Nebraska
   - ○ Another state
   - ○ Foreign country

31. Do you consider yourself to be Hispanic or Latino/a?
   - ○ Yes
   - ○ No

32. What race or races do you consider yourself to be? *Please check all that apply.*
   - ☐ White (Caucasian)
   - ☐ Black or African American
   - ☐ Asian
   - ☐ American Indian or Alaska Native
   - ☐ Native Hawaiian or Other Pacific Islander
   - ☐ Other race(s), please specify:

33. Generally speaking, do you consider yourself a Democrat, a Republican, an Independent, or something else?
   - ○ Democrat
   - ○ Republican
   - ○ Independent
   - ○ Other, please specify:

34. Liberal and conservative are terms often used to describe people's beliefs about politics and government. In general, do you see yourself politically as very liberal, liberal, middle-of-the-road, conservative, very conservative, or something else?
   - ○ Very liberal
   - ○ Liberal
   - ○ Middle-of-the-road
   - ○ Conservative
   - ○ Very conservative
   - ○ Other, please specify:

35. Now we have some statements about how you might have felt during the past week. Below, please indicate the number of days in the past week, including today, that:

	0 days (none)	1	2	3	4	5	6	7 days (every day, all week)
a. You felt sad.	○	○	○	○	○	○	○	○
b. You felt hopeful about the future.	○	○	○	○	○	○	○	○
c. You felt you were as good as other people.	○	○	○	○	○	○	○	○
d. You felt bothered by things that usually don't bother you.	○	○	○	○	○	○	○	○
e. You felt lonely.	○	○	○	○	○	○	○	○
f. You had trouble keeping your mind on what you were doing.	○	○	○	○	○	○	○	○
g. You felt that everything you did was an effort.	○	○	○	○	○	○	○	○
h. You felt fearful.	○	○	○	○	○	○	○	○
i. You talked less than usual.	○	○	○	○	○	○	○	○
j. You felt depressed.	○	○	○	○	○	○	○	○

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36. Do you consider yourself to be Protestant, a Catholic, Jewish, Muslim, or something else?
- Protestant
- Catholic
- Jewish
- Muslim
- None (no religion)
- Other, please specify:

→ Go to question 38

37. Within the Protestant faith, do you consider yourself to be:
- Evangelical Protestant
- Fundamentalist Protestant
- Mainline Protestant
- Liberal Protestant
- Other, please specify:

38. How often do you attend religious services?
- Several times a week
- Once a week
- Nearly every week
- About once a month
- Several times a year
- About once a year
- Less than once a year
- Never

39. In general, how much do your religious or spiritual beliefs influence your daily life?
- Very much
- Quite a bit
- Some
- A little
- None
- Doesn't apply (neither religious nor spiritual)

40. Researchers sometimes need to talk to people more than once when they do studies. We want to know much more willing you would be to agree to doing a second survey if certain incentives, topics, or time limits were addressed.

How much more willing would you be to complete a second survey if:	A lot	Some	A little	Not at all	Makes no difference
a. You received a small gift, such as a magnet or pen?	○	○	○	○	○
b. You received money (cash)?	○	○	○	○	○
c. You received a report on the results from the study?	○	○	○	○	○
d. The survey took less than 15 minutes to complete?	○	○	○	○	○
e. The survey took 15 to 30 minutes to complete.	○	○	○	○	○
f. The survey took more than 30 minutes to complete?	○	○	○	○	○
g. The survey asked about a topic of interest to you?	○	○	○	○	○
h. You knew the organization contacting you?	○	○	○	○	○
i. You received a letter or postcard in the mail ahead of time to let you know about the survey?	○	○	○	○	○
j. You felt comfortable with the interviewer during the first conversation of a telephone survey?	○	○	○	○	○
k. You were compensated for cell phone minutes?	○	○	○	○	○

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You can learn more about NASIS by calling us at 1-800-480-4549 or going to http://bosr.unl.edu/nasis.

