COORDINATED INTELLIGENT TRANSPORTATION SYSTEMS DEPLOYMENT IN NEW YORK CITY (CIDNY)

FINAL REPORT

TASK 7

RESEARCH ON PEDESTRIANS AND CYCLISTS SAFETY USING ITS TECHNOLOGY IN NYC

Performed by: New York University

U.S. Department of Transportation
Federal Highway Administration

NEW YORK STATE OF OPPORTUNITY. Department of Transportation

NEW YORK CITY DOT

University Transportation Research Center - Region 2

ABOUT THE PROGRAM

The FHWA, through its New York Division/New York City Metropolitan office is promoting programs pertaining to urban Intelligent Transportation Systems (ITS) in the region. The NYCDOT and NYSDOT-Region 11 Planning have taken the initiative in working with FHWA to take advantage of this FHWA program. NYCDOT and NYSDOT have developed the Training Courses and Research and Development Programs for the NYCDOT and NYSDOT Coordinated Intelligent Transportation Systems Deployment in New York City (CIDNY) which is a set of multi studies (task assignments) toward the fulfillment of the objectives of these programs.

The 2013 studies are being performed by institutions of the Region 2 University Transportation Research Center (UTRC). The studies focused on the following program areas: Construction Management, Traffic Demand Management, Dynamic Data Collection, Traffic Incident Management, Traffic Signal Timing and Detection Technologies, Strategic ITS Deployment Plan, Pedestrians and Cyclists Safety, Data Storage and Access Platform for MTA Bus Time Data.

The following tasks have been completed under this program.

- *Task 2 – Develop a multi-agency/multi modal construction management tool to enhance coordination of construction projects citywide during planning and operation phases to improve highway mobility and drivers experience*
- *Task 5 –Develop a comprehensive guide to traffic signal timing, new detection technologies and advanced signal timing concepts applicable in New York City*
- *Task 6 – Strategic ITS Deployment Plan For New York City*
- ***Task 7 – Research on Pedestrians and Cyclists Safety Using ITS Technology in NYC***
- *Task 8 – Develop Data Storage and Access Platform for MTA Bus Time Data.*

TASK 7 FINAL REPORT

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16. Abstract

This research project builds on the work and goals of the New York City Department of Transportation NYCDOT) in its long standing efforts to promote the safety of pedestrians, as described in the Vision Zero Initiative and the NYCDOT's 2016 Strategic Plan. As part of the Vision Zero Initiative, in 2015, NYCDOT installed over 400 Leading Pedestrian Intervals, and completed 60 safety projects in Vision Zero Priority Locations. NYCDOT's 2016 Strategic Plan focuses on protecting pedestrians and cyclists as well as on transportation equity as one of the main objectives in the 2016 Strategic Plan. This research worked to promote these goals as well as tying into the Connected Vehicle project through research on Vehicle-to-pedestrian and pedestrian-to-interface systems.

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I. Introduction

This research project builds on the work and goals of the New York City Department of Transportation (NYCDOT) in its longstanding efforts to promote the safety of pedestrians, as described in the *Vision Zero Initiative* and the *NYCDOT's 2016 Strategic Plan*. In February 2014, Mayor de Blasio launched the Vision Zero Action Plan – an interagency effort to eliminate traffic fatalities by 2024. In 2015, the City recorded the fewest pedestrian fatalities, 137 cases, since record keeping began in 1910. In 2015, NYCDOT installed over 400 Leading Pedestrian Intervals, and completed 60 safety projects in Vision Zero Priority Locations. Building off the *Vision Zero Initiative*, *NYCDOT's 2016 Strategic Plan* places particular focus on protecting pedestrians and cyclists, the most vulnerable users of NYC's streets, as well as on transportation equity as one of the main objectives in the 2016 Strategic Plan. Transportation equity means providing all users with access to safe mobility, regardless of where they live and/or their disabilities. This research worked to promote these goals as well as tying into the Connected Vehicle project through research on Vehicle-to-pedestrian (V2P) and pedestrian-to-interface (P2I) systems.

Unlike most other parts of the nation, pedestrians in the New York City constitute the largest share of traffic fatalities. In 2015, there were 233 traffic-related fatalities in New York City; of which, 136 or 58% were pedestrians. Data from the 2013 Traffic Safety Facts reported 68% of pedestrian fatalities and 42% of pedestrian injuries were at non-intersection crossings [1]. In New York State, pedestrians accounted for 27.9% of all fatalities, 8.3% of all pedestrian crashes occurred while the pedestrian was crossing a marked crosswalk with no signal, and 20.2% occurred while the pedestrian was crossing an unmarked crosswalk with no signal [2]. In New York City, 23.6% of crashes occurred when pedestrians were crossing with no signal or crosswalk [3]. Nationwide nighttime crashes (6pm to midnight) account for about 48% of pedestrian fatalities [1]. In New York City, 40% of pedestrian crashes occur between 3pm and 9pm, but most fatalities occur overnight [3]. Figure 1 provides a nationwide overview of pedestrian fatalities.

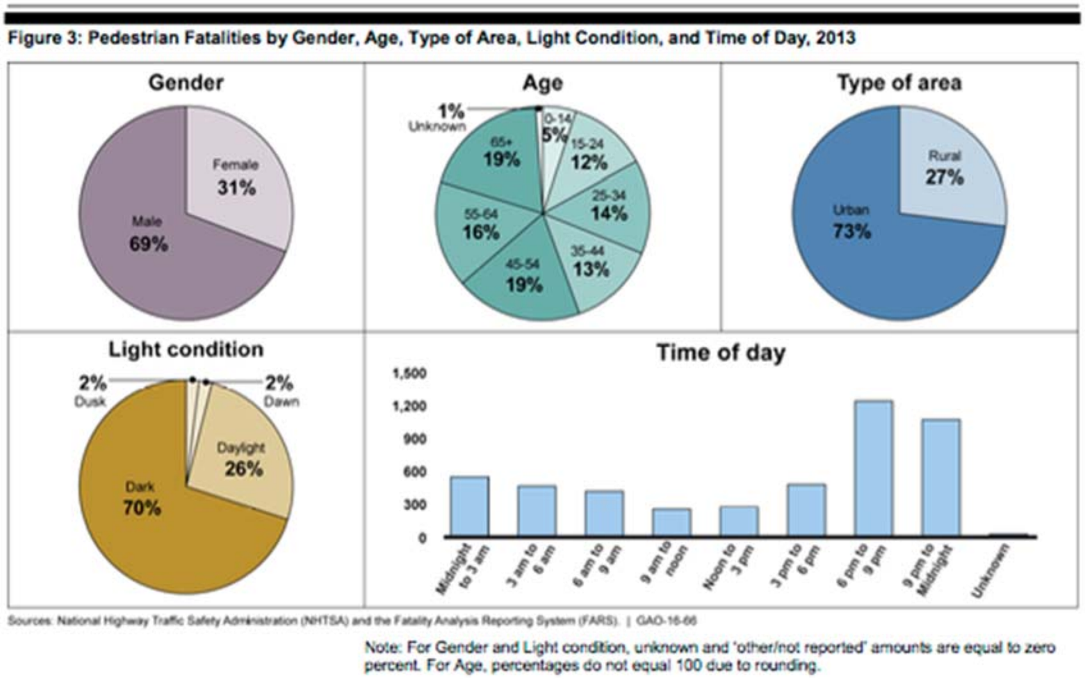

Figure 1. Pedestrian fatalities by gender, age, type of area, light condition, and time of day, 2013 [4].

II. Research Objectives

The purpose of this research was to determine useful countermeasures that could be used in New York City to reduce pedestrian conflicts, injuries, and fatalities, particularly among the most vulnerable users such as the blind and visually impaired. The challenge of this research was to determine which countermeasures could work best in NYC, and to recommend where and when such countermeasures should be used.

The final outcome of this Year 1 research is to recommend countermeasures to test pilot in Year 2. Section V discusses these recommended countermeasures.

