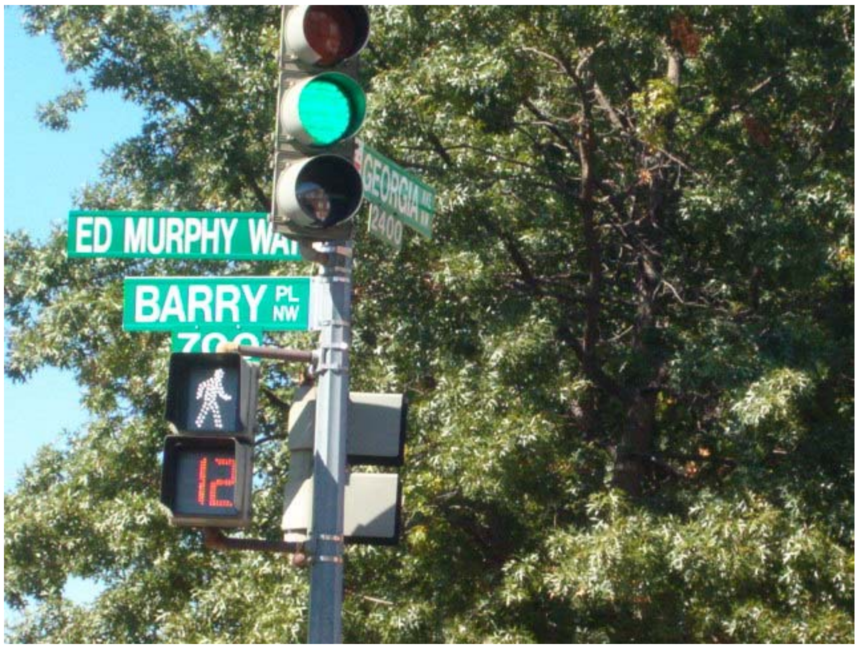
FINAL REPORT

EVALUATION OF COUNTDOWN PEDESTRIAN SIGNALS IN THE DISTRICT OF COLUMBIA



August 7, 2006

Submitted to:

District Department of Transportation
Traffic Services Administration
2000 14th Street, NW
Washington, DC 20009

District Department of Transportation

Prepared by:

Dr. Errol C. Noel, P.E. & Stephen Arhin, P.E.
Howard University Transportation Research Center
2366 6th Street, NW
Washington, DC 20059

HUTRC Technical Report Documentation Page

1. Performing Organization Report No. HUTRC 2006-09	**2. DDOT P.O. No:** P0136253
3. Title and Subtitle Evaluation of Countdown Pedestrian Signals in the District of Columbia	**4. Report Date** April 2006

5. Author(s)

Dr. Errol C. Noel and Mr. Stephen A. Arhin

6. Performing Organization Name and Address Howard University Transportation Research Center 2366 Sixth Street, NW, Room 130 Washington, DC 20059	**7. Contract or FRS No.** HU-633592 **8. Type of Report and Period Covered** Final Report 12/01/2004 – 04/2006

9. Sponsoring Agency Name and Address

District Department of Transportation (DDOT), Transportation Policy & Planning Administration
2000 14th Street, NW, Washington, DC 20009

10. Supplementary Notes

COTR: William McGuirk (202) 671-1493

11. Abstract

Countdown pedestrian signals (CPS) are increasingly used as a device for improving safety at signalized intersections. Using a “before and after” methodology, the research evaluated the effect of CPS installations at fourteen (14) intersections in the District of Columbia where the countdown begins with the steady “WALK” indication. The research examined the impact of CPS on various pedestrian behaviors, such as running, balking, completing crossing during the steady “DON’T WALK” interval, starting to cross during the flashing “DON’T WALK” interval, starting to cross during the steady “WALK” interval, remaining in the crosswalk during the steady “DON’T WALK” interval, remaining in the crosswalk during the display of the green indication for the crossing traffic, walking speed and pedestrian-vehicle conflicts. An attitudinal survey was also conducted at seven intersections. The results of the evaluation were not statistically conclusive about the positive impacts of CPS on pedestrian safety at the majority of intersections. The results were neither indicative of any adverse pedestrian behavior caused by CPS. More than 80% of the pedestrians surveyed favor use of CPS.

12. Key Words

Countdown Pedestrian Signals

13. Security Classif. (of this report)	**14. No. of Pages**	**15. Price**
Unclassified	54	N/A

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Countdown pedestrian signals (CPS) are increasingly being used as an added strategy for improving safety at signalized intersections. There are basically two types of applications used in adjacent states and across the USA: that is, either triggering the countdown on the start of the "WALK" indication or actuating the countdown only during the flashing "DON'T WALK" indication. There is no consensus on the preferred practice, although the latter is required by the MUTCD and practiced in many states. This research examined the effectiveness of countdown pedestrian signals in the District of Columbia where the display of the remaining time for crossing the intersection begins with the steady "WALK" indication. According to available statistics, there were 641 collisions involving pedestrians in the City, between 2001 and 2004. In 2004 alone, pedestrians accounted for 22% of the traffic fatalities in the City, which indicated an overwhelming increase from 2002 where pedestrians only accounted for 8% of the fatalities in the District of Columbia. Pedestrian injuries also increased from 6% in 2002 to 9% in 2004. As part of an overall strategy for improving pedestrian safety, especially at signalized intersections, the District Department of Transportation (DDOT) launched a program for installing CPS at signalized intersections. This research evaluated the impact of CPS on pedestrian behavior in the City and gauged the public's perception of the CPS from a safety standpoint. Fourteen intersections were used for the study. At least one intersection was selected from each of the 8 Wards.

Pedestrian data was collected at the fourteen intersections before and after the installation of the CPS. Video recordings of pedestrian traffic were made during the morning and evening peak periods. The data was then extracted from the video playback from which desired and undesired variables on pedestrian behavior and compliance were obtained. In addition, a survey was conducted to determine the perception of pedestrians' safety level in relation to the CPS. Statistical analyses were conducted at 95% confidence interval to ascertain the significance of the reductions of the undesired variables and the increases in desired variables. From the results, pedestrians overwhelmingly attributed their increased perception of safety in crossing intersections to the presence of the CPS. However, based on the analysis of the data on pedestrian behavior, the results were not unanimously

conclusive about the positive impact of CPS on pedestrian safety at the majority of intersections studied. The results were not indicative of any adverse pedestrian behavior caused by CPS installations. CPS were recognized by pedestrians. More than 80% of the pedestrians surveyed at seven intersections favored the use of CPS.

INTRODUCTION

A pedestrian signal is a of traffic control signal that allocates the right-of-way for the safe passage of pedestrians at signalized intersections and other locations where pedestrians and vehicular traffic are in conflict. According to the Manual on Uniform Traffic Control Devices (MUTCD), pedestrian signals provide a dedicated phase during which the pedestrian can enter the street on the steady "WALK" interval and complete crossing the street during the Flashing "DON'T WALK" or Steady "DON'T WALK" indications (1). These signals may be automatic or activated by pedestrian detectors and manual switches (push buttons). The display consists of a pre-programmed timed sequence of steady "WALK", flashing "DON'T WALK" and steady DON’T WALK indications. Countdown pedestrian signals (CPS) provide a flashing display of the reducing number of seconds remaining until the end of the pedestrian change interval. They may be used to complement conventional pedestrian signals. The main idea behind the CPS is that by providing pedestrians with a measure of how much time is available for crossing an intersection, they will be better able to judge the crossing challenge and make decision in the interest of safety. This research is intended to assess the ability of CPS that begin on the start of the steady “WALK” indication to improve pedestrian safety at signalized intersections.

Prior to the incorporation of the guidelines on CPS into the 2003 MUTCD (1), the use of CPS had been limited in the United States. Since then, information gathered from 35 states, including the District of Columbia by FHWA Division Safety Specialists in late 2004, indicated that over half of the states surveyed use CPS on state projects, while over two-thirds of them permit CPS on local projects. CPS are also used abroad: e.g., the Netherlands, Germany, Canada and Japan. In some of these countries, a dynamic pedestrian signal is also used to advise pedestrians to walk faster as the remaining pedestrian clearance interval diminishes.

The 2003 MUTCD (1) provides the national standards on the use of CPS. The standards of the MUTCD became available when several jurisdictions, across the United States, had already been exploring the value of CPS. California and Maryland, for example, trigger their countdown display at the start of the flashing “DON’T WALK” in conformance with the

MUTCD. Massachusetts and the District of Columbia begin the countdown on the start of the steady “WALK” indication. The general literature reviewed revealed that different approaches have been used to evaluate the CPS due to variations in practice. In addition, some of the evaluations had different objectives. For the most part, however, the emphasis has been on pedestrian behavior due to the CPS and pedestrian acceptance of the CPS. The general literature suggests that CPS are generally liked by the public. On the other hand, the literature is not unanimously conclusive on the positive impact of the CPS on pedestrian behavior.

A majority of the published evaluations were conducted in suburban-like jurisdictions with lower population density than the District of Columbia. The District of Columbia is the seat of the federal government and has a dynamic tourist industry and attracts both employees and visitors from neighboring states. As a strategy for improving pedestrian safety at signalized intersections, the District Department of Transportation (DDOT) launched a program for installing CPS at signalized intersections. The evaluation of the effectiveness of CPS became part of the program since the literature on CPS that begin on the steady “WALK” phase was sparse and non-conclusive. This research is therefore intended to evaluate the impact of CPS on pedestrian behavior in the District of Columbia, a densely populated city, as well as to gauge the public’s perception of the CPS from a safety standpoint. In this research the countdown started at the beginning of the steady “WALK” indication.

PROBLEM STATEMENT

The District of Columbia is challenged to enhance the safety of pedestrians at intersections. The challenge is daunting due to the fact that the millions of visitors and commuters come to the nation’s capital for business and pleasure, as well as due to the increasing and diverse residential population. According to available statistics [(2)], there were 641 collisions involving pedestrians between 2001 and 2004. In 2004 alone, pedestrians accounted for 22% of the traffic fatalities in the City, which indicated an overwhelming increase from 2002 where pedestrians only accounted for 8% of the fatalities in the District of Columbia [2]. Pedestrian injuries also increased from 6% in 2002 to 9% in 2004.

The Metropolitan Police Department (MPD) implemented pedestrian enforcement efforts in areas identified as particularly dangerous, according to crash data provided by DDOT. The MPD conducted a pedestrian safety awareness program where emphasis was placed on educational advertisement and safety tips to help community to increase its awareness of what citizens could do to reduce pedestrian collisions and fatalities, especially at intersections. The Council of the District of Columbia enacted the *Pedestrian Safety Amendment of 2005* on March 16, 2005. The law increased the civil infractions and fines for pedestrians who violate safety measures. Fines range from $10 to $50 [2].

In addition to the enforcement effort, the City launched other initiatives to improve pedestrian safety at intersections, including "Don't Block the Box" intersection signs and the deployment of mini-pedestrian crosswalk signs which are mounted on the double yellow centerlines at both signalized and unsignalized intersections. Public announcements involving the media and handout information were also part of the pedestrian safety initiatives. Starting in 2004, the City began installing CPS at signalized intersections, with the aim of curbing the trend for pedestrian injuries and fatalities. The City deployed several CPS in areas of both high and low pedestrian crossing activities in all of the eight Wards.

Since 1994, a number of studies on the effectiveness of CPS were conducted within the United States and internationally. Many of these studies were conducted in local jurisdictions with lower population densities than the District of Columbia [3, 6]. The results of these studies were generally not unanimously conclusive about the effectiveness of the countdown signals. The deployment of the CPS at intersections in the District of Columbia triggered interest in the need for a statistically driven experiment to ascertain the impact of the CPS on pedestrian safety. This study is therefore intended to shed light on the effectiveness of countdown signals in a densely populated urban environment, like Washington, DC, where improvement of pedestrian safety, in an environment of high vehicular traffic volume, remains a challenge. The outcome of this study is intended to help

DDOT officials in its decision-making processes and also shed light on future actions regarding deployment standards and criteria for use of CPS.

The City had a long tradition of flashing the “WALK” interval, contrary to the standards of the 2003 Edition of the MUTCD and the practice in neighboring jurisdictions. For the purposes of this study, DDOT changed the pedestrian signal display in accordance with the MUTCD at the study intersections. However, contrary to the MUTCD, the beginning of the countdown for the CPS in the District of Columbia remained coincidental with the start of the steady “WALK” interval. CPS deployments in the City display the total walking time remaining until the termination of the pedestrian change interval.

RESEARCH OBJECTIVES

The objectives of the research are as follows:

(a) to determine whether CPS affect pedestrian crossing behavior at signalized intersections

(b) to determine whether CPS affect pedestrians’ perception of safety at signalized.