41. Are there any other things that would make you likely or very likely to complete a survey a second time?
   - ○ Yes, please specify:
   - ○ No

42. Sometimes we do surveys, like this one, by mail. We also do surveys on the phone, on the web, and in person. Which type of survey would you **MOST likely** do?
   - ○ Mail (like this one)
   - ○ Phone
   - ○ Web
   - ○ In person
   - ○ Other, please specify:

43. If we were able to offer you money to participate in a second survey, how much money would it take for you to do a second survey?
   - ○ $0, I'd participate without receiving money.
   - ○ $1 - $5
   - ○ $6 - $10
   - ○ $11 - $15
   - ○ $16 - $20
   - ○ More than $20
   - ○ I would NOT participate for any amount.

44. Sometimes we have short telephone surveys, and sometimes we have longer surveys. What is the longest survey you think you would do on the phone?
   - ○ I would NOT do a phone survey of any length.
   - ○ 10 minutes or less
   - ○ 11 - 15 minutes
   - ○ 16 - 20 minutes
   - ○ 21 - 25 minutes
   - ○ 26 - 30 minutes
   - ○ More than 30 minutes
   - ○ I'd do a phone survey of any length.

45. Do you have a landline (wired) home phone?
   - ○ Yes
   - ○ No

46. Do you have a cell (wireless, mobile) phone for personal use?
   - ○ Yes
   - ○ No → **Go to question 48**

47. Thinking about all the phone calls you make and receive on a regular basis, would you say that you use your cell phone more, less, or about the same amount as your landline (wired) home phone?
   - ○ Use cell phone more
   - ○ Use cell phone less
   - ○ Use cell phone about the same
   - ○ I only have a cell phone. → **Go to question 49**

48. In the next 12 months, how likely are you to stop using your landline (wired) home phone and switch instead to using only a cell phone?
   - ○ Very likely
   - ○ Somewhat likely
   - ○ Not very likely
   - ○ Not at all likely

49. If you were part of a second survey and you moved or changed phone numbers, how would you prefer to tell the researcher about these changes for you to complete the second survey?
   - ○ Mail
   - ○ Email
   - ○ Phone
   - ○ Web page
   - ○ Other, please specify:

Now we would like to know a little bit about your household.

50. Do you or some member of your household own your home outright, buying it, or renting?
   - ○ Own outright
   - ○ Buying (paying a mortgage)
   - ○ Renting
   - ○ Provided as part of job/wages
   - ○ Other, please specify:

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51. Which of the following comes closest to the kind of housing unit you now live in?
- ○ Detached single family house
- ○ Mobile home
- ○ Townhouse/Condominium
- ○ Apartment/Duplex
- ○ Other, please specify:

52. Are you still living in the same residence as you were 2 years ago?
- ○ Yes
- ○ No

53. Do you live on a farm, in open country but not on a farm, or in a town or city?
- ○ Farm
- ○ Open country, but not a farm
- ○ Town or city

54. Including yourself, how many adults age 19 and older live in your household?

☐☐ adults (age 19 and older)

55. How many children ages:

a. 5 and younger live in your household?	☐☐
b. 6 to 12 live in your household?	☐☐
c. 13 to 18 live in your household?	☐☐

56. How many years have you lived in this county? *Please enter "0" if less than 1 year.*

☐☐ year(s)

57. What is your current zip code?

☐☐☐☐☐

Finally, we have a few questions about yourself.

58. Are you:
- ○ Male
- ○ Female

59. In what year were you born?

1 9 ☐☐

60. Would you say that your overall health and well being is excellent, good, fair, or poor?
- ○ Excellent
- ○ Good
- ○ Fair
- ○ Poor

61. Do you smoke cigarettes?
- ○ Yes
- ○ No

62. In your opinion, what is the most important issue currently facing the state of Nebraska?

Thank you! That completes our questions. We greatly appreciate the time you have taken to complete this survey. For your convenience, please use the postage-paid return envelope included in your survey packet to return your questionnaire to the Bureau of Sociological Research.