III. Literature Review

An extensive literature review was done of specific technologies that were chosen in consultation with NYCDOT. Several measures held particular potential and were considered in greater depth. These promising measures included In-Roadway Warning Lights (IRWL) and leading pedestrian intervals (LPI). Section 2.1 is a review of the literature on IRWL technology. Section 2.3 is a review of the literature on LPI. Section 2.2 lists other technologies currently being used or investigated. Finally, a review of New York City initiatives currently being used to improve safety for pedestrians and bicycles is described in Section 5.

In-roadway Warning Lights

In-roadway warning lights are a Manual on Uniform Traffic Control Devices (MUTCD) [5] approved countermeasure for improving pedestrian safety at uncontrolled crosswalks. MUTCD standards for using IRWL state:

1. IRWL shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks with Yield, Stop or signal control.
2. IRWL shall be installed along both sides of the crosswalk and shall span its entire length.
3. IRWL shall initiate operation based on pedestrian actuation, active or passive detection, and shall cease operation at predetermined time with active actuation or after the pedestrian clears the crosswalk with passive detection
4. IRWL shall display a flashing yellow signal indication when activated. The flash rate shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.
5. If used on one lane, one-way roadways, a minimum of two IRWL shall be installed on the approach side of crosswalk. If used on two-lane roadways, a minimum of three IRWL shall be installed along both sides of crosswalk. If used on roadways with more than two lanes, a minimum of one IRWL per lane shall be installed on both sides of crosswalk.
6. IRWL shall be installed in the area between the outside edge of the crosswalk line and 10 feet from the outside edge of the crosswalk. IRWL shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bidirectional.

Overall, the literature on IRWL is positive. Eleven before-after studies were reviewed [6 - 16]. Reference [17] was not a before-after study, but reported interesting insights by the Virgina DOT engineers for four locations. A summary of the findings in each of the reports is shown in Table 1. Six of the eleven before-after study sites were in urban areas, the other five were in suburban locations.

All eleven before-after studies measured an increase in the percent of vehicles that yield to pedestrians after the installation of IRWL. Additionally, the studies that collected data at night all found that there was an even greater increase in vehicles yielding to pedestrians during nighttime [7,13,14,16].

There were other measures of effectiveness reported, but vehicles yielding to pedestrians was the only measure used in all eleven studies.

Three of the studies measured the pedestrian waiting time and all three reported a decrease [8,9,14].

Six of the studies measured vehicle speed [6-9, 11, 16]. Three found speeds to decrease after IRWL installation, two found no change in the speed from before to after

IRWL installation, and one study had mixed results [11]. However, there was some warning the speed benefit of IRWL decreases over time, as vehicles get more familiar with the location and IRWL [6].

Six studies measured pedestrian-vehicle conflicts [6,8,10,11,13,16]. Three found conflicts to be reduced, while the other three found no change.

Six studies measured the percent pedestrians that crossed within the crosswalk. Three found no change [8,10,15] two reported an increase in pedestrians using the crosswalk [9,12], and one study had mixed results [11].

Lastly of the four studies that reported on an increased sense of security, three reported that pedestrians mistakenly believed that vehicles were required to stop for them or did not understand how IRWL worked [8,9,15]. Even the studies that did not do surveys of pedestrians were concerned about the false sense of security that pedestrians may have. This would be of particular concern if adopted in New York City where IRWL would represent a device generally unfamiliar to motorists and pedestrians. It was recommended that signs warning pedestrians that vehicles may not stop be placed at the crosswalk [10,14].

There is also a warning that the placement of the lighthead on the right-hand side of the road can cause a safety problem for bicycles [13].

In the Virginia DOT Guidelines for installing IRWL [17], VDOT traffic engineers gave their opinion as to the effectiveness of IRWL at four sites in suburban Virginia. Three of the four locations were perceived to have a positive effectiveness due to IRWL.

It is important to note that six of the eleven before-after studies had supplementary devices at the location, such as pedestrian crossing signs, with or without lights, and these can be a factor in the results. In Virginia [17], two of the three sites calling IRWL “effective” also had flashing beacons activate upon pedestrian detection.

There are reports of maintenance concerns, but as the technology is improving, maintenance is less of an issue. Snow plows and rain, in particular, have caused problems. In San Francisco, their “Better Streets” guide reported that IRWL have not worked well because of maintenance issues, but they did see a significant increase in vehicles yielding to pedestrians [19]. There has also been some visibility issues reported when vehicles are in a platoon approaching the crosswalk.

Guide books for installation of IRWL, such as Refs [17-19] caution that public education is extremely important and that each particular location should be carefully considered. No set of rules can apply in all situations, and that engineering judgment should be the final evaluator in determining whether IRWL and/or other devices should be used.

TABLE 1. COMPARISON OF IRWL RESEARCH STUDIES

Location	Implementation Date	Technology	Median	Increase in Vehicles yielding to Peds	Decrease in Waiting Time for Peds	Decrease in vehicle speed	Decrease in Conflicts	Increase staying in crosswalk	False sense of Security	Supplement Devices	Ref	Comments
Denville, NJ, Urban	2000	Passive, Microwave	No	Yes	NR	Yes	No change	NR	NR	Striped Crosswalk	6	Striping was added first and later IRWL to do three step comparison; Speed benefit decreases over time; Striping brought down conflicts to almost 0
Cedar Rapids, Iowa, Urban	2004	Passive, Bollards	No	Yes	NR	No Change	NR	NR	NR	None	7	Unusually complex Intersection; Improvement at night
Orlando, FL, Urban	1997	Passive, bollards	No	Yes	NR	No Change	Yes	No change	Yes	None	8	Pedestrians did not understand how IRWL worked (from survey); Further testing recommended
Hawaii, Suburban	2000	Push Button	Yes	Yes	Yes	Yes	NR	Yes	42% Yes	Ped xing signs with blinking lights	9	
Airway Heights, WA, Suburban	2002	Push Button	yes	Yes	Yes	NR	No change	No change	No	ped xing warning signs w/o light	10	Stop bars added after case; Stop bars give added sense of security; signs warning peds that vehicles may not stop are important
Israel, Urban	2002	Passive	No	Yes	NR	Mixed	Yes	Mixed	NR	None	11	Four Sites studied, Conflicts decreased to almost 0%; Decrease in Speed when initial speed >20mph
Amherst, MA, Suburban	2007	Passive, Bollards	No	Yes	NR	NR	NR	Yes	NR	Reflective Pedestrian Crossing Signs	12	
Kirkland, WA, Urban	1997	Push Button	yes	Yes	NR	NR	Yes	NR	NR	None	13	Yield increase especially at night; Concern for bicyclists and placement of lighthead; some maintenance issues (snowplows, rain)
San Jose, CA, Urban	2000	Passive, bollards	No	Yes	NR	NR	NR	NR	NR	Warning signs	14	Yield increase especially at night; some maintenance issues, Overall found IRWL better than Standard overhead flashing beacon
Rockville, MD, Suburban	2004	Passive, bollards		Yes	Yes	NR	NR	No change	Yes	None	15	
Henderson, Nevada, Suburban	2006	Push Button	No	Yes	NR	Yes	No Change	NR	NR	"Yield Here to Pedestrian" Signs	16	Yield increase especially at night;
Route 57,VA	2001	Push Button	Small	No Before/After Studies done. All suburban Locations. General anecdotal results from engineers reported.						None	17	Effective when working
Blacksburg, VA	July 2000	Passive, Microwave	Medium							None	17	Effectiveness Questionable
Arlington County, VA	October 2002	Passive, Bollards with light beam	10 ft							Ped xwalk sign with flashing beacons also activated upon detection	17	Effective
Fairfax County, VA	2002	Push Button	No							Ped xwalk sign with flashing beacons also activated upon detection	17	Effective

The activation method of the IRWL can be either active (pedestrian push button) or passive (automatic detection system). Table 2, taken from Ref [17] shows the advantages and disadvantages of each method.