LITERATURE REVIEW

According to the 2003 Edition of the MUTCD, Section 4E.02; Federal Highway Administration, 2003 [(1)], the conventional pedestrian signal should be compliant with the following sequence of displays:

- **Steady WALK**, signified by a white silhouette of a person, “means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles.”
- **Flashing DON’T WALK (FDW)**, signified by a Portland orange flashing upraised hand, “means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING person (symbolizing WALK) signal indication shall proceed out of the traveled way.”

• **Steady DON'T WALK (SDW)**, signified by a Portland orange steady upraised Hand, "means that a pedestrian shall not enter the roadway in the direction of the signal indication."

Depending on the geometry of the intersection, the minimum length of "WALK" interval may be at least 4 seconds long and need not be sufficient for pedestrians to cross the entire roadway. The "WALK" interval is computed based on the geometry of the intersection and pedestrian walking speed. At locations where a large number of pedestrians cross an intersection, a longer "WALK" interval may be used.

The pedestrian clearance time consists of the pedestrian change time (FDW indication), the yellow time and the "all-red" time. The duration of the clearance interval is based on the street width divided by an average walking speed of 4 feet per second. If elderly pedestrians generally use the crosswalk, it is recommended that the walking speed be reduced to 3.5 feet per second.

Countdown pedestrian signals provide a visual display of the amount of time remaining for pedestrians at signalized intersections to cross a roadway at a crosswalk. According to the 2003 Edition of the MUTCD (1) (Section 4E.07), the CPS shall display the number of seconds remaining until the termination of the pedestrian change interval. The Manual also states that the countdown display shall neither be used during the walk interval nor during the yellow change interval of a concurrent vehicular phase. In practice, the choice of the interval to start the countdown display is largely dependent on the jurisdictional preferences. For example, in Montgomery County, MD, Minneapolis, St. Paul, MN, Las Vegas, NV, and San Jose, CA, the countdown display starts with the FDW. However, in the District of Columbia and Cambridge and Boston, MA, the countdown involves the total time for the WALK and the FDW intervals.

As noted above, since the application of CPS displays varies by jurisdictional practice, the outcome of research conducted in a particular jurisdiction may not necessarily reflect the conditions in another. Most of the reports reviewed in this study largely focused on pedestrians' comprehension of countdown signals.

In 2001, the City of San Jose, California installed CPS at 5 intersections for testing [(6)]. The study was conducted by the San Jose State University and consisted of a "before" (installation of the countdown signals) and "after" evaluation. The countdown started at the same time as the FDW. Among the variables studied were the proportion of pedestrians who arrived during the FDW and waited for the "WALK" before crossing, the proportion of pedestrians that entered during the "WALK", FDW and DW intervals as well as running, baulking and hesitation of pedestrians. An additional survey was also conducted to determine how well pedestrians interpreted the meaning of the FDW indication. From the results 59% of pedestrians gave the wrong interpretation of the FDW signals. Simple frequency analyses of the data was conducted and showed that the differences between the "before" and "after" results were not considerably significant. Although the number of motorist-pedestrian conflicts decreased, the study did not conclude that there was discernable effect due to the CPS.

In 2002, Montgomery County, MD[(7)] conducted a pedestrian survey at locations with CPS to determine the effect of the pedestrian countdown signal at five intersections. The County applied the countdown only to the FDW interval. Comparisons were made between behavioral changes of pedestrians at the same location during daylight hours and in good weather. A survey of 107 pedestrians was conducted to determine their perception of CPS. Observations of pedestrian compliance with the signal and pedestrian-vehicle conflicts were also made. A simple t-test was used to analyze the data. At 3 of the 5 intersections evaluated, there were statistically significant decreases in the number of pedestrians remaining in the crosswalk when conflicting traffic received the green indication. The majority of the pedestrians surveyed correctly explained what the countdown signal phases meant. There was also a significant reduction in the frequency of pedestrian-vehicle conflicts as a result of the installation of the CPS.

A "before" and "after" pedestrian survey was conducted by the Minnesota Department of Transportation (Mn/DOT) in 1999 at six intersections within the metropolitan area of

Minneapolis and St. Paul [8]. Pedestrians were interviewed before and after the countdown signals were installed. Field observations of pedestrian behavior were also made during the two periods. The countdown display was applied during the FDW interval. Overall, 78% of the respondents felt that the CPS was easier to understand than the conventional signal, while only 6% felt that it was more difficult to understand. The research showed that the numerical countdown, displayed during the FDW interval, was intuitively understood and used successfully by pedestrians. However, the study recommended that CPS should not become a standard signal component since the need is not always present. Situations recommended for CPS include long pedestrian crossing distances, crossing to medians and intersections predominantly used by pedestrians with disabilities and elderly individuals.

The Technical Committee of the New England Section of the Institute of Transportation Engineers conducted a study on the CPS that were installed at three intersections in Boston, Massachusetts [9]. The countdown display of the signals was active for the entire “WALK” and FDW intervals, similar to the practice in the District of Columbia. A “before” and “after” study was conducted. The measures of effectiveness investigated were the number of pedestrians starting on WALK, the number of pedestrians starting on FDW, the number of pedestrians finishing during the DW, the number of pedestrians running or aborting, and the number of pedestrian-vehicle conflicts. The research concluded that countdown signals did not cause any significant improvement in the mentioned variables and in some instances actually degraded pedestrian safety.

In early 2001, the San Francisco Department of Parking and Traffic installed and studied countdown signals at 14 intersections. The countdown display was active only in the FDW interval [10]. The study found that the percentage of pedestrians in the crosswalk after the signal turned green for the conflicting vehicular traffic was significantly reduced. There was also a significant decrease in the percentage of pedestrians who started during the FDW as well as a decrease in the percentages of pedestrians running and aborting. The percentage of pedestrian-vehicle conflicts was also reduced. On the basis of these findings, San Francisco proposed to expand its installations of CPS to additional intersections where the crosswalks were at least 40 feet long. Noted exceptions were locations with relatively low pedestrian volumes (under 10 per hour) even during special events and seasonal peaks. It was also found from this study that the pedestrians increased their walking speeds to complete crossing before the end of the pedestrian change interval.

In 1997, a CPS was installed and studied at the intersection of Florida State Route 535 and Hotel Plaza Boulevard in Orlando, Florida [11]. The purpose of the study was to evaluate pedestrian understanding of the CPS through field interviews. Surveys were conducted at random among local citizens and visitors. The selected crosswalk traversed eight lanes and measures about 140 feet in length. The countdown was applied to the entire WALK and FDW intervals. A total of 50 pedestrians were surveyed and the results indicated that 88% understood the functions of new countdown signals. From the responses from US residents and visitors, 91% of the former comprehended the meaning of the signals while to 81% of the visitors understood the functions of the CPS.

In 2003, the Transportation Research Center of University of Nevada conducted an evaluation of the effectiveness of countdown pedestrian signals deployed at 14 intersections in the City's downtown area [12]. The research methodology was one of a "treatment" and "control" type. Among the 14 intersections, 10 were treated with CPS and the remaining 4 "control" sites operated with the conventional pedestrian signals. The countdown display was applied to the FDW phase. The key variables investigated included pedestrian compliance with pedestrian signals, pedestrian–vehicle conflicts, and pedestrians who ran out of time and thus were trapped in the crosswalk. Data collection was conducted with a video recorder. The results indicated that the CPS improved pedestrian compliance with the WALK, FDW and the SDW indications by 29%, 75% and 11% respectively. There was also a substantial reduction in pedestrian-vehicle conflicts, in comparison to the "control" intersections. Field interviews were conducted to receive feedback from pedestrians with regards to their understanding of the countdown signals and the FDW symbol. The results indicated that over 90% understood the general functions of the CPS and the FDW phase. The researchers believed that the CPS had a positive effect on pedestrian crossing behavior, and by inference, countdown signals could mitigate pedestrian crashes.

Huang and Zegeer (2000) [13] conducted an observational study of CPS effectiveness in Lake Buena Vista, Florida. Five intersections were observed: two with CPS and three control sites without CPS. The countdown at the two treatment sites began with the "WALK" interval. Since data was not collected at the intersections before the CPS installation, potential differences between individual sites were not fully accounted for. At each intersection, a single crosswalk was observed for the study. It was found from the analysis that significantly fewer pedestrians began crossing during the WALK signal at CPS locations (47%) than at those with the conventional signal locations (59%). Thus, pedestrians were more likely to begin crossing during the pedestrian change interval rather than wait for the next WALK indication. In addition, contrary to expectations, slightly more pedestrians who could not complete crossing the intersection before the SDW were found at the intersections with CPS (10.5%) than those with the conventional signals (7.7%). The report also reported fewer instances of pedestrians running at locations with CPS (3.4%) than at locations with conventional pedestrian signals (10.4%).

In a study conducted by Botha, et al. (2002) [6] in the City of San Jose, CA little difference in walking speed, unusual behaviors, or motorist behavior between the CPS and the conventional pedestrian signal was observed. Substantial decreases were reported in the frequency of pedestrians running or aborting crossing attempts as well as the frequency of pedestrian/vehicle conflicts.

In Monterey, California, investigators reported an increase in pedestrian walking speeds at locations where CPS were installed [14]. Pedestrians were also found to be more likely to wait at a mid-crossing median for the next WALK phase. The CPS did not appear to have any adverse effect on motorist behavior.

Studies conducted on pedestrian satisfaction and signal preference indicates that pedestrians overwhelmingly approve of the CPS and typically prefer them to the conventional signals. Most of such studies were elements of a larger survey that included all the discussions above. For example in San Francisco [10], 78% of the pedestrians surveyed reported that CPS are “very helpful,” with only 34% for conventional signals. In the same study, 92% of the pedestrians expressed a preference for the CPS.

A study was conducted by Mahach, et al (15) in 2002 to compare pedestrian signal preference among a set of seven signals. These included a conventional pedestrian signal and a CPS which had the countdown staring at the beginning of the steady “WALK” interval. Nearly 60% of the participants selected the CPS as their favorite.

In another study conducted in Minneapolis, MN in 1999, a noteworthy age difference in CPS satisfaction was found, where satisfaction was highest among teens and lowest among older pedestrians. It was suggested by the investigators that age differences such as this warrant additional investigation.

The Rutgers Voorhees Transportation Policy Institute (RVTPI) examined the standards for traffic signals and pavement striping in New Jersey where CPS timing begins with the steady “WALK” interval (16). Based on its study of a CPS installation near a senior citizen complex, RVTPI concluded that CPS seemed more beneficial to the vehicular traffic than to pedestrians, particularly the elderly. RVTPI recommended that other measures be used at intersections where the elderly pedestrian is high, before resorting to the use of CPS.

Although there are some inconsistencies and variations in the measurements of effectiveness, data collection procedures and statistical analyses used in most of the research conducted thus far, some conclusions can be drawn from the literature on the CPS. The variations in the results of the studies may be due to site factors, pedestrian characteristics and the type of CPS application. The general consensus of the literature suggests that the CPS do provide pedestrians with additional information that helps them to cross intersections more successfully. Although there were reductions in the frequencies of some of the undesirable events such as pedestrian-vehicle conflicts, pedestrian running and aborted crossing, some of these reductions were not statistically significant. The literature also suggests that pedestrians overwhelmingly prefer CPS to conventional signals. Further, studies on CPS applied during the steady “WALK” and FDW intervals were very limited in number of treatments observed. It remains unclear as to whether findings from studies that involved countdowns starting on the FDW are also applicable to CPS where the countdown starts on the "WALK" interval.

RESEARCH METHODOLOGY

A before-and-after study was used for comparing the behavior of pedestrians during the treated and untreated conditions. Pedestrian observations were made at 14 crosswalks at 14 intersections before the installation of CPS. After a minimum period of two weeks following the installation of CPS at the same intersections, the pedestrian observations were repeated. The differences in magnitude of each of the variables between the "before" and "after" data were examined for statistical significance. An effort was made to obtain approximately equal sample sizes at all the sites for both before and after periods. In this section, the research hypotheses, criteria for site selection, data collection methodology and statistical analyses are presented.

Hypothesis

The hypotheses (*all at 5% level of significance*) on the impact of CPS on the variables selected for the evaluation are stated below:

Variable 1: Pedestrian running: On the basis of the information provided by the CPS, it is hypothesized that the proportion of pedestrians running should be reduced after the installation of the CPS. It is expected that the information provided by the CPS would cause most pedestrians to walk at speeds that would enable them to cross the intersection without running.

Variable 2: Pedestrian baulking (aborting crossing): The proportion of pedestrians who aborted crossing the intersection should be less due to the information provided by the CPS. In baulking, pedestrians return to the sidewalk without completing a crossing event. Baulking is more likely to occur during the end of the FDW and DW intervals.