Questions or requests from this survey can be directed to:

Bureau of Sociological Research
University of Nebraska-Lincoln
Phone: 800-480-4549 (toll free), Email: bosr@unl.edu

University of Nebraska Lincoln

2010

Appendix B

Variables Used in Statistical Models

Variables Used in Probability of Stopping Model

Variable	Description	Type	Coding
X1	Proceed through (0) or stop (1)	Dependent	Dummy Variable 1/0
X2	Maximum Daily Outside Temperature (°F)	Independent	Integer
X3	Sunday	Independent	Dummy Variable 1/0
X4	Monday	Independent	Dummy Variable 1/0
X5	Tuesday	Independent	Dummy Variable 1/0
X6	Wednesday	Independent	Dummy Variable 1/0
X7	Thursday	Independent	Dummy Variable 1/0
X8	Friday	Independent	Dummy Variable 1/0
X9	Saturday	Independent	Dummy Variable 1/0
X10	Midnight to 1 a.m.	Independent	Dummy Variable 1/0
X11	1 a.m. to 2 a.m.	Independent	Dummy Variable 1/0
X12	2 a.m. to 3 a.m.	Independent	Dummy Variable 1/0
X13	3 a.m. to 4 a.m.	Independent	Dummy Variable 1/0
X14	4 a.m. to 5 a.m.	Independent	Dummy Variable 1/0
X15	5 a.m. to 6 a.m.	Independent	Dummy Variable 1/0
X16	6 a.m. to 7 a.m.	Independent	Dummy Variable 1/0
X17	7 a.m. to 8 a.m.	Independent	Dummy Variable 1/0
X18	8 a.m. to 9 a.m.	Independent	Dummy Variable 1/0
X19	9 a.m. to 10 a.m.	Independent	Dummy Variable 1/0
X20	10 a.m. to 11 a.m.	Independent	Dummy Variable 1/0
X21	11 a.m. to noon	Independent	Dummy Variable 1/0
X22	Noon to 1 p.m.	Independent	Dummy Variable 1/0
X23	1 p.m. to 2 p.m.	Independent	Dummy Variable 1/0
X24	2 p.m. to 3 p.m.	Independent	Dummy Variable 1/0
X25	3 p.m. to 4 p.m.	Independent	Dummy Variable 1/0
X26	4 p.m. to 5 p.m.	Independent	Dummy Variable 1/0
X27	5 p.m. to 6 p.m.	Independent	Dummy Variable 1/0
X28	6 p.m. to 7 p.m.	Independent	Dummy Variable 1/0
X29	7 p.m. to 8 p.m.	Independent	Dummy Variable 1/0
X30	8 p.m. to 9 p.m.	Independent	Dummy Variable 1/0
X31	9 p.m. to 10 p.m.	Independent	Dummy Variable 1/0
X32	10 p.m. to 11 p.m.	Independent	Dummy Variable 1/0
X33	11 p.m. to midnight	Independent	Dummy Variable 1/0
X34	Unused	-	-
X35	Unused	-	-

X36	Required Acceleration	Independent	Real Number
X37	Required Deceleration	Independent	Real Number
X38	Time to Stop Bar	Independent	Real Number
X39	15 Min Traffic on 17th St	Independent	Integer
X40	Presence of a Pedestrian Waiting to Cross 17th St	Independent	Dummy Variable 1/0
X41	Lane	Independent	Integer
X42	Presence of Pedestrian Countdown Timer	Independent	Dummy Variable 1/0
L1	Lane 1 (if X41 is significant)	Independent	Dummy Variable 1/0
L2	Lane 2 (if X41 is significant)	Independent	Dummy Variable 1/0
L3	Lane 3 (if X41 is significant)	Independent	Dummy Variable 1/0