TABLE 2. Advantages and Disadvantages of Activation Method [17]		
Type Activation	Advantage	Disadvantages
Push Button	Familiarity with device; More reliable; Less expensive; Easier to maintain	Ped confusion because Ped signal not present; May be interpreted as giving right of way; May be interpreted as causing vehicles to stop; Difficult to determine duration of crossing time and thus duration of flashing
Passive	IRWL for warning drivers, not peds thus: Less confusing Makes peds more responsible Less disruptive to traffic because peds wait till gap before stepping off curb and activating device; Duration of flashing set more easily	Some systems prone to false activations due to weather, nearby peds, malfunction; Less reliable; More expensive; More difficult to maintain

Use of IRWL in the Village of East Hampton

During the research on the use of IRWL, two locations were studied where IRWLs were placed on the section of State Route 27 called Main Street in the Village of East Hampton. Figures 2 and 3 show figures of the IRWLs at these locations. Pedestrians actuated the system manually by pushing a button.

Figure 2. In-Roadway Warning Lights in the Village of East Hampton, NY

Figure 3. Detail of IRWL in Village of East Hampton

To learn more, telephone interviews were held with Tom Temistokle of the NYSDOT located in Hauppauge, NY, and Michael Bouker, the Deputy Superintendent of the

Department of Public Works in the Village of East Hampton. They provided the following information:

1. Main Street on this section of Rt 27 is the only section that has four travel lanes plus a parking lane, making the roadway difficult to cross. The Village of East Hampton had safety concerns for pedestrians due to significant conflicts between vehicles and pedestrians on this, and requested a safety study by the State.

2. Installing a signal was considered, but the Village did not want another signalized crosswalk on Main Street and thus chose IRWLs.

3. In 2009, the Village and the State began the process of considering IRWL installation. They worked together for permission to install the crosswalk. The State agreed to do the installation. Before installation was started, maintenance and operation of the crosswalk agreements were completed, with the State taking over the maintenance after the first year. Work on actual installation of the IRWLs began in 2012 and was completed approximately one month later.

4. Power for the crosswalks was supplied from nearby pull boxes associated with the decorative street lighting.

5. There has yet to be any official study of vehicle compliance, but from observation, they estimate 70-80% compliance, and see an improvement in pedestrian safety and driver awareness.

6. Rapid Rectangular Flashing Beacons (RRFBs) were also installed for added safety and warning to vehicles. During the peak hours (weekends and holidays), traffic officers are also used for increased safety.

7. In retrospect they believe that having automated actuation instead of manual might have been a better option.

8. In terms of street sweepers, there have not been problems. Snow-plow drivers are instructed to lift plows near the crosswalk.

9. On average, some lights need replacing every four to six months.

10. Other locations in the same corridor are under consideration.

Leading Pedestrian Intervals

Leading Pedestrian Intervals (LPI) are currently being utilized effectively in New York City and around the country to help improve pedestrian safety by reducing the occurrences of conflicts between pedestrians and turning vehicles. The LPI phase gives some seconds (generally up to 7 seconds) of advanced “WALK” time to the pedestrians before conflicting turn vehicles are released. By providing pedestrians the opportunity to enter a crosswalk during the LPI, drivers are afforded greater visibility of pedestrians in the crosswalk before executing their turns, thus improving yielding behavior.

In New York City, there are basic rules of thumb for considering LPI phasing.

1. In Manhattan, LPI signals are considered when there are ≥ 200 vph turning left or right through the crosswalk.
2. In the outer boroughs, there would also have to be greater than 200 pedestrians going through the crosswalk.
3. When there are two or more pedestrian crashes due to left- or right-turning vehicles.
4. School Crossings: 99% of school crosswalks get LPI phasing.
5. Seven second LPI phasing is the standard.

References [20] – [29] discuss research that has been done on LPI phases and their effects on pedestrian safety in other cities. Table 3 shows the results of adding LPI phases. Overall, the research showed improved safety conditions for pedestrians. Immediate improvements in safety after LPI installation were found, which improved even more as drivers and pedestrians became more familiar with the LPI phase.
These references also recommended that locations where LPIs should be considered have one or more of the following factors:

a. High volumes of pedestrians
b. High rates of conflicts
c. More than a typical number of vehicle-pedestrian crashes due to turning vehicles
d. School Crossings and intersections close to schools
e. High volumes of seniors
f. T-intersections and one-way roads, i.e., when vehicles do not need to yield to oncoming traffic

TABLE 3. Summary of Studies on LPI

Ref	Study Location	No. Ints.	Study Type	Results
[20]	Toronto	4		61% reduction of vehicles not yielding to pedestrians, four months after implementing LPI
[21] 2010	College Park, PA	10	Crash Statistic s	Significant decrease as 0.05 level of pedestrian-vehicle crashes. Crash rate decrease greater at high-volume pedestrian locations.
[22] 2008	San Francisco, CA	3	Before / After 4-sec LPI interval	Significant reduction of pedestrians yielding to vehicles, 6.2% to 4% overall; No significant decrease in conflicts
[23] 2009	Miami, FL	2	Before / After 4-sec LPI	Significant increase in drivers turning left yielding to peds (9% before to 18% after); No change in drivers turning right yielding to peds
[24] 2008	Anaheim, CA	1	Before / After	Pedestrians yielding to vehicles significantly decreased when there was high right-turn volumes, but increased at low right-turn volumes. This was a suburban environment, compared to all other studies in urban environments.
[25] 2005	Toronto, ON	3	Before / After 5-sec LPI	One intersection had significant decrease (34%) in vehicles not yielding to pedestrians One intersection had significant increase in vehicles not yielding to pedestrians, but this was probably due to the skewed geometry
[26] 2000	St. Peters-burg, FL	3	Before / After 3-sec LPI interval	Odds of a conflict between pedestrians and vehicles at the beginning of the "WALK" period was reduced by 95%, from an average of 2.5 conflicts to almost zero per 100 pedestrian crossings

The Van Houten, et al. study [26], which collected data at three intersections in St. Petersburg, Florida, also separated the data by age group (seniors versus non-seniors). They found conflicts were significantly reduced in both groups for both right- and left-turning conflicts.

A 1999 study performed in New York City [28] analyzed ten years of crash data (5 years before and 5 years after) and found a 12% decrease in crashes at locations with LPIs and a decrease in the severity of the crashes.

LPIs and Visually Impaired and Blind Pedestrians

Blind and visually-impaired pedestrians find LPI phases very difficult to use effectively, unless there is an APS signal at the location [29]. Without an APS signal, blind and visually-impaired pedestrians often depend on hearing the vehicles begin to move in the parallel direction often referred to as “the surge”. Relying on other pedestrians beginning to move is dangerous for blind/visually-impaired pedestrians because of the regularity of sighted pedestrians crossing against the signal. Even in cases when the blind or visually impaired pedestrian is aware that an LPI phase exists (at a location without APS), it is difficult to realize when the LPI begins and often realizes it too late to start crossing before the conflicting vehicle begins its movement [29].

Additional Countermeasures

Illuminated Pushbuttons

Provide immediate feedback to the pedestrian that the pushbutton is working. Having instantaneous feedback may reduce pedestrian confusion by letting them know that the pushbutton is working, and thus may reduce the number of pedestrians that enter the crosswalk against the signal because they are not sure if the button is working [30, 31].

Pedestrian Switch Pads

Pressure sensitive, tactile pads that adhere to the pedestrian ramp that communicates with the control box when a pedestrian is on the pad. It can also be used to detect bicycles.

The tactile bumps on the pad each have a “high-sensitivity switch”, which can detect the pedestrian's direction of movement. In a pedestrian crosswalk, the switch pad knows whether a person is entering or exiting the crosswalk. Proper placement of these pads is necessary to insure the pedestrian steps on them [31].

C-Walk/SafeWalk

Video detection pedestrian sensors. The sensors detect pedestrians waiting to cross and control the traffic signal to accommodate them. C-Walk, developed by the same company, detects pedestrians already in the crosswalk and can extend the green to accommodate safe walking [32,33]. The sensors can also be used to control IRWL and flashing beacons.

Vehicle-to-pedestrian (V2P) technologies

The U.S. Department of Transportation Connected Vehicle Research is studying the use of wireless networks (such as those that exist in the active traffic signal system of the Midtown in Motion project) to communicate to connected vehicles and smart phones to warn drivers of nearby pedestrians and bicyclists [34-36]. The V2P applications can be developed to provide warnings to vehicles, pedestrians, bicyclists, or any other mode. The ongoing Connected Vehicle Demonstration Project being conducted by NYCDOT is expected to consider establishing communication between pedestrians and the traffic signal (a P2I application).

Smartphone Applications

While smartphones and distracted drivers, pedestrians, and bicyclists have been a major concern to cities, Smartphone applications are now being developed to use their technology to improve safety. Some of the technologies being developed are:

Type N Walk for Android

This application uses the camera in a mobile phone device so that the pedestrian can see what is in front of them while texting, thus seeing the street ahead and any obstacles (Figure 4) [37]. There is some controversy over the use of this application, however, that it may cause pedestrians to be more distracted [38].

Figure 4. Type n Walk application for Android [28]

Mobileye

An android application that warns drivers when pedestrians and bicyclists are too close [39]. A camera is mounted on the windshield and the application communicates with the camera using Bluetooth.

AT&T's DriveMode Application

This application uses the smartphone's velocity detection technology. When it senses that the velocity of the person carrying the phone (driver or passenger) is moving above 25 mph, for instance, it will automatically send "cannot answer" responses to texts and emails. It can also be set to disable the touch screen as well as audio and vibration alerts. [40].

Natural User Interface (NUI) Technology

Can be used to create interfaces for the smartphone that cause fewer distractions. NUI technology means communicating with your device using only natural human movements, such as, voice, sounds, gestures, and touch [41]. The Integrated Digital Media program at the NYU School of Engineering of New York University looked at ways to use NUI to allow pedestrians to communicate with their smartphones while leaving the phones in their bags or pockets. This would be done through wearable devices that would use lights and vibrations to signal the pedestrian, to which the pedestrian can respond by tapping or squeezing the device [38].

Accessible Pedestrian Signals Literature

Accessible pedestrian signals (APS) help visually impaired and blind pedestrians enter a crosswalk safely at the beginning of a "WALK" cycle and help them safely cross the roadway. The MUTCD [42] requires that APS provide both audio and vibrotactile formats of communication. A vibrotactile device has a vibrating surface that blind or visually-impaired pedestrians touch/press to know which direction is being controlled. Often the vibrotactile device is a raised vibrating arrow. Verbal queues may also be provided at APS locations. The MUTCD has detailed standards for what technologies shall or may be used, and how they should be used. Additional references that are important to consult are *The Guide to Best Practices: APS* [43] and the United States Access Board's standards for pedestrian signals [44]. In 2012, the New York City Council enacted a local law requiring NYCDOT to establish an APS program and annually install accessible pedestrian signals at 25 identified intersections. A local law enacted in 2014 increased the minimum number of intersections at which NYCDOT must install an APS to 75.

The challenges that blind or visually impaired pedestrians contend with when approaching an intersection to cross are 1) locating the crosswalk, 2) aligning themselves in the correct direction for entering the crosswalk, and 3) maintaining their path while staying inside the crosswalk until they reach their destination [45]. There is also the challenge of knowing when to begin crossing. The following research looks at ways to improve these tasks for blind and visually impaired pedestrians.

Barlow, et al. [45] compared standard APS signals against beaconing APS signals and also against a raised guide strip for their ability to help blind and visually impaired pedestrians with wayfinding (correctly moving towards the other side of the crosswalk) and staying in the crosswalk on complex intersections. The guide strip was a raised strip of polymer tape (4-inch wide by 0.25-inch high), also known as a temporary rumble strip, installed along the inside edge of the crosswalk. It was found that the beaconing APS and the guide strip both significantly improved the ability to align oneself correctly at the entrance to the crosswalk and to remain in the crosswalk while crossing. Both the guide strip and the beaconing APS were equally effective. There were problems with both applications, however. The guide strips are often hard to find because they do not start at the beginning of the crosswalk (due to interference with drainage) and there is a concern for the usefulness when covered by snow. The beaconing APS needs to be placed directly across the street in the center of the crosswalk to be effective. The paper also recommends that an extended pushbutton press will decrease the possibility of confusion and using the wrong beacon.

Scott, et al. [46] studied the effects of beaconing a signal from the far-side destination corner that would begin before the audible “WALK” signal starts on the original corner in order to help the pedestrian align themselves correctly in the crosswalk. A beaconing signal would also occur during the flashing “DON’T WALK” interval to help with wayfaring. This study wanted to test whether the beaconing caused confusion at busy intersections with multiple crosswalks. An “acoustically complex” intersection was chosen and 216 trials were performed. The results of this study showed that far-side beacons did not contribute to confusion and instead improved the ability to maintain the correct heading. Although only one intersection was studied, the data suggested that there are “strong beneficial effects of beaconing.”

Smart Phone Applications For Blind and Visually-Impaired Pedestrians

Smart phone applications are the newest technology being tested for improving mobility for blind and visually impaired pedestrians. The Global Positioning System (GPS), which is ubiquitous in smart phones, is an obvious technology to use. However, GPS alone has not proven very effective [47,48] because its ability to determine the location of the pedestrian is not accurate enough. However, when GPS is used in combination with other technologies, such as Radio Frequency Identification (RFID), Bluetooth, or Wi-Fi, some promising results are being achieved. None of the smartphone applications are ready for widespread use, but they are being perfected and seem to have great potential.

Professor Chen-Fu Liao from the University of Minnesota [49] is studying the application of smart phones as mobile accessible pedestrian signals (MAPS) for improving safe crossing. MAPS technology can allow the pedestrian to automatically activate the “WALK” signal without having to veer from their path to find the push button. MAPS can give more information about the intersection such as its street name, number of lanes, and direction. With one tap, the app tells the user, “You are pointing east, Harvard Street, 2-lanes” or it will announce “No information in northeast. Please turn for data.” With two taps, the application requests the status of the pedestrian “WALK” signal. It also uses a speech feed. The app communicates with the signal via wireless Bluetooth and each intersection is required to be equipped with Geo-ID Bluetooth as well. The application informs the pedestrian when the “WALK” signal is on and how many seconds are left. In a field experiment, 65% preferred MAPS over a regular push button; 82% liked the geometry information; and 59% liked the signal information. There is a learning curve for using the system but, overall, MAPS demonstrates a high potential.

Crosswatch is a smartphone platform [50] that is being tested and developed to provide guidance to blind and visually impaired travelers at intersections. The main difference from the MAPS application is that Crosswatch would not require special hardware to be installed at each signalized intersection in order to give the user the status of the signal. The Crosswatch system uses computer vision technology from the smartphone’s camera that can give the blind and visually impaired pedestrians “real-time feedback on their orientation to the crosswalk and their location relative to the crosswalk.” Computer vision uses mathematical algorithms to “describe the world that we see in images and reconstruct its properties.” [51]. The pedestrian creates a panorama by pointing the phone at a location and turning in place slowly for a 180-degree arc. (A vibrator is activated if a user points the camera too far down or up.) The smartphone camera provides a pedestrian’s precise location and orientation using information obtained from images acquired both by the camera and from online sensors and offline data. The camera captures intersection features such as crosswalk pavement markings and the “WALK” signal. Crosswalk markings that are detected and have been tested with good results are the striped “Zebra” crosswalk and the two-stripe crosswalk. Coughlan and Shen [50] are working on extending Crosswatch to give more detailed information about the intersection such as the type of intersection, presence and location of traffic signals, signs, walk call buttons and raised medians, as well as real-time information of the status of the traffic and pedestrian signals, and combining this information with GPS. Current work includes creating an extensive GIS library of intersections throughout San Francisco.

Reference [52] discusses possible uses for connected vehicle-to-pedestrian (V2P) technology being tested in applications that USDOT are funding. One of the projects being developed is a mobile accessible pedestrian signal system, which, similar to MAPS, uses smart phones to make automated calls to the traffic system and gives audio cues to help those with visual impairments find the crosswalk and remain in it. This application will also use V2P technology to alert drivers making turns to the presence of a visually impaired pedestrian in the crosswalk.

One of the issues with all of these smartphone applications is that the pedestrian is required to hold the smartphone to activate the technology. Both MAPS [50] and Crosswatch [51] recognize this as a safety issue, so the user is expected to put the smartphone away before entering the crosswalk. References [53-55] discuss using tactile belts to provide a non-visual aid to wayfinding. Professor Liao, with MAPS, will be exploring wearable navigation systems such as smartwatches or belts in the future.

Microsoft has developed a headset for assisting blind and visually impaired people navigate streets [56]. The headset works with Windows phones. It is worn in front of the ear so it does not interfere with the necessary noise sources of traffic and other sounds. The headset gives verbal and non-verbal cues, so if a specific route is requested, clicking sounds let the user know they are on the correct course and when to turn. It relies on GPS and maps in the cloud, but also a network of beacons that need to be attached to street furniture around the city.

Students at Northeastern University [57] created a smartphone application that uses RFID sensors to communicate with mats that would be installed at intersections. The mats are embedded with RFID tags. The RFID sensors are placed in the seeing-eye dog's harness, so that when within one meter of the mat, verbal information about the intersection including name and alignment are given. The graduating students' plan will also look into implanting the sensor into a visually impaired person's cane. Although this application has not been tested outside the university lab, it is an interesting idea.

IBM and Carnegie Mellon University [58] recently released an open platform application created for helping blind and visually impaired pedestrians. Although the applications designed are not yet for intersections, the hope is that it can be updated to help with navigation outside the campus. For navigation around the Carnegie Mellon campus, the application uses smartphone sensors as well as Bluetooth beacons placed around campus walkways. The platform is available free for developers. The tools that are currently available "consists of an application for navigation, a map editing tool and localization algorithms that can help the blind identify in real time where they are, which direction they are facing and additional surrounding environmental information." The Robotics Institute at Carnegie Mellon is also doing research using computer vision for identifying surrounding objects (such as broken sidewalks or debris) for outdoor navigation [59].

IV. Issues for Blind and Visually-Impaired Pedestrians

Meeting With PASS Coalition

On October 7, 2015, a meeting was held with the PASS Coalition to hear their concerns about the safety of blind and visually-impaired pedestrians navigating City streets and to get their feedback on various countermeasures that could improve their safety. PASS members attending the meeting were:

- Maria Hansen
- Ken Stewart
- Gene Bourquin
- Karen Gourgey

The PASS representatives discussed the considerable challenges that blind or visually-impaired pedestrians face when navigating intersections. There was particular concern for the many unusual and complex intersection geometries that are difficult for the large population of blind and visually-impaired pedestrians to navigate, many of whom are over age 55 (eyesight tends to diminish with age), and who tend to walk slower than other pedestrians.

The feedback received on various countermeasures to improve the safety for blind and visually-impaired pedestrians are as follows:

Accessible Pedestrian Signals

- APS units in New York City are generally well maintained.
- PASS indicated that most APS units are correctly aligned with the crosswalk.
- DOT Signal Maintenance Shop responsible for maintaining and repairing APS units.
- PASS inquired if DOT has considered micro-trenching for electrical conduit for more cost effective installation.
- Requested additional information for improved orientation from "extended push" of call button (e.g., skewed geometry, number of travel lanes, number of roadway approaches, or the presence of refuge islands).
- Requested support signage that advises pedestrians that APS units are available for audible output to discourage unnecessary use by sighted pedestrians.
- Continuous operation of APS WALK ticking sound, while of some benefit, is not desired.
- Beacons are not a high priority because of sound overload, which might be confusing to blind pedestrians.

Leading Pedestrian Intervals (LPI)

- Blind pedestrians wait for traffic surge before crossing. With LPIs, there is no surge until parallel traffic is allowed to move.
- Delayed crossings by blind pedestrians waiting for the surge places them in the intersection after the majority of pedestrians have completed their crossing, thus leaving them alone midway in the crosswalk and more vulnerable to turning vehicles.
- Less time to complete the crossing before the start of the "DON'T WALK" phase.
- It was noted that the latest May, 2015 NYCDOT APS Prioritization Tool provides extra weight for installing APS units at intersections with an LPI.

Split Phasing

- Excellent for blind pedestrians for the following reasons:
    - No conflicts with turning vehicles.
    - Know when to start crossing since the traffic surge starts simultaneously with the start of the "WALK" phase.

Exclusive Pedestrian Phase (EPP)

- Very difficult for blind pedestrians to cross.
- Unable to know when the "WALK" signal starts since there is no traffic surge.

- It was noted that the latest May, 2015 NYCDOT APS Prioritization Tool provides extra weight for installing APS units at intersections with an EPP.

Pedestrian plazas, sidewalk extensions and bike lanes

- Textured pavement used in plazas and sidewalk extensions not easily detectable.
- Some crosswalks in older painted pedestrian plazas do not have detectable warning strips (see Figure 5).
- Raised curbs in crosswalk constitute a tripping hazard including bull nose tip protecting bike lanes (see Figure 6).
- Bikes are a special hazard because of their silent operation and when operating illegally on sidewalks or the wrong way on roadway.
- Bike paths immediately adjacent to crosswalk increase the chance of conflicts if blind pedestrian deviates slightly from crosswalk (see Figure 7).

Figure 5. Painted pedestrian plaza without detectable warning strip at crosswalk (Grand Army Plaza, Brooklyn)

Figure 6. Pedestrian Island with bull nose located partially within crosswalk (Eighth Avenue at W.24th Street, Manhattan)

Figure 7. Crosswalk with adjacent bike lane (Grand Army Plaza, Brooklyn)

New Technology

- While an open competitive process to select the desired vendor for the development of the smartphone applications suitable for New York City will be pursued, both NYCDOT and NYU are monitoring the ongoing development and testing of new smartphone technology, such as -MAPS in Minnesota and Crosswatch in San Francisco
- New technology utilizes smart phones and perhaps wearable technology (smart watch, belt, cane) utilizing Bluetooth, RFID GPS, computer vision, V2P, GIS.
- Concern expressed about general availability of smartphones to blind population (low income, unfamiliar with new technologies).
- Difficult to hear verbal messages from smartphones (rapid tick from APS preferred).
- PASS would like to participate in any future testing of new technologies in New York City.

V. Recommended Countermeasures for Blind and Visually-Impaired Pedestrians

Three countermeasures are recommended for pilot testing in CIDNY Year 2 that could help blind and visually-impaired pedestrians navigate intersections in New York City. The three countermeasures are:

1. Extended Press Feature of APS Signals
2. Smartphone Applications
3. Tactile Maps

For each of the countermeasures, it is recommended that both subjective and objective MOEs are found. Subjective MOEs would be obtained from surveying the participants. Objective MOEs would be found either through video recording or manual recording by an observer.

The surveys would ask the participants about the usefulness, ease of use, likelihood of using, confidence in the system, and other questions that will be developed in conjunction with members of the PASS Coalition.

From the objective data, measures could possibly include the use of the pedestrian button on the APS, alignment to the crosswalk, number that keep alignment throughout the crossing, walking speed, and time to step into the crosswalk. The APS units have automatic event loggers that could also be used to collect data.

Final MOEs for each of the countermeasures will be developed in CIDNY Year 2.

Extended Press Feature of APS Signals

The use of the extended pushbutton press of an APS unit is being considered for testing in New York City. The APS devices currently installed in New York City have the ability to provide the extended press feature. The extended press function can optionally provide verbal messages and/or an extension of the "WALK" interval. Extending the "WALK" interval is usually not possible at pretimed signalized intersections, as is the case throughout much of New York City.

APS units in New York City currently provide a verbal message during the "WALK" interval indicating that the pedestrian "WALK" phase has begun and infrequently the name of the street being crossed. The APS unit could also provide the name of the street to cross during the "WALK" interval. Verbal messages could also be provided during the Flashing "DON'T WALK" and the Steady "DON'T WALK" phases. Possible features currently being investigated include providing critical information such as intersection geometry and lane configuration. For instance, to notify the user whether there is a pedestrian refuge island (raised or flush), and/or the presence of a bike lane.

In discussions with Polara Enterprises concerning the APS Extended Press feature's ability of their EZ Communicator Navigator APS devices, we found that:

- The Navigator is a fully integrated APS that offers multiple audible indications to identify to pedestrians information needed to more safely navigate the crosswalk.

- Audio word messages can be programmed by Polara, or by an operator, with software uploaded via USB port for EN2 and EN4 units at the push button station. An Operator uses a PC with a standard USB A/B cable.
- Previous generations of Navigators require the use of voice chips to program word messages; EZ Communicator Navigators (ENAV) do not have voice chips.
- Word messages can be factory installed or installed by an operator using Polara's EZ APS Toolbox software. Audacity, a third party freeware audio recording/editor software, is used as a means (not the sole means) to facilitate recording of 16-Bit wav sound files. Custom sounds and messages can be made provided they are recorded in the appropriate file type.
- APS provides for both momentary and extended button push.
- Extended PUSH TIME function allows the extended push time to be formatted by the operator (agency). This is the amount of time the button on the EPBS has to be pressed and held before enabling Extended Push functions. The choices are: 0-6 seconds in 0.5-second increments. (Default = 1.0 seconds).

The length of the extended press button feature push time is set in the MUTCD [43] as:

"If an extended pushbutton press is used to provide any additional feature(s), a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible "WALK" indication, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible "WALK" indication, and any additional feature(s)."

The Accessible Pedestrian Signals Guide to Best Practices [44] recommends a one-second press as the length of time required to activate the extended press features. The "Best Practices Guide" as well as Reference [60] state that previous APS controllers used a 3-second press. However it was found that most pedestrians will not hold the button long enough and that the 1-second time is preferable [60]. The average duration for the regular pushbutton feature is 0.2 seconds [60].

Proposal to Study Enhanced APS Features

Based on feedback provided at meetings with the representatives of PASS, APS units provide essential information to serve the navigation needs of blind and visually impaired pedestrians. The APS units provide important verbal cues and physical (vibrotactile) sensation about the signal phasing including when the "WALK" phase is on. NYCDOT, in coordination with the blind community, is committed to the expansion of the installation of APS. NYCDOT is now committed to increase the number of new intersections equipped with APS units from 25 to 75 annually. The purpose of this proposal is to test the feasibility and effectiveness of supplementing the functionality of APS units as currently configured by NYCDOT to further enhance the safety of blind and visually-impaired pedestrians.

This proposal seeks to modify existing APS configurations to provide supplemental information about an intersection and provide greater guidance for crossing. Supplemental information could be provided, in part, via the extended press function on the APS unit. Verbal messages and cues could be provided that inform the pedestrian with potentially useful information about the intersection such as:

- number of travel lanes
- direction(s) of vehicle travel
- clearance ("DON'T WALK") phase
- bike lanes
- pedestrian refuge islands
- skewed geometry

Although the current New York City APS units do not have the ability to provide beaconing signals, there is a potential value of beaconing signals to direct the pedestrian to the destination corner at the far-side of the crosswalk to assist in aligning the pedestrian correctly in the crosswalk. Written messages in braille to provide supplemental verbal guidance and other signage, such as tactile maps, could be considered (see Figures 8, 9 and 10). Provisions for sound directionality for the APS speakers could also be evaluated.

Figure 8. Braille street name legend above pushbutton [44].

Figure 9. High contrast raised tactile arrow on pushbutton and high-contrast recessed tactile arrow on sign above call button [44].

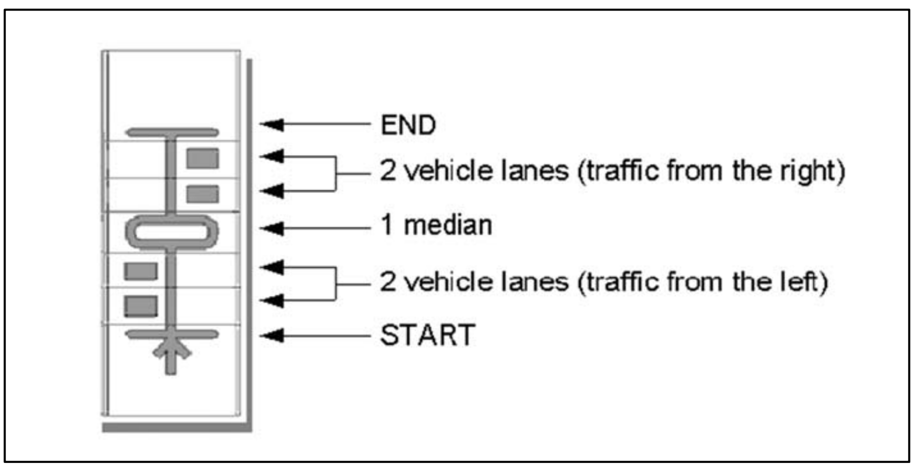

Figure 10. Tactile map read from bottom to top that indicates lanes encountered by pedestrians [44].

The selection of features to be tested would be done in close coordination with NYCDOT and representatives of PASS. The intersection at Seventh Avenue and W23rd Street (Figure 11) is being proposed for testing the effectiveness of tactile maps:

Figure 11. Intersection of 7th Avenue and 23rd Street

Testing would be done with the active participation of blind pedestrians to determine the degree to which the features are understandable and effective in improving safety. Evaluation will include the ability of pedestrians to complete the crossing in a timely manner, avoid physical obstructions and remain within the crosswalk. Issues regarding feasibility and cost for implementation and maintenance of enhanced APS units by NYCDOT would also be considered.

Smartphone Applications and P2I Technology

NYCDOT, in coordination with the NYU team, will be pursuing a vendor to supply the smartphone application to be tested. The chosen vendor will be found through the open competitive process “Call to Innovation.”

As discussed in the literature review, MAPS is a promising smartphone application that assists the blind and visually-impaired pedestrian to navigate signalized intersections. In an effort to better understand the current progress of such applications given NYCDOT’s needs and objectives, the NYU team contacted Professor Liao and arranged a meeting with Professor Liao and the Director of Minnesota Roadway Safety Institute, Professor Max Donath. The meeting occurred on January 11, 2016 at the TRB annual meeting in Washington, D.C., in order find out more about their application. On September 14, 2016, Professors Liao and Donath came to New York City to meet with representatives from NYCDOT and the NYU project team. Attendees at the meeting were:

- Ernest Athanailos,
- Jenny Baez,
- James Celentano,
- Max Donath,
- Chen-Fu Liao,
- Emad Makarious,
- Joe Nieciak,
- John Ornas,
- Elena Prassas,
- Gerard Soffian,
- Marvin Souza

The MAPS application offers the following information to blind and visually-impaired pedestrians:

- Intersection geometry information (number of lanes, barriers, bike lanes, pedestrian islands)
- Signal Information ("WALK" signal notification, remaining seconds for crossing)
- Other mobility and accessibility improvements for user

Using MAPS is accomplished through a smart phone (currently programmed for Android phones only) held by the pedestrian interfacing with the infrastructure in the APS controller (P2I). The user points the smartphone towards the intended crosswalk and performs a single tap on the phone's screen to hear the intersection geometry. The phone can be in sleep mode, and the phone will automatically activate. If the user does not point in the correct direction, a message stating that "no information is available" is heard. In this case, the user would have to reorient themselves until they align with a crosswalk. A double tap on the phone would inform the user when the "WALK" signal begins (and if desired could place a pedestrian call to the controller, however, NYCDOT will unlikely be pursuing this capability).

The MAPS application is currently programmed to disable the audible "WALK" indication if the "WALK" phase has already begun. This is different than current APS units used in New York City, which give a "WALK" message as long as the "WALK" phase is on. Professor Liao made it clear that programming the software to be consistent with NYCDOT APS units is very simple to accomplish.

Additional installation and technical issues covered included:

MAPS DB server installation; centralized approach was suggested.

- o Technological difficulties
  - Range of Bluetooth beacon, confusion between conflicting crosswalks, battery life.

        - The option for a relatively low-cost in-ground installation of Bluetooth with extended battery life was discussed.
    - GPS and Bluetooth enabled software
        - What are the pros and cons of enabling GPS and Bluetooth and what infrastructure is needed to support an efficient system.
        - Ease of installing required hardware.
    - Infrastructure upgrade requirements
        - What exists in current infrastructure, the ability to install and maintain a system from a centralized approach versus manual installation at every location.
    - Budget and completion time
        - Various options were discussed which would depend upon the type of installation and the type of technology utilized (this could include advancing the work in coordination with the NYCDOT Connected Vehicles Demonstration Project).
    - Precision and accuracy concerns
        - Current limitations of the technology, precision meter vs. sub-meter, liability concerns. The positioning accuracy can be improved by adding additional tags to Bluetooth.
    - NYCDOT suggested the possibility of puck hardware installation in the roadway bed
        - Puck installation cost between $1500 and $1600 per intersection, creating easy, affordable and efficient installation of the necessary hardware.
        - One concern to puck installation is that underground installation has the possibility of reducing signal performance.

Additional applications that could be made available through the MAPS application are identifying bus stop locations as well as providing audible information of bus arrival times.

There was some discussion of privacy concerns to users of such applications, but it was noted that most smartphone applications do not track the user.

Concern about latency in satellite communications was mentioned.

Discussion on the next steps needed to proceed in Year 2:

- Component I – Pilot implementation
- Component II – Human subject testing

For Component I to proceed, the following must take place:

- Discussion with NYCDOT's Legal Department to review, request and recommend progression with project
- Street geometry information would need to be provided

- GIS database
- Street geometry changes and revisions database
- Signal timing and phasing assignment**,** retrieved through NYCDOT's Timing Division
- Controller information (data format and structures)
- Development of a formal plan to begin installation and the advent of a pilot program

After the meeting, a hardware tour was provided by John Ornas discussing:

- Current technology overview
- Familiarization with standard New York City controllers
- Integration possibilities of MAPS application into existing infrastructure
- Linkages to central database (TMC)

Participation of PASS in MAPS Testing

A clear understanding and acceptance of the technology by visually impaired participants would be essential for a successful test. Therefore, a meeting with the PASS Coalition, Professors Liao and Donath, and the NYU project team was held in the afternoon of September 14, 2016. Attendees at the meeting were:

- Eugene Bourquin
- Joy Bieder
- Karyl Cafiero
- Max Donath
- Maria Hanson
- Chen-Fu Liao
- Lester Marks
- Elena Prassas
- Bill Sieple
- Gerard Soffian

At the meeting, Professor Liao presented a summary of the MAPS project. He summarized the capabilities of MAPS, its technical structure and results of testing with human subjects. Professor Liao stressed the need for MAPS to be responsive to the real needs of blind and visually-impaired pedestrians and that substantial efforts are being made to ensure its accuracy and reliability.

Professor Liao spoke about the ongoing efforts to improve both the accuracy and precision of the pedestrian's location utilizing Bluetooth beacons and the need to properly position the smart phone device to identify the appropriate crosswalk, including the need to hold the smartphone flat with the screen facing up. The capabilities of MAPS to provide both audible and tactile vibrating indications to the pedestrian was noted, recognizing that verbal messages only might be challenging in noisy environments and for those pedestrians who have hearing impairments.

PASS Coalition members were generally supportive of smartphone applications, such as MAPS, and the use of technology to supplement other navigation aids such as service dogs and the white cane. The Coalition identified the need for financial support to underwrite the costs associated with smartphone ownership and usage. It was stressed that MAPS should provide information about the status of the "WALK" phase in a manner similar to that provided to the general population, that is, not only indicate when the "WALK" phase starts but indicate all times during the phase.

PASS Coalition members have considerable interest in being able to identify the geometry of an intersection, particularly the presence of flush sidewalk extensions and plazas, raised medians and bike lanes. There was also considerable interest expressed in temporary construction and work zone information. Professor Liao indicated that if MAPS does not have current information about the geometry of an intersection, it will note that such information is "not available" rather than provide possibly outdated information.

PASS Coalition indicated that it believes members of the blind community would be interested in participating in follow-up work on the development and testing of such applications.

Tactile Maps

A tactile map is a raised schematic map that describes, through touch, what a pedestrian should expect to encounter as they traverse a crosswalk. The map can be placed on an APS device to supplement information intended to help blind or visually-impaired pedestrians.

Map information may include:

- Number of lanes to be crossed
- Whether the lanes are vehicular, bicycle, or streetcar tracks
- Which direction traffic will be coming from in each lane
- Whether there is a median
- Textured pavement (e.g., flush pedestrian plazas, curb extensions)

A sample tactile map was obtained from the company Prisma Tibro based in Tibro, Sweden (Figure 12). The map is read from the bottom, indicated by an arrow representing the start of the crosswalk, to the top. The symbols indicate lanes and features as they would be encountered by pedestrians. Each Prisma map is made up of changeable 'slugs' inserted into the side of the pushbutton housing. It must be set up for each individual crosswalk of an intersection. The map information is for the crosswalk controlled by that signal only, rather than the entire intersection.

Figure 12. Tactile Map from Prisma Tibro

A tactile map of the crosswalk may be particularly useful at intersections with medians or islands. Pedestrians unfamiliar with the intersection would listen for the locator tone to locate the pushbutton and tactile map. While facing the crossing, the tactile map is 'read' to learn how wide the street is, and what will be encountered in the crosswalk, before they begin to cross. The map also indicates whether the pedestrian signal controlled by that pushbutton provides a crossing time for the entire crosswalk or just to a median or island. If the signal is just for a portion of the street, the map will show the crossing ending with a straight bar (as shown in Figure 12, top symbol) just after the median.

Tactile Map Production

On March 31st, 2016, the NYU team met with Joe Cioffi, Founder/CEO of Click and Go Wayfinding Maps. He was recommended to us by Dr. Eugene A. Bourquin, advisor to the PASS Coalition.

Mr. Cioffi is currently working with NYCDOT to create tactile maps for indoor locations, such as the Staten Island Ferry terminal, in order to provide assistance to blind and visually impaired travelers. (Mr. Cioffi's standard consultation rate is $200 per hour.)

Mr. Cioffi has experience in the design and manufacturing of tactile maps primarily for outdoor college campuses and indoors for institutions open to the general public. He showed photos of several projects in which he has been involved, including the Washington Square campus of NYU.

Mr. Cioffi indicated that he could manufacture tactile signs in metal (magnesium) with a baked enamel surface and textured resin surface, if needed. Mr. Cioffi has sent us a full-size map as a sample of the material used for tactile-map signs that he creates. The metal maps were deemed a good material for the tactile maps. Cioffi recommended that a spacing of 3/32" be maintained between map symbols. He estimated the cost per sign of a size compatible with existing APS units of 5” x 7 11/16” to be $100 - $200.

To conceptualize the physical layout of an area, Mr. Cioffi stated that tactile maps have greater utility than verbal descriptions for blind people. This was also found in observations of neural activity in blind subjects studied by Dr. Lotti Merabat at Harvard University.

There are no universally accepted international or national standards for symbols used in tactile maps. Thus the symbols used in NYCDOT's test of tactile maps should include extensive consultation with the blind and visually impaired communities through entities such as the PASS Coalition.

Low-Energy Bluetooth Beacons

An issue with the tactile maps is how blind and visually-impaired pedestrians would learn the meaning of the symbols. Some type of legend should be provided to explain the symbols used in the tactile maps. One way of providing this information, instead of using a sign in braille, would be to install low-energy Bluetooth beacons at each intersection. Figure 13 shows a photo of the ibeacon created by ClickAndGo, which works with the ClickAndGo iphone application. The beacons would be mounted at a height of about 10 ft. to minimize the risk of vandalism. The beacons could provide verbal information via smart phones that blind or visually impaired can hear through headphones placed behind the ear, so as not to interfere with other sounds. The beacons can be programmed to give any message desired (a word, a sentence, a paragraph). It could be programmed to give definitions of the various symbols, for instance, “circle means bike lane, rectangle means vehicle lane,” etc. The messages could be used to improve the learning curve for using the tactile maps. Exact messages and usages for the beacons would need to be determined in coordination with the PASS Coalition.

At intersections where there may not be a locator tone or APS, a beacon could announce the presence of a tactile map, and explain exactly where it can be found.

The estimated cost for a beacon with a 3 to 5-year service life is $30.

Figure 13. Bluetooth beacon

Proposed Locations for Tactile Map Testing

As noted previously, the intersection of Seventh Avenue and W 23rd Street is being proposed for testing the effectiveness of tactile maps.

When considering the placement of a tactile map on an APS controller, horizontal and vertical orientation was considered, as shown in Figures 14 and 15, respectively.

Figure 14. Horizontal map orientation

Figure 15. Vertical map orientation

Prisma Tibro places the maps in the vertical orientation. Although it seems more logical to place the map horizontally, orienting the map horizontally would limit the number of symbols that could fit on the APS sign, which would not be sufficient for large intersections. Thus it was concluded that the tactile maps should be placed vertically, and ideally in place of the existing APS signage. The final decision on placement will be decided in discussions with the PASS Coalition.

VI. Leading Pedestrian Interval Evaluation

Leading pedestrian intervals (LPIs) are regularly being installed in New York City for the purpose of improving pedestrian safety. LPIs allow the pedestrian to begin crossing before the adjacent vehicles are given the green. The pedestrians thus have a presence in the crosswalk before turning vehicles are allowed to enter, making them more visible, reducing conflicts.

A study to evaluate the effectiveness of LPIs has begun under this research. Video data has been collected at three intersections on Amsterdam Avenue in Manhattan before the LPI phase had been added to the signal phasing. In CIDNY Year 2, the after data will be collected and analysis of the data will be done. Table 4 shows the three intersections and the number of hours of video data that has been collected at each intersection. Table 5 shows the format of the data that is reduced from the video.

Table 4. Data Collected

Intersection	Hours of data
W.78th Street and Amsterdam Ave.	10.5
W.83rd Street and Amsterdam Ave.	12
W.84th Street and Amsterdam Ave.	13

Table 5. Format of Reduced Data

Date	Time	Yields			Conflicts when Pedestrian Starts within 3 sec before “WALK”			Conflicts when Pedestrian Starts within 3 sec after “WALK”		
		Child	Adult	Senior	Child	Adult	Senior	Child	Adult	Senior

Table 5 continued.

Conflicts when Pedestrian Starts during remainder of “WALK” Time			Conflicts when Pedestrian Starts during FDW			Total Pedestrians			Total Vehicles		
Child	Adult	Senior	Child	Adult	Senior	Child	Adult	Senior	Thru	Turn	Bikes

One measure of effectiveness that may be used to compare before and after data is the number of conflicts, normalized over a standard number of pedestrians. A conflict is defined as any abrupt movement made by either the pedestrian or the vehicle in order to avoid collision, or when a vehicle brakes abruptly in order to avoid a collision. Yields will also be reported. A yield is defined when a pedestrian stops in the crosswalk in order to allow the vehicle to make the turn in front of the pedestrian. Final MOEs will be developed in CIDNY Year 2.

VII. Conclusions

The stated goals in *NYCDOT's 2016 Strategic Plan* places particular focus on protecting pedestrians and cyclists, the most vulnerable users of NYC's streets, as well as on transportation equity. Transportation equity means providing all users with access to safe mobility, regardless of where they live and/or their disabilities. This research worked to promote these goals. The research also ties into the Connected Vehicle project through research on Vehicle-to-pedestrian (V2P) and pedestrian-to-interface (P2I) systems. Several innovative countermeasures were considered for use in New York City that could be implemented to improve pedestrian safety and promote the Strategic Plan's goals.

After consideration of the countermeasures available and their usefulness in the City, this research eventually led to concentrating on the needs of blind and visually-impaired pedestrians. There are considerable challenges that blind and visually-impaired pedestrians face when navigating signalized intersections, which makes them a particularly vulnerable group. There is particular concern for the many unusual and complex geometries of signalized intersections and varied signal phasing plans that are difficult for the large population of blind and visually-impaired pedestrians, many of whom are over age 55 (eyesight tends to diminish with age), because this population tends to walk slower than other pedestrians.

Given this focus, the recommended countermeasures for pilot testing in Year 2 include tactile maps, bluetooth beacons, extended press function of the APS unit, and smartphone applications, such as MAPS, to provide more information. The proposed measures to improve the ability of blind and visually impaired pedestrians to more safely navigate the City streets would enhance existing technology and methods currently being applied by NYCDOT. In addition to the need to fully explore the effectiveness of the proposed countermeasures, the project is mindful of the commitment of resources that would be needed to install and maintain new traffic control devices. This consideration would be part of the criteria utilized in their evaluation in the pilot testing.

VIII. Appendix: Summary of Current NYCDOT Vision Zero Initiatives

Vision Zero is New York City's action plan to eliminate pedestrian traffic fatalities and reduce the severity of crashes in the City. There were 63 different initiatives that were part of the initial action plan published by the Mayor's Office. Another 40 initiatives were added to the plan in the Year One report. All of these initiatives have either been completed or are in progress, some of which will be continually ongoing.

The Vision Zero initiative involves several City agencies and groups working together to reach the safety goal of Vision Zero.

1. City Hall has been increasing Vision Zero education and disseminating information through the Program's website and presentations. Legislation has been introduced and promulgated to improve safety and toughen sanctions against dangerous drivers.
2. The New York Police Department has increased enforcement of traffic laws, improved documentation of crash data, and works with the New York City Department of Transportation (DOT) to coordinate safety measures.
3. DOT looks for ways to improve safety by redesigning and improving intersections, installing traffic calming measures, installing accessible pedestrian signals at 75 intersections yearly, expanding and improving the bicycle network, targeting priority locations based on past crash history, and much more. Fifty-eight of the 103 initiatives are being undertaken by DOT, many in coordination with other City agencies.
4. The Taxi and Limousine Commission is working with City Hall to add safety features into taxis, better educate drivers, and increase enforcement and sanctions.
5. Department of Citywide Administrative Services is looking into and has already started adding new technologies to City vehicles to improve safety, such as backup cameras, speed recording devices, and others.
6. Department of Health and Mental Hygiene is keeping track of public health data related to crashes and providing reports to the Vision Zero Task Force, as well as in public health reports.

The complete Vision Zero Action Plan can be found on the Vision Zero website. http://www.nyc.gov/html/visionzero/pages/home/home.shtml

Some of the specific programs that have been implemented are:

Pedestrian Safety Action Plan creates a safety plan for each borough prioritizing locations for safety improvement projects.

a. Complete Streets plan and design roadways to consider the safe, convenient mobility of all roadway users of all ages and abilities. This includes pedestrians, bicyclists, public transportation riders and motorists; it includes children, the elderly, and persons with disabilities. Complete Street roadway design features include bicycle lanes, new crosswalks, bus bulbs, and traffic calming measures.
b. Neighborhood Slow Zones program works in small communities of local streets to reduce crashes and change driver behavior. Communities submit an application to request a slow zone in their neighborhood. The DOT reviews the applications and decides which communities to work with. Speed limits are then reduced from 25 to 20 mph, in addition to other traffic calming treatments being implemented.
c. Safe Streets for Seniors concentrates on locations where there are more than an average number of seniors, such as in the vicinity of senior housing and centers. Crash data is examined to pick locations where high numbers of seniors are involved in crashes. Some of the changes being made include increased pedestrian walking times at intersections, new pedestrian safety islands, wider medians, narrower roads, and new signal controls.
d. Safe Routes to Schools is a program to improve safety at the schools that have the highest number of accidents. 135 schools were chosen in the first round of this program. New traffic and pedestrian signals were installed, as were speed humps to slow down vehicles, signs showing the existence of a school crosswalk were upgraded and made more visible, and the crosswalks themselves were made more visible. In addition an education program was implemented that involved reaching out to the principals and parents. DOT has documented 100 schools where more than 75% of vehicles near the school are speeding. In addition, speed cameras are now in place at the maximum amount of locations (140) authorized by the State as the current school year began. As DOT has implemented more speed camera locations, daily violations have dropped by an average of 60 percent.
e. Safe Routes to Transit is a program to improve safe access to subway and bus stations. This initiative looks to improve safety at: bus stops under el trains for both pedestrians and vehicles, reduce congestion near subway entrances, and sidewalks by bus stops where walking is difficult.
f. Street Design is a program to create a City that is more favorable to pedestrian needs.
g. WalkNYC aims to improve signage for pedestrian wayfinding, to be similar and as comprehensive as signs for vehicles informing them which way to go.

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