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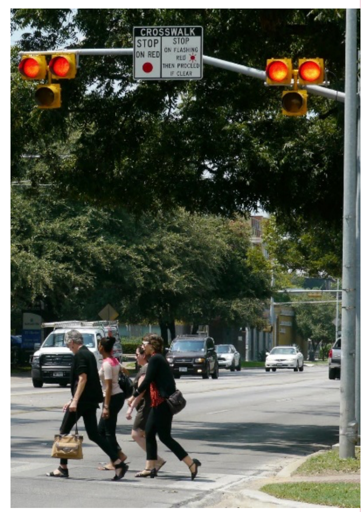

Evaluating the Pedestrian Hybrid Beacon's Effectiveness: A Case Study in New Jersey

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ABSTRACT

The main objective of this report is to evaluate the behavior of pedestrians and drivers around Pedestrian Hybrid Beacon (PHB) signals and to educate pedestrians and drivers on how to act during each sequence of the signal. To this end, the behavior of pedestrians and motorists at PHB signals was observed and measured using video cameras at three PHB locations in New Jersey. This report also provides the detailed results of a behavioral survey designed to gauge public awareness and comprehension of PHB signals in the state. Together, the video data and survey results reflect the current level of public understanding and effectiveness of PHBs in New Jersey.

EXECUTIVE SUMMARY

Motor vehicle crashes, specifically those involving pedestrians, are a serious issue related to roadway safety in the United States. Over the past several decades, we have witnessed a concerning increase in the number of pedestrian fatalities due to crashes. According to the National Highway Traffic Safety Administration (NHTSA), pedestrian fatalities in motor vehicle crashes increased 53% from 2009 to 2018 in the United States. In 2018, around 6,500 pedestrian fatalities occurred, which was the highest for any year since 1990 (NHTSA, 2019). In New Jersey alone, 79 pedestrians were killed due to motor vehicle crashes from January to June 2019. Hence, in order to address this issue and better understand the rise in pedestrian fatalities, research studies are needed to evaluate the effectiveness of existing countermeasures that seek to improve pedestrian safety.

The Pedestrian Hybrid Beacon (PHB) is a high-intensity, pedestrian-activated signal placed at a midblock or intersection crosswalk. It was introduced into the MUTCD in 2009 (Fitzpatrick et al., 2019), and since then, its popularity has increased throughout the country, including in New Jersey. Concerns have been raised about driver and pedestrian comprehension of the PHB based on previous research and its recent introduction in New Jersey.

The main focus of this report is to evaluate the effectiveness of PHB signals at high-risk locations in the state of New Jersey through an analysis of observational data. In this analysis, the effectiveness of the PHB signal was evaluated by defining specific measures of effectiveness based on the compliance and non-compliance behavior of pedestrians and motorists during each phase of the signal. Three locations were selected for further analysis by considering factors such as the number of pedestrian crossings, different community types (e.g., urban, suburban, campus area), and diverse demographics. Video data were collected for the three selected locations, and the defined measures of effectiveness were manually recorded by monitoring the video data.

In addition, this report aims to measure public awareness and comprehension of PHB signals. To achieve this, a web-based behavioral survey was developed and distributed to 79,567 randomly selected email addresses in ten cities, including both those with and without PHBs installed. In the survey, respondents were asked whether they had heard of or seen a PHB in the past and about their level of understanding of each phase of the PHB system (after being provided with a description of each signal phase), including which phases allow motorists and pedestrians to proceed. The survey also asked respondents about their demographic, transportation, and employment information, as well as whether they believed taking the survey increased their understanding of the PHB.

Overall, the observational analysis indicated a high rate of pedestrians who jaywalked, specifically in Morristown (Location #3). The study also revealed that a varying

percentage of motorists crossed during the pedestrian crossing phase at two locations. The behavioral analysis demonstrated that despite the increasing popularity of the PHB in New Jersey, the majority of respondents are still unfamiliar with the PHB signal and its phases. The survey results also showed that simple diagrams and explanations distributed in an online format can effectively increase public understanding of the PHB.

CHAPTER 1: INTRODUCTION

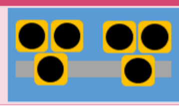
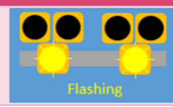
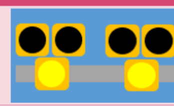
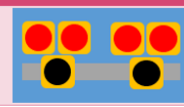
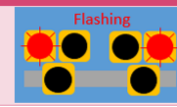
Background

The Pedestrian Hybrid Beacon (PHB) is a descendant of the Pedestrian Light Controlled Crossing (Pelican) signal first installed in the United Kingdom in 1969. The Pelican signal was adapted by Richard Nassi, the transportation administrator in Tucson, Arizona, who created the High-Intensity Activated Crosswalk (HAWK) beacon in the late 1990s (Fitzpatrick et al., 2017). He intended to create a roadway crossing treatment that would be appropriate for wide, high-speed roadways. Nassi’s creation attracted national attention, and over time the HAWK beacon was adopted as an experimental crossing treatment elsewhere in the United States, where it became known as the PHB (FHWA, 2014a). The PHB was introduced to the Manual on Uniform Traffic Control Devices (MUTCD) in 2009 as an approved traffic control device (MUTCD, 2009). Since then, the popularity of the PHB has increased nationwide, yet public awareness of the signal varies throughout the country. This lack of public awareness raises questions about the effectiveness and safety of the PHB in regions where these signals are relatively new and not yet commonplace, such as New Jersey (FHWA, 2014b).

Figure 1. PHB signal in Speedwell Ave., Morristown, New Jersey

A photo of the PHB signal is presented in Figure 1. The PHB consists of between two and four beacon heads on mast arms, each fitted with a yellow signal below two red signals. Pedestrians activate the PHB using a push button, after which the signal cycles through five phases. Table 1 displays the pedestrian and motorist signal phases of the PHB.

Table 1. Pedestrian and motorist signal phases of the PHB

Phase	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Motorist Signal					
Motorist Action	Proceed Through Crossing	Slow down for Pedestrians	Prepare to Stop for Pedestrians	Stop for Pedestrians	Stop and Proceed when Clear
Pedestrian Signal					
Pedestrian Action	Push Button to Cross	Wait for Cross Signal	Wait for Cross Signal	Begin Crossing	Finish Crossing

In the first phase, the signal is dark, indicating that motorists may proceed through the crosswalk. During this phase, pedestrians should activate the signal using the push button. After activation, the yellow signal will begin to flash, indicating to motorists that the signal has been activated and vehicles should slow down for pedestrians. In the third phase, the signal displays a solid yellow light, which indicates that motorists should prepare to stop for pedestrians. In the fourth phase, two solid red signals are displayed, indicating that motorists must stop. This phase is the pedestrian crossing interval, and pedestrians are given a "Walk" signal. In the fifth phase, a flashing red light alternates between the two red signals, indicating that the pedestrian clearance interval has begun and pedestrians should finish crossing. During this phase, motorists may proceed through the crosswalk when pedestrians have cleared the roadway. After the end of the fifth phase, the PHB returns to the default dark state.

The signaling of the PHB can be difficult to understand for someone who has no experience with it, and due to the rarity of the PHB, motorists and pedestrians are often confused by the meaning of the signals. Frequently, drivers are unsure of when they are required to yield to pedestrians and when they may proceed through the intersection, and pedestrians may not understand when they are permitted to cross. As a result, the PHB's ability to increase pedestrian safety may be stymied if motorists and pedestrians are unfamiliar with its operation.

Literature Review

In recent years, a number of studies have focused on determining the effectiveness of the PHB to increase driver yielding at major pedestrian crossings and measuring the extent to which the public understands the operation of the signal.

1. Improving Pedestrian Safety at Unsignalized Crossings

This study attempted to provide engineering countermeasures for enhancing pedestrian safety at high-speed and high-volume roadways located at unsignalized intersections, as well as suggest modifications to the MUTCD pedestrian traffic signal warrant. By conducting a field study, the authors investigated driver and pedestrian behavior at site locations equipped with pedestrian crossing treatments. Forty-two locations from seven states were selected, and four hours of video data were collected for these locations. Five of the 42 locations had HAWK signals, all of which were located in Tucson, Arizona. Results showed that sites with active HAWK signals had driver compliance rates of more than 95% (97% for staged pedestrian crossing and 99% for general population pedestrian crossing). It was also shown that the number of lanes does not affect the performance of site locations with treatments, including HAWKs. As part of this study, an on-street pedestrian survey was also conducted to obtain knowledge about pedestrian experiences and their needs at locations with pedestrian crossing treatments. Seven locations (one of which had a HAWK signal) were selected for survey distribution. Results obtained from this survey indicated that pedestrians feel safer at crossings with HAWK signals, due to increased vehicle control. It was also found that drivers' unpredictability, traffic volume, and vehicle speed are the pedestrians' main concerns (Fitzpatrick et al., 2006).

2. Safety Effectiveness of HAWK Pedestrian Treatment

The main contribution of this research was to conduct a before-and-after study to assess the safety performance of high-intensity activated crosswalk (HAWK) signals using an empirical Bayes (EB) method. Safety performance functions (SPFs) were established by applying reference data collected at 21 different locations before and after the installation of a HAWK signal (36 months before and 36 months after the installation). Crash data was also obtained by the city of Tucson, Arizona. The study suggests that the increase in driver yielding resulting from the installation of a HAWK signal directly translates into increased pedestrian safety. The study demonstrated a 21% reduction in total crashes and a 69% reduction in pedestrian-related crashes. That result represents a significant improvement in pedestrian safety and suggests that the HAWK or PHB signal can be an effective tool if the public is educated about how to use it (Fitzpatrick and Park, 2009).

3. D.C. Experience with the HAWK-Hybrid Pedestrian Signal and Rectangular Rapid Flashing Beacons

This study investigated the effectiveness of a PHB installed by the District Department of Transportation (DDOT) in Washington, D.C. To this end, pedestrian behavior and driver compliance with the PHB signal were observed. It was found that only 51% of pedestrians activated the signal when crossing the street. However, the PHB was the first of its kind in the region, and pedestrians had a low level of familiarity with it (Branyan, 2010).

4. Effectiveness of a Pedestrian Hybrid Beacon at Mid-Block Pedestrian Crossings in Decreasing Unnecessary Delay to Drivers and a Comparison to other Systems

This study evaluated the performance of PHB devices installed in the City of Lawrence, Kansas. By comparing PHB devices installed on two streets (11th Street and New Hampshire Street) with a signalized midblock crossing, the effectiveness of the PHB in decreasing unnecessary resultant delay to drivers was investigated. Sixty hours of video from both intersections were recorded, and parameters including delay measurements, driver and pedestrian characteristics, and driver and pedestrian compliance to the signal were examined. An intercept survey was also conducted to evaluate the level of familiarity among drivers with the PHB. Thirty-five out of 250 survey forms (14% response rate) were responded to and returned. The results obtained from analysis and a t-test showed that deployed PHB devices on both intersections effectively reduced unnecessary delays to drivers (Godavarthy, 2010).

5. Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities

This report was conducted by the National Cooperative Highway Research Program (NCHRP) and attempted to investigate the existing issues related to two intersections in terms of the accessibility of these locations for blind pedestrians. The studied locations were one-lane and two-lane roundabouts and intersections with channelized right-turn lanes. As part of this study, the effectiveness of an installed PHB as a pedestrian crossing treatment at a two-lane roundabout in Golden, Colorado, was examined. Results showed that crossing delay for blind pedestrians was decreased on average by 10.2 seconds. It was also found that the possibility of pedestrian-vehicle intervention at the studied location decreased from 2.8% to 0.0% after PHB deployment (Schroeder et al., 2011).

6. Road Commission for Oakland County PHB and RRFB Study

The main objective of this study was to investigate the existing safety and accessibility-related issues of blind individuals crossing a multilane roundabout located in Oakland County, Michigan. To do so, pre-test and post-test research were conducted to assess the crossing performance of a PHB-signalized intersection located at Maple Road and Drake Road. Two groups of individuals, including blind and sighted individuals, participated in this research. During the pre-test study, all participants were assigned to cross the location four times (four round trip crossings). In the post-test, the PHB was activated by a specialist, and the participants' crossings were observed. Video cameras were also installed to obtain information such as vehicular queue length in the pre-test study and capture pedestrian and driver behavior in the post-test study. Results indicated that the activation of the PHB led to a large decrease in the intervention rate for blind individuals (from 7.7% to 0.0% for three-lane entry and from 9.6% to 0.8% for three-lane exit). It was also shown that the crossing delay for blind participants was reduced after PHB activation. The study concluded that the safety of blind participants was increased by the activation of the PHB (Road Commission for Oakland County PHB and RRFB Study, 2011).

7. Evaluation of Alternative Pedestrian Traffic Control Devices

This study focused on conducting a static survey on the level of driver familiarity with PHB operation. To this end, three groups of people of different ages were identified, and a total of 12 questions were prepared for this survey. The study showed that drivers are confused about the operation of PHB signals. The authors also strongly suggested a public education program during the deployment of PHBs to improve driver understanding (Zaworski and Mueller, 2012).

8. Investigation of Operations of Hawk Pedestrian Treatment

This study examined the modeling of pedestrian delay at locations with HAWK signals by employing the Generalized Linear Model (GLM). The proposed model is comprised of pedestrian arrival rate, the distance between the intersection and the HAWK signal, minor street arrival rate, and major street arrival rate. By applying various combinations of vehicle and pedestrian volume, the minimum green time for vehicles was determined from VISSIM simulations. Afterward, the effectiveness of HAWK installation on pedestrian delay was explored. It was found that in high-demand situations, the recommended minimum distance between stop-controlled intersection and HAWK by MUTCD is not adequate. A model for the minimum green time for vehicles was developed based on the proposed pedestrian delay model. This study also proved the effectiveness of the proposed pedestrian delay model in determining pedestrian delay (Li, 2012).

9. Simulator Study of Driver Responses to Pedestrian Treatments at Multilane Roundabouts

In this study, a STISIM Drive M400 driving simulator equipped with an eye tracker was used to investigate the effectiveness of three different treatments, including a PHB system, in increasing driver yielding time. This research was conducted at North Carolina State University. Data were obtained from 45 subjects consisting of 60% male and 40% female. Results indicated that the driver yielding rate increases by deploying any kind of beacon treatment. Furthermore, the results obtained from the driver's eye-tracking showed that drivers' attention to pedestrians and deployed beacons increases as a result of crosswalk relocation (Salamati et al., 2012).

10. Effect of Pedestrian Impedance on Vehicular Capacity at Multilane Roundabouts with Consideration of Crossing Treatments

This study aimed to assess the effectiveness of pedestrian impedance as a function of driver yielding on the vehicular entry capacity at multilane roundabouts. First, a calibrated microsimulation model was applied to capture correlations and record any volume and driver yielding changes. Then, impedance models were proposed for roundabouts with the PHB system. It was found that the severity of pedestrian impedance increases when the pedestrian flow rate is high. It was also concluded that varying driver yielding rates have a minimal effect on pedestrian impedance for congested roundabout approaches (Schroeder et al., 2012).

11. Evaluating Pedestrian Safety Improvements: Final Report

The main contribution of this study was to perform safety evaluation research on the effectiveness of three pedestrian countermeasures, including Pedestrian Hybrid Beacons (PHB), in-street signs, and Rectangular Rapid Flashing Beacons (RRFB). As a first step, ten locations equipped with PHBs and eight locations equipped with RRFBs in Michigan were selected, and the yielding behavior of drivers to pedestrians was observed. Results showed that the yielding rate in these locations in Michigan is lower compared to an FHWA study conducted in Tucson, Arizona. This result can be attributed to people's lower level of familiarity with these devices in Michigan. It was also indicated that PHB signals installed at roundabouts with three lanes have better performance compared to RRFBs. However, both devices have the same performance at the roundabouts with two lanes. As a second step, this study evaluated the effectiveness of in-street signs at six locations in Michigan. It was concluded that the yielding rate of drivers to pedestrians at these locations was similar to the rates reported in other comparable studies. As a third step, an intercept survey was conducted to gauge the level of pedestrian and driver familiarity with the operation of PHBs, RRFBs, and in-street signs. Three locations were selected, and survey questions were distributed among 300 drivers and 300 pedestrians. Results obtained from surveys proved the need for greater public education on the operation of these new pedestrian countermeasures. Finally, a statistical analysis was developed to investigate the crashes that occurred at locations with Pedestrian Countdown Timers (PCT) in Michigan. Results showed that PCTs were effective in reducing crashes at these locations (Van Houten and LaPlante, 2012).

12. Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research

The main goal of this paper was to summarize the available research on the evaluation of pedestrian safety countermeasures. As part of this study, the performance of Pedestrian Hybrid Beacons installed in Tucson, Arizona, and Charlotte, North Carolina, was reviewed. In Arizona, a 97% motorist yielding rate was observed in five PHB locations in Tuscon. In 2012, by studying 12 PHB locations again in Tuscon, a 69% decrease in pedestrian crashes was concluded. Reviewing the three PHB sites in Charlotte showed a reduction in pedestrian-vehicle conflict and in the percentage of trapped pedestrians. An increase in the motorist yielding rate was also observed (Mead et al., 2014).

13. A Comparison of Gateway In-Street Sign Configuration to Other Driver Prompts to Increase Yielding to Pedestrians at Crosswalks

The main objective of this study was to compare a gateway in-street sign configuration with a Pedestrian Hybrid Beacon and Rectangular Rapid Flashing Beacon. Two PHB sites and one RRFB site equipped with gateway in-street sign configurations in Michigan were selected, and the driver yielding behavior upon activation of the beacon by pedestrians was observed. Results suggested that deploying PHBs and in-street signage is the most effective configuration resulting in 13% more yielding compared with the gateway in-street sign configuration alone. Results also showed that the yielding behavior for an RRFB system and the gateway in-street signs is almost the same. Hence, it is more effective from a financial perspective to deploy the gateway in-street signs alone (Bennett et al., 2014).

14. Characteristics of Texas Pedestrian Crashes and Evaluation of Driver Yielding at Pedestrian

Treatments

This study was conducted into two phases: the first involved the performance evaluation of PHBs installed at 32 locations in Texas by measuring the percentage of drivers yielding, while the second investigated drivers' yielding behavior by conducting a before-and-after field study. Two types of data, including site locations' characteristics and video data, were collected in this study. The staged pedestrian protocol was utilized to collect the driver yielding data. The video was collected by two cameras, allowing the researchers to review behavior data previously collected by observers. Analyses were then conducted to achieve the study's goals. Logistic regression was applied in this study to analyze the collected data. Results obtained from the first phase indicated that the rate of driver yielding was 89%. Results from the second phase of this study showed that the driver yielding improved by 35 to 80% after the PHB installation. It was also found that almost 94% of the non-staged pedestrians activated the treatment (Fitzpatrick et al., 2014).

15. Evaluation of PHB Mid-Street Crossing System in Las Vegas, Nevada-Pedestrian Perspectives

This study aimed to evaluate the safety performance of a PHB signal deployed in Las Vegas, NV, in 2012. Driver and pedestrian data were collected one week before and after PHB deployment as well as one year after deployment using two cameras. Statistical analysis was developed to achieve the performance evaluation. Results indicated that pedestrian crossing time improved, which resulted in a decrease in unnecessary driver delay time. Results also showed that the number of vehicles that stopped for pedestrians increased. An increase in the number of pedestrians avoiding jaywalking and activating signals was also observed. (Eapen, 2014).

16. Pedestrian Hybrid Beacon Crosswalk System (PHB) or High-Intensity Activated Crosswalk (HAWK) Evaluation

The performance of a PHB system deployed in the state of Vermont was investigated over a three-year period in this study. Parameters, including advance speed, approach speed, and yielding compliance, were measured. Two different crossing scenarios (each of which was performed 200 times) were developed, and driver behavior before and after the PHB system installation was observed visually. Results indicated that the yielding compliance and the number of vehicles slowing down increased by 18% and 89%, respectively, after the PHB system installation (Lincoln and Tremblay, 2014).

17. Rectangular Rapid Flashing Beacons and Pedestrian Hybrid Beacons: Pedestrian and Driver Behavior Before and After Installation

Assessing pedestrian behavior and driver yielding rates before and after deployment of PHBs (at one site) and RRFBs (at four locations) as treatments at locations in Texas was the main contribution of this study. Three components of data, including onsite driver yielding documentation, site characteristics, and video of drivers and pedestrians, were collected in this research study. The study results revealed that deploying PHB and RRFB led to an improvement of 35% to 80% in the proportion of yielding vehicles. It was also concluded that at locations with treatments, about 94% of nonstaged pedestrians activated the treatment devices (Brewer et al., 2015).

18. Pedestrian and Motorists' Actions at Pedestrian Hybrid Beacon Sites: Findings from a Pilot Study

This study investigated motorist and pedestrian behavior at locations equipped with PHB devices and examined the performance of these devices in improving the safety of pedestrians. Oberservers gathered field data during both morning and evening peak hours over time (1 month before the PHB deployment and 1, 3, 6, and 12 months after the PHB deployment) at three locations in the city of Charlotte, North Carolina. The data were analyzed using statistical and descriptive analyses, including a two-portion z-test and one-tail two-sample t-test. Parameters related to operational aspects of roadways, including average traffic speed, traffic counts, pedestrian-vehicle conflicts, the number of pedestrians trapped in the middle of the street, and motorist and pedestrian behavior, were selected as measures of effectiveness in the analysis process. Results indicated that average traffic speed increased only at one PHB location. Other parameters, including pedestrians trapped in the middle of the street, pedestrian-vehicle conflicts, and the number of motorists not yielding to pedestrians, experienced a decreasing trend (Pulugurtha and Self, 2015).

19. Evaluation of the Effectiveness of a HAWK Signal on Compliance in Las Vegas Nevada

A study of a PHB site in Las Vegas, Nevada, compared pedestrian behavior before and after the installation of a PHB system. Two cameras were installed near the HAWK signal site to capture pedestrian and vehicle movements as well as signal operation. The study found that the rate of jaywalking in the location decreased from 32.6% of crossings to 8.2%. The study also noted an average 5.3-second decrease in pedestrian crossing time, as pedestrians were not waiting on the median halfway across. Despite the decrease in jaywalking, the study indicated that pedestrians only activated the signal 62% of the time. This activation rate was attributed to pedestrians' unfamiliarity with PHBs (Paz et al., 2016).

20. Study of Pedestrian Hybrid Beacon's Effectiveness for Motorists at Midblock Pedestrian Crossings

This study investigated the performance of a PHB system in reducing unnecessary delay to drivers. Two PHB signals installed at two pedestrian crossings in Lawrence, Kansas, were selected as case studies. A total of 60 hours of video data was collected from both sites. It was found that drivers had a low level of understanding of the newly installed PHB. Based on video taken at the PHB site, the researchers found that only 27% of drivers understood that they were allowed to proceed through the intersection during the flashing red signal if the crosswalk was clear. This suggests that when a region does not have experience with PHBs, education is necessary to increase driver familiarity (Godavarthy et al., 2016).

21. Road User Behaviors at Pedestrian Hybrid Beacons

This study investigated pedestrian and driver behavior at PHB sites. Twenty locations in the cities of Tucson and Austin were selected, and video data (about 78 hours) was collected for these locations. The videos were recorded between 6:30 a.m. and 6:30 p.m., during the daytime, and during dry weather conditions. Results showed that pedestrians almost always activated the PHB when crossing. However, the utilization rate is a function of the roadway volumes and posted speed limit at the time. According to this study, 80% of pedestrians activated the signal when vehicle volumes exceeded six vehicles per minute per lane, and 98% of pedestrians activated the signal when volumes exceeded ten vehicles per minute per lane. As for speed, 91% of pedestrians activated the signal when the posted speed limit was 45 mph, but as few as 75% of pedestrians activated the signal when the posted speed limit was 40 mph or less. However, pedestrian familiarity with the signal is an important factor (Fitzpatrick and Pratt, 2016).

22. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments

The main purpose of this research was to provide crash modification factors for four pedestrian crosswalk treatment types, including advance yield or stop markings and signs (AS), Pedestrian Hybrid Beacons (PHB), Rectangular Rapid Flashing Beacons (RRFB), and pedestrian refuge islands (RI). A total of 975 site locations from 14 cities were selected, and data related to treatment characteristics, traffic, pedestrian crashes, other crash types, and geometric and roadway characteristics were gathered. The data was then analyzed using before–after empirical Bayesian analysis and cross-sectional regression models to investigate the effectiveness of treatments on crash risk. Based on results obtained from this study, PHBs had the best performance among the four treatment types (reducing crash risk by 55%) (Zegeer et al., 2017).

23. Pedestrian Hybrid Beacon signals: Identifying Characteristics Associated with Negative Consequences to Reduce Danger at Mid-Block Locations

Pulugurtha et al. examined 13 midblock PHB sites in Charlotte, North Carolina, to determine which characteristics were associated with negative effects on motorist safety. Researchers examined crash data at each location before and after the installation of a PHB. Data regarding the land use, roadway characteristics, demographics, and socioeconomic characteristics of each area were also collected. The study found that motorist crashes increased in 5 of the 13 locations, while there was no significant change in pedestrian crashes in the locations. The researchers suggested that the installation of a PHB was more likely to lead to an increase in motorist crashes along high-volume, high-speed roadways, and in mixed-use, high-density areas. Finally, researchers noted several measures that could help combat the increase in motorist crashes, including advance warning signage or signals ahead of the PHB and an educational campaign to increase motorist awareness and understanding (Pulugurtha et al., 2018).

24. Analysis of the Effectiveness of RRFB and PHB to Encourage Driver Stopping Behavior

This study focused on the evaluation of the effectiveness of different crosswalk control devices in increasing vehicle yielding and stopping rates for pedestrians at mid-block or unsignalized crosswalks. The study observed vehicles' yielding behavior at different locations with three crosswalk control types, including marking only, PHB, and Rectangular Rapid Flashing Beacon (RRFB). It was found that crosswalks with marking-only treatments had the lowest rates of Stop and Stop+Yield (17% and 36%, respectively). The crosswalks with RRFB had 33% and 63% for Stop and Stop+Yield rates, respectively. The crosswalks with PHBs as control devices had the highest Stop and Stop+Yield rates, 78% and 82%, respectively (Bolen et al., 2018).

25. Current Policies throughout the Nation for Pedestrian Hybrid Beacon (PHB) Installation

This research comprehensively assessed the application and current policies of PHBs related to dark signals across the United States. Based on this study, a dark signal "represents a situation in which a traffic signal is not functioning as it should be." Results indicated that 37 out of 50 states had passed laws regulating drivers' maneuvers at dark signals. Results also showed that 41 states had deployed PHB systems, and seven states have agreed to deploy this system, but the installation has not been completed yet (DeLorenzo, 2019).

26. Explaining Crash Modification Factors: Why It's Needed and How It Might be Done

This research focused on the simulation of Pedestrian Hybrid Beacon capabilities in modifying the probability of pedestrian crashes. Vehicle and pedestrian encounters were simulated by assuming that all drivers try to brake in this type of encounter. Afterward, the crash modification factor was determined by changing the range of careful pedestrians. As a result of this study, a hypothesis was developed that the PHBs can be effective in reducing crashes by modifying pedestrian behavior (Davis, 2019).

27. Highway 141 Step Innovation Study

The main goals of this study were as follows: assessing the existing issues related to bicyclists and pedestrians within the Highway 141 project corridor, investigating the possible countermeasures for the existing issues, and suggesting the best countermeasures for employment. As part of this study, the possibility of installing a PHB along Highway 141 was investigated to address the inadequate gap in traffic for pedestrian crossing and to increase pedestrian safety. Using SimTraffic, the average delay per vehicle in the area was determined under two conditions, one without a PHB (the existing condition) and one with a PHB installed. Results of the SimTraffic analysis showed that the average delay increases by 2.8 seconds per vehicle when one PHB is installed within the study area. This delay in vehicular traffic seems reasonable to provide a pedestrian with adequate time for crossing. It was ultimately suggested that a PHB be implemented at one location along Highway 141 near Bradley Street (Highway 141 Step Innovation Study, 2019).

28. Improving Pedestrian Hybrid Beacon Crosswalk by Using Upstream Detection Strategy

In this study, the authors utilized an upstream detection (UD) strategy for PHB devices with the goal of decreasing waiting time for pedestrians at the crossing. High-resolution cameras were installed on tall buildings to collect video data at two crossings in the urban area of Nanjing, China. Vehicle and pedestrian speed data and road geometry data were obtained from recorded videos. By counting manually, parameters including signal timing, pedestrian compliance rate, pedestrian volume, vehicle composition, and vehicle volume were also extracted from the videos. Afterward, by applying obtained parameters as outputs, simulation models of PHBs with UD were developed in VISSIM. Finally, a t-test was carried out to assess the success of the UD application for PHB devices. Results indicated that the UD strategy increases vehicle delay and decreases pedestrian waiting time (Yang et al., 2019).

29. Evaluation of Pedestrian Hybrid Beacons on Arizona Highways

The main purposes of this study were to investigate the safety and operational effectiveness of PHBs deployed on Arizona's state highways, to examine the correlation between crashes at PHB site locations and the roadway characteristics, to examine the correlation between crashes at PHB site locations and the distance from adjacent signalized intersections, and to assess ADOT guidance on the deployment of PHBs and site selection. In this study, a total of 10 site locations having higher operating speed conditions were selected, and about 40 hours of video were recorded. It was concluded that severe rear-end crashes, pedestrian crashes, and severe crashes decreased by 29%, 46%, and 25%, respectively. The safety benefits of PHB deployment were also proven in this study (Fitzpatrick et al., 2019).

30. Effect of Pedestrian Hybrid Beacon Signal on Operational Performance Measures at the Mid-block Location and Adjacent Signalized Intersection

The main objective of this study was to assess the effectiveness of PHB application on adjacent signalized intersections and operational performance measures at mid-block crosswalks. Three intersections equipped with PHB signals in Charlotte, North Carolina, were selected. Maximum queue length and delay time at the three locations, as well as their adjacent signalized intersections, were determined using VISSIM software. In addition, the impact of various parameters (including the distance between a PHB location and its adjacent signalized intersection, the increase in traffic volume, and pedestrian volume) on the maximum queue length and delay time were examined. Results showed that the amount of delay decreases with the increasing distance of PHB locations from signalized intersections. Results also indicated that the maximum length and delay increase as the pedestrian and traffic volume increases (Teketi and Pulugurtha, 2020).

Table 2. tabulates the summary of conducted studies on the effectiveness of PHB signals in terms of the type of data they collected.

Table 2. Summary of previous studies on the effectiveness of PHB signals in terms of the type of collected data.

Study Num.	State	Simulation	Data Collected Field Data	Crash Data	Survey Data	Ref.
1	Different States	No	Yes	No	Yes	Fitzpatrick et al. (2006)
2	Arizona	No	Yes	Yes	No	Fitzpatrick and Park (2009)
3	Washington	No	Yes	No	No	Branyan (2010)
4	Kansas	No	Yes	No	Yes	Godavarthy (2010)
5	Colorado	No	Yes	No	No	Schroeder at el. (2011)
6	Michigan	No	Yes	No	No	Road Commission for Oakland County PHB and RRFB Study (2011)
7	Oregon	No	No	No	Yes	Zaworski and Mueller (2012)
8	Texas	Yes	No	No	No	Li (2012)
9	North Carolina	Yes	No	No	No	Salamati et al. (2012)
10	North Carolina	Yes	No	No	No	Schroeder et al. (2012)
11	Michigan	No	Yes	No	Yes	Van Houten, R. and LaPlante (2012)
13	Michigan	No	Yes	No	No	Bennett et al. (2014)
14	Texas	No	Yes	Yes	No	Fitzpatrick (2014)
15	Nevada	No	Yes	No	No	Eapen (2014)
16	Vermont	No	Yes	No	No	Lincoln and Tremblay (2014)
17	Texas	No	Yes	No	No	Brewer et al. (2015)
18	North Carolina	No	Yes	No	No	Pulugurtha and Self (2015)
19	Nevada	No	Yes	No	No	Paz et al. (2016)
20	Kansas	No	Yes	No	No	Godavarthy et al. (2016)
21	Arizona	No	Yes	No	No	Fitzpatrick and Pratt (2016)
22	14 Cities	No	Yes	Yes	No	Zegeer et al. (2017)
23	North Carolina	No	Yes	Yes	No	Pulugurtha et al. (2018)
24	Georgia	No	Yes	No	No	Bolen et al. (2018)
25	United States	No	No	No	No	DeLorenzo (2019)
26	Minnesota	Yes	No	No	No	Davis (2019)
27	Arkansas	Yes	No	No	No	Highway 141 Step Innovation Study (2019)
28	Nanjing, China	Yes	Yes	No	No	Yang et al. (2019)

29	Arizona	No	Yes	Yes	No	Fitzpatrick et al. (2019)
30	North Carolina	Yes	No	No	No	Teketi and Pulugurtha (2020)

The previous studies were also summarized based on the duration of their data collection periods and the rationale for selected locations (tabulated in Table 3).

Table 3. Summary of previous studies in terms of duration of data collection period and rationale for selected locations.

Study Num.	Type of Data (Video/Observation/Other)	Video/Observation Duration (h)	Num. of Location(s)	Reason for Location(s) Selection	Ref. (Date)
1	Video & field observation	4 hr or min of 100 pedestrian crossing events	5 PHB locations	NA	Fitzpatrick et al. (2006)
2	Video	24 hr for each location (for pedestrian crossing counting)	5 Hawk locations	Sites installed HAWK more than 18 months before the study, and also those sites at which the "Mickey Mouse ears" arrangement was installed new (21 locations) were selected.	Fitzpatrick and Park (2009)
3	Field observation	4 hr	1 HAWK location	Pedestrians of the community (especially the elderly) found this location to be difficult and unsafe to cross and complained about that.	Branyan (2010)
4	Video	60 hr	1 PHB location	NA	Godavarthy (2010)
6	Video & field observation	8 days before installation & 8 days after installation	1 PHB location	NA	Road Commission for Oakland County PHB and RRFB Study (2011)
14	Video & field observation	6 hr before installation & 4 hr after installation	1 PHB location	NA	Fitzpatrick (2014)
16	Field observation	2 days (six months prior and after installation)	1 PHB location	This location was selected since it is located in an area with high traffic flow.	Lincoln and Tremblay (2014)

17	Video & field observation	6 hr	One PHB location	NA	Brewer et al. (2015)
18	Field observation	20 hr for each location	3 PHB locations	These locations were selected since they are not in the same area or along the same corridor (geographically distributed locations). Also, these locations were located in areas with different land use, demographic, and socio-demographic characteristics.	Pulugurtha and Self (2015)
19	Video	1 week before and 1 week after the HAWK installation	1 HAWK location	The location was selected since it is a rapid bus transit corridor and known as one of the busiest roads in Las Vegas.	Paz et al. (2016)
20	Video	60 hr for each location	2 PHB locations	NA	Godavarthy et al. (2016)
21	Video	More than 78 hr (min of 50 pedestrian crossing events or 4 hr of data for each location)	20 PHB locations	Cities of Austin and Tucson were selected since they have the greatest diversity in site characteristics of interest to this study.	Fitzpatrick and Pratt (2016)
22	Field observation	1 to 2 hr for each location	4 PHB locations	These locations were selected since they are located in areas with a high risk of pedestrian crashes (having transit stops and 4 or more lanes and pedestrian crossings), and pedestrian treatments are more likely to be required in these locations.	Zegeer et al. (2017)
23	Other (demographic, land use, on-network characteristics, and socio-economic)	4 years (2010-2013)	13 PHB locations	These sites were located in the vicinity of the residential and commercial area, elementary schools, and parks.	Pulugurtha et al. (2018)
28	Video	2 hr for each location	2 PHB locations	NA	Yang et al. (2019)

29	Video	4 hr or min of 100 pedestrian crossing events	10 PHB locations	“1-PHB crossings of streets with higher posted speed limits (45 mph or 50 mph) 2-PHB crossings on ADOT highways 3-Non-school crossings (no yellow school crosswalks or 15-mph portable signs at the crossings) 4-Statewide data collection to the extent practical 5-PHBs at a mix of midblock crossings or intersections/driveways with side-street traffic.”	Fitzpatrick et al. (2019)

Findings

According to the literature review, the following findings were obtained:

- Past studies considered different criteria for the duration of data collection. Most of the studies collected video data ranging from 2 to 6 hours or 100 pedestrian crossings for each location.
- Past studies considered different criteria for site selection, including areas with a high risk of pedestrian crashes, high traffic flow, higher posted speed limits, different land uses, and demographic and socio-demographic characteristics.
- PHB signal evaluation studies are lacking in the state of New Jersey.

Objectives of the Study

This study focuses on the effectiveness of PHB signals on the safety of road users in the state of New Jersey. The main objectives of this report are as follows:

- Evaluate the behavior of pedestrians around PHB signals
- Evaluate the behavior of motorists around PHB signals
- Gauge public awareness and comprehension of PHB signals
- Educate pedestrians, motorists, and bicyclists on how to appropriately use PHB signals
- Provide recommendations for transportation agencies

CHAPTER 2: OBSERVATIONAL DATA ANALYSIS

The main purpose of this section is to investigate the performance of PHB signals on the behavior of road users. In this study, three site locations with PHB signals were considered for analysis, and field data were collected. The collected data were then analyzed in order to quantify the measures of effectiveness.

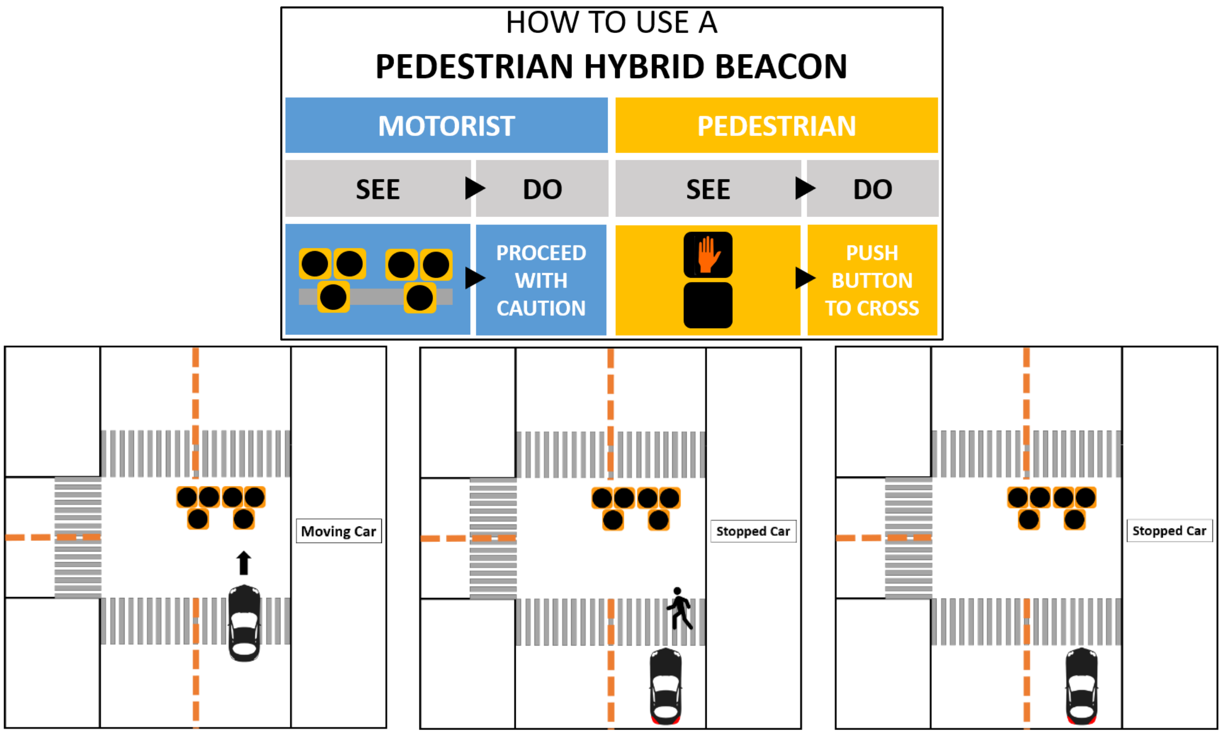
Methodology

In order to achieve the main objective of the study, evaluating PHB signals on the behavior of road users, specific measures of effectiveness were considered. These measures were defined based on the compliance and non-compliance behavior of pedestrians and motorists during each phase of the PHB signal. The considered measures of effectiveness are as follows:

1. **The percentage of drivers exhibiting compliance/non-compliance behavior when the signal is not activated:** When the signal is not activated and there is no pedestrian on the road, the compliance behavior for motorists is to cross the crossing without stopping at the signal. Moreover, if there are some pedestrians waiting for the street to become clear without pushing the PHB button, the compliance behavior for motorists is to cross the crossing without stopping for the pedestrians. On the other hand, non-compliance behaviors for motorists include stopping for pedestrians who have not pushed the button or stopping for the signal due to confusion about the signal operation.
2. **The percentage of drivers exhibiting compliance/non-compliance behavior when the signal is activated:** During the flashing yellow phase, the compliance behavior for motorists is to slow down for pedestrians, although they are still allowed to drive through the crosswalk. Since pedestrians are not allowed to cross during this phase, the non-compliance behavior for motorists is to stop for pedestrians and allow them to cross. During the solid yellow phase, the compliance behavior for drivers is to prepare to stop for pedestrians, although they are still allowed to drive through the crosswalk. The non-compliance behavior is to stop for pedestrians and allow them to cross. During the solid red phase, motorists must stop for crossing pedestrians as compliance behavior. The non-compliance behavior for motorists during this phase is to cross the crossing. Finally, during the flashing red phase, the compliance behaviors for motorists are to stop when there are pedestrians crossing or cross when the street is clear. The non-compliance behavior is to stop due to confusion about the signal operation when the street is clear.
3. **The percentage of pedestrians jaywalking:** According to New Jersey Statute 39:4-32 & 33 (NJDHTS, 2020), pedestrians must obey pedestrian signals and use crosswalks at signalized intersections. Hence, in this study, jaywalking was defined as any pedestrian behavior involving crossing either against the "stop" or red signal at a crosswalk, whether marked or unmarked, or at a location other than the pedestrian crosswalk.

4. **The percentage of pedestrians who do not wait for the signal:** For this measure of effectiveness, the percentage of pedestrians who pushed the button and crossed the street any time before the solid and flashing red phase was recorded.
5. **The percentage of pedestrians waiting for the proper signal phase for the crossing:** The only phases during which pedestrians are allowed to cross the street are solid and flashing red phases. The percentage of pedestrians who crossed the street during these phases was recorded for this measure of effectiveness.

Figures 2 to 6 illustrate the measures of effectiveness for motorists during different phases of the PHB signal.

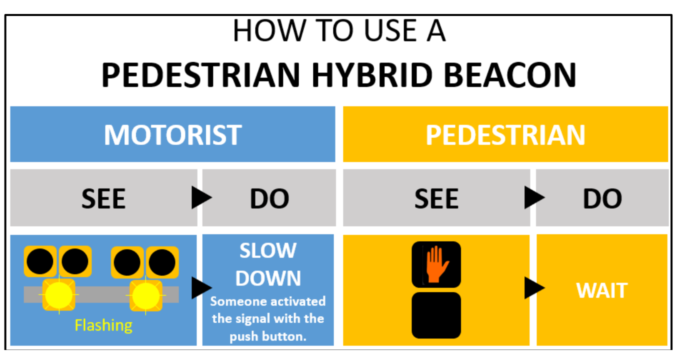


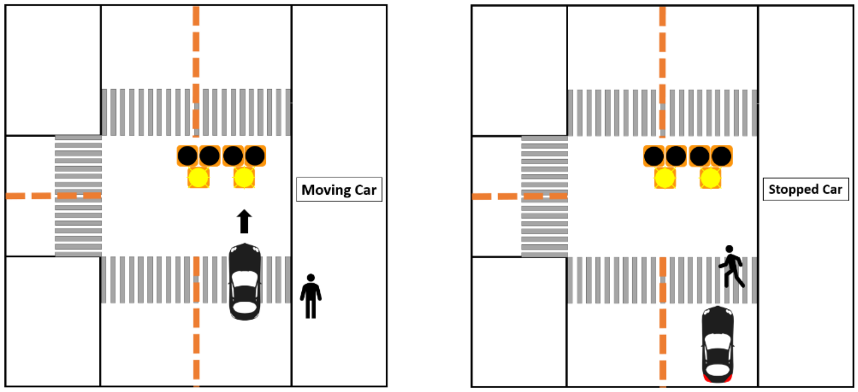
(a) Compliance
Cross the crossing when clear

(b) Non-Compliance
Stop for the pedestrians to cross

(c) Non-Compliance
Stop for the signal due to the confusion

Figure 2. Compliance and non-compliance behavior of motorists during phase one

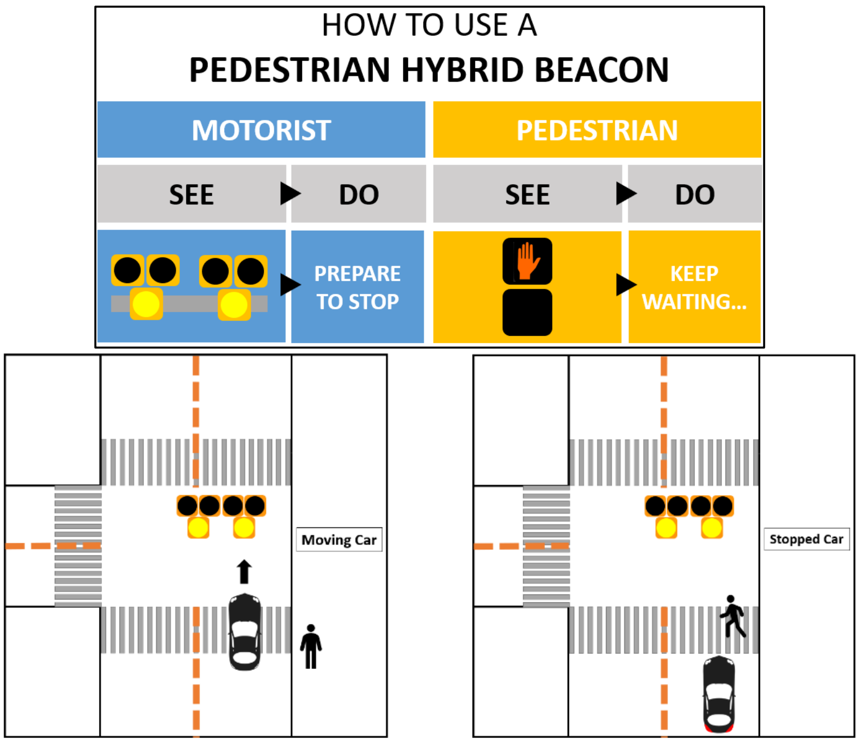




(a) **Compliance**
Cross the crossing

(b) **Non-Compliance**
Stop for the pedestrians to cross

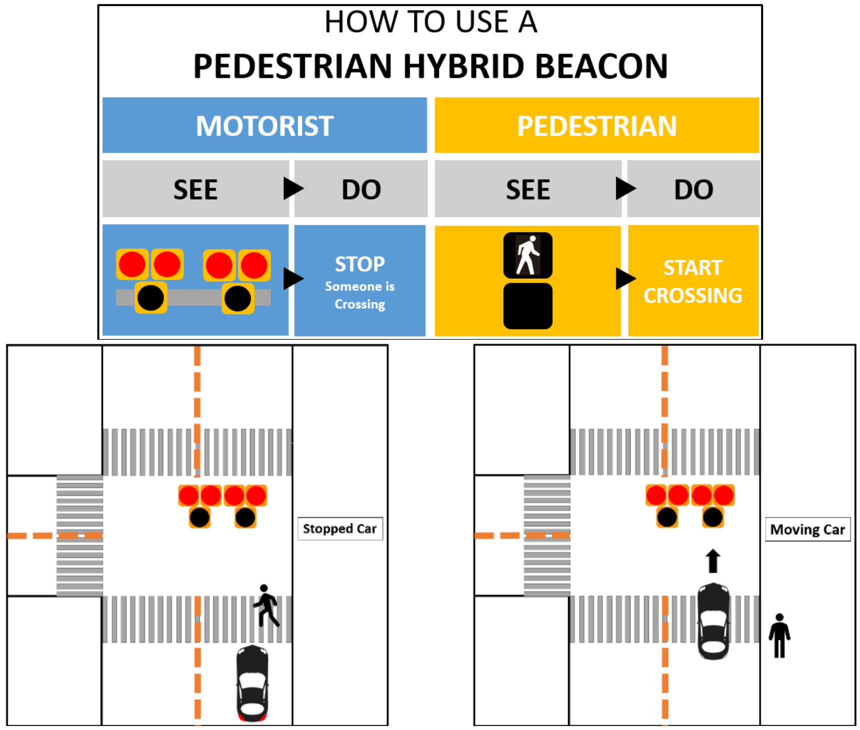
Figure 3. Compliance and non-compliance behavior of motorists during phase two



(a) **Compliance**
Cross the crossing

(b) **Non-Compliance**
Stop for the pedestrians to cross

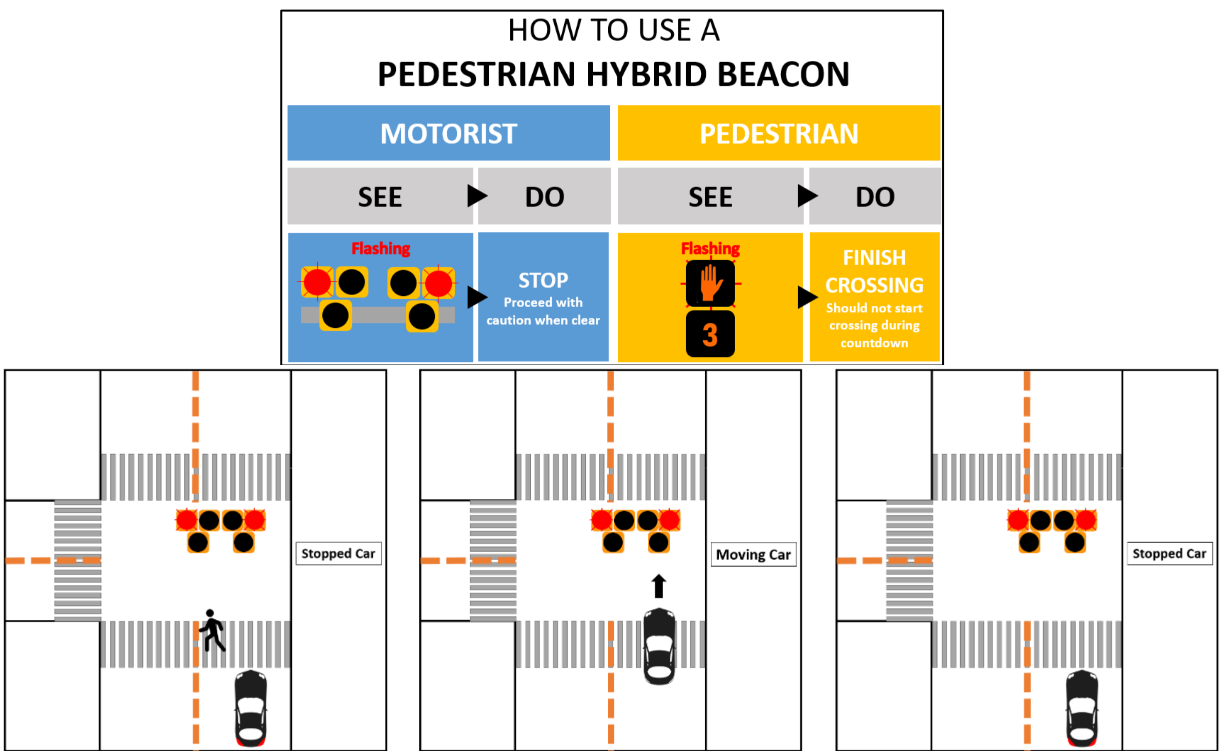
Figure 4. Compliance and non-compliance behavior of motorists during phase three



(a) Compliance
Stop for the pedestrians to cross

(b) Non-Compliance
Cross the crossing

Figure 5. Compliance and non-compliance behavior of motorists during phase four



(a) Compliance
Stop for the pedestrians when it is not clear

(b) Compliance
Cross the crossing when it is clear

(c) Non-Compliance
Stop for the signal due to the confusion

Figure 6. Compliance and non-compliance behavior of motorists during phase five

In order to validate the results, a two-sample z-test for proportions was used to determine if the change in the crossing rate was statistically significant. Using the proportions and sample size for the AM and PM crossing rates in each location, statistical calculations were done to verify whether or not it is possible to reject the null hypothesis. The null hypothesis in this study is that the crossing rate does not change during the AM and PM periods. The fundamental equations to conduct the z-test are as follows:

$$\mathrm{Z} = \frac{\hat{\rho}_2 - \hat{\rho}_1}{\sqrt{\hat{\rho}(1-\hat{\rho})\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}}$$

$$\hat{\rho} = \frac{\mathrm{X}_1 - \mathrm{X}_2}{n_1 - n_2}$$

$$\hat{\rho}_1 = \frac{\mathrm{X}_1}{n_1}$$

$$\hat{\rho}_2 = \frac{\mathrm{X}_2}{n_2}$$

where:

- X_1: the number of pedestrian actions (Jaywalked/Activated, Crossed Early/Activated, Waited for Signal) for pedestrians for AM period, or the number of non-compliance behavior during each phase for motorists for AM period.
- X_2: the number of pedestrian actions (Jaywalked/Activated, Crossed Early/Activated, Waited for Signal) for pedestrians for PM period, or the number of non-compliance behavior during each phase for motorists for PM period.
- n_1: the measure of effectiveness for the AM period
- n_2: the measure of effectiveness for the PM period
- $\hat{\rho}_1$: the probability that a person did not comply with the regulations during the AM period
- $\hat{\rho}_2$: the probability that a person did not comply with the regulations during the PM period
- $\hat{\rho}$: pooled sample proportion or a combined average of probabilities

For the pedestrian, the null hypothesis indicates that the rate of pedestrian actions during the AM period is equal to the PM period (H_0: $\hat{\rho}_1 = \hat{\rho}_2$) and the alternative hypothesis indicates that the rate of pedestrian actions during the AM period is not equal to the PM period (H_1: $\hat{\rho}_1 \neq \hat{\rho}_2$). To analyze the results obtained from the z-test, it is necessary to calculate the significance level, which ranges from 0 to 1. It is common among researchers to utilize the significance values of 0.01, 0.05, or 0.10 for 99%, 95%, and 90% confidence levels, respectively. The p-value is the probability of occurrence of an event when the null hypothesis is true. If the p-value is less than the significance level, the hypothesis test is statistically significant. In this report, a 95% confidence level was selected. If the calculated p-value is less than 0.05, it can be concluded that there is a significant difference between the rates of pedestrian actions between AM and PM periods.

Site Selection

In order to investigate the effectiveness of PHB signals, the first step was to identify sites with PHBs already installed. The research team conducted a comprehensive search to identify these sites for potential further study. The team also prepared an information-seeking survey about the locations of PHB signals in the state of New Jersey and distributed the survey among members of the New Jersey County and Municipal Traffic Engineers Association. In this survey, respondents were asked whether they were aware of any PHB implementation in New Jersey and whether they knew of any other resources that could help with finding PHB locations in the state. The questionnaires for this survey are provided in Appendix A. Based on the results of the survey, ten locations in which PHB signals have already been implemented were identified for further investigation (Figure 7). The key characteristics of the ten potential sites are provided in Table 4.

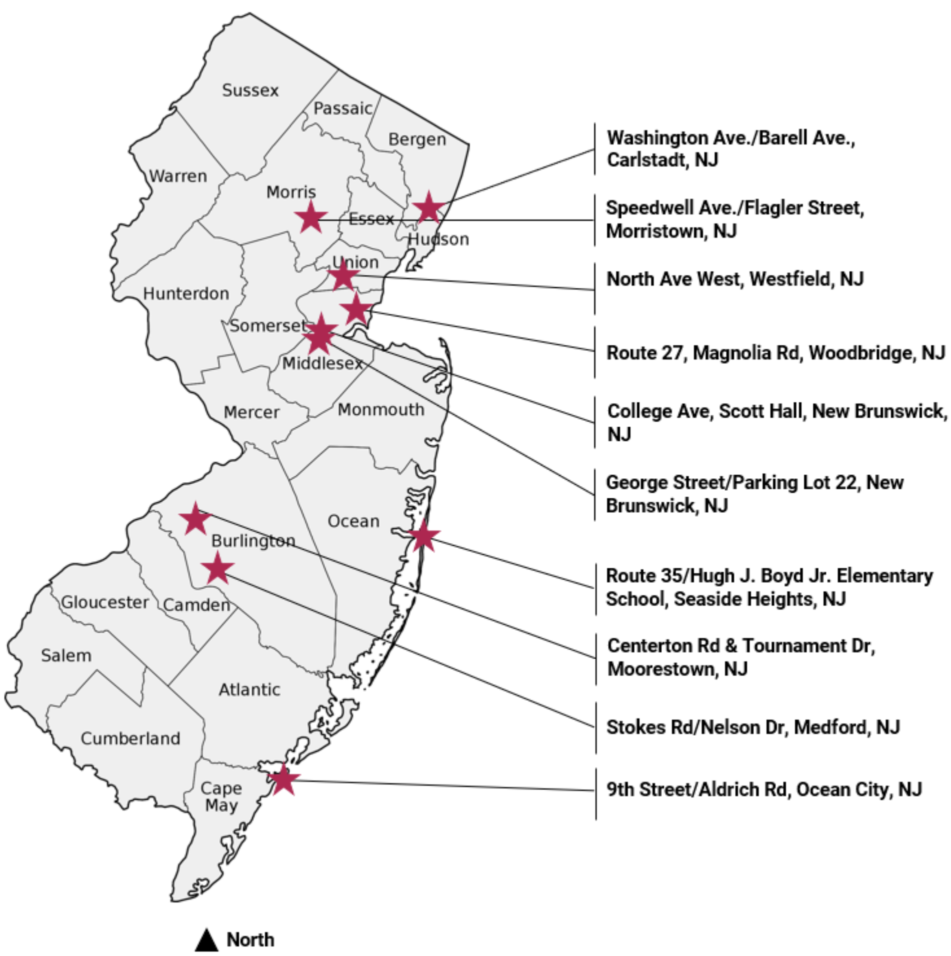
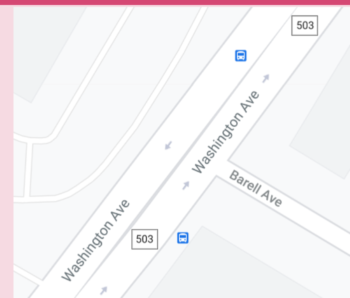
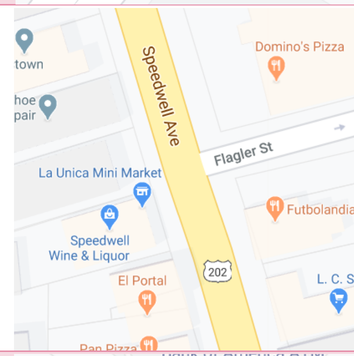
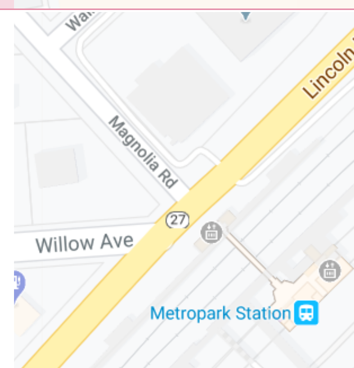
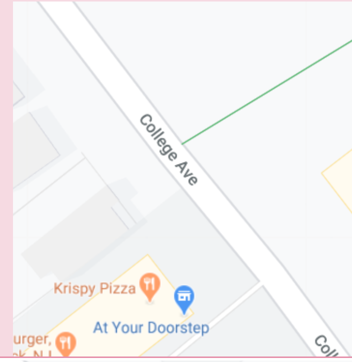
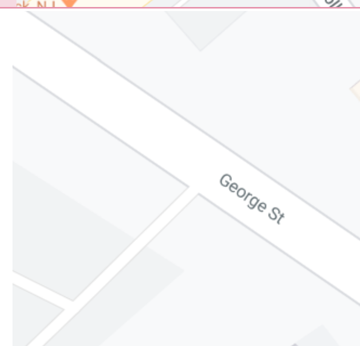
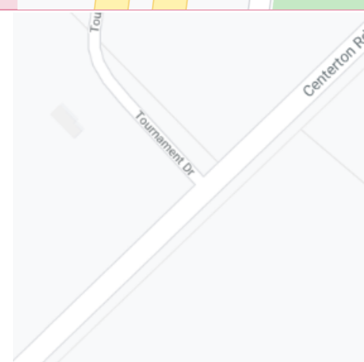
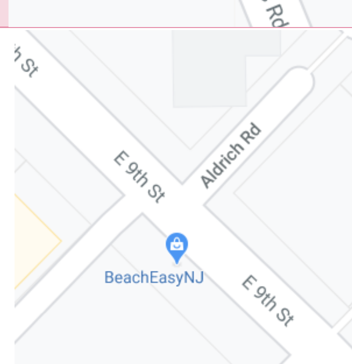


Figure 7. Ten sites with a PHB system

Table 4. Selected site characteristics

#	City	Road	At/ Between	Location Type	# of Lanes	AADT	Location on the Map
1	Carlstadt	Washington Ave.	Barrell Ave.	T-Intersection	4	19042	
2	Morristown	Speedwell Ave. (US-202)	Flagler Street	T-Intersection	2	11390	
3	Westfield	North Ave. West	Charles Street and Clark Street	Midblock	2	13512	
4	Woodbridge	Route 27	Magnolia Rd	T-Intersection	4	21729	

5	New Brunswick	College Ave.	Scott Hall	Midblock	2	N/A	
6	New Brunswick	George Street	Parking Lot 22	T-Intersection	2	7387	
7	Seaside Heights	Route 35	Hugh J. Boyd Jr. Elementary School	Midblock	6	12033	
8	Moorestown	Centerton Rd	Tournament Drive	T-Intersection	2	8039	

9	Medford	Stokes Rd	Nelson Dr	T-Intersection	3	15470	
10	Ocean City	9^{th} Street	Aldrich Rd	T-Intersection	4	13913	

In order to obtain sufficient data, locations with high pedestrian and traffic volumes were prioritized for investigation. However, due to the ongoing COVID-19 pandemic, it was difficult to find sites with a high volume of traffic and pedestrian crossings. Of these ten sites, three locations were selected for further analysis, with considerations made for additional factors such as different community types (e.g., urban, suburban, campus area) and diverse demographics. Figure 8 shows the locations of the three sites that were ultimately selected for further video analysis.

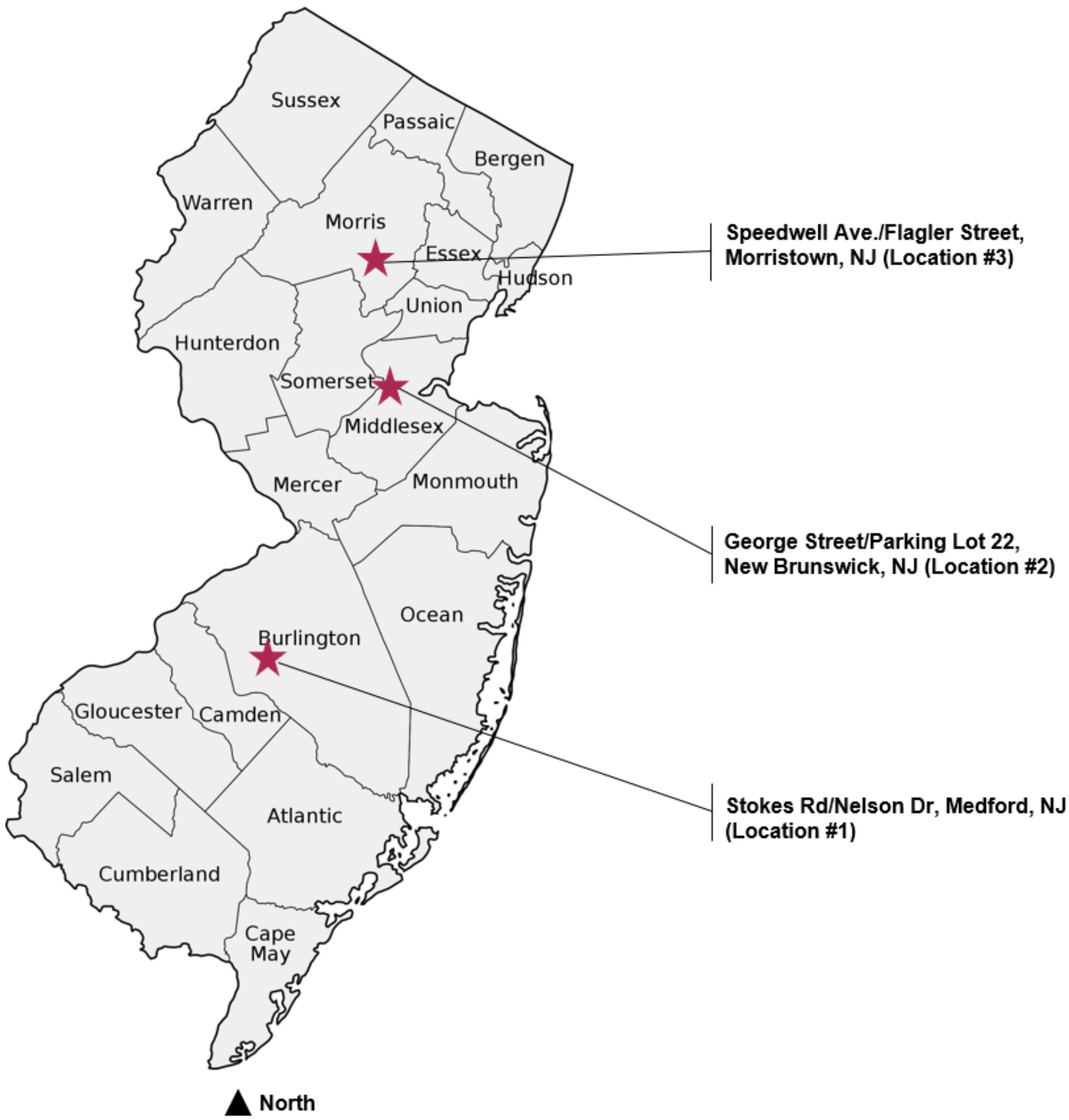


Figure 8. Three selected sites for video analysis in the state of New Jersey.

Stokes Rd/Nelson Dr, Medford, NJ (Location #1)

Medford is a township located in Burlington County, New Jersey. This township encompasses an area of 38.8 square miles with a population of 23,293 in 2018. The T-intersection of Stokes Rd and Nelson Dr is located approximately one mile from the Medford Lakes fire station and a US post office. Surrounding land uses are primarily commercial. The intersection is surrounded by two banks (Bank of America and WSFS Bank), a barbershop, and the Hawthorne Gallery and Frame Shop. Stokes Rd is a two-way street with one travel lane in each direction. This road runs in the north-south direction. Nelson Dr is a one-lane street running in the east-west direction.

George Street/Parking Lot 22, New Brunswick, NJ (Location #2)

New Brunswick is a city located in Middlesex County, New Jersey. This city encompasses an area of 5.2 square miles with a population of 56,084 in 2018. The T-intersection of George Street and Parking Lot 22 is located on the Rutgers University campus. Hence, the surrounding land uses are institutional. The intersection is surrounded by Rutgers University's Hardenburgh Hall, the Rutgers Student Activities Center, and Parking Lots 22 and 20. George Street is a two-way street with one lane in each direction. The road runs in the east-west direction.

Speedwell Ave./Flagler Street, Morristown, NJ (Location #3)

Morristown is a town located in Morris County, New Jersey. This town encompasses an area of 2.9 square miles with a population of 18,769 in 2018. From the north, the T-intersection of Speedwell Ave. and Flagler Street is located about a quarter-mile from the Morristown Fire Department, a Jewish Center, St. Margaret's Church, and Shepard Preparatory High School. At the south end, the intersection is surrounded by supermarkets and restaurants. This location is also surrounded by two T-intersections with regular traffic signals. The PHB signal at this location cooperates with the two mentioned traffic signals. Hence, upon pushing the button, the PHB signal is not activated immediately, and pedestrians at this location need to wait until the surrounding traffic lights turn red before the PHB signal is activated. Speedwell Ave. is a two-way avenue with two lanes in each direction. This road runs in the north-south direction. Flagler Street is a one-lane, one-way street running in the east direction.

Video Data Collection

For locations #1 and #2, video data were collected using two cameras set up on streetlight poles on each side of the PHB, capturing the entire PHB site. Both cameras were aimed such that the signal heads of the PHB were in view and that pedestrian entry to the crosswalk was visible. This was important to allow researchers to determine what phase was occurring at any given time when watching the video. However, for location #3, only one camera set up on the tripod was used to collect the video data. Additionally, cameras were placed out of the immediate view of motorists and pedestrians to minimize the effect filming the intersection had on road users' behavior. Video was collected for six hours in the AM period and for six hours in the PM period for locations #1 and #2. For location #3, however, video data were collected for three hours in the AM period and three hours in the PM period. Figures 9 to 11 illustrate the camera locations and the camera views for the three selected sites. After video data were collected, the research team watched the video and manually recorded the defined measures of effectiveness.

Figure 9. Camera locations and views, Stokes Rd/Nelson Dr, Medford, NJ (Location #1)

Figure 10. Camera locations and views, George Street/Parking Lot 22, New Brunswick, NJ (Location #2)

Figure 11. Camera location and view, Speedwell Ave./Flagler Street, Morristown, NJ (Location #3)

Results

In this section, the data that was collected at the three PHB sites will be discussed. Table 5 below presents the background information for the data collection, including the collection period and total recorded pedestrian and motorist crossings. Tables 6 and 7 list the overall results of the data collection at each location.

Table 5. Background information for video data collection dates.

Location	Date	Time	Collection Period	Total Crossing Ped.	Total Crossing Mot.
Medford	9/13/2020	AM	11:00 AM to 02:00 PM	12	6017
	9/14/2020		10:00 AM to 01:00 AM		
	9/13/2020	PM	03:00 PM to 06:00 PM	3	5750
	9/14/2020		03:00 PM to 06:00 PM		
New Brunswick	9/14/2020	AM	09:00 AM to 03:00 PM	7	2852
	9/13/2020	PM	03:00 PM to 09:00 PM	13	2187
Morristown	10/23/2020	AM	11:00 AM to 02:00 PM	377	4288
	10/23/2020	PM	03:00 PM to 06:00 PM	477	4978

Table 6. Overall results of pedestrian crossing for video data collection.

Period	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Jaywalked
Stokes Rd/Nelson Dr, Medford, NJ (Location #1)						
AM	0.00%	0.00%	0.00%	91.67%	8.33%	0.00%
PM	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
George Street/Parking Lot 22, New Brunswick, NJ (Location #2)						
AM	0.00%	0.00%	0.00%	57.14%	0.00%	42.86%
PM	0.00%	0.00%	0.00%	7.69%	0.00%	92.31%
Speedwell Ave./Flagler Street, Morristown, NJ (Location #3)						
AM	3.71%	0.27%	0.53%	2.65%	1.59%	91.25%
PM	3.98%	2.31%	0.63%	4.61%	5.45%	83.02%

Table 7. Overall results of motorist crossing for video data collection.

Period	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		
	NCB* (Stopped)	CB* (Crossed)	NCB (Stopped)	CB (Crossed)	NCB (Stopped)	CB (Crossed)	CB (Stopped)	NCB (Crossed)	CB (Stopped not clear)	NCB (Stopped Clear)	CB (Crossed Clear)
Stokes Rd/Nelson Dr, Medford, NJ (Location #1)											
AM	0.00%	100.00%	14.29%	85.71%	75.00%	25.00%	89.47%	10.53%	21.43%	33.33%	45.24%
PM	0.02%	99.98%	0.00%	100.00%	75.00%	25.00%	70.00%	30.00%	0.00%	0.00%	100.00%
George Street/Parking Lot 22, New Brunswick, NJ (Location #2)											
AM	0.18%	99.82%	0.00%	100.00%	0.00%	0.00%	50.00%	50.00%	0.00%	100.00%	0.00%
PM	0.14%	99.86%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%	0.00%
Speedwell Ave./Flagler Street, Morristown, NJ (Location #3)											
AM	7.94%	92.06%	72.22%	27.78%	52.78%	47.22%	59.38%	40.63%	21.35%	35.96%	42.70%
PM	10.36%	89.64%	18.97%	81.03%	33.33%	66.67%	55.21%	44.79%	33.86%	26.77%	39.37%
***NCB: Non-Compliance Behavior**											
***CB: Compliance Behavior**											

Pedestrians: At Location #1, all pedestrians crossed during the crossing phases (Phase 4 and 5), and no jaywalking pedestrians were recorded during either the AM or PM periods. However, at Location #2, 57.14% and 7.69% of pedestrians crossed during the crossing phases (Phase 4 and 5) in the AM and PM periods. At location #3, a total of 854 pedestrians crossed the street during both the AM and PM periods. As shown in Table 6, the percentage of pedestrians crossing during the pedestrian crossing interval was only 4.24% and 10.06% during both AM and PM periods, respectively, while the rest jaywalked.

Motorists: At location #1, almost all motorists exhibited compliance behavior in Phases 1, 2, 4, and 5 (during both AM and PM periods). However, in Phase 3 at this location, three-fourths of the motorists exhibited non-compliance behavior. At location #2, nearly all motorists exhibited non-compliance behavior in Phase 5 and compliance behavior in Phase 1 and 2. No crossing of motorists was observed in Phase 3 at this location. Finally, at Location #3, more than two-thirds of the motorists demonstrated the compliance behavior in Phases 1 and 5.

Pedestrian Crossing Behavior Categories

Pedestrian crossing behaviors were grouped into three decision categories: pedestrians who activated the signal but crossed without waiting until the crossing interval; pedestrians who both activated the signal and crossed during either the crossing phase or the pedestrian clearance phase; and pedestrians who did not activate the signal at all or who jaywalked. Table 8 below lists the percentage of pedestrians who fell into each category for each data collection location.

Table 8: Pedestrian crossing rates for each of the three categories of crossing behaviors.

Location	Time	Pedestrian Crossing Categories		
		Activated, Crossed Early	Activated, Waited for Signal	Did not activate/ Jaywalked
Medford (Location #1)	AM	0.00%	100.00%	0.00%
	PM	0.00%	100.00%	0.00%
New Brunswick (Location #2)	AM	0.00%	57.14%	42.86%
	PM	0.00%	7.69%	92.31%
Morristown (Location #3)	AM	4.51%	4.24%	91.25%
	PM	6.92%	10.06%	83.02%

As shown in the table, at Location #1, all pedestrians crossed during the permitted phases. During the AM period at Location #2, 42.86% of pedestrians jaywalked, while the rest of the pedestrians activated the signal and waited for it. During the PM period, a higher rate of pedestrians jaywalked (92.31%), and the rest (7.69%) activated the signal and waited for it. Location #3 had the highest rate of pedestrian non-activation, with 91.25% of pedestrians jaywalking during the AM period. After activating the signal, 4.51% of pedestrians crossed early while 4.24% of pedestrians waited for the signal to turn red before crossing. The PM period at Location #3 saw a lower rate of jaywalking compared to the AM period, with 83.02% of pedestrians crossing without activating the signal. However, the rates of pedestrians who crossed early and waited for the signal were higher than the AM period at 6.92% and 10.06%, respectively.

In addition, the effect that the data collection period had on the crossing rates of pedestrians was examined. This analysis aimed to determine the degree to which the crossing rates for each category changed between the AM and PM data collection periods in each location. To accomplish this, the crossing rate in the AM was subtracted from the crossing rate in the PM for each data collection location. A negative change signifies that the crossing rate decreased from the AM to the PM, and a positive change signifies an increase in the crossing rate from the AM to the PM. In order to validate these results, a two-sample z-test for proportions was used to determine if the change in the crossing rate was statistically significant. Using the proportions and sample size for the AM and PM crossing rates in each location, the z-value was calculated and used to determine if the change in the crossing rates is considered significant. The results of this analysis can be found in Table 9. Based on Table 9, no changes in crossing rates were observed for Medford from AM to PM period. For New Brunswick, a significant difference was observed in both “Activated, Waited for Signal” and “Did not activate/Jaywalked” crossing rates from AM to PM. Similarly, for Morristown, a significant difference was observed in both “Activated, Waited for Signal” and “Did not activate/Jaywalked” crossing rates with the p-values of 0.00134 and 0.00045, respectively.

Table 9: Two-sample z-test for proportions results of the change in crossing rates from the AM to the PM period in each location.

Location	Rate Code	Change	Z-Value	P-Value
Medford (Location #1)	Activated, Crossed Early	0.00%	NA	NA
	Activated, Waited for Signal	0.00%	NA	NA
	Did not activate/ Jaywalked	0.00%	NA	NA
New Brunswick (Location #2)	Activated, Crossed Early	0.00%	NA	NA
	Activated, Waited for Signal	-49.45%	2.436	0.01485*
	Did not activate/ Jaywalked	49.45%	2.436	0.01485*
Morristown (Location #3)	Activated, Crossed Early	2.41%	1.489	0.13650

	Activated, Waited for Signal	5.82%	3.207	0.00134*
	Did not activate/ Jaywalked	-8.23%	3.511	0.00045*
*Statistically significant change between AM and PM periods				

Discussion

The results from the video data collection help illustrate road user behaviors at the three PHB locations. For pedestrians, the first important observation was that only a few pedestrian crossings were observed at Locations #1 and #2. However, at Location #3, a significant number of pedestrians crossed the street during the study period. At Location #1, all observed pedestrians activated the PHB signal and waited for the crossing signal before entering the crosswalk. However, at Locations #2 and #3, most of the pedestrians jaywalked, meaning they crossed the street out of the crosswalk or did not activate the signal at all. This suggests that pedestrians at these two locations generally do not understand the meaning of the signals presented to them. Moreover, it is important to note that the land use type of Location #3 is mainly commercial, and there were many pedestrians who crossed the street for work purposes (carrying some boxes from one store to another). As mentioned before, the PHB signal at this location is coordinated with the two nearby traffic signals, and it takes a while to be activated after pushing the button. This may be one of the reasons why local pedestrians (crossing for work purposes) are unwilling to activate the signal. It was also observed that pedestrians who crossed early or without activating the signal did so because they were able to find sufficient gap acceptance (the gap between vehicles for crossing the street) in the roadway without the signal. Therefore, further progress needs to be made in order to increase pedestrian compliance with the signal.

For motorists, the highest rate of compliance behavior was noted in both AM and PM periods at Location #1 in the city of Medford, when nearly or exactly 100.00% of motorists were observed to have compliance behavior during Phases 1 and 2. They also had more than 70.00% of compliance behavior during Phase 4. This suggests that motorists generally understand or comply with the pedestrian crossing signal of the PHB at Location #1. Moreover, it was also observed that motorists were confused by the fifth phase of the signal, which is the pedestrian clearance interval. During the fifth phase, motorists are instructed to proceed with caution if all crossing pedestrians have left the roadway. Many motorists would continue to yield through the end of the fifth phase even after pedestrians had left the crosswalk. This rate varied widely, with the lowest rate of 26.77% occurring in the PM period in Location #3 in Morristown and the highest rate of 100.00% in both the AM and PM periods at Location #2 in New Brunswick. This observation suggests that motorists lack a full understanding of the meaning of the fifth phase of the PHB.

CHAPTER 3: Behavioral Data Analysis

Introduction

The main intent of this chapter is to evaluate the level of familiarity pedestrians and motorists have with PHB signals. To this end, a web-based survey was developed and distributed throughout different communities in New Jersey.

Methodology

The research team developed a web-based survey that included a variety of questions related to PHB signals. In this survey, respondents were asked whether they had heard of or seen a PHB in the past. To measure comprehension, the survey also asked respondents to choose which phases allow motorists and pedestrians to proceed. The survey questioned respondents about their level of understanding of each phase of the PHB system after providing them with a description of each phase. Other questions pertained to respondents' demographics, transportation, and employment information, as well as whether they believed taking the survey increased their understanding of the PHB. The questions included in this survey are provided in Appendix A.

Ten cities were selected as the target communities for the survey distribution. For comparison purposes, four out of the ten cities, including Medford, Morristown, New Brunswick, and Woodbridge, have already implemented PHB signals while the others have not. Figure 12 shows the locations of the cities selected for survey distribution within New Jersey. Survey results were compiled in Excel, and the responses for each question were analyzed. For nine questions, the Mann-Whitney U test was utilized to assess significant differences in responses for the two groups of cities. The cities without any PHB implementation were placed in Group 1, while the cities with PHBs were placed in Group 2.

The Mann-Whitney U test is a non-parametric test that can be used to determine whether the means of two independent samples are equal (Salkind, 2010). In this test, no assumptions are made about the distributions of the data. The Mann-Whitney for Groups 1 and 2 can be calculated using the following equations:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

where:

- n_1: the number of respondents for Group 1
- n_2: the number of respondents for Group 2
- R_1: the rank sum for Group 1
- R_2: the rank sum for Group 2

In order to analyze the survey, it is necessary to calculate the significance level, which ranges from 0 to 1. It is common among the researchers to utilize significance values of 0.01, 0.05, or 0.10 for 99%, 95%, and 90% confidence levels, respectively. The p-value is the probability of occurrence of an event when the null hypothesis is true. If the p-value is less than the significance level, the hypothesis test is statistically significant. For this analysis, a 95% confidence level was selected. Therefore, if the calculated p-value is less than 0.05, it can be concluded that there is a statistically significant difference between the responses of Groups 1 and 2.

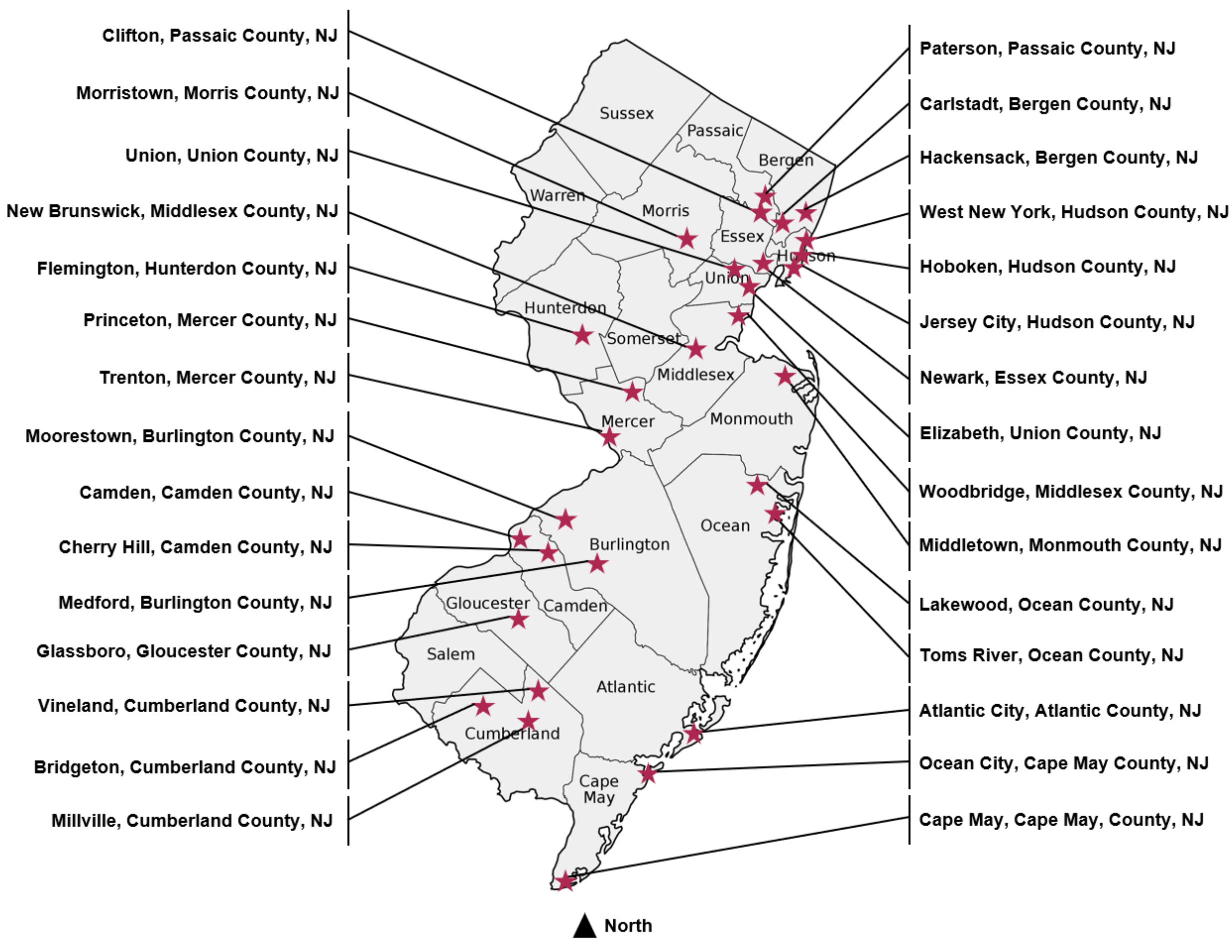


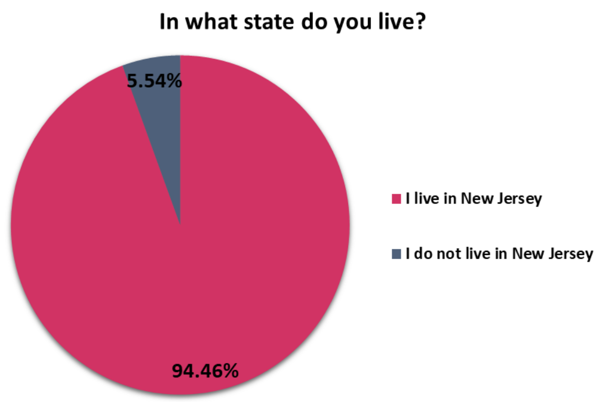
Figure 12. The location of the 30 selected cities for survey distribution on the map of New Jersey.

Survey Evaluation

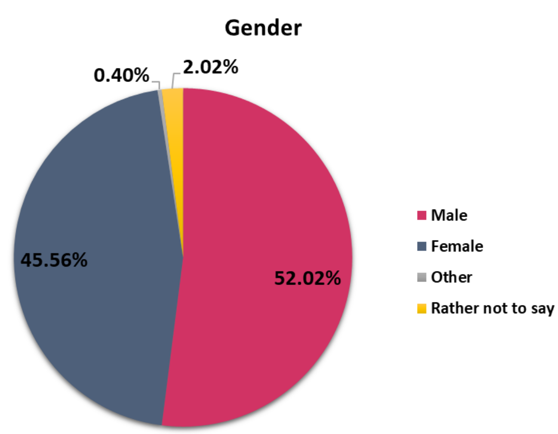
The survey was distributed to 79,567 randomly selected email addresses in the study communities, and 321 complete responses were received. The survey results were divided into several categories, which are described in the following sections:

Respondents' Demographic Profile

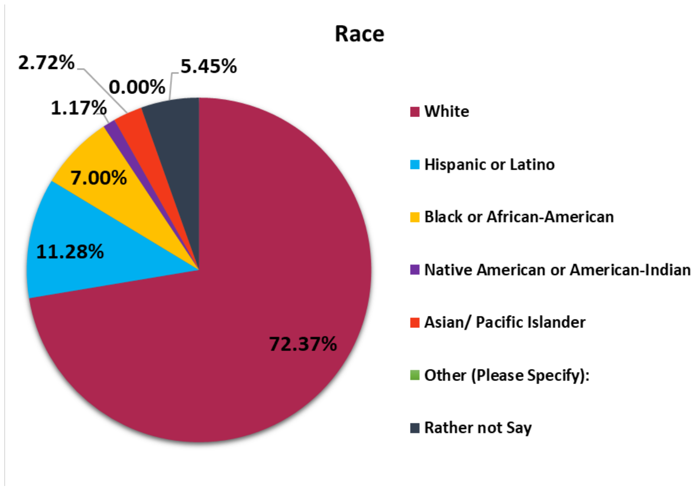
Figure 13 indicates the demographic profile of the respondents in this survey. Included are the statistics for state residence, gender, race, and age. The demographic questions in the survey were intended to determine whether or not the group of respondents is representative of the population at large. In terms of gender, the majority of the respondents are male (52.02%). Racially, the survey group is skewed white, with 72.37% of the survey group identifying as such. Concerning age, 20.25% of the respondents (a plurality) are 65 years old or older.



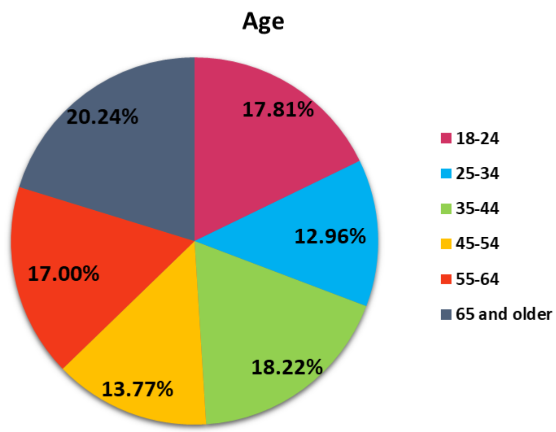
a)



b)



c)



d)

Figure 13. The survey respondents' demographic profile, including a) Jersey residency, b) gender, c) race, and d) age.

Figure 14 shows the modes of transportation used by the respondents. This information helps determine the experiential background of the survey group. As shown, 94.76% of survey respondents use a personal car every week, while 45.56% walk. This suggests that the survey group contains a good mix of individuals familiar with the experiences of both motorists and pedestrians.

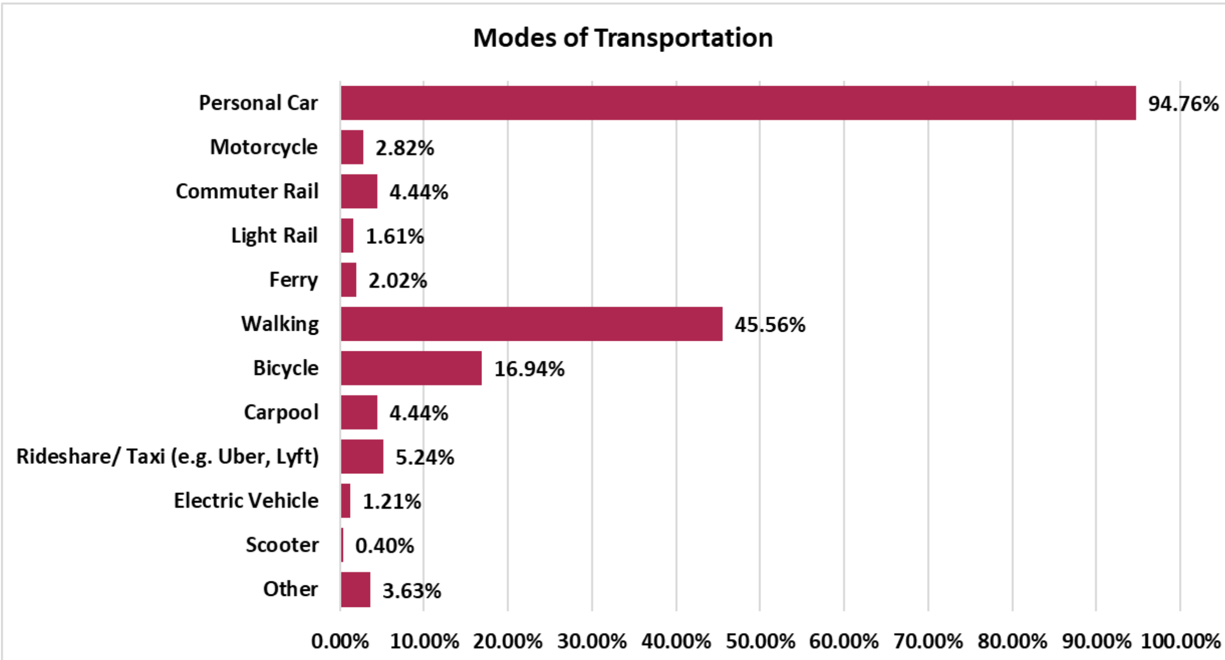
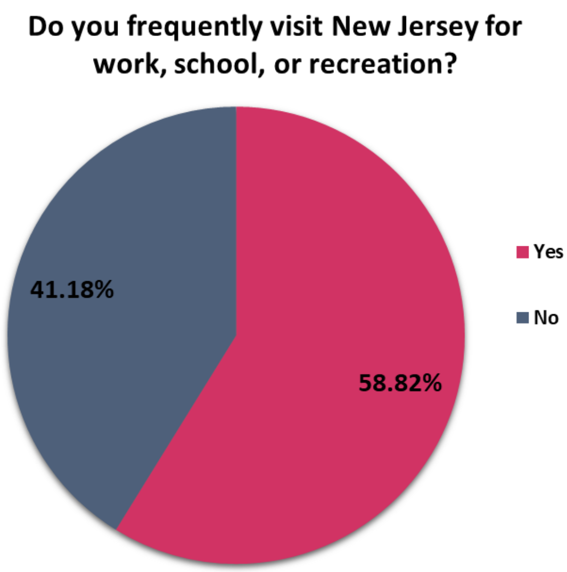
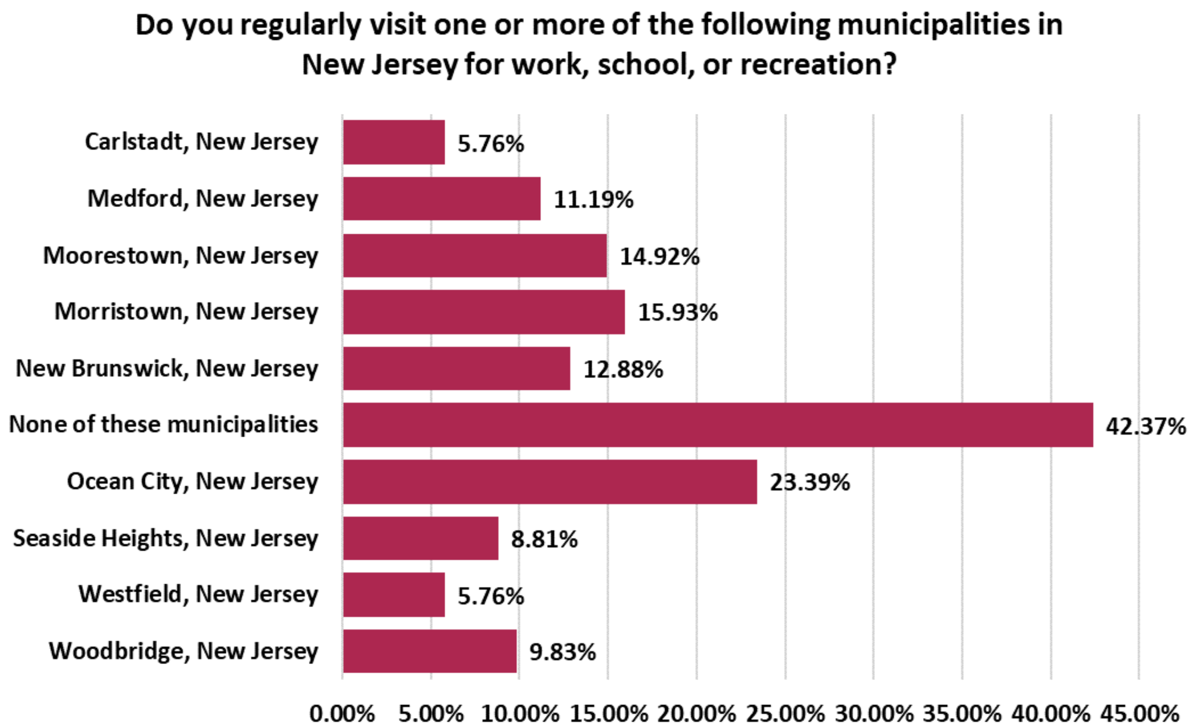


Figure 14. The survey respondents' weekly transportation usage information.

As shown in Figure 15, 58.82% of survey respondents visit New Jersey for work, school, or recreation, although many (42.37%) do not regularly visit the mentioned municipalities.



a) Percentage of respondents who do and do not frequently visit New Jersey



b) Percentage of respondents who visit selected New Jersey municipalities

Figure 15. The survey respondents' information regarding visits to New Jersey

Figure 16 displays information about living in New Jersey. As shown in this figure, the vast majority (93.10%) of survey respondents have lived in New Jersey for more than five years.

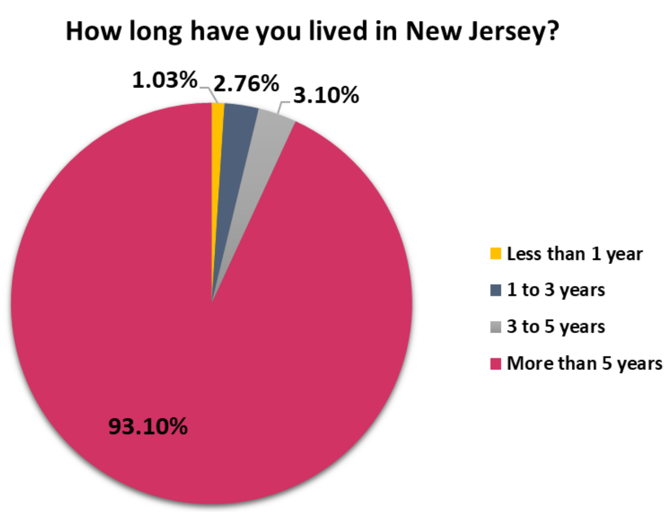


Figure 16. The survey respondents' information about living in New Jersey.

Familiarity with the Pedestrian Hybrid Beacon

Survey participants were also asked whether they had heard of, utilized, or traveled through a PHB signal, and the responses for these questions were compared for the two considered groups (respondents from communities with and without PHBs installed). The results, summarized in Table 10, indicate that there is no significant difference between the responses of the two groups.

Table 10. Results of familiarity with PHB signal (Part 1).

Heard of/Utilized/Traveled through PHB Signal …							
	Group 1 (n)	Group 2 (n)	Total (n)	Delta Mean Rank	Mann-Whitney U	Z	p-value
Have you previously heard of a Pedestrian Hybrid Beacon (PHB) or HAWK Signal?	204	96	300	-1.75	9678	-0.268	0.789
Have you utilized a Pedestrian Hybrid Beacon as a Pedestrian?	52	34	86	-6.27	755	-1.316	0.188
Have you traveled through a Pedestrian Hybrid Beacon as a Motorist?	51	34	85	3.33	799	-0.949	0.342

Survey participants were given a picture of a PHB signal and were asked whether they had seen this signal before. The results summarized in Table 11 indicate no significant difference between the two study groups.

Table 11. Results of familiarity with PHB signal (Part 2).

Seen PHB Signal							
	Group 1 (n)	Group 2 (n)	Total (n)	Delta Mean Rank	Mann-Whitney U	Z	p-value
Do you believe that you have previously seen a Pedestrian Hybrid Beacon?	204	96	300	15.67	8769	-1.571	0.116

Survey participants were also asked how often they used a PHB signal and whether they had seen drivers fail to stop for pedestrians at a PHB signal. The results, summarized in Table 12, show no significant difference was between the two study groups.

Table 12. Results of familiarity with PHB signal (Part 3).

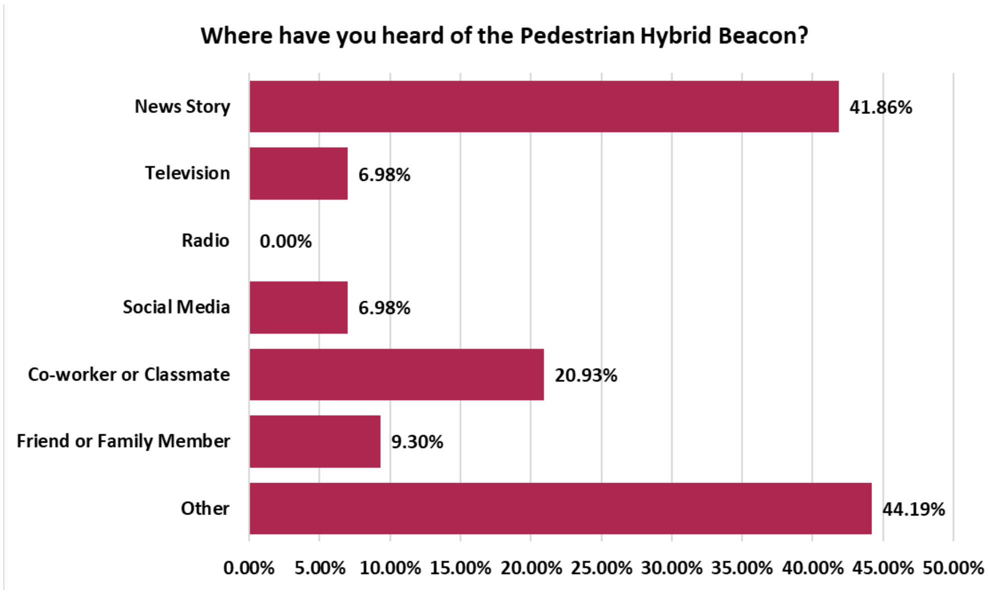
How Often …							
	Group 1 (n)	Group 2 (n)	Total (n)	Delta Mean Rank	Mann-Whitney U	Z	p-value
In the past month, how often have you utilized a Pedestrian Hybrid Beacon, as a Pedestrian?	28	14	42	2.52	172.5	-0.678	0.498
In the past month, how often have you traveled through a Pedestrian Hybrid Beacon, as a Motorist?	40	30	70	9.01	445.5	-1.918	0.055
In the past week, how often have you seen drivers not stopping for pedestrians in the crosswalk while traveling through a Pedestrian Hybrid Beacon?	160	79	239	-3.87	6115.5	-0.466	0.641

Survey participants were also asked how safe they felt while using a PHB signal (results summarized in Table 13). According to Table 13, no significant difference was observed between the two study groups.

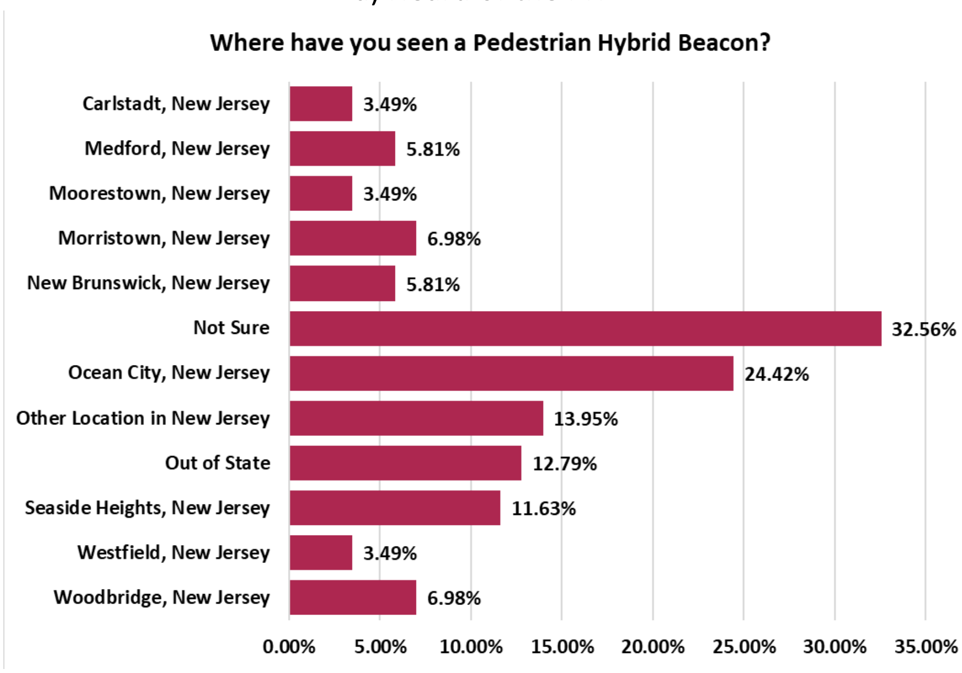
Table 13. Results of familiarity with PHB signal (Part 4).

How Safe …							
	Group 1 (n)	Group 2 (n)	Total (n)	Delta Mean Rank	Mann-Whitney U	Z	p-value
How safe did you feel while utilizing Pedestrian Hybrid Beacon as a Pedestrian?	28	14	42	2.94	168.5	-0.81	0.418
How safe did you feel while traveling through a Pedestrian Hybrid Beacon as a Motorist?	39	29	68	-1.17	546	-0.261	0.794

Figure 17 shows where survey respondents have heard of or seen a PHB. The results show that 44.19% have heard about the PHB from other sources (including seeing on the street or hearing from the school/college), followed by 41.86% from news stories. Moreover, about a third of respondents (32.56%) were unsure where they had seen a PHB signal, while 24.42% reported that they had seen the signal in Ocean City, New Jersey.



a) Heard of the PHB



b) Seen PHB signal

Figure 17. Results of familiarity with PHB signal (Part 5).

Comprehension of the Pedestrian Hybrid Beacon

After showing pictures of the motorist and pedestrian signals of each phase of the PHB, the survey asked participants to indicate during which of the phases pedestrians and motorists are allowed to cross. Table 14 lists the survey results regarding respondents' comprehension of each PHB signal for pedestrians and motorists.

Table 14. Results of the respondents' initial understanding of the PHB phases.

Based on the following pictures, select all phases that indicate a motorist is allowed to cross the Pedestrian Hybrid Beacon.						
Phase	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Motorist Signal		Flashing			Flashing	
Motorist Survey Result	73.78%	65.17%	47.57%	5.24%	7.49%	72.66%
Based on the following pictures, select all phases that indicate a pedestrian is allowed to cross the Pedestrian Hybrid Beacon.						
Phase	Phase 1 through 3			Phase 4	Phase 5	Phase 6
Pedestrian Signal					29 Flashing	
Pedestrian Survey Result	3.15%			98.60%	71.33%	2.80%

The results of the respondents' understanding of the different phases of the PHB are as follows: 98.60% of respondents indicated that pedestrians may pass during Phase 4, 71.33% indicated that pedestrians may pass during Phase 5, and only 3.15% indicated that pedestrians may pass Phase 1 through 3. For motorists, 73.78% selected Phase 1, 65.17% selected Phase 2, 47.57% selected Phase 3, 5.24% selected Phase 4, 7.49% selected Phase 5, and 72.66% selected Phase 6. After being presented with a short description of what a PHB is and how it functions, respondents were asked if they would support a proposal to install a PHB in place of a standard signal at a crossing near their home (shown in Figure 18). 38.84% of the respondents indicated that they would be very likely to support the proposal, 25.62% were somewhat likely, and 10.74% were very unlikely to support such a proposal.

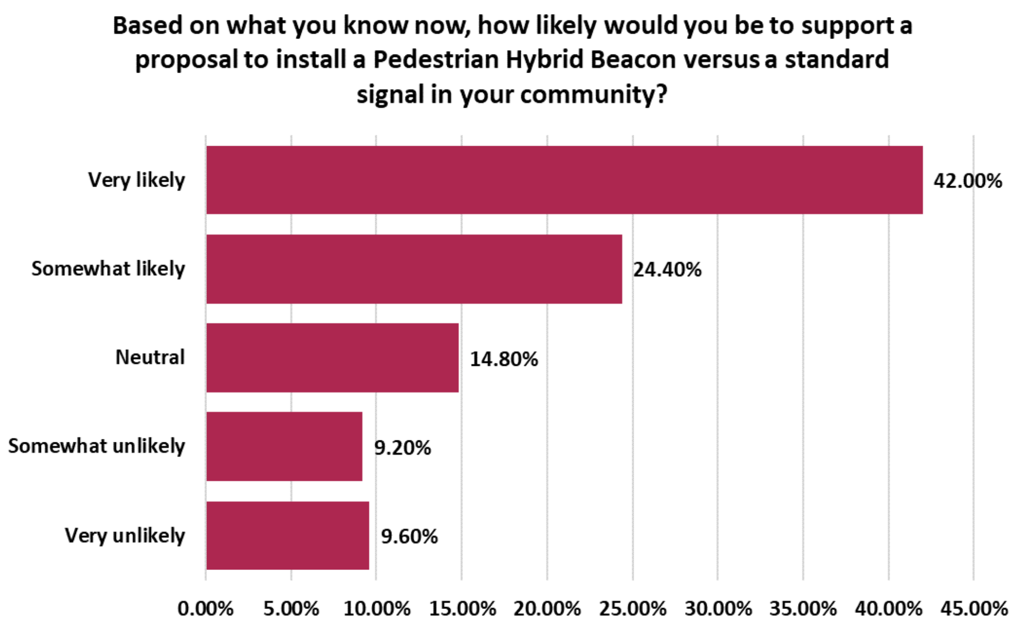
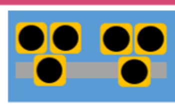
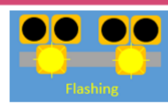
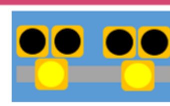
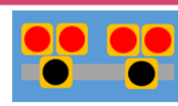
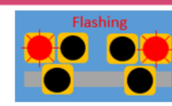


Figure 18. Results for the respondents' information about whether they support a proposal for installing a PHB signal in their community.

Respondents were also asked about their level of understanding of the phases of the PHB for pedestrians and motorists. For each phase, respondents were shown a chart displaying the signal and given a description of what motorists and pedestrians may do during this signal. Respondents then answered questions about their understanding of the signal. Table 15 lists the results of respondents' understanding of each PHB signal for motorists and pedestrians.

Table 15. The results of respondents' understanding of each PHB signal for motorists and pedestrians.

		How well do you feel you understand each phase as a pedestrian/motorist?				
Participant Response		**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**
Motorist Signal						
Survey Result	Very well	49.82%	53.05%	53.31%	76.77%	55.73%
	Somewhat well	25.83%	32.44%	31.91%	18.90%	28.85%
	Neutral	11.07%	9.92%	6.61%	2.76%	6.32%
	Not very well	9.59%	3.44%	5.84%	1.18%	5.93%
	Not well at all	3.69%	1.15%	2.33%	0.39%	3.16%
Pedestrian Signal						
Survey Result	Very well	57.52%	64.59%	65.22%	79.92%	65.86%
	Somewhat well	24.06%	24.12%	23.32%	16.14%	24.10%
	Neutral	9.40%	6.23%	6.72%	2.36%	3.61%
	Not very well	6.02%	3.50%	3.16%	0.79%	4.02%
	Not well at all	3.01%	1.56%	1.58%	0.79%	2.41%

Additionally, respondents were asked about how serious an issue they think pedestrian safety is in the state of New Jersey (shown in Figure 19). 65.08% of respondents believe that pedestrian safety in New Jersey is a very serious problem, 29.37% believe it is a somewhat serious problem, and 5.56% believe it is not a serious problem.

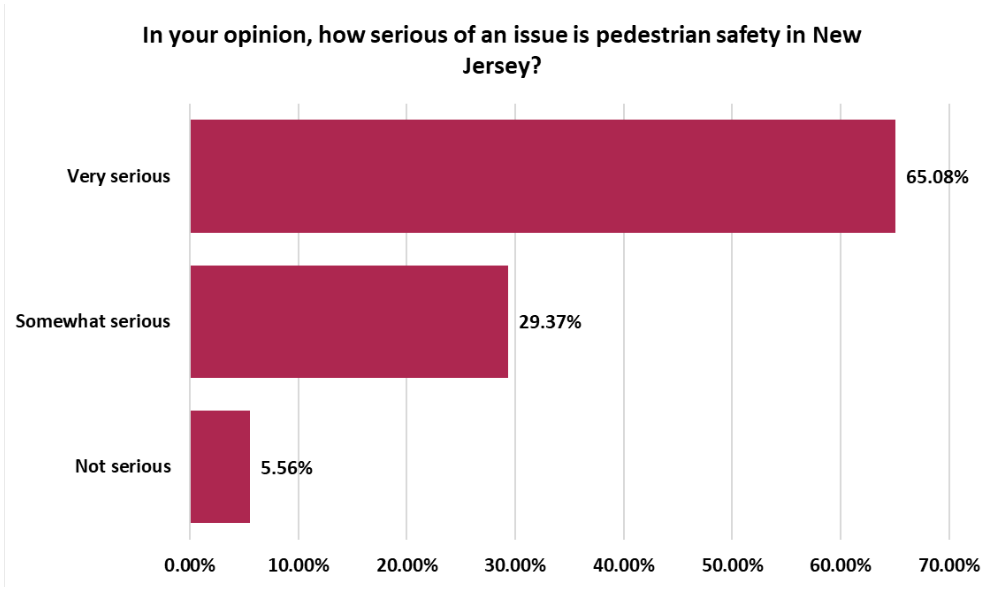


Figure 19. The results of respondents' opinions on how serious of an issue pedestrian safety is in New Jersey.

Effect of the Survey on Public Understanding

The survey also asked participants whether taking the survey increased their understanding of the operation of the PHB. As shown in Figure 20, many respondents believed that the survey increased their understanding of the PHB system, with 82.60% of respondents indicating that the survey increased their understanding very well or fairly well. This suggests that the level of public understanding of the PHB is low and that short, online educational tools might be effective at increasing public knowledge.

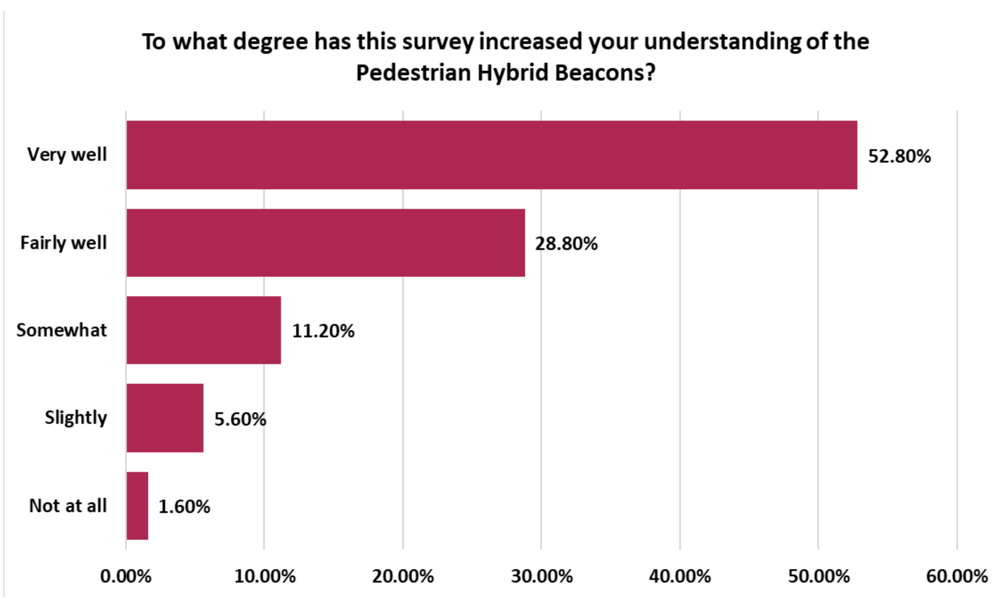


Figure 20. Results for the effect the survey had on respondents' understanding of the PHB.

Discussion

The survey data results are useful in understanding the public's awareness and comprehension of the PHB signal. The survey showed that the majority of respondents were unfamiliar with the PHB, with 85.86% of respondents having never heard of the PHB, and slightly less than one-third (28.81%) of the respondents reporting having seen a PHB in the past. Only 43 out of 86 pedestrians reported having used the PHB as a pedestrian, and 71 out 85 motorists reported having crossed a PHB.

Respondents were also asked about their initial understanding of the phases of the PHB. The vast majority of respondents correctly identified that pedestrians may not cross during phases 1-3. Additionally, virtually all respondents indicated that pedestrians may cross during phase 4, the pedestrian crossing interval. Slightly more than 70.00% of respondents recognized that pedestrians may cross during the fifth phase of the signal. These results suggest that pedestrians are able to decipher the meaning of the pedestrian phases overall, but comprehension of the fifth phase is lower than that of the fourth. The results for the motorist signals were more mixed. About three-quarters of respondents indicated that motorists may pass during phase 1, but only 65.17% and 47.57% of respondents said the same for phases 2 and 3, respectively. The vast majority of respondents recognized that motorists are not permitted to pass during phase 4, but only 7.49% recognized that motorists may pass during phase 5. These results suggest that while respondents understand when motorists must yield to pedestrians, they are unsure of when they are permitted to pass the PHB when in a vehicle.

Next, respondents were asked to characterize their understanding of each phase of the PHB after being provided with an explanation of each phase. For the motorist signal phases, the majority of respondents felt they understood each phase "very well" or "somewhat well." Respondents felt the most confident about phase 4, with 76.77% understanding it very well. For the pedestrian signal phases, similar results were observed. Respondents felt the most confident about phase 4, with 79.92% understanding it very well. These results indicate that the pedestrian phases are broadly comprehensible for pedestrians. Furthermore, 82.60% of respondents reported that taking the survey increased their understanding of the PHB signal. This result, as well as the increase in respondents' comprehension between the preliminary and final comprehension questions, suggest that simple diagrams and explanations distributed in an online format may effectively increase public understanding of the PHB.

Finally, respondents were asked whether they had any comments they would like to add about their experience with PHBs. Seventeen respondents directly mentioned that they found the PHB signal very confusing and that there is a need to educate people about the functionality of this signal. There were also a few negative comments about the high expense of PHB implementation and the lack of need for these signals. Some respondents, however, had positive comments about PHBs, noting that the signals would add to road users' safety.

CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

The PHB signal has proven in previous studies to be an effective method of increasing pedestrian safety and motorist yielding on roadways with high speed limits and wide crossings. However, the effectiveness of the PHB is limited by a lack of public understanding of the signal and its functionality. Motorists in particular have difficulty understanding the PHB phases. The video data collected during this study from three locations in New Jersey revealed several important observations about pedestrian and motorist behavior at PHB signals. A varying rate of motorists crossed during the pedestrian crossing phase at three locations. Additionally, it was found that the rate of motorist non-compliance with the fourth phase was greater in the PM period than in the AM period in two of the three locations. Moreover, many motorists continued to yield through the end of the fifth phase, even after pedestrians had cleared the intersection. For the pedestrians, it was found that a minority of the pedestrians activated the PHB and waited for the correct signal before crossing (except for Location #1 in Medford during both the AM and PM periods). Moreover, the majority of pedestrians jaywalked, especially at Location #3 in Morristown.

Respondents to the survey indicated that most of them generally understood the different phases of the PHB after being given a brief description of each phase for motorists and pedestrians. The vast majority of survey respondents correctly identified the phases when pedestrians and motorists are permitted to cross, which may be due to the fact that the pedestrian signal of the PHB is virtually identical to the signal found at most other intersections. Furthermore, the majority of respondents correctly identified the phases when motorists are allowed to cross.

There are several possible ways to increase public understanding of the PHB. First of all, the New Jersey MVC Handbook, which is used to educate new drivers and currently makes no mention of the PHB, can be updated to include information on how drivers should behave around PHB signals. The manual in its current iteration actually contradicts appropriate PHB protocol by stating that drivers should treat an unlit signal as a four-way stop controlled intersection. Additionally, the only mention of a flashing red signal is for railroad crossing signals, where a driver is required to stop rather than yield and cross when clear. Updating the MVC Handbook to include motorist instructions for the PHB would help increase driver familiarity with the signal.

In addition, a public education campaign for PHBs could be an effective way to increase public awareness and understanding. As discussed earlier, after reading short descriptions of the phases of the PHB, the vast majority of survey respondents indicated that their understanding of the PHB had increased. This suggests that a public education campaign could be a useful tool to increase public knowledge of the signal and how it works. As the PHB becomes an increasingly common feature in New Jersey communities, it will be essential to ensure that the public is aware of this system and how to navigate through this signal, allowing the PHB to operate effectively and maximize driver and pedestrian safety.

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APPENDIX A: SURVEY ON PHB LOCATIONS IN NJ

Evaluating the Pedestrian Hybrid Beacon's Effectiveness: A Case Study in New Jersey

Rowan University, on behalf of the New Jersey Department of Transportation (NJDOT) is conducting a study to evaluate public awareness of Pedestrian Hybrid Beacon Signals in the State of New Jersey. The Pedestrian Hybrid Beacon is a pedestrian signal designed to improve pedestrian safety at major pedestrian crossings. It is activated by the pedestrian with a push-button, and it cycles through five signals to warn motorists of the crossing and tells them when they must stop for crossing pedestrians. In the following, the team seeks information about your awareness of PHB signal implementation in your county/municipality.

We sincerely appreciate your cooperation. If you or anyone at your agency has any questions, please contact the study's Principal Investigator, Dr. Mohammad Jalayer at 856-256-5397 or jalayer@rowan.edu.

Thank you.
Mohammad Jalayer

Q1

Name of your county/municipality:

Q2

Name of the agency your work for:

Q3

Name of the department/division within the agency (if any):

Q4

The title of your position:

Q5

Are you aware of any PHB implementation in your county/municipality?

- Yes
- No

Q6

How many locations are there in your county/municipality with PHB signal?

- One location
- Two locations

- Three locations
- Four locations
- I am not aware.
- Other (please specify):

Q7

Please provide the following information about the location with PHB signal in your county/municipality:

- Latitude and Longitude:
- Date of implementation:
- Traffic signal face time:

Q8

Do you know anybody else in your agency that can provide us with information about PHB signal locations in New Jersey?

- Yes
- No

Q9

Please provide the contact information of that person below:

- Full name:
- Name of agency:
- Email address:
- Phone number:

Q10

Do you know any other resources that can help us with finding PHB signal locations in New Jersey?

- Yes
- No

Q11

Please provide the information for that resource:

Q12

Comments: Is there any additional comment you would like to add about PHB location?

APPENDIX B: PHB SURVEY QUESTIONNAIRES

Research Agreement

You are invited to participate in a research study being conducted by Rowan University on behalf of the New Jersey Department of Transportation (NJDOT) to evaluate public awareness of Pedestrian Hybrid Beacon Signals in the State of New Jersey. In the following survey, the team seeks information about your knowledge and experiences toward this type of signal.

This survey should take you approximately 5 to 10 minutes to complete. Your participation in the survey is completely voluntary, and there are no risks to participation. You may skip any questions you are not comfortable answering. If at any time you wish to stop participating, you are free to do so with no penalty to you. This research is confidential. Confidential means that the research records will include some information about you, such as your age. However, the research team and the Institutional Review Board at Rowan University are the only parties that will be allowed to see the full set of data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. All study data will be kept for three years post-study.

If you have any questions at any time about the research or the procedures described above, or if you need assistance in completing the survey, you may contact the study principal investigator Dr. Mohammad Jalayer at jalayer@rowan.edu. If you have any questions about your rights as a participant in this study, you may contact the Rowan University Institutional Review Board, Tel: 856-256-4567 Email: eirb@rowan.edu.

Please print a copy of this consent form for your records. If you are 18 years of age or older, understand the statements above, and will consent to participate in the study, click on the "I Agree" button to begin the survey. If not, please click on the "I Do Not Agree" button which you will exit this program.

- I Agree
- I Do Not Agree

Age Verification

Are you 18 years of age or older?

- Yes
- No

State

In what state do you live?

- I live in New Jersey
- I do not live in New Jersey

Visit NJ

Do you frequently visit New Jersey for work, school, or recreation?

- Yes
- No

City Options

Do you regularly visit one or more of the following municipalities in New Jersey for work, school, or recreation? [Check all that apply]

- Carlstadt, New Jersey
- Medford, New Jersey
- Moorestown, New Jersey
- Morristown, New Jersey
- New Brunswick, New Jersey
- Ocean City, New Jersey
- Seaside Heights, New Jersey
- Westfield, New Jersey
- Woodbridge, New Jersey
- None of these municipalities

Zip code

Please enter your home zip code below:

Zip code:

Time in NJ

How long have you lived in New Jersey?

- Less than 1 year
- 1 to 3 years
- 3 to 5 years
- More than 5 years

Heard of PHB

Have you previously heard of a Pedestrian Hybrid Beacon (PHB) or HAWK Signal?

- Yes
- No

Heard of PHB Follow-up

Where have you heard of the Pedestrian Hybrid Beacon?

- News Story
- Television
- Radio
- Social Media
- Co-worker or Classmate
- Friend or Family Member
- Other (Please Specify):

PHB Picture

Based on the picture below, showing a Pedestrian Hybrid Beacon, do you believe that you have previously seen a Pedestrian Hybrid Beacon?

- Yes
- No
- Maybe/Note sure

Seen PHB Follow-up

Where have you seen a Pedestrian Hybrid Beacon? [Check all that apply]

- Carlstadt, New Jersey
- Medford, New Jersey
- Moorestown, New Jersey
- Morristown, New Jersey
- New Brunswick, New Jersey
- Ocean City, New Jersey
- Seaside Heights, New Jersey
- Westfield, New Jersey
- Woodbridge, New Jersey
- Other Location in New Jersey (Please Specify):
- Out of State
- Not Sure

Used PHB

Have you utilized a Pedestrian Hybrid Beacon as a **Pedestrian**?

- Yes
- No

Have you traveled through a Pedestrian Hybrid Beacon as a **Motorist**?

- Yes
- No

Used Ped Follow-up

In the past month, how often have you utilized a Pedestrian Hybrid Beacon, as a **Pedestrian**?

- A great deal
- A moderate amount
- Occasionally
- Rarely
- Never

How safe did you feel while utilizing Pedestrian Hybrid Beacon, as a **Pedestrian**?

- Very safe

- Safe
- Neither safe nor unsafe
- Unsafe
- Very unsafe

Used Motor Follow-up

In the past month, how often have you traveled through a Pedestrian Hybrid Beacon, as a **Motorist**?

- A great deal
- A moderate amount
- Occasionally
- Rarely
- Never

How safe did you feel while traveling through a Pedestrian Hybrid Beacon, as a **Motorist**?

- Very safe
- Safe
- Neither safe nor unsafe
- Unsafe
- Very unsafe

Prelim Phases Intro

In the next two questions, we will measure your understanding of the different phases of the Pedestrian Hybrid Beacon. You will be asked to select the phases in which pedestrians and motorists are allowed to cross a Pedestrian Hybrid Beacon.

Prelim Phases Ped

Based on the following pictures, select all phases that indicate a pedestrian is allowed to cross the Pedestrian Hybrid Beacon.

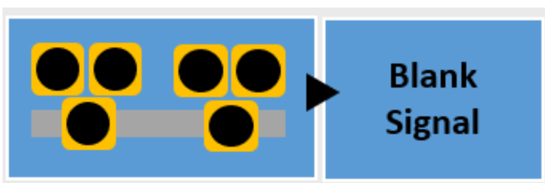
- Phases 1-3: 

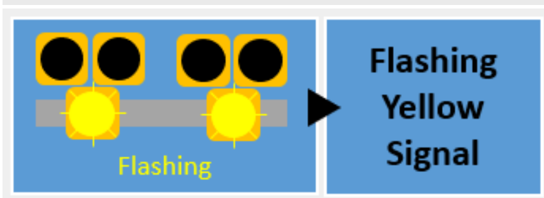
- Phase 4: 
- Phase 5: 

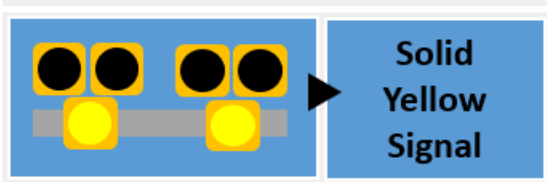
- Phase 6: 
- None of the above

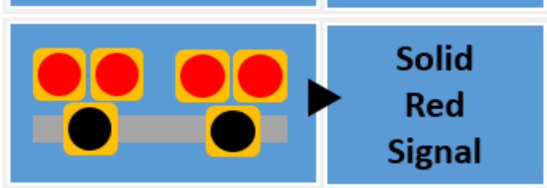
Prelim Phases Motor

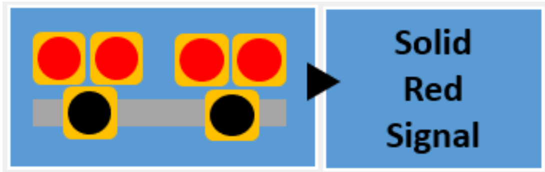
Based on the following pictures, select all phases that indicate a motorist is allowed to cross the Pedestrian Hybrid Beacon.

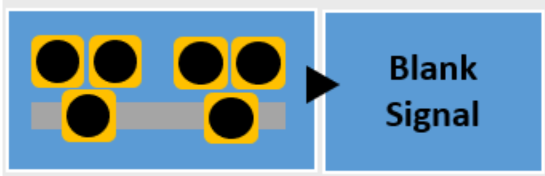
- Phase 1: 

- Phase 2: 

- Phase 3: 

- Phase 4: 

- Phase 5: 

- Phase 6: 

- None of the above

PHB Description

The Pedestrian Hybrid Beacon is a pedestrian signal designed to improve pedestrian safety at major pedestrian crossings. It is activated by the pedestrian with a push-button, and it cycles through five signals to warn motorists of the crossing and tell them when they must stop for crossing pedestrians.

PHB Signal Introduction

In this next section, you will see pictures describing the signal phases of the PHB. These phases tell the drivers when to yield, and the pedestrians when it is safe to cross.

PHB Signal 1

In the first phase of the PHB, the signal is dark until a pedestrian activates the push-button. Motorists are allowed to proceed through the crosswalk.

How well do you feel you understand the first signal phase for **Motorists**?

- Very well
- Somewhat well
- Neutral

- Not very well
- Not well at all

How well do you feel you understand the first signal phase for **Pedestrians**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

PHB Signal 2

In the second phase of the PHB, the yellow signal flashes to indicate that a pedestrian has activated the push-button. Motorists should slow down while approaching the crosswalk, and pedestrians should wait for the cross signal.

How well do you feel you understand the second signal phase for **Motorists**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

How well do you feel you understand the second signal phase for **Pedestrians**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

PHB Signal 3

In the third phase of the PHB, a solid yellow signal is displayed. Motorists should prepare to stop for crossing pedestrians, and pedestrians must continue to wait for the cross signal.

How well do you feel you understand the third signal phase for **Motorists**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

How well do you feel you understand the third signal phase for **Pedestrians**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

PHB Signal 4

In the fourth phase of the PHB, the signals display a solid red light. This is the cross signal, and pedestrians may begin to cross the roadway. Motorists must stop and wait for the cross signal to end.

How well do you feel you understand the fourth signal phase for **Motorists**?

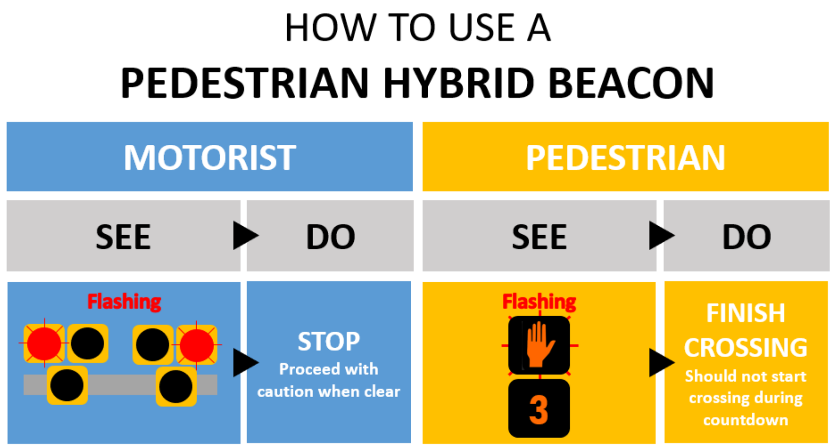
- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

How well do you feel you understand the fourth signal phase for **Pedestrians**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

PHB Signal 5

In the fifth phase of the PHB, the signals display a flashing red light. This light indicates that the cross signal is ending, and that pedestrians should clear the crosswalk. Motorists should make sure that the crosswalk is clear, and then proceed with caution when clear.



How well do you feel you understand the fifth signal phase for **Motorists**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

How well do you feel you understand the fifth signal phase for **Pedestrians**?

- Very well
- Somewhat well
- Neutral
- Not very well
- Not well at all

Pedestrian Crashes

In the past week, how often have you seen drivers not stopping for pedestrians in the crosswalk while traveling through a Pedestrian Hybrid Beacon?

- A great deal
- A moderate amount
- Occasionally
- Rarely
- Never

In your opinion, how serious of an issue is pedestrian safety in New Jersey?

- Very serious
- Somewhat serious
- Not serious

Pedestrian Law

Do you think the following statement is true or false?

"Motorists are required by law to stop and stay stopped for pedestrians in marked crosswalks, and that failing to do so can lead to a traffic ticket, 2 points on your license, and a $200 fine."

- True
- False

Increased Understanding

Based on what you know now, how likely would you be to support a proposal to install a Pedestrian Hybrid Beacon in your community?

- Very likely
- Somewhat likely
- Neutral
- Somewhat unlikely
- Very unlikely

Based on what you know now, how likely would you be to support a proposal to install a Pedestrian Hybrid Beacon versus a standard signal in your community?

- Very likely
- Somewhat likely
- Neutral
- Somewhat unlikely
- Very unlikely

To what degree has this survey increased your understanding of the Pedestrian Hybrid Beacons?

- Very well
- Fairly well
- Somewhat
- Slightly
- Not at all

Demographics Intro

Please tell us a few details about yourself. Your responses will be confidential and will not be connected to you personally.

Gender

What is your sex?

- Male
- Female
- Other
- Rather not to Say

Age

What is your age?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and older

Race

What is your race? [Check all that apply]

- White
- Hispanic or Latino
- Black or African-American
- Native American or American-Indian
- Asian/ Pacific Islander
- Other (Please Specify):
- Rather not Say

Language

Do you speak any languages besides English at home?

- Yes (Please Specify):

- No
- Rather not say

Transportation

Which mode(s) of transportation do you use on a weekly basis? [Check all that apply]

- Personal Car
- Motorcycle
- Commuter Rail
- Light Rail
- Ferry
- Walking
- Bicycle
- Carpool
- Rideshare/ Taxi (e.g. Uber, Lyft)
- Electric Vehicle
- Scooter
- Other (Please Specify):

Driver's License

Do you have a valid driver's license?

- Yes
- No

Comments

- Is there any additional comment you would like to add about your experience on PHB?

End of Survey

This is the end of the survey. When you are finished, please click on the "next" button below to submit your responses. Otherwise, you may review or change your answers by clicking on the "previous" button below.