Variables Used in Speed Gain at Stop Bar of Vehicles during the Yellow Phase Model

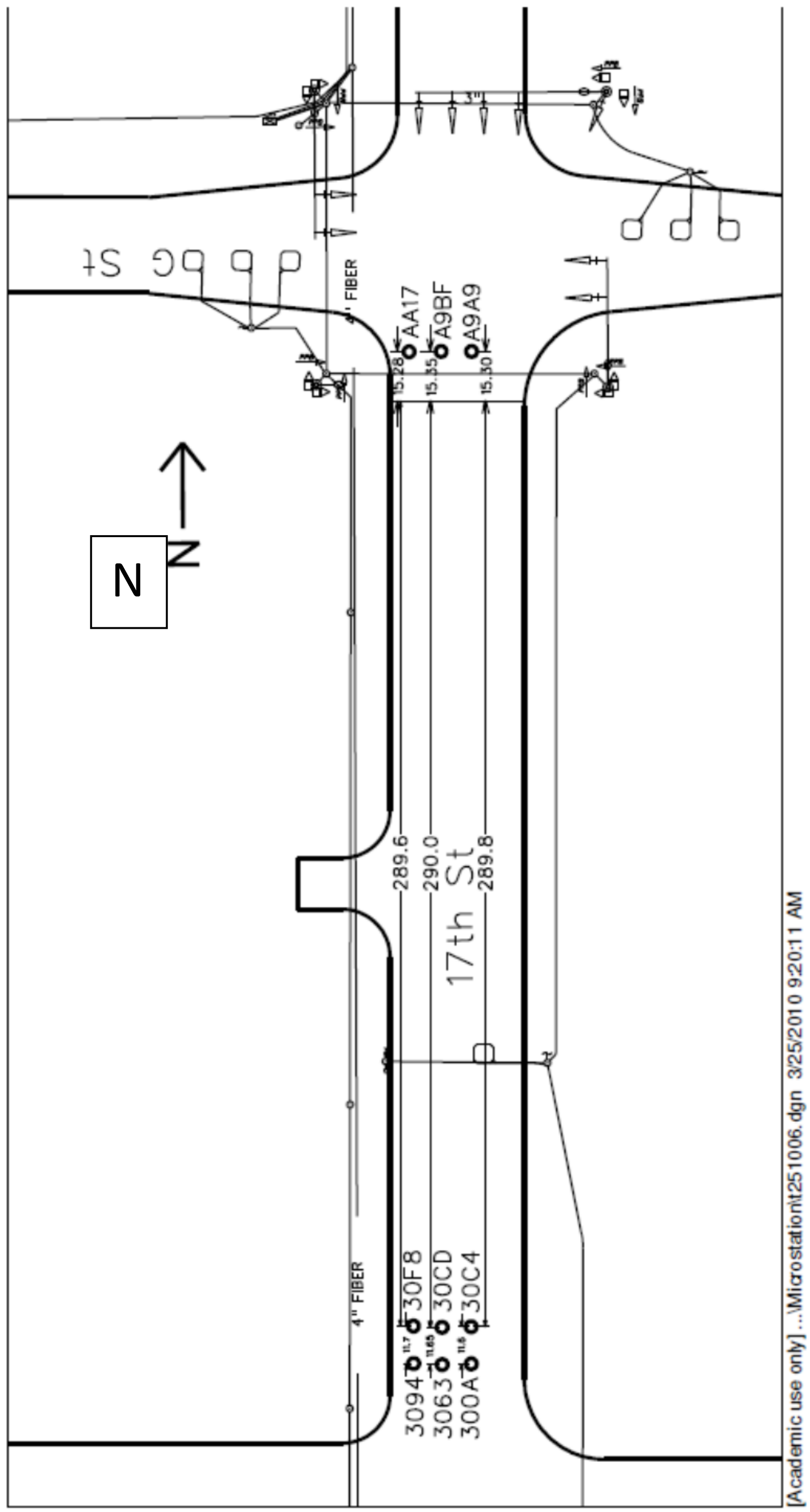
Variable	**Description**	**Type**	**Coding**
X1	Speed at Stop Bar	Dependent	Real Number
X2	Maximum Daily Outside Temperature (°F)	Independent	Integer
X3	Sunday	Independent	Dummy Variable 1/0
X4	Monday	Independent	Dummy Variable 1/0
X5	Tuesday	Independent	Dummy Variable 1/0
X6	Wednesday	Independent	Dummy Variable 1/0
X7	Thursday	Independent	Dummy Variable 1/0
X8	Friday	Independent	Dummy Variable 1/0
X9	Saturday	Independent	Dummy Variable 1/0
X10	Midnight to 1 a.m.	Independent	Dummy Variable 1/0
X11	1 a.m. to 2 a.m.	Independent	Dummy Variable 1/0
X12	2 a.m. to 3 a.m.	Independent	Dummy Variable 1/0
X13	3 a.m. to 4 a.m.	Independent	Dummy Variable 1/0
X14	4 a.m. to 5 a.m.	Independent	Dummy Variable 1/0
X15	5 a.m. to 6 a.m.	Independent	Dummy Variable 1/0
X16	6 a.m. to 7 a.m.	Independent	Dummy Variable 1/0
X17	7 a.m. to 8 a.m.	Independent	Dummy Variable 1/0
X18	8 a.m. to 9 a.m.	Independent	Dummy Variable 1/0
X19	9 a.m. to 10 a.m.	Independent	Dummy Variable 1/0
X20	10 a.m. to 11 a.m.	Independent	Dummy Variable 1/0
X21	11 a.m. to noon	Independent	Dummy Variable 1/0
X22	Noon to 1 p.m.	Independent	Dummy Variable 1/0
X23	1 p.m. to 2 p.m.	Independent	Dummy Variable 1/0
X24	2 p.m. to 3 p.m.	Independent	Dummy Variable 1/0