Variable 3: Pedestrian-vehicle conflicts: This is generally defined as an event involving a pedestrian and a vehicle where either a pedestrian (or group) takes an evasive action to avoid collision with a vehicle. These actions could be a pedestrian running, aborted walking, or a vehicle braking or weaving to avoid pedestrian-vehicle collisions. There is the expectation that with the CPS, both pedestrians and motorists would have common information on the remaining crossing time and would use it to avoid conflicting actions. It is therefore hypothesized that the proportion of the pedestrians who experience conflicts with vehicles should be less at intersections with CPS than those without CPS.

Variable 4: Pedestrian completing their crossing during the SDW: The information provided by the CPS in the District indicates the time available for crossing an intersection, before the start of the steady DW interval. With the installation of the CPS, it is hypothesized that the proportion of the pedestrians who complete crossing during the SDW should be less at sites with CPS than at sites without CPS.

Variable 5: Pedestrian beginning to cross during the FDW: Pedestrians are not expected to begin crossing an intersection during the FDW interval. In the case of conventional pedestrian signal, pedestrians have no way of knowing the number of seconds left for crossing. During that interval, the number of seconds left for crossing should be close to zero. On the basis of the information provided by the CPS, it is therefore hypothesized that the proportion of the pedestrians who begin to cross during the FDW interval will be less than that for crosswalks without CPS.

Variable 6: Average walking speed: The average walking speed of pedestrians is usually taken as 4ft/second for design purposes. However, if the majority of pedestrians in the design area are classified as being elderly, a walking speed of 3.5ft/second would be appropriate for the signal design. Based on the information provided by the CPS, it is hypothesized that the average walking speed of pedestrians will increase since pedestrians will tend to complete their crossing before the time elapses.

Variable 7: Pedestrian beginning to walk during the steady WALK indication: Pedestrians are supposed to begin crossing an intersection during the steady WALK indication. It is therefore hypothesized that with the installation of the CPS, a higher proportion of pedestrians will be found beginning to cross during the steady WALK.

Variable 8: Pedestrian who started walking during the SDW:

With the CPS in operation, the general expectation is that pedestrians would be more attentive at intersections thereby obeying all related regulations. The information provided by the CPS is expected cause pedestrians to comply with pedestrian crossing regulation by not crossing during the SDW interval. It is hypothesized that the proportion of pedestrians who crossed the intersection during the SDW would be reduced due to the information provided by the CPS.

Variable 9: Pedestrians who remained in the crosswalk at the onset of the SDW: It is hypothesized that fewer pedestrians will remain in the crosswalk at the beginning of the SDW indication with the use of the CPS. Pedestrians are expected to clear the crosswalk before the SDW interval.

Variable 10: Pedestrians who remained in the crosswalk at the release of opposing vehicular traffic: It is hypothesized that fewer pedestrians will remain in the crosswalk at the release of the opposing vehicular traffic indication with the use of the CPS. Pedestrians are expected to clear the crosswalk before the right-of-way is given to the opposing vehicular traffic.

Site Description

In consultation with DDOT officials, the research team initially selected 17 sites from a list of over 60 potential intersections. The criteria used for selection included the representation of at least 1 intersection in each of the eight Wards, high pedestrian activity, and potential pedestrian activity generators in the environs of the intersection. Due to weather-related conditions, however, the research team was unable to collect data at three intersections. Table 1 shows the list of intersections used for this study.

All the intersections selected for this study typically had asphalt pavement surfaces and were generally level on from all approaches. The intersections had sidewalks on all quadrants and were equipped with, at a minimum, two handicap ramps. The travel lanes varied from one to three per approach and were 11-12 feet wide. All the intersections carried standard pavement markings for lane lines, stop bar and crosswalks. The Reed Street leg of intersection number 6 was channelized with a raised crosswalk median and islands. Figure 1 shows a map of the District of Columbia depicting the locations of the intersections in all the 8 Wards. Except for the intersection of Rhode Island Avenue and Reed Street, all the other intersections do not have channelizations for turns.

The traffic signal heads at all intersections were corner-mounted on pedestals or utility poles. All the intersections were located within environs with high pedestrian activity. These include restaurants, offices, strip shops, metropolitan bus stops and transfer points, subway stations, educational institutions, and various tourist attractions. Pedestrian activities were usually high in the morning peak between 6:30 a.m. to 10:00 a.m. and between 4:00 p.m. to 6:30 p.m. in the evening peak.

Two of the busiest intersections of studied were 14th and U Streets NW, and Rhode Island Avenue and Reed Street NE which are located in Wards 1 and 6, respectively are shown in Figures 2 and 3, respectively. The high pedestrian traffic at the intersection of 14th and U Streets were due to employers and shoppers of the area as well as bus transfer activity. The intersection of Rhode Island Avenue and Reed Street NE serves as an access point to a shopping mall and the Rhode Island Metro Station. Many patrons walk to these facilities during peak travel periods. The schematics and photographs of the remaining study intersections are presented in Appendix A.

Table 1: Intersections used for Evaluation of CPS in the District of Columbia

No.	Intersection*	Ward	Length of Crosswalk (ft)	Countdown Duration (Sec.)	
				AM	PM
1	7th Street and F Street, NW	2	65.6	23	24
2	13th Street and U Street, NW	1	48.5	42	47
3	14th Street and U Street, NW	1,2	62.3	50	45
4	7th Street, Florida Ave. & Georgia Ave, NW	1	53.3	43	37
5	Georgia Ave and Barry Place, NW	1	52.9	15	22
6	Rhode Island & Reed Street, NE	5	59.1	35	42
7	7th Street & Michigan Ave, NE	5	58.1	27	29
8	North Capitol Street & H Street, NE	6	72.8	42	48
9	7th Street and Pennsylvania Ave, SE	6	41.2	41	41
10	Nebraska Ave & New Mexico Ave, NW	3	43.2	46	43
11	Western Ave & Wisconsin Ave, NW	3	66.5	59	52
12	Benning Road & Minnesota Ave, NE	7	75.2	46	46
13	Martin Luther King Jr. Avenue & Malcom X Avenue, SE	8	36.1	50	50
14	Georgia Ave & Quincy Ave, NW	4	35.7	16	16

**There are no pedestrian actuated signals at these locations.*

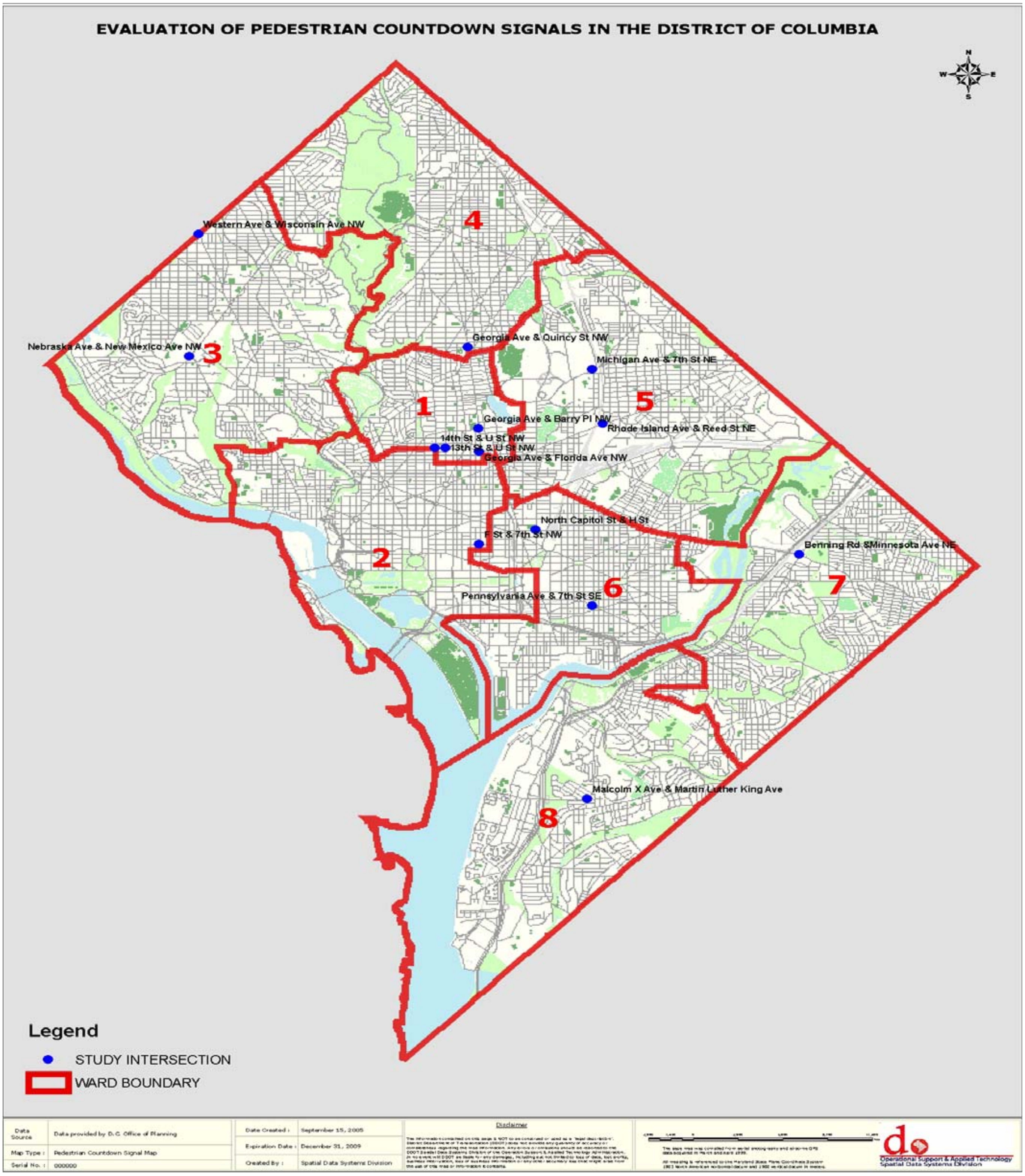
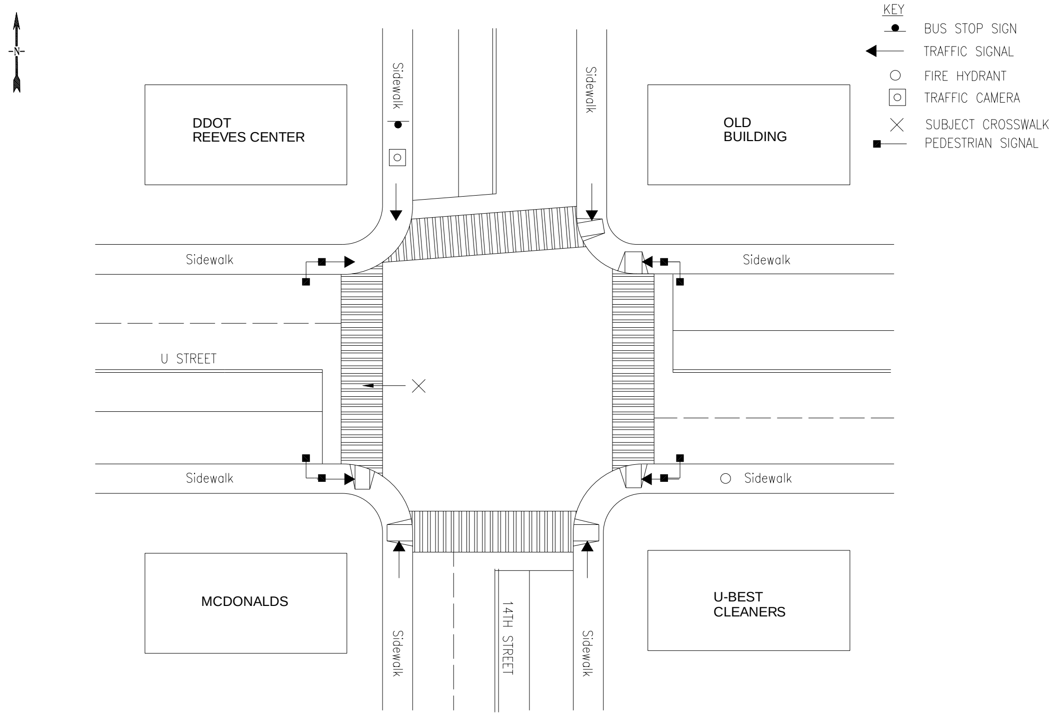
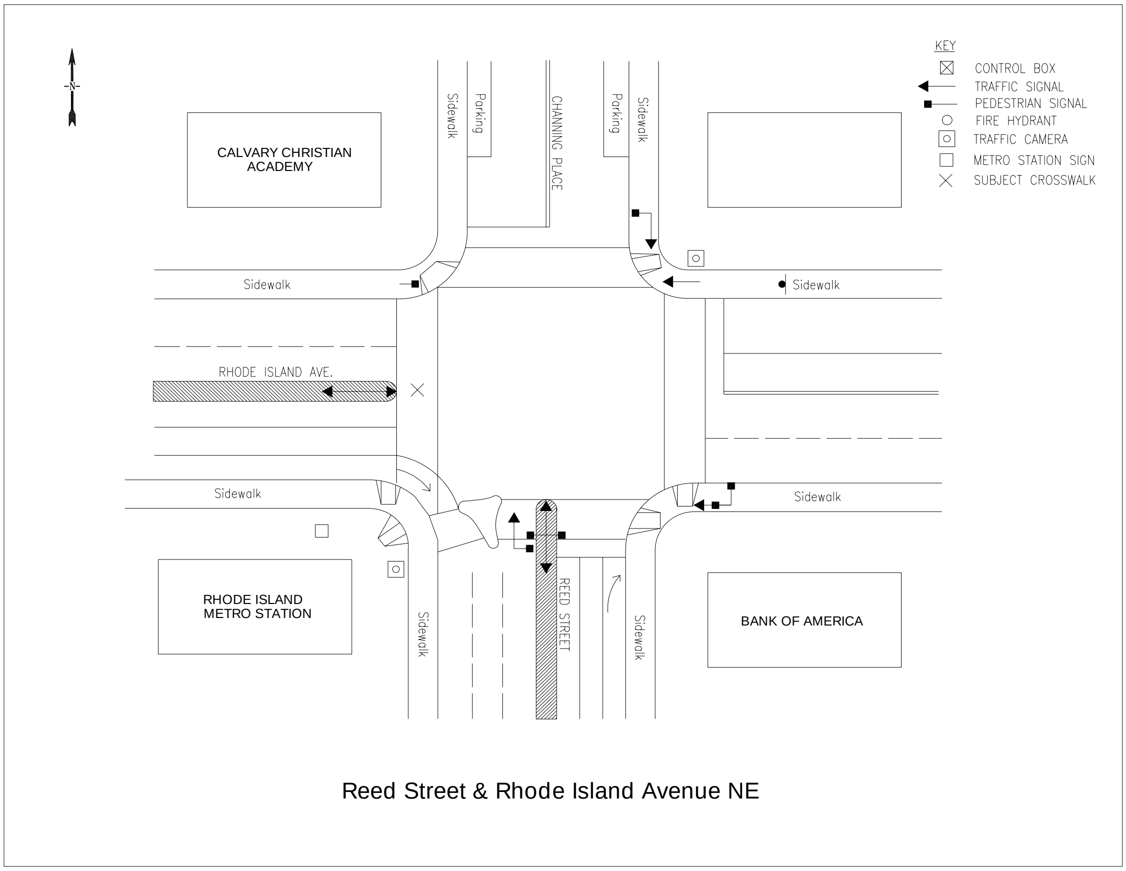


Figure 1: Map Showing Intersection Study Locations



14th & U Streets NW

Figure 2



Reed Street & Rhode Island Avenue NE

Figure 3

Data Collection and Reduction

One crosswalk at each of the fourteen intersections was selected for two-hour videotaping of pedestrians during the morning and evening peak periods. The recordings were made for both "before" and "after" the installation of the CPS. The camera was positioned in such a manner so as to capture the pedestrian signal phases as the pedestrians cross the intersection. The video recording was done between 7:30 a.m. and 10:30 a.m. for the morning peak period and between 4:00 p.m. and 6:30 p.m. for the evening peak period. The data was collected during the period January through April, 2005.

For each study intersection, the "after" collection was started about 3-4 weeks after the CPS was installed. The interim between the two data collection periods enabled pedestrians to familiarize themselves with the new device. Video taping during the "before" and "after' scenarios was done during the same weekday and peak periods. Video editing equipment was used to review the tape and to obtain the pedestrian counts during the observation periods, as well as the frequencies of the following 10 variables were extracted:

- Variable 1: pedestrian running,
- Variable 2: pedestrian balking (aborting crossing),
- Variable 3: pedestrian-vehicle conflicts
- Variable 4: pedestrian completing their crossing during the SDW
- Variable 5: pedestrian beginning to cross the FDW
- Variable 6: average walking speed
- Variable 7: pedestrian beginning to walk during the steady WALK indication
- Variable 8: pedestrian who started crossing during the SDW
- Variable 9: pedestrians who remained in the crosswalk at the onset of the SDW
- Variable 10: pedestrians who remained in the crosswalk at the release of the opposing vehicular traffic

The research team used basic video editing devices to extract frequencies for the observed variables. At each intersection, approximately equal sample sizes were chosen for the "before" and "after" scenarios.

The raw data for the ten variables during the a.m. peak period is presented in Table 2. The entire set of raw data is presented in Appendix B. The proportion for each variable was calculated by dividing the frequency by the number of pedestrians in the associated sample. A sample of the computed proportions of pedestrians who were observed running during the "before" and "after" observations for both a.m. and p.m. peak periods is presented in Table 3. Similar calculations for the other variables are presented in Appendix C.

A pedestrian attitudinal survey was conducted at the following 7 intersections:

- Rhode Island Avenue & Reed Street, NW
- 7th Street and Pennsylvania Avenue, NW
- 14th Street and U Street, NW
- 7th Street and F Street, NW
- Alabama Avenue and Good Hope Road, SE
- Western Avenue and Wisconsin Avenue, NW
- North Capitol Street and H Street, NE

The survey was conducted after the installation of the CPS during 3 weekdays (Thursday, Friday and Tuesday, in August 2005) under good weather, between 9:00 a.m. and 2 p.m. A total of 102 pedestrians were surveyed. The survey was tailored toward evaluating pedestrians' perception of safety due to the installation of the CPS. The following questions were asked in the survey:

1. How safe do you feel crossing this intersection?
2. Is your sense of safety due to the CPS?
3. Does the CPS help you make a decision about crossing this intersection safely?
4. Do you feel turning vehicles comply with the CPS?

A summary of the results of the pedestrian survey is presented in Table 4. The raw responses to the questions are presented in Appendix D.

Table 2: Sample Raw Data for Variables During A.M. Peak "Before" Period

No.	INTERSECTION	VARIABLES 1	2	3	4	5	6*	7	8	9	10	SAMPLE SIZE	STUDY CROSS WALK
1	7th and F Street, NW	6	5	10	60	23	13.1	111	66	25	7	200	East
2	13th Street and U Street, N.W.	6	14	4	9	11	10.3	80	29	6	2	120	South
3	14th Street and U Street, N.W.	7	28	21	11	8	15.4	64	28	8	1	100	West
4	7th Street, Florida and Georgia Avenue, N.W.	6	5	8	15	17	11.8	123	10	13	2	150	East
5	Georgia Avenue and Barry Place, N.W.	7	22	7	7	7	10.6	48	45	8	5	100	South
6	Rhode Island Avenue and Reed Street, N.E.	4	4	2	5	9	11.6	30	36	9	2	75	South
7	7th Street and Michigan Avenue, N.E.	1	0	1	8	8	10.5	26	5	11	1	39	West
8	North Capital and H Street, N.E.	16	6	20	30	35	15.0	108	7	37	7	150	East
9	7th Street and Pennsylvania Avenue, S.E.	6	2	8	5	11	8.1	80	9	2	1	100	East
10	Nebraska Avenue and New Mexico Avenue, N.W.	8	2	14	3	14	7.7	75	11	11	0	100	East
11	Western Avenue and Wisconsin Avenue, N.W.	17	2	43	12	16	14.6	81	3	11	0	100	East
12	Benning Road and Minnesota Avenue, N.E.	3	3	2	5	10	17.0	37	3	11	1	50	East
13	Martin Luther King Jr. and Malcolm X Avenue, S.E.	4	0	4	6	8	8.3	37	8	7	3	53	East
14	Georgia Avenue and Quincy Street, N.W.	1	4	10	9	9	7.6	49	36	5	0	94	West

**Variable 6 is in seconds; other variables are in frequencies*

Table 3: Proportions of Pedestrians who were observed running, Variable 1

No.	INTERSECTION	AM			PM			AM		PM	
		SUBJECTS			SUBJECTS			PROPORTIONS		PROPORTIONS	
		"Before"	**"After"**	N_{AM}	**"Before"**	**"After"**	N_{PM}	P_{RR1}	P'_{RR1}	$_{RR2}$	P'_{RR2}
1	7th and F Street, NW	6	6	200	10	3	200	0.030	0.030 P	0.050	0.015
2	13th Street and U Street, N.W.	6	5	120	3	4	120	0.050	0.042	0.025	0.033
3	14th Street and U Street, N.W.	7	3	100	1	4	110	0.070	0.030	0.009	0.036
4	7th Street Florida and Georgia Avenue, N.W.	6	3	150	2	9	150	0.040	0.020	0.013	0.060
5	Georgia Avenue and Barry Place, N.W.	7	2	100	4	0	100	0.070	0.020	0.040	0.000
6	Rhode Island Avenue and Reed Street, N.E.	4	4	75	2	2	70	0.053	0.053	0.029	0.029
7	7th Street and Michigan Avenue, N.E.	1	1	39	4	2	70	0.026	0.026	0.057	0.029
8	North Capital and H Street, N.E.	16	9	150	12	10	150	0.107	0.060	0.080	0.067
9	7th Street and Pennsylvania Avenue, S.E.	6	2	100	5	7	100	0.060	0.020	0.050	0.070
10	Nebraska Avenue and New Mexico Avenue, N.W.	8	4	100	7	4	100	0.080	0.040	0.070	0.040
11	Western Avenue and Wisconsin Avenue, N.W.	17	8	100	15	14	100	0.170	0.080	0.150	0.140
12	Benning Road and Minnesota Avenue, N.E.	3	6	50	2	2	50	0.060	0.120	0.040	0.040
13	Martin Luther King Jr. and Malcolm X Avenue, S.E.	4	6	53	6	8	56	0.075	0.113	0.107	0.143
14	Georgia Avenue and Quincy Street, N.W.	1	4	94	0	3	100	0.011	0.043	0.000	0.030

Table 4: Summary of Pedestrian Survey

QUESTION	RESPONSES	TOTALS	PERCENTAGE
1	Very Safe	39	*38.2*
	Somewhat	43	*42.2*
	Not Safe	20	*19.6*
2	Yes	67	*65.7*
	Somewhat	16	*15.7*
	No	19	*18.6*
3	Yes	81	*79.4*
	Somewhat	14	*13.7*
	No	7	*6.9*
4	Yes	30	*29.4*
	Somewhat	32	*31.4*
	No	40	*39.2*

Statistical Analysis

The test statistic primarily used for this study is that of proportion *p*. The Student's *t*-statistic was used to test the hypotheses described above. In the analysis, the assumption was made that for each variable defined above, the probability of the occurrence of an event is not close to zero. Thus the normal approximation to the binomial distribution was used to analyze the data. In general, for the significance of difference test, the *t*-statistic was calculated from the following formula:

$$t = (p_1 - p_2) / \sqrt{[p_0 q_0 (1/n_1 + 1/n_2)]} \qquad (1)$$

where:

$$p_0 = (p_1 n_1 + p_2 n_2) / (n_1 + n_2) \qquad (2)$$

$$q_0 = 1 - p_0 \qquad (3)$$

where subscripts 1 and 2 refer to the proportions and samples for the "before" and "after" scenarios. For the *t*-distribution, typically when the degrees of freedom exceed 32, the distribution approximately resembles the normal distribution. The analysis was conducted at a 5% level of significance.

In general, the hypothesis could be stated mathematically as:

H_0: $P_b = P_{a,}$ and that the observed differences are due to chance (i.e., the CPS is ineffective)
H_1: $P_b > P_{a,}$ and that the CPS is effective,
where P_b and P_a denote the respective proportions for the "before" and "after" scenarios.

For the case where an increase in proportion (or average variable) is expected, the alternate hypothesis would be H_1: $P_b < P_{a,}$ and that the CPS is effective.

Using a one-tailed test at 5% significance level, H_1 would be reject if the z-score is greater than the critical value determined to be 1.645.

RESULTS

The detailed analyses conducted (using Microsoft EXCEL) are presented in Appendix E. For each variable, the analysis was conducted for both a.m. and p.m. peak periods. The samples used at each intersection were approximately equal for both the "before" and "after" scenarios and ranged from 39 to 200.

Pedestrian Running

As hypothesized, the proportion of pedestrians recorded running at each intersection was expected to be reduced as a result of the CPS at 5% level of significance. Tables 5a and 5b respectively show the results of the analysis conducted for this variable for a.m. and p.m. peak periods.

From the tables, in the a.m. peak hours, there were reductions in proportions of pedestrians who were found running at 8 of the 14 intersections, while there was no indicated impact on this behavior at 3 intersections. There were increases in the proportions of pedestrians running at 3 of the intersections. In the p.m. peak period, 6 of the intersections had reduced proportions of running pedestrians, 2 showed no impact on this pedestrian behavior, while the remaining 6 showed an increase in proportion.

Table 5a: Results for "*Pedestrian Running*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.030	0.030	0.000	0.5000	No
2	13th Street & U Street NW	0.050	0.042	0.309	0.3788	No
3	14th Street & U Street NW	0.070	0.030	1.298	0.0972	No
4	7th Street, Florida Ave & Georgia Ave	0.040	0.020	1.015	0.1550	No
5	Georgia Ave & Barry Place NW	0.070	0.020	1.705	0.0441	Yes
6	Rhode Island Ave & Reed Street NE	0.053	0.053	0.000	0.5000	No
7	7th Street & Michigan Ave NE	0.026	0.026	0.000	0.5000	No
8	North Capitol Street & H Street NE	0.107	0.060	1.462	0.0718	No
9	7th Street & Pennsylvania Ave SE	0.060	0.020	1.443	0.0745	No
10	Nebraska Ave & New Mexico Ave NW	0.080	0.040	1.191	0.1168	No
11	Western Ave & Wisconsin Ave NW	0.170	0.080	1.924	0.0272	Yes
12	Benning Road & Minnesota Ave NE	0.060	0.120	-1.048	0.8527	No
13	Martin L. King Jr. & Malcom X Ave SE	0.075	0.113	-0.665	0.7468	No
14	Georgia Ave & Quincy Street NW	0.011	0.043	-1.360	0.9131	No

Table 5b: Results for "*Pedestrian Running*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.050	0.015	1.974	0.0242	Yes
2	13th Street & U Street NW	0.025	0.033	-0.384	0.8506	No
3	14th Street & U Street NW	0.009	0.036	-1.357	0.5874	No
4	7th Street, Florida Ave & Georgia Ave	0.013	0.060	-2.150	0.9842	No
5	Georgia Ave & Barry Place NW	0.040	0.000	2.020	0.0217	Yes
6	Rhode Island Ave & Reed Street NE	0.029	0.029	0.000	0.5000	No
7	7th Street & Michigan Ave NE	0.057	0.029	0.835	0.2020	No
8	North Capitol Street & H Street NE	0.080	0.067	0.443	0.3289	No
9	7th Street & Pennsylvania Ave SE	0.050	0.070	-0.595	0.7242	No
10	Nebraska Ave & New Mexico Ave NW	0.070	0.040	0.930	0.1761	No
11	Western Ave & Wisconsin Ave NW	0.150	0.140	0.201	0.4204	No
12	Benning Road & Minnesota Ave NE	0.040	0.040	0.000	0.5000	No
13	Martin L. King Jr. & Malcom X Ave SE	0.107	0.143	-0.571	0.7161	No
14	Georgia Ave & Quincy Street NW	0.000	0.030	-1.745	0.9595	No

From the results, the reductions in the proportion of pedestrians who were found running were statistically significant at only 2 intersections in both the a.m. and p.m. peak periods. The reductions was consistently significant at Georgia Avenue and Barry Place intersection for both a.m. and p.m. periods. For both a.m. and p.m. peak hours, there were no reduction at 3 of the intersections. Thus, the null hypothesis would be rejected at the 2 intersections that showed statistically significant reductions in proportions of pedestrians running (i.e., the CPS was effective in reducing the number of pedestrians running at 2 intersections).

Pedestrian Balking (False Starts)

It was expected that the proportion of pedestrians who balked at each intersection would be reduced as a result of the CPS at 5% level of significance. Tables 6a and 6b show the results of the analysis conducted for balking pedestrians during the a.m. and p.m. peak periods, respectively.

In the a.m. peak period, there were reductions in proportions of pedestrians who had false starts at 8 of the fourteen intersections while there was no indicated impact on this behavior at 3 intersections. Also at 2 intersections, there were no pedestrians who had false starts. The reductions in the proportion of pedestrians who started walking and returned to the curb due to the release of the conflicting traffic were found to be statistically significant at 2 intersections (No. 3 and No. 5). Thus the null hypothesis would be rejected at only those 2 intersections. In order words, the CPS significantly reduced the number of false starts at those 2 intersections for the a.m. peak period. In the p.m., the impact of the CPS on this variable was positive at only 1 intersection.

Pedestrian-Vehicle Conflict

The results for the evaluation of pedestrian-vehicle conflicts are presented in Tables 7a and 7b for the a.m. and p.m. peak periods, respectively. It was hypothesized that the proportion of pedestrians who encounter conflicts with vehicles would be reduced due to the

Table 6a: Results for "*Pedestrian Balking*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.025	0.010	1.144	0.1263	No
2	13th Street & U Street NW	0.117	0.100	0.415	0.3389	No
3	14th Street & U Street NW	0.280	0.160	2.048	0.0203	Yes
4	7th Street, Florida Ave & Georgia Ave	0.033	0.080	-1.748	0.9598	No
5	Georgia Ave & Barry Place NW	0.220	0.080	2.772	0.0028	Yes
6	Rhode Island Ave & Reed Street NE	0.053	0.080	-0.655	0.7437	No
7	7th Street & Michigan Ave NE	-	-	-	-	-
8	North Capitol Street & H Street NE	0.040	0.033	0.307	0.3793	No
9	7th Street & Pennsylvania Ave SE	0.020	0.060	-1.443	0.9255	No
10	Nebraska Ave & New Mexico Ave NW	0.020	0.010	0.582	0.2804	No
11	Western Ave & Wisconsin Ave NW	0.020	0.010	0.582	0.2804	No
12	Benning Road & Minnesota Ave NE	0.060	0.020	1.021	0.1537	No
13	Martin L. King Jr. & Malcom X Ave SE	-	-	-	-	-
14	Georgia Ave & Quincy Street NW	0.043	0.053	-0.342	0.6337	No

Table 6b: Results for "*Pedestrian Balking*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.070	0.110	-1.398	0.9189	No
2	13th Street & U Street NW	0.167	0.142	0.536	0.2959	No
3	14th Street & U Street NW	0.145	0.200	-1.070	0.8577	No
4	7th Street, Florida Ave & Georgia Ave	0.067	0.027	1.642	0.0503	No
5	Georgia Ave & Barry Place NW	0.110	0.000	3.412	0.0003	Yes
6	Rhode Island Ave & Reed Street NE	0.029	0.057	-0.835	0.7980	No
7	7th Street & Michigan Ave NE	0.000	0.057	-2.029	0.9788	No
8	North Capitol Street & H Street NE	0.033	0.040	-0.307	0.1207	No
9	7th Street & Pennsylvania Ave SE	0.110	0.060	1.268	0.1024	No
10	Nebraska Ave & New Mexico Ave NW	-	-	-	-	-
11	Western Ave & Wisconsin Ave NW	0.020	0.000	1.421	0.0776	No
12	Benning Road & Minnesota Ave NE	0.160	0.060	1.598	0.0550	No
13	Martin L. King Jr. & Malcom X Ave SE	0.036	0.071	-0.839	0.7993	No
14	Georgia Ave & Quincy Street NW	0.020	0.030	-0.453	0.6747	No

Table 7a: Results for “*Pedestrian-Vehicle Conflict*” – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.050	0.120	-2.510	0.9940	No
2	13th Street & U Street NW	0.033	0.083	-1.652	0.9508	No
3	14th Street & U Street NW	0.210	0.200	0.175	0.4305	No
4	7th Street, Florida Ave & Georgia Ave	0.053	0.067	-0.486	0.6866	No
5	Georgia Ave & Barry Place NW	0.070	0.180	-2.352	0.9907	No
6	Rhode Island Ave & Reed Street NE	0.027	0.107	-1.964	0.9752	No
7	7th Street & Michigan Ave NE	0.026	0.128	-1.700	0.9554	No
8	North Capitol Street & H Street NE	0.133	0.167	-0.808	0.7906	No
9	7th Street & Pennsylvania Ave SE	0.080	0.050	0.860	0.1948	No
10	Nebraska Ave & New Mexico Ave NW	0.140	0.170	-0.586	0.7211	No
11	Western Ave & Wisconsin Ave NW	0.430	0.200	3.501	0.0002	Yes
12	Benning Road & Minnesota Ave NE	0.040	0.100	-1.176	0.8802	No
13	Martin L. King Jr. & Malcom X Ave SE	0.075	0.075	0.000	0.5000	No
14	Georgia Ave & Quincy Street NW	0.106	0.106	0.000	0.5000	No

Table 7b: Results for “*Pedestrian-Vehicle Conflict*” – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.105	0.035	2.744	0.0030	Yes
2	13th Street & U Street NW	0.058	0.042	0.592	0.2768	No
3	14th Street & U Street NW	0.091	0.273	-3.496	0.9998	No
4	7th Street, Florida Ave & Georgia Ave	0.073	0.027	1.854	0.0318	Yes
5	Georgia Ave & Barry Place NW	0.090	0.180	-1.862	0.9687	No
6	Rhode Island Ave & Reed Street NE	0.171	0.157	0.228	0.4098	No
7	7th Street & Michigan Ave NE	0.043	0.057	-0.388	0.6509	No
8	North Capitol Street & H Street NE	0.547	0.427	2.079	0.0188	Yes
9	7th Street & Pennsylvania Ave SE	0.010	0.020	-0.582	0.7196	No
10	Nebraska Ave & New Mexico Ave NW	0.100	0.230	-2.477	0.9934	No
11	Western Ave & Wisconsin Ave NW	0.580	0.460	1.698	0.0447	Yes
12	Benning Road & Minnesota Ave NE	0.080	0.100	-0.349	0.6366	No
13	Martin L. King Jr. & Malcom X Ave SE	0.107	0.071	0.663	0.2538	No
14	Georgia Ave & Quincy Street NW	0.050	0.140	-2.170	0.9850	No

information provided by the CPS. The analysis was conducted at 5% significance level. The results indicate that there were both increments and reductions in the proportions of pedestrians involved in vehicular conflicts during both a.m. and p.m. peak periods. In the a.m. peak period, only 1 of the three reductions was statistically significant, while in the p.m. peak, 4 intersections recorded statistically significant reductions. At 2 intersections in the a.m. peak period, there was no impact of the CPS on the pedestrian-vehicle conflict since the proportions obtained were equal. Therefore, the null hypothesis is rejected for those intersections which recorded statistically significant reductions in the proportions of pedestrians who experienced conflicts with vehicles.

Pedestrians Completing Crossing during SDW

On the basis of the information provided by the CPS, it was hypothesized that the proportion of the pedestrians who begin to cross during the SDW interval would be reduced after the installation of the CPS. The results of the evaluation are presented in Tables 8a and 8b for the a.m. and p.m. peak hours respectively. The results show that the reductions in proportions were statistically significant at 3 intersections in the a.m. peak period, and at 4 intersections in the p.m. peak period. At 10 of the intersections, a negative impact, which is an increase in the proportion of pedestrians crossing during the SDW, was observed.

Pedestrian Starting to Cross during FDW

It was hypothesized that the proportion of the pedestrians who begin to cross during the FDW phase would be reduced after the installation of the CPS. This hypothesis was evaluated at 5% level of significance. The results of the analysis are presented in Tables 9a and 9b for the a.m. and p.m. peak hours respectively. Although there were reductions in the proportion of pedestrians who started crossing the intersection during the FDW interval, these reductions were significant only at 4 intersections in the a.m. peak period. In the p.m. peak period, none of the reductions were

Table 8a: Results for "*Pedestrian Completing Crossing during SDW*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.300	0.115	4.562	0.0000	Yes
2	13th Street & U Street NW	0.075	0.075	0.000	0.5000	No
3	14th Street & U Street NW	0.110	0.090	0.471	0.3187	No
4	7th Street, Florida Ave & Georgia Ave	0.100	0.080	0.605	0.2725	No
5	Georgia Ave & Barry Place NW	0.070	0.090	-0.521	0.6989	No
6	Rhode Island Ave & Reed Street NE	0.067	0.067	0.000	0.5000	No
7	7th Street & Michigan Ave NE	0.205	0.077	1.627	0.0519	No
8	North Capitol Street & H Street NE	0.200	0.107	2.243	0.0124	Yes
9	7th Street & Pennsylvania Ave SE	0.050	0.010	1.658	0.0487	No
10	Nebraska Ave & New Mexico Ave NW	0.030	0.070	-1.298	0.9028	No
11	Western Ave & Wisconsin Ave NW	0.120	0.100	0.452	0.3256	No
12	Benning Road & Minnesota Ave NE	0.100	0.020	1.684	0.0461	Yes
13	Martin L. King Jr. & Malcom X Ave SE	0.113	0.057	1.045	0.1479	No
14	Georgia Ave & Quincy Street NW	0.096	0.043	1.437	0.0753	No

Table 8b: Results for "*Pedestrian Completing Crossing during SDW*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.150	0.085	2.019	0.0218	Yes
2	13th Street & U Street NW	0.100	0.067	0.934	0.1751	No
3	14th Street & U Street NW	0.109	0.073	0.938	0.1741	No
4	7th Street, Florida Ave & Georgia Ave	0.067	0.047	0.749	0.2269	Yes
5	Georgia Ave & Barry Place NW	0.040	0.030	0.385	0.3502	No
6	Rhode Island Ave & Reed Street NE	0.114	0.029	1.969	0.0245	Yes
7	7th Street & Michigan Ave NE	0.014	0.029	-0.584	0.7203	No
8	North Capitol Street & H Street NE	0.073	0.020	2.190	0.0143	Yes
9	7th Street & Pennsylvania Ave SE	0.020	0.030	-0.453	0.6747	No
10	Nebraska Ave & New Mexico Ave NW	0.040	0.060	-0.649	0.7418	No
11	Western Ave & Wisconsin Ave NW	0.020	0.020	0.000	0.5000	No
12	Benning Road & Minnesota Ave NE	0.080	0.040	0.842	0.1999	No
13	Martin L. King Jr. & Malcom X Ave SE	0.071	0.125	-0.953	0.8296	No
14	Georgia Ave & Quincy Street NW	0.020	0.170	-3.617	0.9999	No

Table 9a: Results for “*Pedestrian Starting During FDW*” – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.115	0.110	0.158	0.4371	No
2	13th Street & U Street NW	0.092	0.100	-0.219	0.0868	No
3	14th Street & U Street NW	0.080	0.120	-0.943	0.3271	No
4	7th Street, Florida Ave & Georgia Ave	0.113	0.093	0.569	0.2847	No
5	Georgia Ave & Barry Place NW	0.070	0.080	-0.268	0.1058	No
6	Rhode Island Ave & Reed Street NE	0.120	0.093	0.529	0.2984	No
7	7th Street & Michigan Ave NE	0.205	0.103	1.255	0.1047	No
8	North Capitol Street & H Street NE	0.233	0.133	2.238	0.0126	Yes
9	7th Street & Pennsylvania Ave SE	0.110	0.010	2.977	0.0015	Yes
10	Nebraska Ave & New Mexico Ave NW	0.140	0.140	0.000	0.5000	No
11	Western Ave & Wisconsin Ave NW	0.160	0.090	1.497	0.0672	No
12	Benning Road & Minnesota Ave NE	0.200	0.040	2.462	0.0069	Yes
13	Martin L. King Jr. & Malcom X Ave SE	0.151	0.113	0.574	0.2831	No
14	Georgia Ave & Quincy Street NW	0.096	0.032	1.790	0.0367	Yes

Table 9b: Results for “*Pedestrian Starting During FDW*” – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.105	0.095	0.333	0.3694	No
2	13th Street & U Street NW	0.067	0.100	-0.934	0.8249	No
3	14th Street & U Street NW	0.036	0.082	-1.430	0.9236	No
4	7th Street, Florida Ave & Georgia Ave	0.053	0.040	0.547	0.2920	No
5	Georgia Ave & Barry Place NW	0.040	0.020	0.829	0.2035	No
6	Rhode Island Ave & Reed Street NE	0.100	0.043	1.313	0.0946	No
7	7th Street & Michigan Ave NE	0.029	0.043	-0.455	0.6756	No
8	North Capitol Street & H Street NE	0.040	0.020	1.015	0.1550	No
9	7th Street & Pennsylvania Ave SE	0.000	0.010	-1.003	0.8420	No
10	Nebraska Ave & New Mexico Ave NW	0.130	0.110	0.435	0.3317	No
11	Western Ave & Wisconsin Ave NW	0.030	0.030	0.000	0.5000	No
12	Benning Road & Minnesota Ave NE	0.100	0.060	0.737	0.2305	No
13	Martin L. King Jr. & Malcom X Ave SE	0.071	0.143	-1.222	0.8892	No
14	Georgia Ave & Quincy Street NW	0.030	0.080	-1.551	0.9395	No

found to be statistically significant. In both the a.m. and p.m. peak periods, 1 intersection recorded no change in the proportion of pedestrians who started crossing during the FDW interval.

Pedestrian Walking Speed

It was hypothesized that the average walking speed of pedestrians would be higher in the "after" period (W_a, when the CPS is in operation) than in the "before" period (W_b). With the information provided by the CPS, pedestrians were expected to complete their crossing before the time to cross elapses. The information is therefore expected to cause them to increase their walking speed. The summary of the analysis for the a.m. and p.m. peak periods is presented in Tables 10a and 10b respectively.

From the results, there were increases in average walking speeds at 5 intersections each in the a.m. peak (Nos. 3, 5, 7, 8 and12) period and the p.m. peak period (Nos. 3, 5, 8, 11 and 12). These increases were not statistically significant at these intersections at 5% level of significance. Therefore the general notion that the average walking speeds of pedestrians would be increased due to the information provided by CPS was not confirmed at the chosen level of significance.

Pedestrian Starting to Cross During the Steady WALK

It was hypothesized that with the installation of the CPS, a higher proportion of sampled pedestrians would begin to cross during the steady WALK. The results of the evaluation are presented in Tables 11a and 11b for the a.m. and p.m. peak periods, respectively.

From the results, the increases were found to be statistically significant at 3 intersections during the a.m. peak period, and at 2 intersections in the p.m. peak period. Thus the null hypothesis would be rejected at these intersections during the periods when the increases were statistically significant.

Table 10a: Results for "*Pedestrian Average Walking Speed*" – A.M. Peak

No.	Intersection	W_b	W_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	5.0	4.9	-0.540	0.7055	No
2	13th Street & U Street NW	4.7	3.8	-2.249	0.9878	No
3	14th Street & U Street NW	4.0	4.1	0.034	0.4862	No
4	7th Street, Florida Ave & Georgia Ave	4.5	4.3	-0.501	0.6919	No
5	Georgia Ave & Barry Place NW	5.0	5.2	0.627	0.2653	No
6	Rhode Island Ave & Reed Street NE	5.1	4.4	-1.983	0.9763	No
7	7th Street & Michigan Ave NE	5.5	5.6	0.118	0.4529	No
8	North Capitol Street & H Street NE	4.9	5.3	0.964	0.1676	No
9	7th Street & Pennsylvania Ave SE	5.1	4.7	-1.560	0.9406	No
10	Nebraska Ave & New Mexico Ave NW	5.6	5.1	-1.887	0.9704	No
11	Western Ave & Wisconsin Ave NW	4.6	4.6	0.137	0.4456	No
12	Benning Road & Minnesota Ave NE	4.6	4.7	0.073	0.4709	No
13	Martin L. King Jr. & Malcolm X Ave SE	4.3	4.0	-1.158	0.8766	No
14	Georgia Ave & Quincy Street NW	4.7	4.5	-0.742	0.7711	No

Table 10b: Results for "*Pedestrian Average Waking Speed*" – P.M. Peak

No.	Intersection	W_b	W_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	4.9	4.9	-0.117	0.5464	No
2	13th Street & U Street NW	4.3	4.3	0.000	0.5000	No
3	14th Street & U Street NW	4.5	4.7	0.380	0.3521	No
4	7th Street, Florida Ave & Georgia Ave	5.0	4.2	-1.273	0.8986	No
5	Georgia Ave & Barry Place NW	4.6	4.8	0.509	0.3053	No
6	Rhode Island Ave & Reed Street NE	4.8	4.4	-0.811	0.7912	No
7	7th Street & Michigan Ave NE	5.3	5.1	-0.476	0.6831	No
8	North Capitol Street & H Street NE	4.7	4.9	0.500	0.3084	No
9	7th Street & Pennsylvania Ave SE	4.8	4.3	-1.395	0.9185	No
10	Nebraska Ave & New Mexico Ave NW	5.2	5.1	-0.450	0.6738	No
11	Western Ave & Wisconsin Ave NW	4.4	5.0	1.449	0.0737	No
12	Benning Road & Minnesota Ave NE	4.8	4.9	0.185	0.4267	No
13	Martin L. King Jr. & Malcolm X Ave SE	4.7	4.3	-0.950	0.8289	No
14	Georgia Ave & Quincy Street NW	5.0	4.6	-1.369	0.9145	No

Table 11a: Results for "*Pedestrian Starting During Steady WALK*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.555	0.625	1.423	0.0773	No
2	13th Street & U Street NW	0.667	0.733	1.127	0.1299	No
3	14th Street & U Street NW	0.640	0.580	-0.870	0.8078	No
4	7th Street, Florida Ave & Georgia Ave	0.820	0.687	-2.679	0.9963	No
5	Georgia Ave & Barry Place NW	0.480	0.340	-2.013	0.9779	No
6	Rhode Island Ave & Reed Street NE	0.400	0.480	0.987	0.1618	No
7	7th Street & Michigan Ave NE	0.667	0.590	-0.703	0.7589	No
8	North Capitol Street & H Street NE	0.720	0.793	1.480	0.0694	No
9	7th Street & Pennsylvania Ave SE	0.800	0.910	2.209	0.0136	Yes
10	Nebraska Ave & New Mexico Ave NW	0.750	0.800	0.847	0.1986	No
11	Western Ave & Wisconsin Ave NW	0.810	0.890	1.584	0.0566	No
12	Benning Road & Minnesota Ave NE	0.740	0.940	2.728	0.0032	Yes
13	Martin L. King Jr. & Malcom X Ave SE	0.698	0.830	1.602	0.0546	No
14	Georgia Ave & Quincy Street NW	0.521	0.660	1.928	0.0269	Yes

Table 11b: Results for "*Pedestrian Starting During Steady WALK*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.650	0.650	0.000	0.5000	No
2	13th Street & U Street NW	0.633	0.617	-0.267	0.6051	No
3	14th Street & U Street NW	0.600	0.682	1.265	0.3970	No
4	7th Street, Florida Ave & Georgia Ave	0.867	0.867	0.000	0.5000	No
5	Georgia Ave & Barry Place NW	0.380	0.670	4.106	0.0000	Yes
6	Rhode Island Ave & Reed Street NE	0.500	0.500	0.000	0.5000	No
7	7th Street & Michigan Ave NE	0.514	0.343	-2.049	0.9798	No
8	North Capitol Street & H Street NE	0.773	0.887	2.613	0.0045	Yes
9	7th Street & Pennsylvania Ave SE	0.600	0.500	-1.421	0.9224	No
10	Nebraska Ave & New Mexico Ave NW	0.760	0.850	1.606	0.0541	No
11	Western Ave & Wisconsin Ave NW	0.940	0.950	0.310	0.1218	No
12	Benning Road & Minnesota Ave NE	0.600	0.540	-0.606	0.7277	No
13	Martin L. King Jr. & Malcom X Ave SE	0.821	0.554	-3.058	0.9989	No
14	Georgia Ave & Quincy Street NW	0.580	0.680	1.465	0.4285	No

Pedestrians who started crossing during the SDW

The stated hypothesis is that the proportion of pedestrians who started crossing during the SDW would be reduced with the installation of the CPS. With the CPS in operation, is expected that pedestrians would not randomly use the crosswalk, without paying attention to the signal on display. This was evaluated at 95% confidence interval.

The results of the analysis for the a.m. and p.m. peak periods are presented in Tables 12a and 12b respectively. The results show a decrease in pedestrians who started crossing during the SDW interval at 9 of the 14 intersections during the a.m. peak period. In the a.m. peak, all the decreases in proportions were not statistically significant. However, in the p.m. peak period, only 3 of the 7 intersections that showed a reduction in crossing during the SDW.

Pedestrians who remained in crosswalk at the onset of the SDW

The information provided by the CPS gives pedestrians information as to the number of seconds remaining to complete crossing an intersection. This duration comes to an end at the beginning of the SDW interval. It was therefore hypothesized that the proportion of the pedestrians who remain in the crosswalk at the beginning of the SDW interval would be reduced after the installation of the CPS. The results of the evaluation are presented in Tables 13a and 13b for the a.m. and p.m. peak hours respectively. From the tables, 11 intersections experienced a reduction in the proportion of pedestrians who remained in the crosswalk at the beginning of the SDW interval in the a.m. peak period, 3 of which showed statistical significance at 5% level of significance. In the p.m. peak period, 5 intersections experienced reductions with only 1 being statistically significant.

Pedestrians who remained in crosswalk at the release of opposing vehicular traffic

It is hypothesized that the information provided by the CPS will enable pedestrians to complete crossing an intersection before the release of the opposing conflicting vehicular traffic. The results of the evaluation are presented in Tables 14a and 14b for the a.m. and p.m. peak hours respectively. From the tables, 8 intersections in the a.m. peak period experienced a reduction in the proportion of pedestrians who remained in the crosswalk at the release of the opposing vehicular traffic, 3 of which showed statistical significance at 5% level of significance. In the p.m. peak period, however, only 2 intersections experienced reductions with only 1 being statistically significant at 5% level of significance. At 8 of these intersections (3 in the a.m. peak and 5 in the p.m. peak) comparisons were not made since no record of pedestrians for this variable was made for both the "before" and "after" scenarios.

Pedestrian Survey

To evaluate pedestrian perception of level of safety that can be attributed to CPS at intersections, questionnaires were developed and responses were obtained at 7 field sites. The responses were tallied and percentages of the responses were computed. The results are presented in Figures 4 and 5.

From Figure 4, about 80% of the respondents felt very safe and somewhat safe when crossing the intersections. The remainder did not feel safe crossing the intersections. This is an indication that, on the whole, a majority of pedestrians in the City feel confident about crossing the intersections safely.

From Figure 4, approximately 81% of the respondents attributed their confidence in being able to cross safely due to the presence of the CPS. This shows that the confidence with which pedestrians cross the intersections could be due to the information provided by the CPS. Figure 5 shows the responses on questions 3 and 4.

The majority of the pedestrians surveyed (i.e., 93%) indicated that CPS help them make informed decisions about crossing the intersections. On the compliance of motorists with the CPS, especially to reduce conflicts with pedestrians, about 61% generally feel motorists comply, while the remainder thinks otherwise.

Table 12a: Results for "*Pedestrian who started crossing during the SDW*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.330	0.265	1.422	0.0775	No
2	13th Street & U Street NW	0.242	0.167	1.441	0.0748	No
3	14th Street & U Street NW	0.280	0.300	-0.312	0.6224	No
4	7th Street, Florida Ave & Georgia Ave	0.067	0.220	-3.790	0.9999	No
5	Georgia Ave & Barry Place NW	0.450	0.580	-1.839	0.9671	No
6	Rhode Island Ave & Reed Street NE	0.480	0.427	0.656	0.2559	No
7	7th Street & Michigan Ave NE	0.128	0.308	-1.920	0.9726	No
8	North Capitol Street & H Street NE	0.047	0.073	-0.972	0.8346	No
9	7th Street & Pennsylvania Ave SE	0.090	0.080	0.254	0.3999	No
10	Nebraska Ave & New Mexico Ave NW	0.110	0.060	1.268	0.1024	No
11	Western Ave & Wisconsin Ave NW	0.030	0.020	0.453	0.3253	No
12	Benning Road & Minnesota Ave NE	0.060	0.020	1.021	0.1537	No
13	Martin L. King Jr. & Malcom X Ave SE	0.151	0.057	1.592	0.0556	No
14	Georgia Ave & Quincy Street NW	0.383	0.309	1.073	0.1415	No

Table 12b: Results for "*Pedestrian who started crossing during the SDW*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.245	0.255	-0.231	0.5913	No
2	13th Street & U Street NW	0.300	0.283	0.284	0.3882	No
3	14th Street & U Street NW	0.364	0.236	2.060	0.0197	Yes
4	7th Street, Florida Ave & Georgia Ave	0.080	0.093	-0.410	0.6593	No
5	Georgia Ave & Barry Place NW	0.580	0.310	3.842	0.0001	Yes
6	Rhode Island Ave & Reed Street NE	0.400	0.457	-0.683	0.7527	No
7	7th Street & Michigan Ave NE	0.457	0.614	-1.864	0.9688	No
8	North Capitol Street & H Street NE	0.187	0.093	2.329	0.0099	No
9	7th Street & Pennsylvania Ave SE	0.400	0.490	-1.281	0.8998	No
10	Nebraska Ave & New Mexico Ave NW	0.110	0.040	1.879	0.0301	Yes
11	Western Ave & Wisconsin Ave NW	0.030	0.020	0.453	0.3253	No
12	Benning Road & Minnesota Ave NE	0.300	0.400	-1.048	0.8527	No
13	Martin L. King Jr. & Malcom X Ave SE	0.107	0.304	-2.573	0.9950	No
14	Georgia Ave & Quincy Street NW	0.390	0.240	2.283	0.0112	Yes

Table 13a: Results for "*Pedestrian Remaining in Crosswalk at SDW*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.125	0.120	0.153	0.439	No
2	13th Street & U Street NW	0.050	0.050	0.000	0.500	No
3	14th Street & U Street NW	0.080	0.200	-2.445	0.993	No
4	7th Street, Florida Ave & Georgia Ave	0.087	0.067	0.651	0.258	No
5	Georgia Ave & Barry Place NW	0.080	0.010	2.388	0.008	Yes
6	Rhode Island Ave & Reed Street NE	0.120	0.080	0.816	0.207	No
7	7th Street & Michigan Ave NE	0.282	0.154	1.371	0.085	No
8	North Capitol Street & H Street NE	0.247	0.140	2.339	0.010	Yes
9	7th Street & Pennsylvania Ave SE	0.020	0.050	-1.154	0.876	No
10	Nebraska Ave & New Mexico Ave NW	0.110	0.080	0.723	0.235	No
11	Western Ave & Wisconsin Ave NW	0.110	0.100	0.231	0.409	No
12	Benning Road & Minnesota Ave NE	0.220	0.040	2.676	0.004	Yes
13	Martin L. King Jr. & Malcom X Ave SE	0.132	0.075	0.955	0.170	No
14	Georgia Ave & Quincy Street NW	0.053	0.021	1.156	0.124	No

Table 13b: Results for "*Pedestrian Remaining in Crosswalk at SDW*" – P.M. Peak

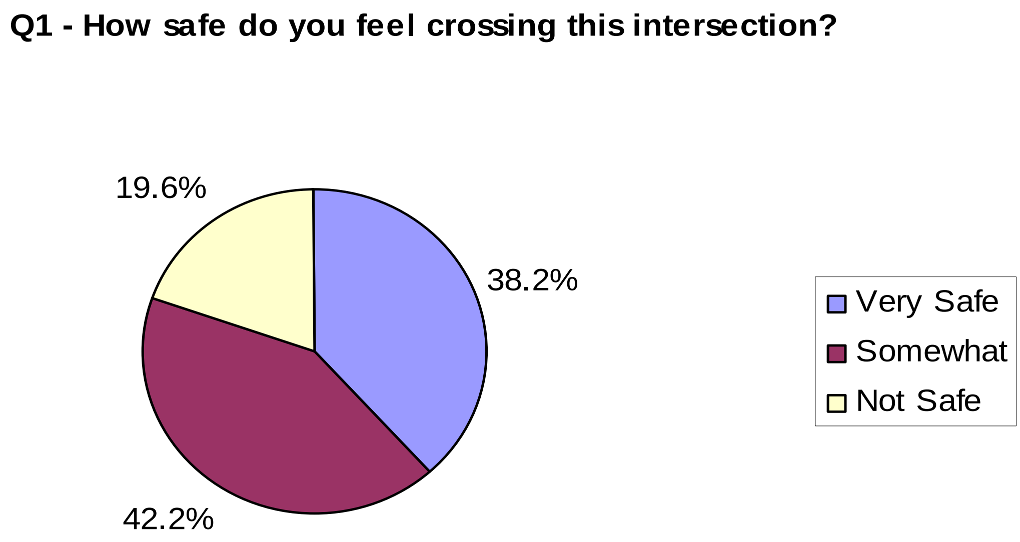
No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.120	0.090	0.979	0.164	No
2	13th Street & U Street NW	0.033	0.075	-1.426	0.923	No
3	14th Street & U Street NW	0.082	0.155	-1.671	0.953	No
4	7th Street, Florida Ave & Georgia Ave	0.087	0.093	-0.202	0.580	No
5	Georgia Ave & Barry Place NW	0.040	0.010	1.359	0.087	No
6	Rhode Island Ave & Reed Street NE	0.014	0.114	-2.412	0.992	No
7	7th Street & Michigan Ave NE	0.100	0.029	1.723	0.042	Yes
8	North Capitol Street & H Street NE	0.013	0.053	-1.930	0.973	No
9	7th Street & Pennsylvania Ave SE	0.040	0.040	0.000	0.500	No
10	Nebraska Ave & New Mexico Ave NW	0.000	0.020	-1.421	0.922	No
11	Western Ave & Wisconsin Ave NW	0.020	0.060	-1.443	0.926	No
12	Benning Road & Minnesota Ave NE	0.120	0.080	0.667	0.252	No
13	Martin L. King Jr. & Malcom X Ave SE	0.107	0.143	-0.571	0.716	No
14	Georgia Ave & Quincy Street NW	0.070	0.120	-1.206	0.886	No

Table 14a: Results for "*Pedestrian Remaining in Crosswalk at release of conflicting traffic*" – A.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.035	0.040	-0.263	0.604	No
2	13th Street & U Street NW	0.017	0.025	-0.452	0.674	No
3	14th Street & U Street NW	0.010	0.040	-1.359	0.913	No
4	7th Street, Florida Ave & Georgia Ave	0.013	0.007	0.580	0.281	No
5	Georgia Ave & Barry Place NW	0.050	0.010	1.658	0.049	Yes
6	Rhode Island Ave & Reed Street NE	0.027	0.000	1.424	0.077	No
7	7th Street & Michigan Ave NE	0.026	0.000	1.006	0.157	No
8	North Capitol Street & H Street NE	0.047	0.020	1.287	0.099	No
9	7th Street & Pennsylvania Ave SE	-	-	-	-	N/A
10	Nebraska Ave & New Mexico Ave NW	0.000	0.010	-1.003	0.842	No
11	Western Ave & Wisconsin Ave NW	-	-	-	-	N/A
12	Benning Road & Minnesota Ave NE	0.020	0.000	1.005	0.157	No
13	Martin L. King Jr. & Malcom X Ave SE	0.057	0.000	1.757	0.039	Yes
14	Georgia Ave & Quincy Street NW	-	-	-	-	N/A

Table 14b: Results for "*Pedestrian Remaining in Crosswalk at release of conflicting traffic*" – P.M. Peak

No.	Intersection	P_b	P_a	z-statistic	p-value	Significant?
1	7th Street & F Street NW	0.020	0.035	-0.917	0.820	No
2	13th Street & U Street NW	0.033	0.017	0.827	0.204	No
3	14th Street & U Street NW	0.018	0.027	-0.452	0.675	No
4	7th Street, Florida Ave & Georgia Ave	0.007	0.013	-0.580	0.719	No
5	Georgia Ave & Barry Place NW	0.070	0.010	2.165	0.015	Yes
6	Rhode Island Ave & Reed Street NE	0.000	0.014	-1.004	0.842	No
7	7th Street & Michigan Ave NE	-	-	-	-	N/A
8	North Capitol Street & H Street NE	0.000	0.007	-1.002	0.842	No
9	7th Street & Pennsylvania Ave SE	0.000	0.010	-1.003	0.842	No
10	Nebraska Ave & New Mexico Ave NW	-	-	-	-	N/A
11	Western Ave & Wisconsin Ave NW	0.000	0.010	-1.003	0.842	No
12	Benning Road & Minnesota Ave NE	-	-	-	-	N/A
13	Martin L. King Jr. & Malcom X Ave SE	-	-	-	-	N/A
14	Georgia Ave & Quincy Street NW	-	-	-	-	N/A



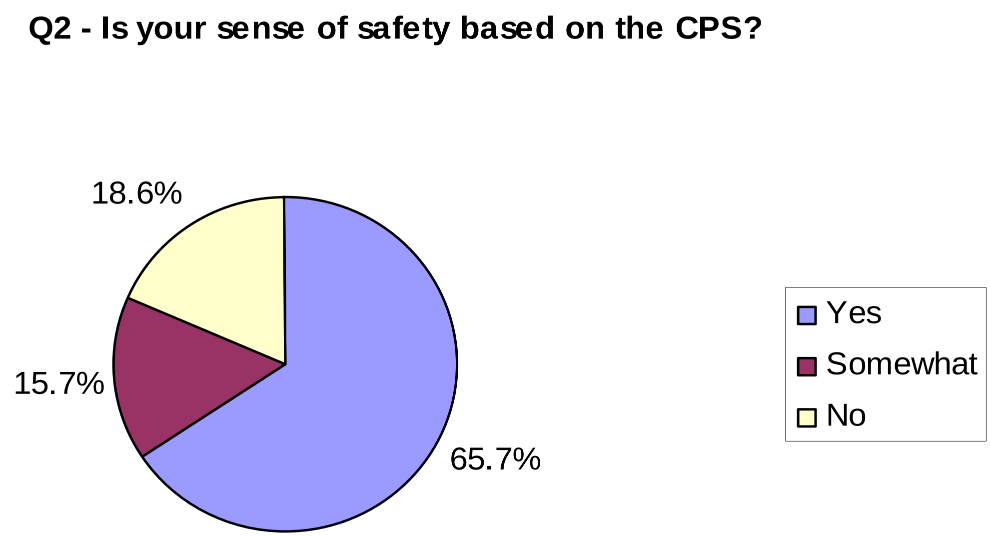
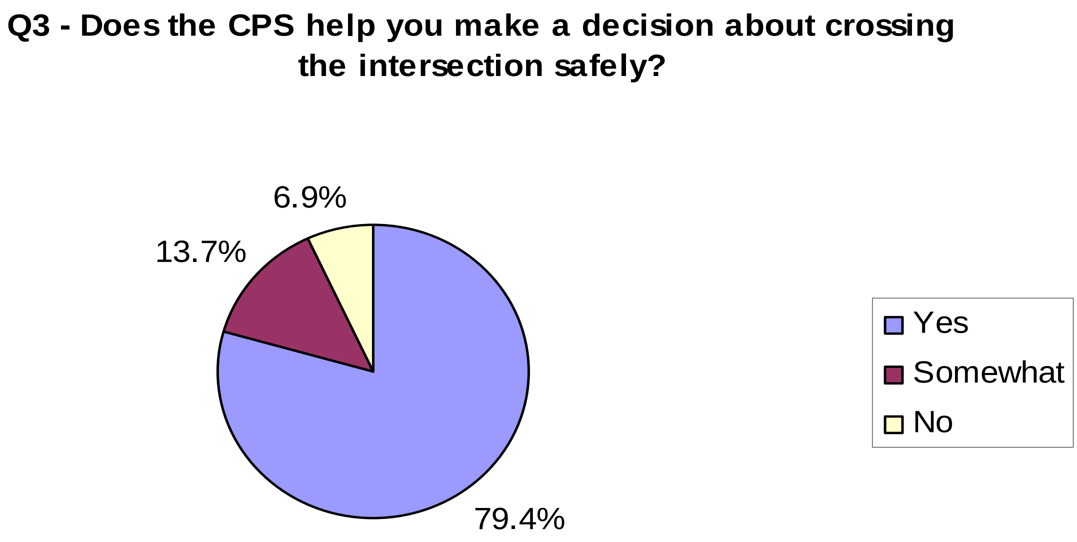


Figure 4: Responses to Questions 1 and 2



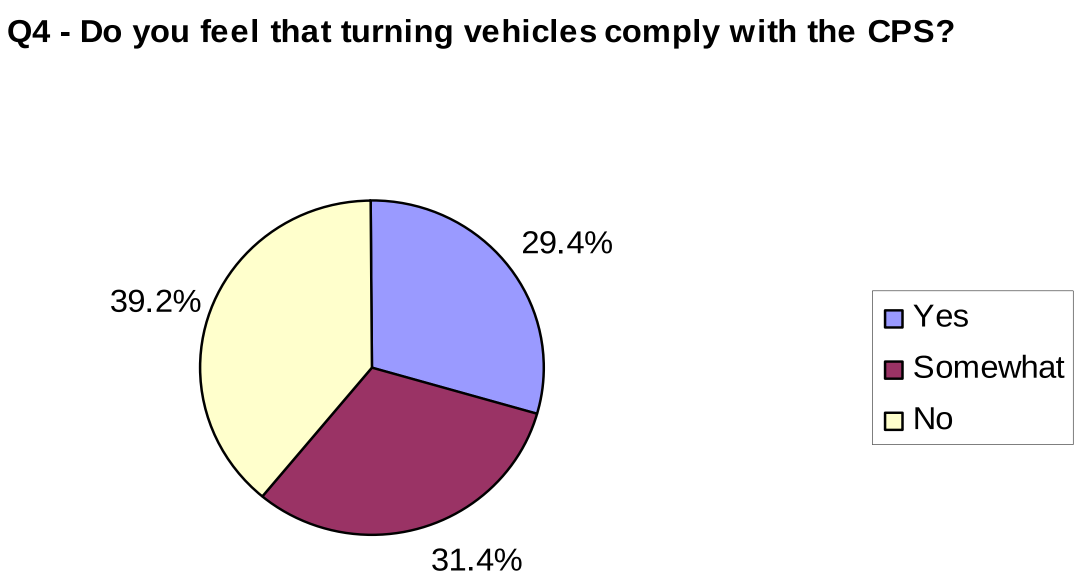


Figure 5: Responses to Questions 3 and 4

DISCUSSION

Countdown pedestrian signals were installed in the City to generally reduce undesired variables (and increase desired variables) in order to improve the safety of pedestrians crossing an intersection. The research therefore focused on the variables whose reductions and increases are known to be correlated with improving the safety of pedestrians at intersections.

Out of the 14 intersections studied, there were reductions in the proportion of pedestrians who run at 8 in the a.m. peak period and 6 intersections in the p.m. peak period. Statistical significance of these reductions was confirmed at only 2 of the intersections each for both a.m. and p.m. peak periods. Since running is an undesirable behavior, a reduction of the proportion of the runners would potentially increase the safety of pedestrians at the 2 intersections. Thus, about 14% of the intersections studied were positively impacted by the installation of the CPS.

The CPS was expected to provide information to pedestrians to enable a reduction in the frequency of false starts. Thus, with the information provided, it was expected that false starts would be reduced significantly. From the results, however, significant reductions in the variable was experienced only at 2 intersections in the a.m. peak period and 1 intersection in the p.m. peak period, representing an average of 14% of the intersections in the a.m. and 7% in the p.m. On the whole, a greater number of intersections recorded reductions in the a.m. peak period than in the p.m. peak period.

It was expected that pedestrian-vehicle conflicts at intersections would be reduced due to the information provided by the CPS. However, from the analyses, fewer reductions in the proportions of pedestrians who had conflicts with vehicle at the intersections were recorded. In the a.m. peak period, 1 intersection recorded a significant reduction in this undesired proportion, while in the p.m. peak period, 4 intersections recorded significant reductions. Thus, on average, about 18% of the intersections experience reductions in pedestrian-vehicle conflicts for both a.m. and p.m. peak periods.

It is desirable to have a reduction in the proportion of pedestrians who complete crossing during the SDW interval. From the results of the analyses, 3 intersections recorded statistically significant reductions in the proportion of pedestrians who completed their crossing during the SDW in the a.m. peak period. Four intersections recorded statistically significant reductions in the p.m. peak period. This signifies an average of 25% of the intersections for both a.m. and p.m. peak periods.

Typically, with the information provided by the CPS, it is expected that pedestrians would comply with the meaning of the FDW. Thus, the CPS should cause a reduction in the proportion of pedestrians who start crossing the intersection during the FDW interval. From the analyses, the reductions recorded were found to be statistically significant at 4 intersections in the a.m. peak period. However, in the p.m. peak period, none of the reductions were found to be statistically significant. On the whole, it could be stated that the CPS had a significant impact on pedestrian compliance with the FDW interval in the a.m. peak period at 29% of the intersection studied. In the p.m. peak period, the impact on this compliance was not significant.

CPS were expected to cause an increase in the proportion of pedestrians who start to cross an intersection during the steady “WALK”. This desired increase was significant at only one intersection in the a.m. peak period and at two intersections in the p.m. peak period. Generally, in the a.m. peak period, 71% of the intersections recorded increases in this proportion, while 43% of the intersections recorded increases in the p.m. peak period.

The results indicate that the CPS did not have any statistically significant effect on the average walking speeds of pedestrians in both the a.m. and p.m. peak periods. For both peak periods, 57% of the intersections studied actually recorded reductions in the average walking speeds of pedestrians.

In the a.m. peak period, 64% of the intersections recorded reductions in the proportions of pedestrians who started crossing during the SDW. Fifty percent (50%) of the intersections recorded reductions in the p.m. peak period. However, statistically significant reductions were recorded only in the p.m. peak period at 4 intersections.

It is desirable to have a reduction in the proportion of pedestrians who remained in the crosswalk at the beginning of the SDW interval. From the results of the analyses, about 79% of the intersections used in the study recorded reductions in the proportion of pedestrians who completed their crossing at the beginning of the SDW in the a.m. peak period. Three intersections showed statistically significant reductions. One intersection recorded statistically significant reductions in the p.m. peak period out of a total of 5 intersections that recorded reductions in the proportion of pedestrians remaining in the crosswalk at the onset of the SDW interval.

From the analysis, approximately 72% of the intersections indicated a reduction in the proportions of the pedestrians surveyed who remained in the crosswalk at the release of the opposing vehicular traffic in the a.m. peak period. Twenty-five percent of the reductions showed statistical significance. In the p.m. peak period, one intersection recorded statistical significance in the reduction.

On the whole, from the survey results, pedestrians were generally attributing their improved perception of safety in crossing intersections to the presence of CPS. It could also be stated from the results that pedestrians overwhelmingly feel that CPS help them to make better crossing decisions, thereby improving safety.

CONCLUSION

The District Department of Transportation has a goal of increasing the safety of pedestrians at intersections and on street segments through the use of a variety of solutions. The CPS is one of the many initiatives to improve pedestrian safety at intersections. The results of the evaluation of CPS are not conclusive about positive impacts on pedestrian behavior at intersections where the countdown timing begins with the start of the “WALK” indication.

For each of the variables studied there was no majority of the intersections showing statistically significant improvements as a result of CPS deployments. Based on the information examined in this research, there is no basis for any warning about the potential danger of CPS in promoting undesirable pedestrian behavior at signalized intersections where the countdown timing begins with the “WALK” indication.

Pedestrians were unanimously conclusive about their increased perception of safety due to the presence of the CPS. It would appear the CPS promotes an increase in consciousness of the crossing activity. This is an important safety benefit.

Based on the survey results, CPS appear to have has an immediate favorable impact on pedestrians’ perception of safety and confidence in crossing intersections. However, in the case of pedestrian behavior at crosswalks (that is, the reduction of undesired behaviors and the increase of desired behaviors), the CPS had both positive and negative effects at the study intersections.

The majority of investigations on CPS focused on applications during the FWD interval. This is also the condition recommended by the MUTCD (1). The results of such investigations were mixed and should not be applied over to the applications used in the City, where CPS are active during the “WALK” indication. It is, however, important to recognize that the trend in countdown installations involves applications during the FDW indication.

REFERENCES

1. Federal Highway Administration (2003). *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition.* Washington, DC: Federal Highway Administration.
2. District Department of Transportation: www.ddot.gov
3. Farraher, B.E.B. (2000). *Pedestrian Countdown Indication – Market Research and Evaluation.* Minnesota Department of Transportation Web site: http://www.dot.state.mn.us/metro/trafficeng/signals/files/compendium.pdf
4. Fundamentals of Traffic Engineering, Institute of Transportation Studies. University of Berkeley, 14th Edition. May 1996.
5. M. Spiegel and L. Stephens. *Statistics.* Third edition. Schaum's Outline Series, 1998.
6. Botha, J.L., Zabyshny, A.A., Day, J.E., Northouse, R.L., Rodriguez, J.O., & Nix, T.L. (2002). *Pedestrian Countdown Signals: An Experimental Evaluation – Volume 1*. Retrieved October 16, 2003 from City of San Jose, California Web site: www.ci.san-jose.ca.us/dot/forms/ report_pedcountdown.pdf
7. Eccles, K.A. (2003). *Evaluation of Pedestrian Countdown Signals.* Silver Spring, MD: Prepared by BMI-SG for Montgomery County Maryland and Maryland State Highway Administration.
8. Cook Research & Consulting, Inc. (1999). *Countdown Pedestrian Indication Market Research.* Minneapolis, MN: Mn/DOT's Metropolitan Division Traffic Engineering Section City of Chicago Department of Transportation (2002).
9. Ken Petraglia. New England Chronicle. May 2004. *An Evaluation of Countdown Pedestrian Signals.*
10. DKS Associates (2001). *San Francisco Pedestrian Countdown Signals: Preliminary Evaluation Summary.* San Francisco, CA: San Francisco Dept. of Parking and Traffic.

11. Chester, D.C., Hammond, M. 1998. *Evaluation of Pedestrian Understanding of Pedestrian Countdown Signals*. 68th Annual Meeting of Institute of Transportation Engineers.

12. Pulugurtha, S. S. and S. S. Nambisan. *Effectiveness of Pedestrian Countdown Timers to Enhance Safety In Las Vegas.* Institute of Transportation Engineers District 6 Annual Meeting, Sacramento, CA. June 2004.

13. Huang, H., & Zegeer, C. (2000). *The effects of pedestrian countdown signals in Lake Buena Vista*. Retrieved October 16, 2003 from Florida Department of Transportation Website: www11.myflorida.com/safety/ped_bike/handbooks_and_research/research/CNT-REPT.pdf

14. Leonard, J., Juckes, M., & Clement, B. (1999). *Safety & Behavior: Behavioral Evaluation of Pedestrians and Motorists Towards Pedestrian Countdown Signals.* Laval, Quebec: Prepared by Dessau-Soprin Inc. for the city of Monterey, California.

15. Mahach, K., Nedzesky, A.J., Atwater, L., & Saunders, R. (2002). *A comparison of pedestrian signal heads*. ITE Annual Meeting Compendium.

16. Rutgers Voorhees Transportation Policy Institute, "*Review of Traffic Signal Standards and Striping Schemes*", Final Draft Report, March 2002.

17. Jeremiah P. Singer, Neil D. Lerner (2005) *Countdown Pedestrian Signals: A Comparison of Alternative Pedestrian Change Interval Displays*. WESTAT, Rockville, MD.