X25	3 p.m. to 4 p.m.	Independent	Dummy Variable 1/0
X26	4 p.m. to 5 p.m.	Independent	Dummy Variable 1/0
X27	5 p.m. to 6 p.m.	Independent	Dummy Variable 1/0
X28	6 p.m. to 7 p.m.	Independent	Dummy Variable 1/0
X29	7 p.m. to 8 p.m.	Independent	Dummy Variable 1/0
X30	8 p.m. to 9 p.m.	Independent	Dummy Variable 1/0
X31	9 p.m. to 10 p.m.	Independent	Dummy Variable 1/0
X32	10 p.m. to 11 p.m.	Independent	Dummy Variable 1/0
X33	11 p.m. to midnight	Independent	Dummy Variable 1/0
X34	Unused	-	-
X35	Speed at Onset of Yellow	Independent	Real Number
X36	Required Acceleration	Independent	Real Number
X37	Required Deceleration	Independent	Real Number
X38	Time to Stop Bar	Independent	Real Number
X39	15 Min Traffic on 17th St	Independent	Integer
X40	Presence of a Pedestrian Waiting to Cross 17th St	Independent	Dummy Variable 1/0
X41	Red Light Runner	Independent	Dummy Variable 1/0
X42	Lane	Independent	Integer
X43	Presence of Pedestrian Countdown Timer	Independent	Dummy Variable 1/0
L1	Lane 1 (if X42 is significant)	Independent	Dummy Variable 1/0
L2	Lane 2 (if X42 is significant)	Independent	Dummy Variable 1/0
L3	Lane 3 (if X42 is significant)	Independent	Dummy Variable 1/0

Appendix C

Location of Sensys Sensors

S. 17th St. and G St.:



N. 27th St. and Cornhusker Hwy: