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Safety Effects of the Yellow Light Border (YPB) Pedestrian Signal

An Evaluation Study

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EXECUTIVE SUMMARY

In an urban setting, interactions between vehicles and pedestrians at signalized intersections give rise to potential conflicts when vehicles make a right or permissive left turn and pedestrians use the crosswalk simultaneously. Generally, crosswalks parallel to moving vehicular traffic are served simultaneously. Thus, potential conflict situation arises when there is any turning movement of the traffic. Since the motorists focus mostly on the signal heads to make any maneuvering decision, the movement of the pedestrians as per the pedestrian signal head is not readily observed. In addition, low light or inclement weather conditions can also contribute to poor visibility condition.

To address these safety issues at signalized intersections, California Department of Transportation (Caltrans) suggested a prototype device to enhance the pedestrian signal indications with a ring of yellow LED border that will activate when the call button is pushed. The purpose of the additional lights is to serve as a quick visual cue for pedestrians to confirm their button push being registered and for motorists engaged in turning maneuver to observe for the pedestrians entering a crosswalk on the near-side or far-side.

This study was carried out following a previous study by Caltrans *(1)*, with a goal to evaluate the anticipated benefit of the yellow pedestrian border (YPB) signal in a more diverse setting with five different locations around California. The study aims to determine whether the additional feature to the traditional pedestrian signal provides an overall benefit to both vehicular traffic and pedestrians, resulting in improved interactions between vehicles and pedestrians at intersection. The improvement is measured and evaluated by comparing different type of conflicts, violations, and extra-push events for before and after YPB installations.

Forty prototype YPB modules were manufactured to conduct the evaluations at the five intersections and data for each location was reviewed for before and after condition for seven consecutive days, 16 hours each day. The extent of learning period was two to eight weeks before the after-condition study to get the pedestrians and motorists accommodated with the features and purpose of YPB.

The number of pedestrian-vehicle conflicts at the five intersections before and after YPB installations show quite mixed results. Some intersections saw significant reductions while others show significant increases. After normalizing for pedestrian volume, the cumulative average from the five study locations showed a slight increase in pedestrian-vehicle conflicts when the YPB modules were installed (3.63%). But when normalized by turning vehicular traffic volume, the cumulative average of total number of conflicts with respect to the total turning volume showed a decrease of 7.86% at Locations 1, 2, and 3. A weighted average of the conflict results with two factors (pedestrian volume and right-turning traffic volume) showed a fractional decrease of 0.35%. The diversity of the pedestrian behavior, alternate intersection geometry, different learning period, and inadequate flyer information for different locations are possibly responsible for the

diverse results. For instance, location 3 (Fort Bragg) and location 4 (Laguna) showed a sharp increase of conflicts, whereas the other three locations showed a moderate decrease of conflicts for the after condition with respect to pedestrian volume.

For turning conflicts, the cumulative average for left-turn and right-turn conflicts with respect to the turning traffic volume showed a decrease of 18.53% and 19.57% in both cases. Since all the locations do not have same data points, a weighted average for the turning conflicts (left and right combined) showed an overall decrease of 19.12%.

Compared to the conflict situations, YPB signals had more cumulative impact on the pedestrians' behavior by reducing the overall no-push, extra-push, and violation events. The cumulative average of no-push, extra-push, and violation with respect to pedestrian volume showed a decrease of 21.56%, 34.40% and 45.08%, respectively. Thus, from the pedestrian safety perspective, the addition of YPB significantly improves the pedestrian behavior. Though the expected benefit is related to the increment of vehicle yielding to the pedestrians for safe interactions, the study results showed a minor decrease. However, this is not a major issue since in all the study locations except one, the vehicles yielded more than 85% of the time for all the conflicting situations recorded during the study period.

The experimental results showed that YPB is a positive addition to a standard pedestrian signal since it is very effective in enhancing safety by ensuring compliance of the pedestrians. Moreover, the bright LED border serves as an additional visual cue for the motorist maneuvering any turning movement at the urban signalized intersection. Moreover, the visibility of the border will aid pedestrians and motorists during low light or inclement weather conditions when there is a high potential for conflict.

ACKNOWLEDGEMENTS

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Maintenance Electrical Crew of Districts 1, 4, and 12, for installing the cameras and YPB modules at all five locations.

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INTRODUCTION

In an urban setting, interactions between vehicles and pedestrians at signalized intersections give rise to potential conflicts when vehicles make a right or permissive left turn and pedestrians use the crosswalk simultaneously. Generally, crosswalks parallel to moving vehicular traffic are served simultaneously. Thus, potential conflict situations arise when there is any turning movement of the traffic. Since the motorists focus mostly on the signal heads to make any maneuvering decision, the movement of the pedestrians as per the pedestrian signal head is not readily observed. Generally, the motorists observe pedestrians waiting to cross on the near side of the intersection unlike the pedestrians on the far-side which is generally out of their direct line-of-sight. Since the pedestrian crossing is limited on the crosswalk, the conflict between traffic and pedestrian in signalized intersections can be divided into three types considering the movement classification of traffic which are left, through, and right.

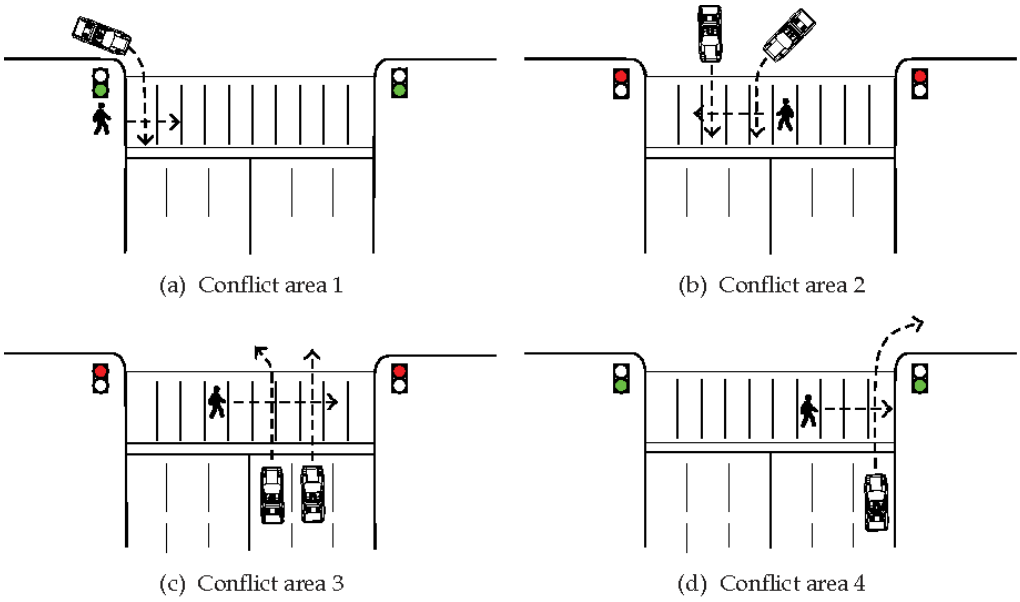


Figure 1: Conflict between Pedestrian and motorist at Signalized Intersection (2).

For right-turning conflicts ((a) & (d)), the motorists tend to turn just as the pedestrian is stepping off the curb into the crosswalk. In response, the pedestrians usually stop midway and give right-of-way to the turning vehicle or, wait for any gestures by the drivers to continue the crossing. Whereas, the motorist usually reacts by a sudden stop or swerving around the pedestrian to complete the turning action. In case of permissive left-turn conflicts ((b) & (c)), motorists tend to follow the overhead signal and execute the turning movement without noticing the pedestrians on the far side. The reactive response of both pedestrian and driver in this case is similar to that of right-turn conflict. Through conflict between traffic and pedestrian generally arises when the traffic traverses the intersection at the last moment of the green phase and faces the pedestrian over

the crosswalk at the through approach. In this situation, the motorist either slows down to yield or speeds up to move through any gap among the crossing pedestrians. In other scenarios such as Figure 1 (b) & (c), the conflicts arise due to the violation of pedestrian signal by pedestrians, crossing indiscriminately without any regard for the signal phase.

To address these safety issues at signalized intersections, California Department of Transportation (Caltrans) suggested a prototype device to enhance the pedestrian signal indications with a ring of yellow LEDs border that will activate when the call button is pushed. The purpose of the additional lights is to serve as a quick visual cue for the motorists engaged in turning maneuver to observe for the pedestrians entering a crosswalk on the near-side or far-side. The LED border concept works as an additional feature with the existing pedestrian facilities to inform motorists and pedestrians that the WALK symbol is pending. In this system, the yellow border will turn on and remain lit until the end of the pedestrian WALK phase. The border will turn off once the WALK symbol switches to countdown initiation and after that the signal will only display the red hand until the call button is pushed. Notably, the yellow border will be activated for the two pedestrian signal heads of the specific crosswalk once the call button is pushed by a pedestrian on any one side of the intersection.

Figure 2: Working Cycle of the Yellow LED Border Pedestrian Signal

The yellow pedestrian border (YPB) operates as an actuated system once the call button is pushed, thus providing confirmation to the pedestrians that the signal has received the call. This feature is similar to the Accessible Pedestrian Signal (APS) systems that consist of a single LED or audible information to relay the confirmation. However, the presence of a LED light on the pedestrian signal may relay more insightful information to the pedestrian compared to the small LED indication of APS and/or audible tone from the push button device.

Since the yellow LED border indicates that the crosswalk signal is pending after pressing the call button, pedestrians are more likely to wait for rather than violate the signal. Vehicles traversing the intersection will notice the LED border more and know that there are Pedestrians waiting on the far-side or near-side of the crosswalk. Also, because the yellow LED border is an indicator of the push button, pedestrians will push the button fewer times. Moreover, it would provide improved service to pedestrians using the facility and reduced wear on the call buttons.

Results from a previous experiment at Distirct-2, Caltrans *(1)* showed that the proposed LED border provide greater confidence to the pedestrians about successful signal call and pending WALK phase. This action would most likely lower the surprise moments between pedestrians and vehicles, resulting in better yielding behavior from both road users. As noted earlier in different type of conflicts, traffic negotiating a right or permissive left turn at an intersection will have the information beforehand that the WALK symbol is pending either from the near or far-side of the crosswalk and proceed with more caution. Notably, the YPB may also address the common problem of pedestrian compliance by relaying confirmation of the call button, since some pedestrians may become impatient and search for an opportunity to cross before the WALK indication is visual.

This study is carried out following the 2014 Distirct-2 study with a goal to evaluate the anticipated benefit of the YPB signal in a more diverse urban and suburban setting with five different locations around California. The study aims to determine whether the additional feature to the traditional pedestrian signal provides an overall benefit to both vehicular traffic and pedestrians, resulting in improved interaction between vehicles and pedestrians at intersection. The improvement is measured and tested by comparing different type of conflicts, violation, and extra-push events for before and after YPB installation.

PRIMARY DATA REVIEW

The primary data items considered in this study is described briefly in this section.

Vehicle Pedestrian Conflicts

Conflicts between pedestrians and turning (right or left) traffic arise at intersections, since crosswalks parallel to moving vehicular traffic are served simultaneously. Different types of conflicts and possible responses of pedestrians or motorists have been noted in the previous section. ***A conflict was recorded when either a motorist or pedestrian yielded to give the right-of-way.*** This study focuses on the conflicts relevant to the pedestrians and denotes the conflicts into three segments considering the movement direction of the motorist, **(i) right-turn conflict; (ii) left-turn conflict, (iii) through conflict.**

Yielding is the consequence of the conflict situation, where any of the interacting entities either pedestrian or motorist must stop and give the right-of-way to avoid imminent crash. Thus, **yielding data** for this study was recorded in two parts, (i) **pedestrian yielding**; (ii) **motorist yielding**.

Extra call button push

Call button push provides a way to ensure pedestrian compliance since it provides assurance to the pedestrian that the signal has been called for. However, longer waiting period and absence of any visual or audible feedback may prompt pedestrians to push the call button multiple times. In some cases, the same call button is pushed by multiple pedestrians during the same crossing phase for reassurance that the pedestrian signal is called. These actions reduce the service life of the call button. Compared to the Accessible Pedestrian Signal (APS) and other systems, the addition of YPB provides a continuous visual indication of the forthcoming WALK phase that will encourage pedestrians to push the button fewer times, which in turn will ensure improved service and reduced wear. For this reason, the extra call button pushes were considered a relevant data item for the study of before and after condition. However, distance form the camera, partial obstruction made it difficult to record all the extra push events accurately.

No call button Push

The video data showed that the crossing for most of the pedestrians on the minor approach crosswalks at different locations without pushing the call button was a common event. Since the locations are major-minor connecting type, the pedestrian signal time is more available for the two crosswalks across the minor approach compared to the major approach. For this reason, most of the residents in the area do not seem to push the call button for the pedestrian signal while crossing these crosswalks. Also, in some cases pedestrians crossed the road seeing other pedestrians crossing the other crosswalk on the other side of the major approach in parallel without pushing the call button. On that note these crossing events are not normal, yet out of the range of pedestrian phase violation, thus recorded as no-push event. For this reason, the crossing without pushing call button was considered a relevant data item for the study of before and after condition and recorded as no-push event.

Violation

Violation of any type of signal either traffic or pedestrian engenders a critical scenario where any potential conflict may result in a crash, since the motorist or pedestrian is eager to cross the intersection without following the traffic rules and guidelines. Violations by both pedestrians and motorists at the study locations were recorded.

Pedestrian Questionnaire Survey

A questionnaire survey for the pedestrians was carried out at the study locations to understand the impact of YPB. The survey consists of 5-questions with a point scale ranging from 1-5 adopted from the previous study at District 2, Caltrans. The five questions were based on five attributes of

the experimental pedestrian signal: (i) visibility; (ii) reliability; (iii) ensure compliance; (iv) conflicting resolution; and (v) safety. Details of the survey questions and results are presented afterwards.

STUDY LOCATIONS

Previously the experimental devices were tested at five locations of District 2, Caltrans. Now the devices are tested five different locations around California. The locations are enumerated as follows.

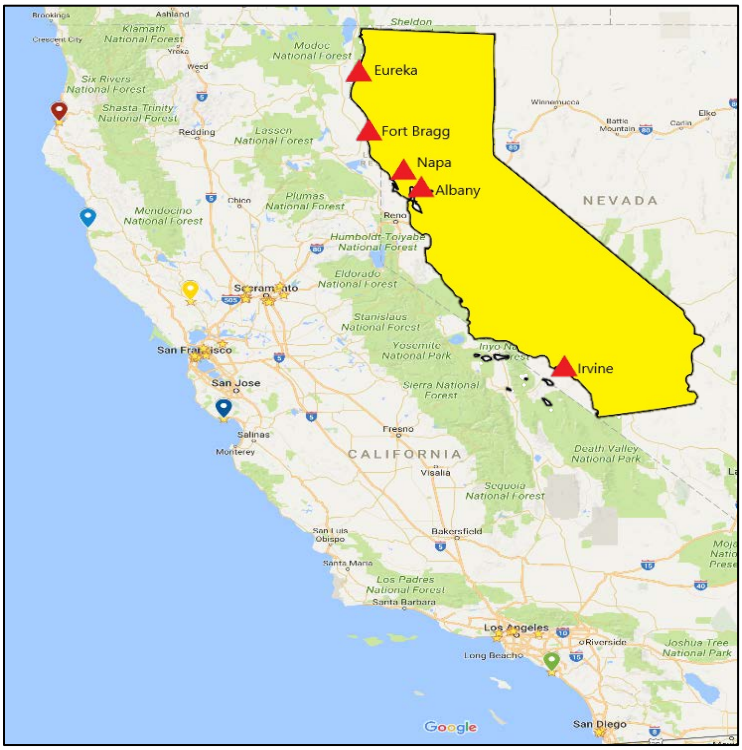


Figure 3: Experimental Locations around California

Table- 1: Experimental Locations for Yellow Pedestrian Border

Location No.	Caltrans District	County	Intersection
1	4	Napa County	(SR-29) Mains St. / Adams St. (Napa Valley)
2	1	Humbolt County	W 14 St. / Redwood Hwy (SR-101) (Eureka)
3	1	Mendocino County	Redwood Ave / Main St. (Fort Bragg)
4	12	Orange County	Coast Hwy (SR-1) / Broadway (Laguna Beach)
5	4	Alameda County	Fairmount / Sao Paolo Avenue (R123) (Albany)

All these locations are operated and maintained by Caltrans. Further discussion and specifics about each location is provided in next section of the report.

For data collection each of the listed locations was observed for before and after condition using digital video recording equipment. The before condition refers to the regular scenario without the installed yellow LED border on the pedestrian signal. Considering the movement period of the pedestrians, 16-hours of data (*6:00 AM – 10:00 PM*) was recorded for each of the observed days. Data from seven consecutive days are reported for the before condition and another seven consecutive days are reported for the after condition for each respective location.

A learning period of at least two weeks was established in between the recording of before and after condition for the pedestrians and motorists. The after-condition data was collected when the road users have had enough opportunity to observe the function and purpose of the installed YPB modules. The length of the learning period varied from location to location due to weather, holidays, and installation schedule of the modules.

Location 1: Adams St. / Mains St.

The first study location was the intersection of Adams Street and Mains Street (*Figure 4*) at Napa County. The traffic signal at this intersection is operated and maintained by District 4, Caltrans. This is a major-minor type intersection where Adams St. serves as the minor connection. The major approach consists of four lanes both way and protected left-turns for the traversing traffic. Whereas the minor street consists of two lanes for both way traffic. The intersection has four crosswalks connecting every corner of the road. Since the intersection is a major-minor connecting type, the pedestrian signal time is more available for the two crosswalks across the Adams Street (minor) compared to that on the Main Street (major). A gas station is located at the north corner of the intersection and the other three corners consist of clothing shops, bank, and random shops; attracting fair volume of pedestrians.

A Wi-Fi camera setup was used to record the video data for the before and after condition at the location. The cameras were mounted on the mast of the traffic signal pole and powered through the controller cabinet. The video recording equipment including DVR unit, power units, wireless signal receiver, internet modem was housed in the signal controller cabinet during the entire study period. The detail schematics of the camera installation process and mounting location is presented in the camera installation section. The cameras for this location were setup in such way that each of the four crosswalks was covered through a camera. Detailed schematic drawing of the location is provided in the data analysis section.

The video data for the before condition were collected for more than four weeks at the intersection and from that pool of data seven consecutive days were selected for analysis.

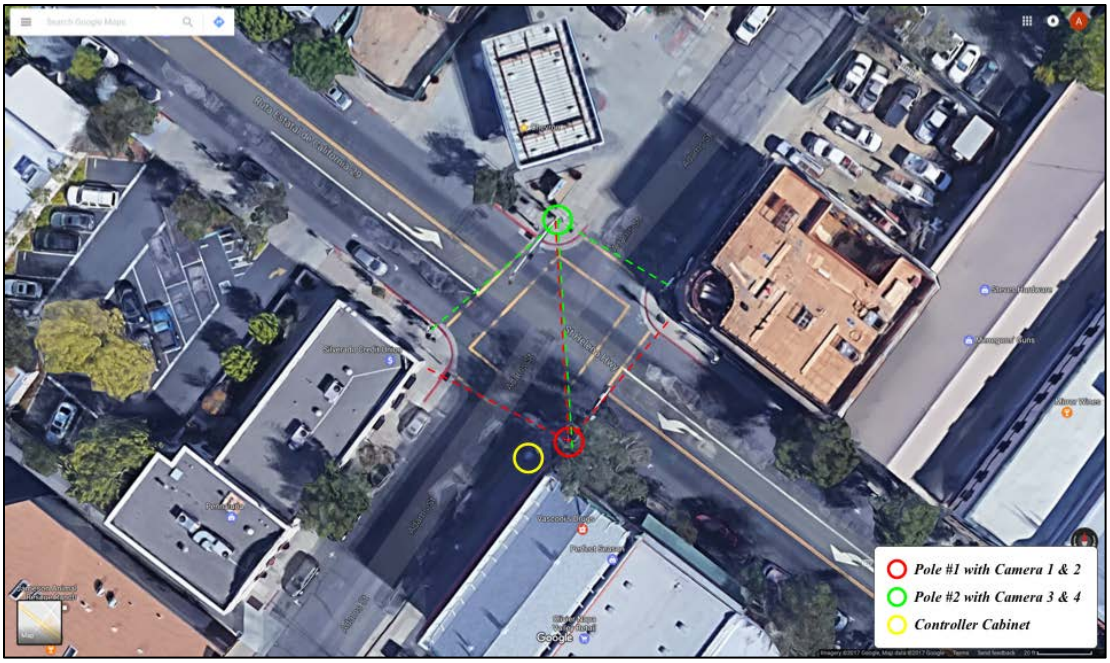


Figure 4: Intersection of Adams Street / Mains Street, Napa County, District 4, Caltrans

The adaptation period is an important part of the experimental process to understand the operation and purpose of the YPB modules. In general, it was planned to install the YPB and wait for at least four weeks to get the pedestrians accommodated with this new feature installed in the pedestrian signal before starting with the after-condition study. In this case the learning period was about five weeks. After which the after study was initiated.

Though the cameras were fitted to appropriate vantage points such as traffic signal poles to capture the full width of the corresponding crosswalks, the observation of the extra-push events were much limited. This limitation was attributed to the distance, locations, and visibility of the push button in terms of camera position.

Location 2: West 14 St. / Redwood Hwy (SR-101)

The second study location was the intersection of West 14th Street and Redwood Highway (SR-101) (Figure 5) at Eureka, Humbolt County. The traffic signal at this intersection is operated and maintained by District 1, Caltrans. The Redwood Hwy approach consists of five lanes both way including a protected left-turn for the traversing traffic. The West 14th Street consists of four lanes for both way traffic with a protected left-turn. The intersection has four crosswalks connecting every corner of the road. A gas station is located at the southeast corner of the intersection and the other three corners consist of automotive shop, restaurant, and parking space; attracting fair volume of pedestrians. The geometric feature of the second location was different from the first one, thus the pedestrian crossing phase was longer (25 seconds).

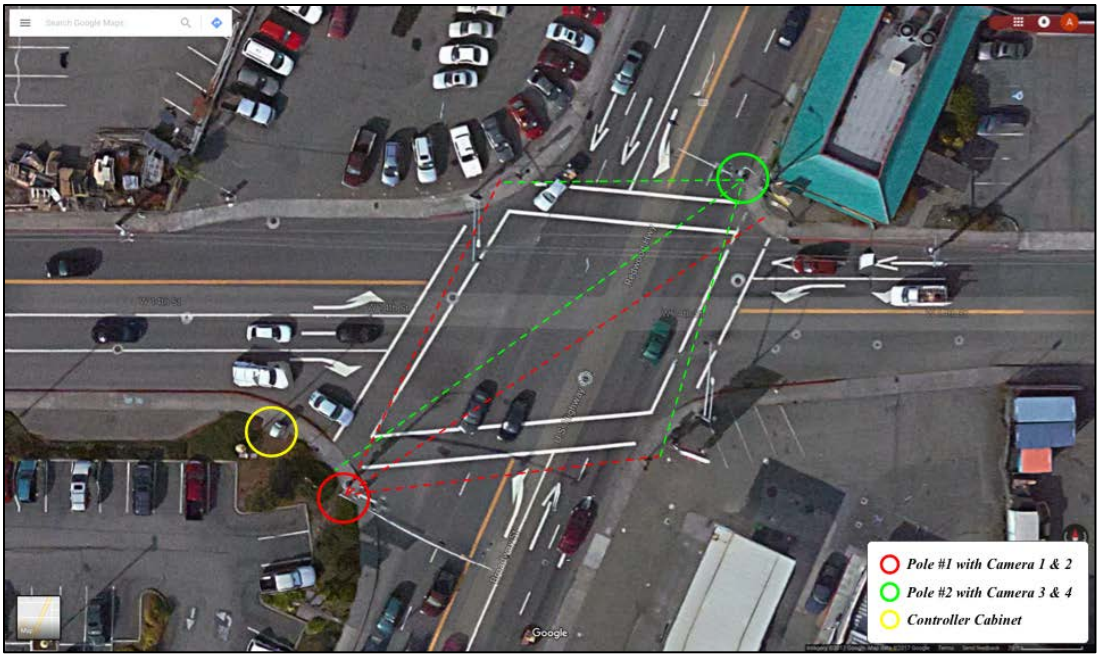


Figure 5: Intersection of West 14 St. / Redwood Hwy (SR-101), Eureka, Humbolt County, District 1, Caltrans

A Wi-Fi camera setup was used to record the video data for the before and after condition at the location. The cameras were mounted on the mast of the traffic signal pole and powered through the controller cabinet. The video recording equipment including DVR unit, power units, wireless signal receiver, internet modem was housed in the signal controller cabinet during the entire study period. The detail schematics of the camera installation process and mounting location is presented in the camera installation section. The cameras for this location were setup in such way that each of the four crosswalks was covered through a camera.

Since, the adaptation period is an important part of the experimental process to understand the operation and purpose of the YPB modules, it was planned to provide at least four weeks before the after-condition study. However, due to schedule delay and travelling, the learning period was shortened to two weeks before the after-condition study was initiated.

Though the cameras were fitted to appropriate vantage points such as traffic signal poles to capture the full width of the corresponding crosswalks, the observation of the extra-push events were much limited. This limitation was attributed to the distance, locations, and visibility of the push button in terms of camera position.

Location 3: Redwood Ave / Main St.

The third study location was the intersection of Redwood Avenue / Main St. (Figure 6) at Fort Bragg, Mendocino County. The traffic signal at this intersection is operated and maintained by District 1, Caltrans. The Redwood Hwy approach consists of five lanes both ways including a

protected left-turn for the traversing traffic. The West 14th Street approach consists of four lanes for both way traffic with a protected left-turn. The intersection consists of four crosswalks connecting every corner of the road. A gas station is located at the southeast corner of the intersection and the other three corners consist of automotive shop, restaurant, and parking space; attracting fair volume of pedestrians. The geometric feature of the second location was different from the first one and the crosswalk was much longer in length, thus the pedestrian crossing phase was longer (25 seconds).

Similar wireless camera equipment was used to record the video data for the before and after condition. The cameras were mounted on the mast of the traffic signal pole and powered through the additional power-unit from the external light source. The additional video recording instruments as noted earlier for other locations, were housed in the signal controller cabinet during the entire study period. The detail schematics of the camera installation process and mounting location is presented in the camera installation section. Though the cameras were setup in such way that each of the four crosswalks was covered, the signal interruption of the video feed resulted from the distance and steel construction of the controller cabinet. For this reason some of the video data was not continuous throughout the recorded days. In these instances, other camera channels with quality video feed were used to cover the lapse.

Since, the adaptation period is an important part of the experimental process to understand the operation and purpose of the YPB modules, it was planned to provide at least four weeks before the after-condition study. However, due to schedule delay and travelling issues, the learning period was shortened to two weeks before the after-condition study was initiated.

For this location, though the cameras were fitted to appropriate vantage points such as traffic signal poles to capture the full width of the corresponding crosswalks, the observation of the extra-push events were much limited. This limitation can be attributed to the distance, locations, and visibility of the push button from the camera position. The video data for the before condition were collected for more than three weeks at the intersection and from that pool of data seven consecutive days were selected for analysis. Similarly, data from two consecutive weeks was recorded for the after-condition study and from that data pool seven consecutive days were selected for analysis.

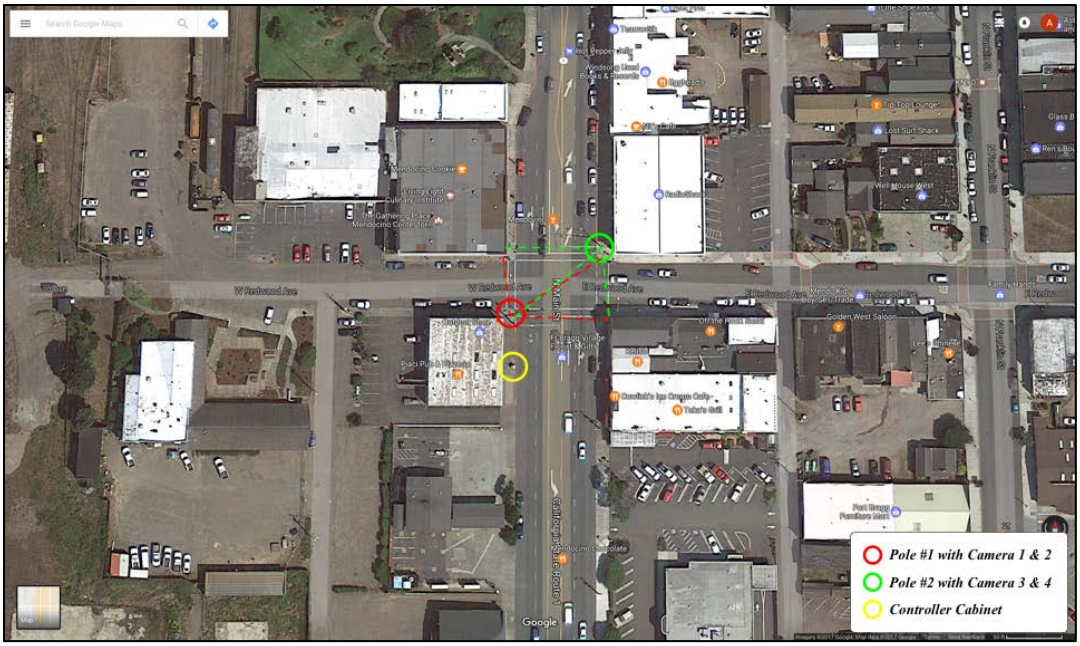


Figure 6: Intersection of West 14 St. / Redwood Hwy (SR-101), Fort Bragg, Humbolt County, District 1, Caltrans

Location 4: Coast Hwy (SR-1) / Broadway Street

The fourth study location was the intersection of Coast Hwy (SR-1) / Broadway Street (*Figure 7*) at Laguna Beach, Orange County. The traffic signal at this intersection is operated and maintained by District 12, Caltrans. The study location is a T-intersection connecting the state highway (SR-1) with the Broadway street at Laguna Beach. For this reason, the traffic volume traversing the intersection is quite high compared to other study locations. Moreover, being a tourist attraction point the two crosswalks served much higher volume of pedestrians. The SR-1 Hwy approach consists of five lanes both ways including a protected left-turn for the traversing traffic. Similarly, the Broadway Street approach consists of five lanes for both way traffic with a protected left-turn. The intersection consists of two crosswalks connecting three corners of the T-intersection. A gas station is located at the northwest corner of the intersection and the other two corners consist of restaurants, and the beach; attracting high volume of pedestrians.

As noted for the previous locations, a Wi-Fi camera setup was used to record the video data for the before and after condition at the location. The cameras were mounted on the mast of the traffic signal pole and powered through the additional power-unit from the external light source. The video recording equipment including DVR unit, power surge unit, wireless signal receiver, internet modem was housed in the signal controller cabinet during the entire study period. The detail schematics of the camera installation process and mounting location is presented in the camera installation section.

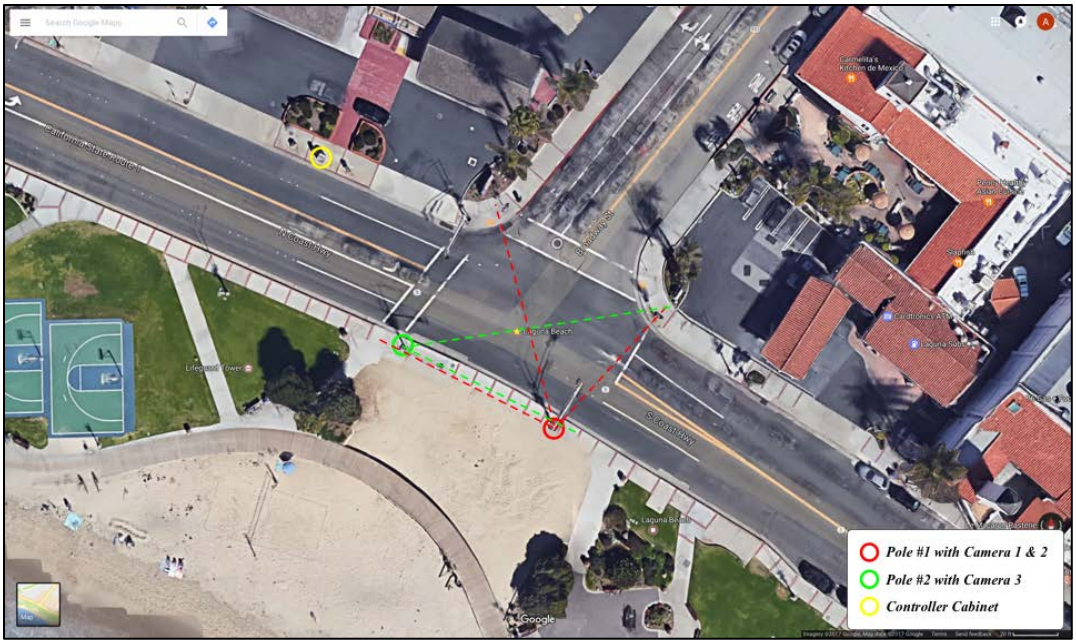


Figure 7: Coast Highway (SR-1) / Broadway Street, Laguna Beach Intersection, Orange County, District 12, Caltrans

Though the adaptation period is an important part of the experimental process to understand the operation and purpose of the YPB modules, only two weeks period was provided for this location due to schedule delay and travelling issues.

The cameras were fitted to traffic signal poles to capture the full width of the corresponding crosswalks. However, the observation of the extra-push events was limited due to the distance, locations, and high volume of pedestrians obstructing the visibility of the push button from the camera position. The video data for the before condition were collected for two weeks at the intersection and from that pool of data seven consecutive days were selected for analysis. Similarly, data from two consecutive weeks was recorded for the after-condition study and seven consecutive days were used for the analysis.

Location 5: Fairmount / Sao Paolo Avenue (R123)

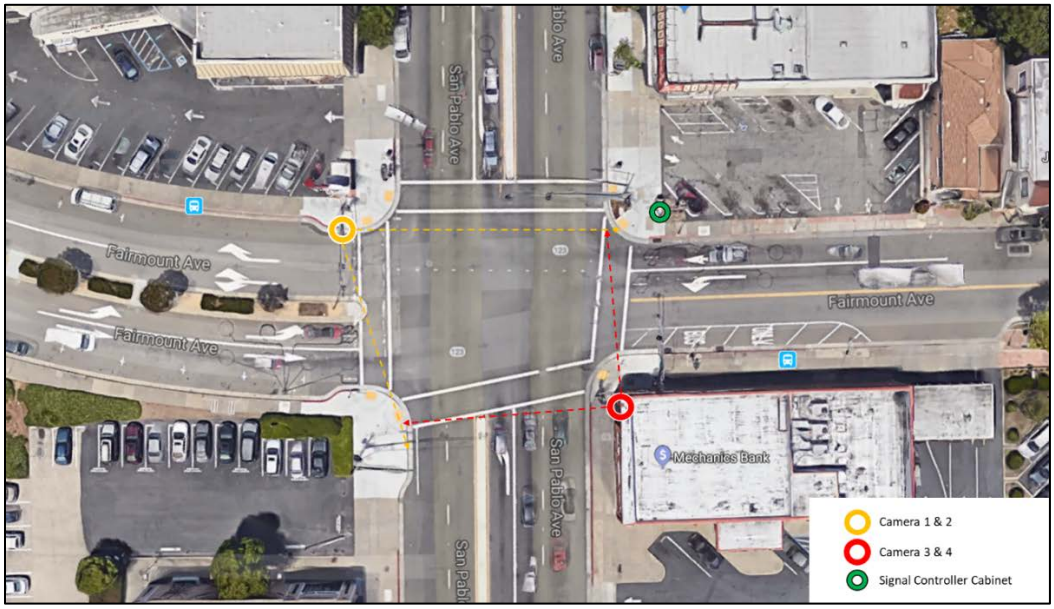


Figure 8: San Pablo Avenue (SR-123) / Fairmount Avenue, Albany, District 4, Caltrans

The fifth study location was the intersection of San Pablo Avenue / Fairmount Avenue *(Figure 8)* at Albany. The traffic signal at this intersection is operated and maintained by District 4, Caltrans. The study location was a four-way intersection connecting the state highway (SR-123) with the Fairmount Avenue at Albany. The SR-123 Hwy approach consists of five lanes both ways including a protected left-turn for the traversing traffic. Similarly, the Fairmount Avenue approach consists of four lanes for both way traffic with a protected left-turn. The intersection consists of four crosswalks connecting all four corners of the intersection. A bank is located at the northeast corner of the intersection and the other corners consist of restaurants, and shops, attracting moderate volume of pedestrians.

As noted for the previous locations, a Wi-Fi camera setup was used to record the video data for the before and after condition at the location. The cameras were mounted on the mast of the traffic signal pole and powered through the additional power-unit from the external light source. The video recording equipment including DVR unit, power surge unit, wireless signal receiver, internet modem was housed in the signal controller cabinet during the entire study period. The detail schematics of the camera installation process and mounting location is presented in the camera installation section.

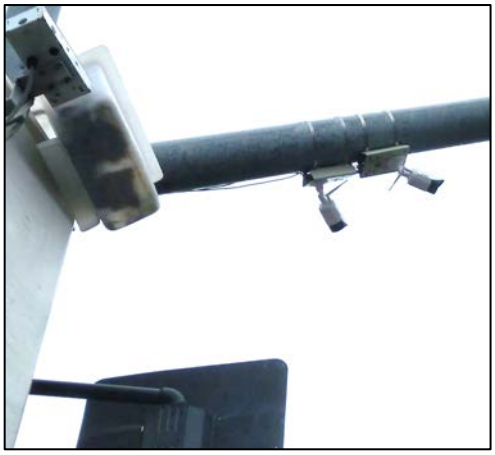
Though the adaptation period is an important part of the experimental process to understand the operation and purpose of the YPB modules, only two weeks period was provided for this location due to schedule delay and travelling issues. For video recording, cameras were fitted to traffic signal poles to capture the full width of the corresponding crosswalks. However, the observation of the extra-push events was limited due to the distance, locations, and high volume of pedestrians

obstructing the visibility of the push button from the camera position. The video data for the before condition were collected for two weeks at the intersection and from that pool of data seven consecutive days were selected for analysis. Similarly, data from two consecutive weeks was recorded for the after-condition study and seven consecutive days were used for the analysis. Further detail on the recorded data is provided in the data analysis section.

EQUIPMENT INSTALLATION

Camera Installation

The camera installation process for this study involved three different steps: (i) wire installation; (ii) Power installation; and (iii) Camera installation. The most common installation point for the cameras were the signal poles or light poles on the corners of the intersections. For installation on the Signal poles the cameras were mounted on the mast or arm of the pole and positioned to cover the entire width of the studied crosswalk. In some instances, two cameras were mounted on the same signal pole focusing different crosswalks to make use of the height and distance. Also, because some intersections had two large signal poles with adequate height for the cameras for major-minor type connection such as Location 1 (Napa Valley).



(a)

(b)

Figure 9 ((a) & (b)): Two types of Camera position on the Signal Pole Mast

Schematic drawing of the camera location for a typical four-legged intersection is presented in *Figure 10*. The figure shows the situation where each camera was installed at each of the signal poles to cover the entire width of the crosswalks.

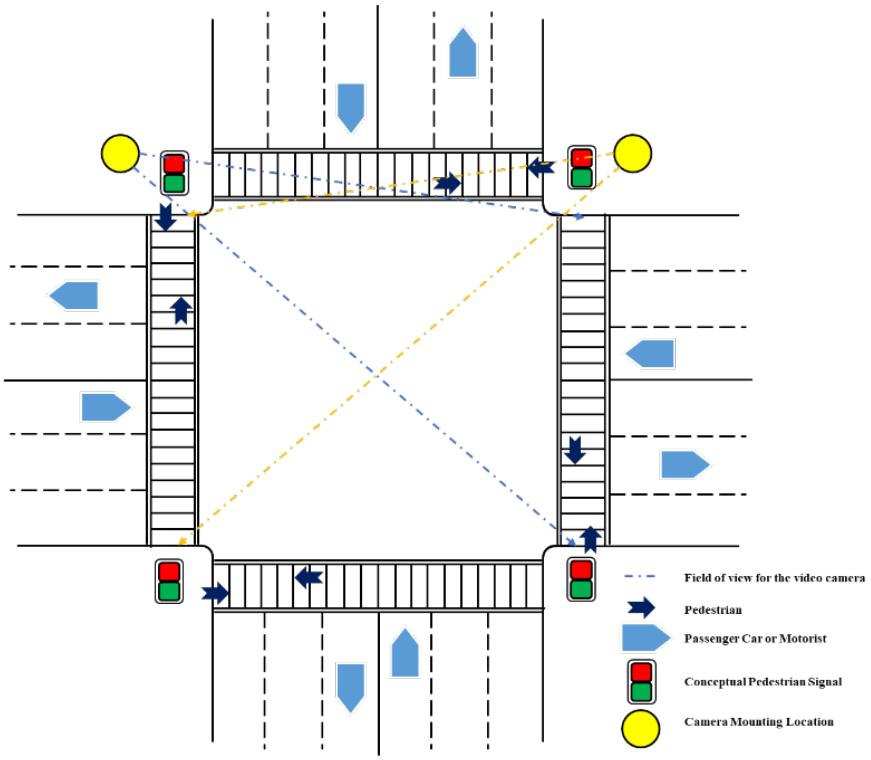
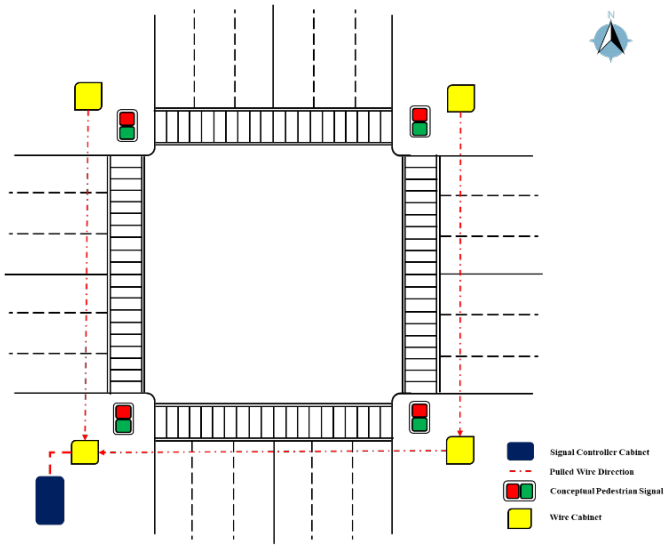


Figure 10: Schematic Drawing of Cameras Mounted on Signal Pole

The wire installation process involves pulling the wire through the wire cabinet at each corner of the intersection where the camera was installed. Four sets of camera installation involved four distinct wires pulled through the wire cabinet towards the signal controller box where the power sources were housed.

(a) Wire Cabinet beside the Signal Pole



(b) Schematic Drawing of the Wire Cabinets at a Typical Four-way Intersection

(c) Drilling hole in the small wire box on the signal pole

(d) Installing camera on the signal pole mast

Figure 11: Wire Installation and Camera Mounting on the Signal Pole

The power source (Power-surge), video recording DVR, wireless signal receiver, and internet modem were placed in the signal controller cabinet for all the study locations. Notably, the Wi-Fi signal strength of the cameras were interrupted and weakened due to the distance from the mounting location and the steel structure of the cabinet.

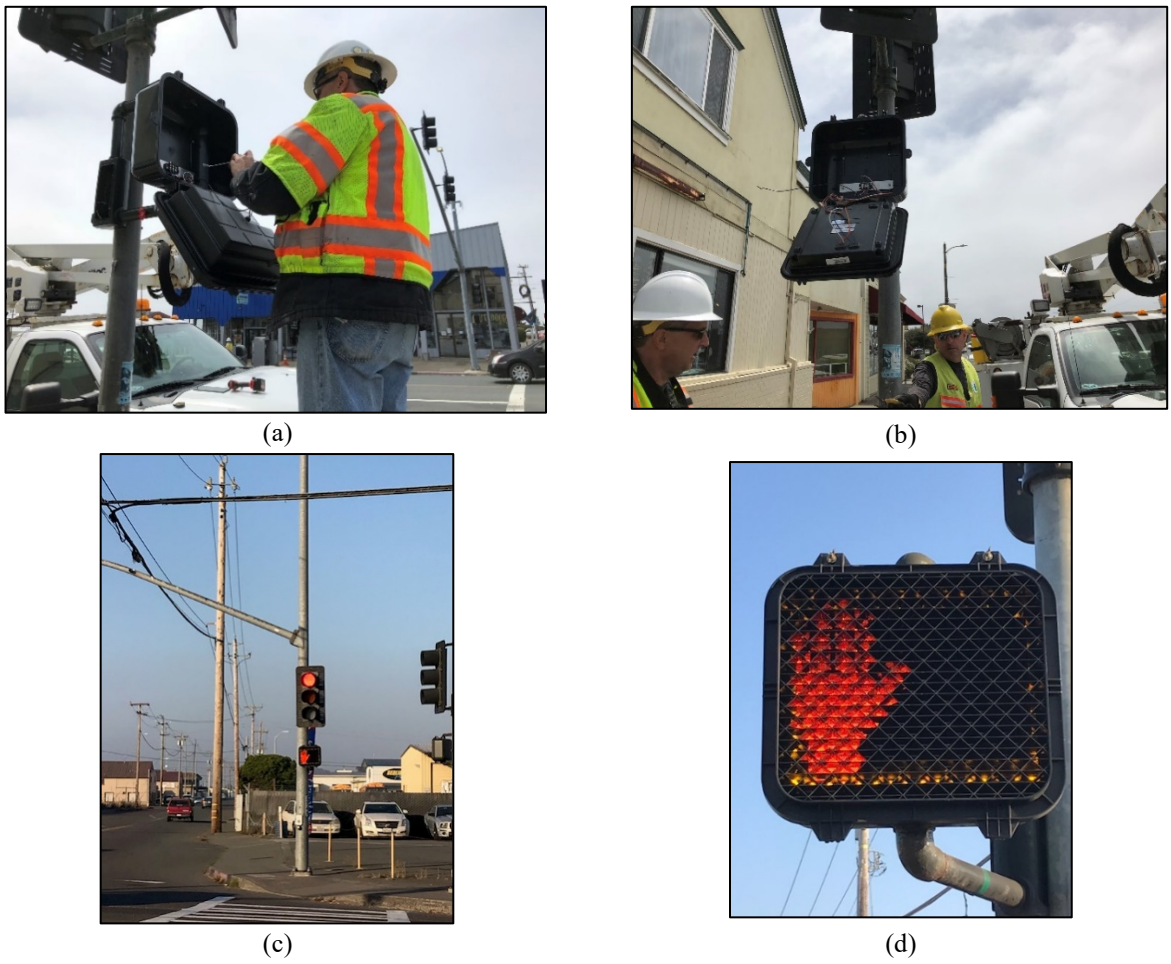
(a)

(b)

Figure 12 (a)-(b): Typical arrangement of the equipment housed inside the Signal Controller cabinet to provide power for the cameras and other devices

Forty prototype YPB modules were manufactured to conduct the evaluations at five intersections. In most of the study locations, the modules were setup during the camera installation or in the same week and the yellow LED border feature were turned off during the before condition study period. The YPB modules were installed by the electrical maintenance team of Caltrans Districts 1, 4, and 12.

Yellow Pedestrian Border Installation



(a) (b)

(c) (d)

Figure 13 (a-d): Typical installation of the YPB modules at the study locations by the Caltrans Maintenance team

DATA ANALYSIS

The critical part of data analysis involves the methodology of the data recording process. The events data (such as conflicts, violations, pushes) from the video cameras are recorded in Excel format to account for the detail movement patterns of the vehicular and pedestrian traffic. Description of the summary data for each of the corresponding location is provided in the Appendices. Primary data analysis items for the study locations are described briefly in the following passages.

The critical right-turn or left-turn volume represents the relevant turning volume where the conflicts between pedestrian and vehicle occurred predominantly in that intersection. For a four-legged intersection, there are eight left and right turns, among which relevant 4 or 6 turns were

selected. Thus, the critical turning volume only represents a volume relevant to the recorded conflict.

The hourly distribution of the relevant turning volumes was recorded for most of the locations except for location 4 and location 5 due to time and labor constraints and large volume of traffic traversing through the state highway.

Key to anticipating pedestrian conflict potential is pedestrian volume, which serves as the exposure term. For instance, an intersection with zero pedestrian crashes over a given period is not a representative sample for pedestrian safety analysis *(3)*. For this reason, **a ratio between number of conflicts and pedestrian volume of the study locations is adopted in this study**. This ratio highlights the relationship between the crossing pedestrians and conflict number, representing the vulnerability of the pedestrians for the study location.

Additionally, since the study by National Cooperative Highway Research Program (NCHRP) listed traffic volume (turning movement count) and pedestrian volume as potential pedestrian crash risk variables for intersection analysis, **the conflict ratio between number of conflicts and critical turning volume is used to draw comparison between before and after condition** *(4)*. For instance, there are eight turning movements including left-turn and right-turn in a typical four-legged intersection. However, for any intersection all the turning movement do not contribute to the recorded conflicts. For instance, out of the four right-turn movement, two or three turns may result in majority of the right-turn conflict for a location. Similarly, out of the four left-turn movements, one or two turns may reflect majority of the left-turn conflicts. Thus, including all the turning movements in calculating the ratio between conflict count (right, left, or through) and traffic volume (left, right, or through) may understate the actual major conflict type (left or right). Thus, the left-turn or right-turn conflict ratio termed in this study is the ratio of critical and relevant left or right turning traffic volume with respect to the recorded left-turn or right-turn conflicts.

Statistical Data Items

Mean: Mean of a variable represent the value when the summation of all observations of that variable is divided by the total number of observations.

Median: Median reflects the actual observation value exactly from the middle of the observations for a variable.

Standard Deviation: Standard deviation or SD of a variable is the measure of dispersion of a set of observations from the mean of that variable. SD measures the absolute variability of a distribution, where higher dispersion shows greater value of SD and higher magnitude of deviation of the value from the mean.

Minimum: Minimum value shows the lowest value among the observations of a variable.

Maximum: Maximum value shows the highest value among the observations of a variable.

Range: Range defines the difference between the maximum and minimum value of the observations for a variable.

Standard Error: Standard Error or SE of a variable represents the square of the deviation of each observation from the mean of the entire data sample of that variable.

Density Distribution: Density plot shows the distribution of data over a continuous interval or time period, where the peaks of the plot display the position where values are concentrated over the interval. The density chart type used in this report is a variation of a Histogram that uses kernel smoothing to plot values, allowing for smoother distributions by smoothing out the noise. This is because Density Plots are better at determining the distribution shape because they are not affected by the number of bins used in a Histogram. For instance, a Histogram comprising of only 4 bins would not produce a distinguishable enough shape of distribution as a 20-bin Histogram would. However, with Density Plots, this is not a considerable issue.

Location 1: Adams St. / Mains St. (Napa)

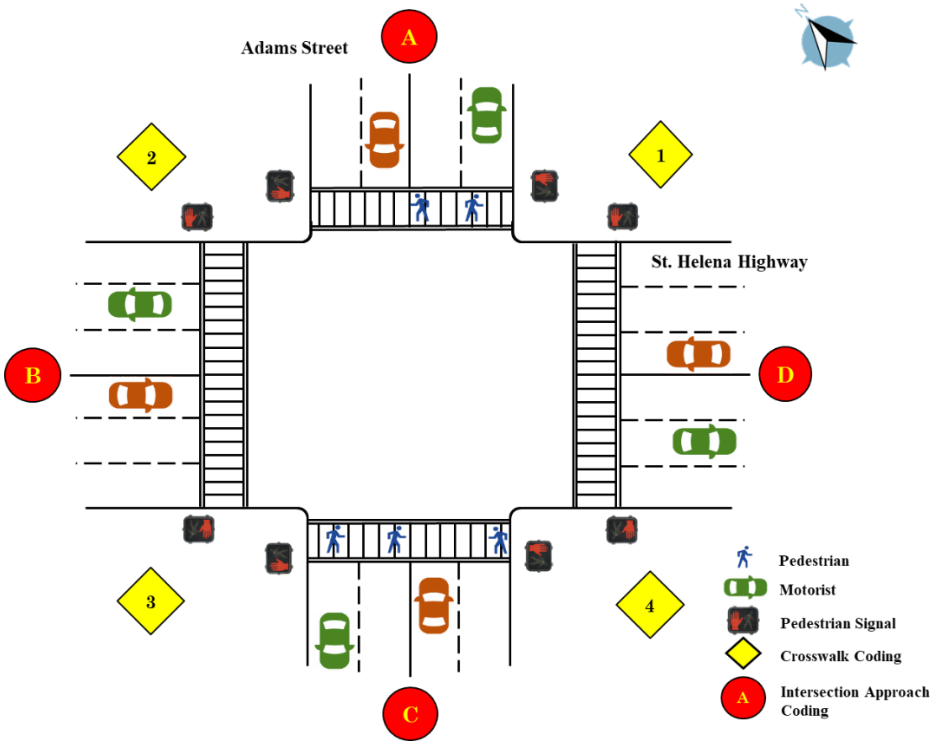


Figure 14: Schematic Coding of Location 1: Adams St. / Mains St., Napa County for Data Recording

The video data for the before-condition was collected for seven consecutive days, from December 18-24, 2017. The YPB modules were installed later November 2017 and turned on July 2018. The

learning period was about eight weeks for the motorists and pedestrians to become accustomed with the new feature of the installed YPB modules. The after-condition video data was recorded from September 2-8, 2018.

Table- 2: Before Condition Summary of Location 1 from December 18-24, 2017

BEFORE	12/18/2017	12/19/2017	12/20/2017	12/21/2017	12/22/2017	12/23/2017	12/24/2017	Sum
Pedestrian Violation	130	77	98	90	115	282	117	909
Vehicle Violation	0	0	1	1	2	1	1	6
Total Violation	130	77	99	91	117	283	118	915
Extra Push	6	24	10	3	6	10	2	61
No-Push	89	96	131	120	104	314	142	996
Left-turn Conflict	230	247	293	180	171	169	83	1373
Right-turn Conflict	161	184	187	116	147	184	86	1065
Through Conflict	1	2	5	0	1	1	0	10
Total Conflict	392	433	485	296	319	354	169	2448
Pedestrian Yield	13	14	22	27	38	25	15	154
Vehicle Yield	380	420	464	269	283	332	154	2302
Critical Left-turn Veh Vol	1070	1254	1254	1242	1315	866	685	7686
Critical Right-turn Veh Vol	1681	1740	1771	1670	1892	1476	1336	11566
Total Ped Vol	2366	2118	2177	2408	2718	3275	2219	17281

The summary results of the before condition shows that there were few vehicle violations compared to pedestrians and majority of the motorists involved in a conflict with the pedestrians yielded to give the right-of-way. For the statistical analysis, the minimum, maximum, and range depict the statistical values **within the hourly distribution** of the recorded days. This means that the maximum and minimum statistics shows the highest and lowest value recorded in an hour of the observation period, whereas the range suggest the difference between the max and minimum value for that hour. For instance, maximum number of pedestrians recorded for an hour of the before condition was 592.

Table 3: Statistical Summary of Before Condition of Location 1 from December 18-24, 2017

BEFORE	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	8.1160714	8.1326231	7.0	0	44	44	0.7684607
Vehicle Violation	0.0535714	0.2261820	0.0	0	1	1	0.0213722
Total Violation	8.1696429	8.1272408	7.0	0	44	44	0.7679521
Extra Push	0.5446429	1.1459949	0.0	0	6	6	0.1082863
No-Push	8.8928571	7.8158503	7.0	0	40	40	0.7385284
Left-turn Conflict	12.2589286	11.8798380	9.0	0	40	40	1.1225392

Right-turn Conflict	9.5089286	9.6216681	5.5	0	34	34	0.9091622
Through Conflict	0.0892857	0.3925792	0.0	0	3	3	0.0370952
Total Conflict	21.8571429	20.7784786	14.5	0	66	66	1.9633817
Pedestrian Yield	1.3750000	1.9130891	0.5	0	8	8	0.1807699
Vehicle Yield	20.5535714	19.6380947	14.0	0	62	62	1.8556255
Critical Left-turn Veh Vol	68.6250000	39.2437807	70.5	7	149	142	3.7081887
Critical Right-turn Veh Vol	103.2678571	48.5356713	111.0	8	201	193	4.5861899
Total Pedestrian Vol	154.2946429	140.5728075	107.0	3	595	592	13.2828818

Table- 4: After Condition Summary of Location 1 from September 2-8, 2018

AFTER	9/2/2018	9/3/2018	9/4/2018	9/5/2018	9/6/2018	9/7/2018	9/8/2018	Sum
Pedestrian Violation	98	56	36	23	28	32	49	322
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	98	56	36	23	28	32	49	322
Extra Push	6	5	21	16	5	11	12	76
No-Push	136	99	53	44	32	32	79	475
Left-turn Conflict	108	80	41	63	83	69	94	538
Right-turn Conflict	88	52	24	34	35	56	72	361
Through Conflict	0	0	1	3	2	1	4	11
Total Conflict	196	132	66	100	120	126	170	910
Pedestrian Yield	20	18	2	3	2	1	2	48
Vehicle Yield	176	114	64	97	118	126	168	863
Critical Left-turn Veh Vol	690	683	1111	742	726	703	694	5349
Critical Right-turn Veh Vol	1200	1009	1763	1288	1175	1385	1147	8967
Total Pedestrian Vol	4373	2806	1036	1284	1311	1943	2357	15110

The summary results of the after condition shows that there were no violations related to vehicle and majority of the motorists involved in a conflict with the pedestrians yielded to give the right-of-way. The results showed that the left-turn conflict is slightly higher than the right-turn conflict and the number of recorded through conflict is minimal.

The statistical summary of the after condition shows that there is a moderate difference (19.3846) in the mean of the recoded pedestrian volume with the before condition. Both the dataset from before and after condition has very high SD compared to other locations. For this reason, the distribution of the pedestrian volume data points is spread out over a large range of values.

Table- 5: Statistical Summary of After Condition of Location 1 from September 2-8, 2018

AFTER	MEAN	SD*	MEDIAN	MIN	MAX	RANGE	SE*

Pedestrian Violation	2.8750000	2.7774024	2.0	0	12	12	0.2624399
Vehicle Violation	0.0000000	0.0000000	0.0	0	0	0	0.0000000
Total Violation	2.8750000	2.7774024	2.0	0	12	12	0.2624399
Extra Push	0.6785714	0.9416708	0.0	0	5	5	0.0889795
No-Push	4.2410714	3.3023211	3.0	0	15	15	0.3120400
Left-turn Conflict	4.8035714	4.5099276	4.0	0	18	18	0.4261481
Right-turn Conflict	3.2232143	3.2981289	2.0	0	17	17	0.3116439
Through Conflict	0.0982143	0.3276952	0.0	0	2	2	0.0309643
Total Conflict	8.1250000	6.9088336	7.0	0	27	27	0.6528234
Pedestrian Yield	0.4285714	0.9464422	0.0	0	5	5	0.0894304
Vehicle Yield	7.7053571	6.4551654	7.0	0	24	24	0.6099558
Critical Left-turn Vehicle Vol	47.7589286	25.5904140	51.0	1	122	121	2.4180668
Critical Right-turn Vehicle Volume	80.0625000	37.0284238	75.0	9	172	163	3.4988572
Total Pedestrian Volume	134.9107143	126.0534388	98.0	5	630	625	11.9109304

The video data showed that the crossing for most of the pedestrians on the minor (Adams St.) approach crosswalks without pushing the call button was a common event. Since the intersection was a major-minor connecting type, the pedestrian signal time is more available for the two crosswalks across the Adams Street (minor) compared to that on the Main Street (major). For this reason, most of the residents in the area do not seem to push the call button for the pedestrian signal while crossing these two crosswalks unlike tourists.

Moreover, in some cases crossing without pushing the call button is observed on the crosswalks at the major approach. In these cases, pedestrians crossed the major crosswalk at the time that is aligned with the pedestrian phase time, without pressing the push button to activate the pedestrian signal. In some of the observed cases pedestrians just crossed the road seeing other pedestrians crossing the other crosswalk on the other side of the major approach in parallel without pushing the call button. On that note, these crossing events are not normal, yet out of the range of pedestrian phase violation, thus recorded as no-push event. For these reasons, the number of no-push events for this location was high for before and after. The number of no-push events recorded during the before condition were 996 for 17,281 pedestrians. Applying this ratio, the expected no-push events during the after condition would be 871. However, the actual recorded number was 475 for the after-condition period, which is a 45.46% decrease. Notably, during the study period, the pedestrian volume gradually went down after evening (7:00 pm) and most of the events recorded were no-push events on the minor crosswalks for the last few hours of the recording window.

In the before-condition, 2,448 conflicts were recorded for 17,281 pedestrians. If this ratio is applied to the number of pedestrians recorded during the after-condition period (15,110), the expected number of conflicts would be 2,140. However, the actual number of conflicts recorded during the after-condition was 910, which is 57.47% lower than expected conflicts of 2,140. These conflicts when compared with the recorded volume of turning vehicles for before (19,252) and after

(14,316) condition also showed decreasing trend, a 50% decrease in the conflicts from the expected value of 1,820. Averaging the conflict results using two factors (pedestrian volume and turning traffic) yields an overall decrease of 53.73%.

At this location, pedestrian violations decreased during the after-condition study period. Before the YPB modules were installed, 915 violations were recorded for 17,281 pedestrians. Considering this ratio, the number of expected violations would be 800 for the after-condition study period. However, during the after-condition review, 322 violations were recorded for 15,110 pedestrians, which is 59.75% lower than the expected violations. Notably, pedestrians were accountable for most of the recorded violations during the entire study period including before (99.34%) and after (100%) condition.

The number of extra button pushes increased after the installation of the YPB modules. In the before condition, there were 61 extra button pushes for 17,281 pedestrians. However, for the after-condition the recorded extra button pushes was 76, a 43.39% increase than the expected value of 53, considering the ratio of the before condition. This is because some of the recorded events showed that pedestrians did not understand the purpose and feature of the yellow border light and pressed the call button multiple times even after seeing the border light being on. In most of these extra-push events multiple pedestrians pushed the call button although the yellow border light is turned on after the first push. This is possibly due to the absence of proper flyer information about the YPB and its functional addition for the pedestrians and traffic.

In most of the conflict events recorded for the before-and-after condition, the motorists yielded majority of the times. For instance, out of 2,448 recorded conflicts motorists yielded 2,302 times (94%) during the before condition and 863 times (94.84%) out of 910 conflicts during the after-condition period.

Table- 6: Before and After Comparison for Location 1

LOCATION 1	Conflict / Pedestrian Volume	LT* Conflict / LT Traffic Volume	RT* Conflict / RT Traffic Volume	Conflict / Turning Traffic Volume	Extra Push / Pedestrian Volume	No Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
Change in Percentage (%)	**-57.47%**	**-43.67%**	**-56.3%**	**-50%**	**+43.39%**	**-45.46%**	**-59.75%**	**+0.84%**

LT- Left-turn, *RT- Right-turn

Location 2: West 14 St. / Redwood Hwy (Eureka)

This study location is a large intersection with five lanes for both way traffic for all the approach legs. As a result, the pedestrian crossing period and the vehicle traversing period is longer compared to other study locations. Notably, the left-turn conflicts in this location is much severe compared to other study locations because drivers tend to overlook the crossing pedestrians even during the pedestrian crossing phase. In some instances, the drivers fail to notice the crossing

pedestrian on the far-side and yield or negotiate at the last moment inside the intersection, blocking the queued motorist destined to the same approach or through traffic from the other approach. This aggressive driving behavior may be due to the small green time for the protected left-turn (AD) (Figure 15) at W 14th Street, which is often maneuvered by large vehicles such as trucks and semitrailers.

The video data for the before-condition was collected for seven consecutive days, from May 6-12, 2018. The YPB modules were installed on later that week and turned on after the before study period. The learning period was about 6 weeks for the motorists and pedestrians to become accustomed with the new feature of the installed YPB modules. The after-condition video data was recorded from July 1-7, 2018.

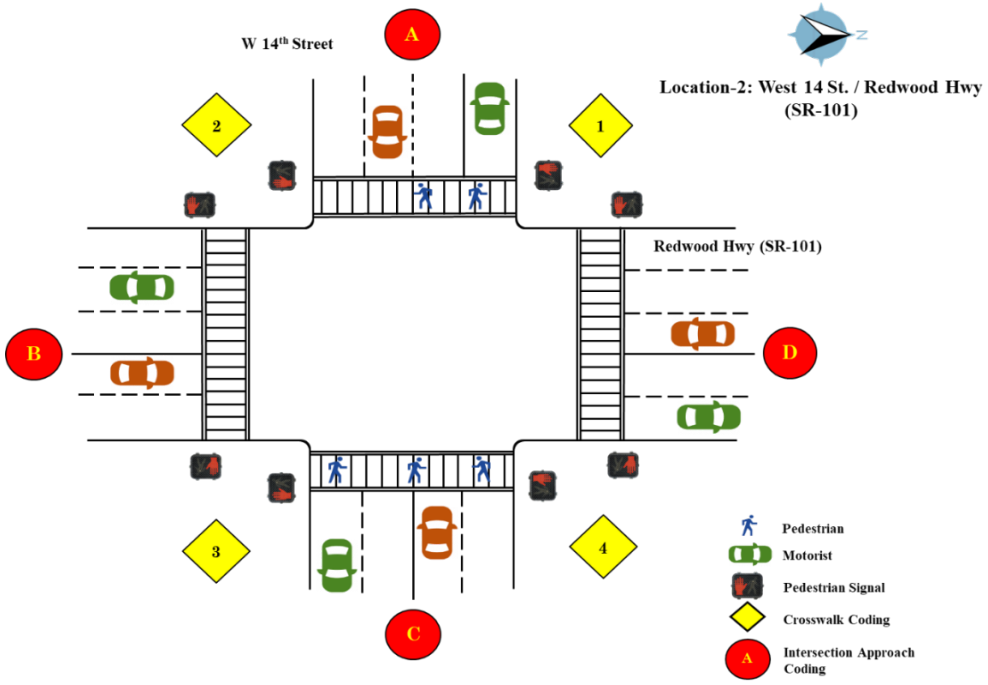


Figure 15: Schematic Coding of Location 2: West 14 St. / Redwood Hwy, Eureka for Data Recording

Table- 7: Before Condition Summary of Location 2 from May 6-12, 2018

BEFORE	5/6/2018	5/7/2018	5/8/2018	5/9/2018	5/10/2018	5/11/2018	5/12/2018	Summation
Pedestrian Violation	19	15	19	27	14	24	21	139
Vehicle Violation	1	0	0	0	1	1	5	8
Total Violation	20	15	19	27	15	25	26	147
No-Push	35	42	42	46	38	38	26	267
Extra Push	0	2	1	0	1	1	0	5
Left-turn Conflict	31	36	33	19	24	30	40	213
Right-turn Conflict	25	54	43	38	55	45	31	291

Through Conflict	2	0	1	1	1	1	1	7
Total Conflict	58	90	77	58	80	76	72	511
Pedestrian Yield	12	19	18	12	8	13	18	100
Vehicle Yield	46	71	59	46	72	63	54	411
Critical Left-turn Veh Vol	1830	2620	2609	2934	3028	3272	2641	18934
Critical Right-turn Veh Vol	1221	2079	2154	2238	2030	2245	1929	13896
Total Pedestrian Vol	288	404	319	390	358	351	335	2445

Table- 8: Statistics Summary of Before Condition of Location 2 from May 6-12, 2018

BEFORE	MEAN	SD*	MEDIAN	MIN	MAX	RANGE	SE*
Pedestrian Violation	1.2410714	1.2024415	1.0	0	6	6	0.1136200
Vehicle Violation	0.0714286	0.2914483	0.0	0	2	2	0.0275393
Total Violation	1.3125000	1.2946964	1.0	0	7	7	0.1223373
Extra Push	0.0089286	0.0944911	0.0	0	1	1	0.0089286
No-Push	2.3839286	1.8220152	2.0	0	8	8	0.1721643
Left-turn Conflict	1.9017857	1.6763314	2.0	0	7	7	0.1583984
Right-turn Conflict	2.5982143	2.3803241	2.0	0	10	10	0.2249195
Through Conflict	0.0625000	0.2431494	0.0	0	1	1	0.0229755
Total Conflict	4.5625000	2.9737023	5.0	0	12	12	0.2809885
Pedestrian Yield	0.8928571	1.1178901	1.0	0	5	5	0.1056307
Vehicle Yield	3.6696429	2.4619204	3.5	0	10	10	0.2326296
Critical Left-turn Veh Vol	169.0535714	92.3811961	166.5	9	350	341	8.7292025
Critical Right-turn Veh Vol	124.0714286	61.5097904	123.5	11	282	271	5.8121289
Total Pedestrian Vol	21.8303571	9.6933974	21.0	0	52	52	0.9159400

*SD (Standard Deviation), *SE (Standard Error)

The statistical results of the before condition shows that there were few violations related to vehicle and majority of the motorists involved in a conflict with the pedestrians yielded to give the right-of-way. The minimum, maximum, and range depict the statistical values within the hourly distribution of the recorded days. This means that the maximum and minimum statistics shows the highest and lowest value recorded in an hour of the observation period, whereas the range suggest the difference between the max and minimum value for that hour.

Table- 9: After Condition Summary of Location 2 from July 1-7, 2018

AFTER	7/1/2018	7/2/2018	7/3/2018	7/4/2018	7/5/2018	7/6/2018	7/7/2018	Sum
Pedestrian Violation	25	34	36	32	6	10	9	152
Vehicle Violation	2	1	1	0	0	0	0	4
Total Violation	27	35	37	32	6	10	9	156
Extra Push	0	0	0	1	2	0	0	3

No-Push	48	35	21	55	15	16	17	207
Left-turn Conflict	28	25	19	45	37	36	29	219
Right-turn Conflict	24	62	68	22	32	45	41	294
Through Conflict	1	0	2	0	0	0	0	3
Total Conflict	53	87	89	67	69	81	70	516
Pedestrian Yield	12	31	26	3	1	5	3	81
Vehicle Yield	42	57	63	64	68	78	67	439
Critical Left-turn Veh Vol	1994	3214	3318	1206	1860	1249	2279	15120
Critical Right-turn Veh Vol	1593	2438	2468	1023	1461	1118	2089	12190
Total Pedestrian Vol	264	435	424	258	474	373	476	2704

The summary results of the after condition shows that there were few violations related to vehicle and majority of the motorists involved in a conflict with the pedestrians yielded to give the right-of-way. The results showed that the right-turn conflict is slightly higher than the left-turn conflict and the number of recorded through conflict is minimal.

Table- 10: Summary Statistics of After Condition of Location 2 from July 1-7, 2018

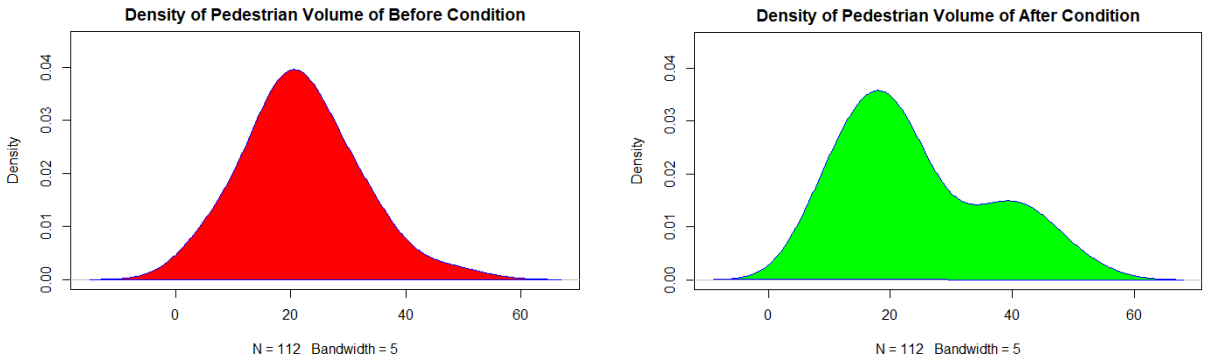
AFTER	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	1.4017857	1.2976751	1.4826	0	6	6	0.1226188
Vehicle Violation	0.0357143	0.1864109	0.0000	0	1	1	0.0176142
Total Violation	1.4375000	1.3068168	1.4826	0	6	6	0.1234826
Extra Push	0.0267857	0.1621823	0.0000	0	1	1	0.0153248
No-Push	1.8482143	1.7148520	1.4826	0	7	7	0.1620383
Left-turn Conflict	1.9553571	2.0681558	2.2239	0	12	12	0.1954224
Right-turn Conflict	2.6250000	2.6950906	2.9652	0	12	12	0.2546621
Through Conflict	0.0267857	0.1621823	0.0000	0	1	1	0.0153248
Total Conflict	4.6071429	3.8819451	4.4478	0	17	17	0.3668093
Pedestrian Yield	0.7232143	1.2463266	0.0000	0	5	5	0.1177668
Vehicle Yield	3.9196429	3.3748898	2.9652	0	16	16	0.3188971
Critical Left-turn Vehicle	135	87.4353300	103.0407	18	330	312	8.2618621
Critical Right-turn Vehicle	108.8392857	60.5318104	69.6822	12	240	228	5.7197184
Total Pedestrian	24.1428571	12.0665252	10.3782	6	53	47	1.1401795

***SD (Standard Deviation), *SE (Standard Error)**

The statistical result of the after condition shows that the mean and SD of pedestrian volume is 24.143 and 12.066, respectively. Also, the mean and SD of the total number of conflict recorded for the after condition is 4.607 and 3.882.

For this location, the density plot of pedestrian volume (*Figure 16*) shows that the shape of the distribution is quite different with nearly identical peak and dissimilar tail value. The after-condition data is more dispersed compared to the before-condition distribution. The before-

condition distribution shows that most of the observations are in between 0 to 40. Notably there is a minor difference (2.312) in the mean pedestrian volume for before and after condition.



(a) (b)

Figure 16: Density plot of the pedestrian volume for (a) before and (b) after condition

In the before-condition, 511 conflicts were recorded for 2,445 pedestrians. The number of recorded conflicts were very high compared to the pedestrian volume in this location. Applying this ratio to the number of pedestrians counted during the after-condition period (2704), the expected number of conflicts would be 565. However, the actual number of conflicts recorded during the after-condition was 516, **which is 8.67% lower than expected conflicts**. These conflicts when **compared with the recorded volume of turning vehicles** for before (32830) and after (27310) condition **showed a 21.41% increase**, as the expected conflicts corresponding to the lower turning volume of 27310 is 425. After averaging the conflict results using the two factors (pedestrian volume and turning traffic) yields an overall increment of 6.37%.

At this location, pedestrian violations decreased during the after-condition study period. Before the YPB modules were installed, 147 violations were recorded for 2445 pedestrians. Considering this ratio, the number of expected violations would be 163 for the after-condition study period. However, during the after-condition review, 156 violations were recorded for 2704 pedestrians, which is 4.29% lower than the expected violations. Notably, pedestrians were accountable for most of the recorded violations during the entire study period including before (94.56%) and after (97%) condition.

Camera angle, visibility, and distance from crossing made it difficult to record the extra button pushes at this location. The number of extra button pushes also reduced after the installation of the YPB modules. In the before condition, there were 5 extra button pushes for 2445 pedestrians. However, for the after-condition the recorded extra button pushes was 3, a 40% reduction than the expected value of 5.

Crossing the intersection over the crosswalk without pushing the button, even when the pedestrian phase is aligned with the crossing time was a common event at this location. Crossing without pushing the call button is recorded as no-push event in this case. The number of no push event recorded during the before condition was 267 for 2445 pedestrians. Applying this ratio, the expected no-push events during the after condition would be 295. However, the actual recorded number was 207 for the after-condition period, which a 29.83% overall decrease.

For Eureka, presence of homeless population around the study location generated some unexpected pedestrian traffic with many no-push events and violation. Specifically, after evening as the road traffic draws down, the movement of these pedestrians at the *W 14th street* increased manifold. Notably, bicycle was the common non-motorized vehicle used over the crosswalks without pushing the call button (no-push). Many of the surrounding pedestrians crossed the road from the middle of the approach that is identical to jaywalking, even when their crossing time was aligned with the pedestrian crossing phase.

In most of the conflict events recorded for the before and after condition, the motorists yielded majority of the times. For instance, out of 511 recorded conflicts motorists yielded 411 times (80.43%) during the before condition and 439 times (85%) out of 516 conflicts during the after-condition period.

Table- 11: Before and After Comparison of Location 2

LOCATION 2	Conflict / Pedestrian Volume	LT Conflict / LT Traffic Volume	RT Conflict / RT Traffic Volume	Conflict / Turning Traffic Volume	Extra Push / Pedestrian Volume	No Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
Change in Percentage (%)	**-8.67%**	**+28.8%**	**+15.29%**	**+21.41%**	**-40%**	**-29.83%**	**-4.29%**	**+5%**

Location 3: Redwood Ave / Main St. (Fort-Bragg)

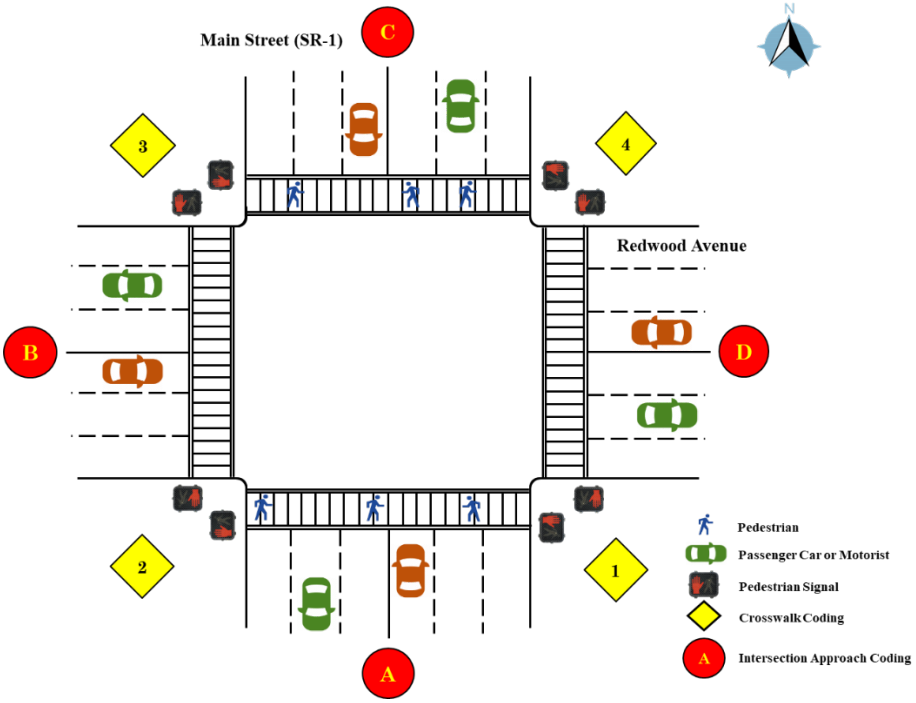


Figure 17: Schematic Coding of Location 3 (Redwood Ave / Main St., Fort Bragg) for Data Recording

The video data for the before-condition was collected for seven consecutive days, from May 6-12, 2018. The YPB modules were installed on later that week and turned on after the before study period. The learning period was about 4 weeks for the motorists and pedestrians to become accustomed with the new feature of the installed YPB modules. The after-condition video data was recorded from June 17 - 23, 2018.

Table- 12: Before Condition Summary of Location 3 from May 6-12, 2018

BEFORE	5/6/2018	5/7/2018	5/8/2018	5/9/2018	5/10/2018	5/11/2018	5/12/2018	Summation
Pedestrian Violation	14	1	1	0	2	3	2	23
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	14	1	1	0	2	3	2	23
Extra Push	5	2	2	4	2	2	2	19
Left-turn Conflict	35	32	11	12	18	17	22	147
Right-turn Conflict	15	15	11	7	8	12	13	81
Through Conflict	1	0	0	0	0	0	0	1
Total Conflict	51	47	22	19	26	29	35	229
Pedestrian Yield	0	1	0	0	0	1	0	2
Vehicle Yield	51	46	22	19	26	28	35	227
Critical Left-turn Veh Vol ** (DA + BC)	698	865	150	145	129	135	215	2337

Critical Right-turn Veh Vol** (AD+CB+BA+DC)	1040	1512	1322	1443	1304	1430	1788	9839
Total Pedestrian Vol	786	664	1851	2128	1846	1811	2317	11403

***SD (Standard Deviation), *SE (Standard Error), **Schematic Drawing**

Table- 13: Statistical Summary of Before Condition of Location 3 from May 6-12, 2018

BEFORE	MEAN (N=112)	SD*	MEDIAN	MIN	MAX	RANGE	SE*
Pedestrian Violation	0.2053571	0.5222680	0	0	3	3	0.0493497
Vehicle Violation	0	0	0	0	0	0	0
Total Violation	0.2053571	0.5222680	0	0	3	3	0.0493497
Extra Push	0.1696429	0.4221010	0	0	2	2	0.0398848
Left Turn Conflict	1.3125000	1.5713152	1.48	0	9	9	0.1484753
Right Turn Conflict	0.7232143	1.0839519	0	0	6	6	0.1024238
Through Conflict	0.0089286	0.0944911	0	0	1	1	0.0089286
Total Conflict	2.0446429	2.3418957	1.48	0	15	15	0.2212883
Pedestrian Yield	0.0178571	0.1330273	0.00	0	1	1	0.0125699
Vehicle Yield	2.1517857	2.4976018	2.97	0	15	15	0.2360012
Critical Left Turn Vehicle Volume ** (DA + BC)	20.8660714	23.0199661	8.15	0	89	89	2.1751823
Critical Right Turn Vehicle Volume ** (AD+CB+BA+DC)	87.8482143	44.9376364	51.15	8	222	214	4.2462075
Total Pedestrian Volume	101.8125000	63.1474082	70.42	2	249	247	5.9668692

***SD (Standard Deviation), *SE (Standard Error), **Schematic Drawing**

The summary results of the before condition shows that there was no violation related to vehicle and most of the yielding maneuver during conflicting situations were undertaken by the motorist instead of pedestrians.

For the statistical summary, the minimum, maximum, and range depict the statistical values within the hourly distribution of the recorded days. This means that the maximum and minimum statistics shows the highest and lowest value recorded in an hour of the observation period, whereas the range suggest the difference between the max and minimum value for that hour. For instance, maximum conflict recorded for an hour during the after condition was 8.

Table- 14: After Condition Summary of Location 3 from June 17-23, 2018

AFTER	6/17/18	6/18/18	6/19/18	6/20/18	6/21/18	6/22/18	6/23/18	Summation
Pedestrian Violation	2	1	0	0	0	0	0	3
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	2	1	0	0	0	0	0	3
Extra Push	2	1	0	0	1	0	1	5
Left-turn Conflict	19	30	24	18	25	22	41	179

Right-turn Conflict	14	12	1	1	6	6	6	46
Through Conflict	0	0	0	0	0	0	0	0
Total Conflict	33	42	25	19	31	28	47	225
Pedestrian Yield	1	0	0	0	0	0	0	1
Vehicle Yield	32	42	25	19	31	28	47	224
Critical Left-turn Vehicle Volume ** (DA + BC)	616	751	695	586	710	786	671	4815
Critical Right-turn Vehicle Volume ** (AD+CB+BA+DC)	929	1008	901	770	956	958	1033	6555
Total Pedestrian	983	990	725	644	871	905	1580	6698

***SD (Standard Deviation), *SE (Standard Error), **Schematic Drawing**

Table- 15: Statistical Summary of After Condition of Location 3 from June 17-23, 2018

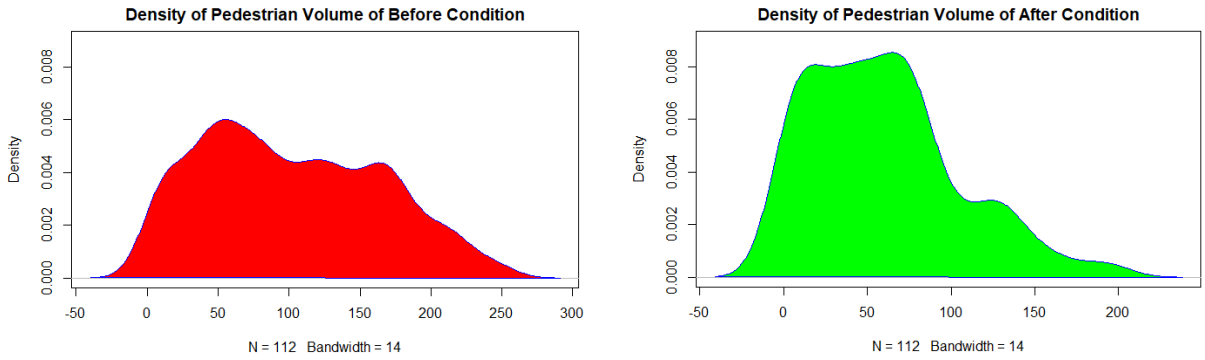
AFTER	MEAN (N=112)	SD*	MEDIAN	MIN	MAX	RANGE	SE*
Pedestrian Violation	0.0267857	0.1621823	0	0	1	1	0.0153248
Vehicle Violation	0	0	0	0	0	0	0
Total Violation	0.0267857	0.1621823	0	0	1	1	0.0153248
Extra Push	0.0446429	0.2074466	0	0	1	1	0.0196019
Left-turn Conflict	1.6272727	1.7757753	1.0	0	7	7	0.1693135
Right-turn Conflict	0.4181818	0.8170412	0	0	4	4	0.0779018
Through Conflict	0	0	0	0	0	0	0
Total Conflict	2.0089286	2.0859700	1.0	0	8	8	0.1971056
Pedestrian Yield	0.0089286	0.0944911	0	0	1	1	0.0089286
Vehicle Yield	2.0000000	2.0838288	1.0	0	8	8	0.1969033
Critical Left Turn Vehicle Volume ** (DA + BC)	42.9910714	22.4348890	42.0	2	93	91	2.1198977
Critical Right Turn Vehicle Volume ** (AD+CB+BA+DC)	58.5267857	29.0392589	62.0	3	117	114	2.7439520
Total Pedestrian Volume	59.8035714	44.7281759	54.5	1	196	195	4.2264154

***SD (Standard Deviation), *SE (Standard Error), **Schematic Drawing**

The summary results of the after condition shows that the vehicle violation and conflict at through directional movement of the motorists was zero. As for the yielding situations, most of the yielding maneuvers were undertaken by the motorist instead of pedestrians.

Density plot of pedestrian volume shows that the shape of the distribution is quite different with dissimilar peak and tail value. The before-condition data has a lower peak and more dispersed compared to the after-condition distribution. The after-condition distribution shows that most of

the observations are in between 0 to 100. Notably there is a significant difference (42.00893) in the mean pedestrian volume for before and after condition.



(a) *(b)*

Figure 18: Density plot of the pedestrian volume for (a) before and (b) after condition

In the before-condition, 229 conflicts were recorded for 11,403 pedestrians. Applying this ratio to the number of pedestrians counted during the after-condition period (6,698), the expected number of conflicts would be 135. However, the actual number of conflicts recorded during the after-condition was 225, **which is 66.67% higher than expected conflicts**. The conflicts when compared with the recorded volume of turning vehicles for before (12,176) and after (11,370) condition also showed increasing trend, **a 5% increase in the conflicts**. Thus, in comparison to both pedestrian volume and turning traffic volume, the number of conflicts were higher than expected at this location. Averaging the conflict results with two factors yields an overall increment of 35.835%.

At this location, **pedestrian violations decreased** during the after-condition study period. Before the YPB modules were installed, 23 violations were recorded for 11,403 pedestrians. Considering this ratio, the number of expected violations would be 14 for the after-condition study period. However, during the after-condition review, 3 violations were recorded for 6,698 pedestrians, **which is 78% lower than the expected violations**. Notably, all the recorded violations during the entire study period including before and after condition were related to pedestrians.

The number of extra button pushes also reduced after the installation of the YPB modules. In the before condition, there were 19 extra button pushes for 11,403 pedestrians. However, for the after-condition the recorded extra button pushes was 5, a 54.5% reduction than the expected value of 11.

In most of the conflict events recorded for the before and after condition, the motorists yielded almost all the time during a conflict. For instance, out of 229 recorded conflicts motorists yielded 227 times (99%) during the before condition study and 224 times (99.5%) out of 225 conflicts during the after-condition study.

Table- 16: Before and After Comparison of Location 3

LOCATION 3	Conflict / Pedestrian Volume	LT Conflict / LT Traffic Volume	RT Conflict / RT Traffic Volume	Conflict / Turning Traffic Volume	Extra Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
Change in Percentage (%)	**+66.67**	**-40.73%**	**-14.81%**	**+5%**	**-54.5%**	**-78%**	**+0.5%**

Location 4: Coast Hwy / Broadway St (Laguna Beach)

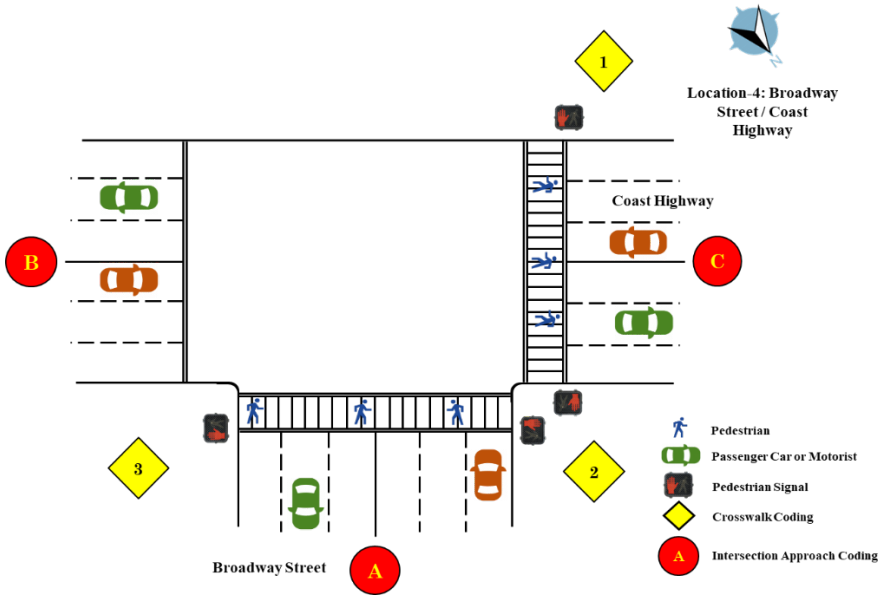


Figure 19: Schematic Coding of Location 4 (Coast Hwy / Broadway St, Irvine) for Data Recording

The video data for the before-condition was collected for seven consecutive days, from August 3-9, 2018. The YPB modules were installed on later that week and turned on after the before study period. The learning period was about 2 weeks for the motorists and pedestrians to become accustomed with the new feature of the installed YPB modules. The after-condition video data was recorded from August 27 – September 2, 2018.

Table- 17: Before Condition Summary of Location 4 from August 3-9, 2018

BEFORE	8/3/2018	8/4/2018	8/5/2018	8/6/2018	8/7/2018	8/8/2018	8/9/2018	Sum
Pedestrian Violation	27	28	10	5	0	6	7	83
Vehicle Violation	1	0	0	0	5	0	0	6
Total Violation	28	28	10	5	5	6	7	89

Extra push	18	7	0	0	5	0	1	31
No-Push	4	2	0	0	0	0	0	6
Left-turn Conflict	62	66	8	5	10	13	8	172
Right-turn Conflict	920	975	1347	1075	1039	1139	1178	7673
Through Conflict	4	7	0	0	1	0	0	12
Total Conflict	986	1048	1355	1080	1050	1152	1186	7857
Pedestrian Yield	55	19	0	0	2	1	2	80
Vehicle Yield	931	1028	1355	1080	1048	1151	1184	7777
Total Right-turn	4047	5221	5468	4932	4385	5369	5684	35106
Pedestrian Volume	7787	9637	11256	6070	5857	6322	7013	53942

The summary results of the before condition shows that there was only 6 vehicle violation out of 89 violations and most of the yielding maneuver during a conflicting situation were undertaken by the motorist instead of pedestrians.

For the pedestrian volume the statistical summary shows that the mean and SD of the recorded data was 481.625 and 297.134, respectively. Higher value of standard deviation corresponds to higher deviation from the mean, which means the data points are spread over a large range of values. Also, the maximum pedestrian volume recorded in an hour during the before condition period was 1150.

Table- 18: Statistical Summary of Before Condition of Location 4 from August 3-9, 2018

BEFORE	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	0.7410714	1.2283845	0.0	0	7	7	0.1160714
Vehicle Violation	0.0535714	0.2630139	0.0	0	2	2	0.0248525
Total Violation	0.7946429	1.2312624	0.0	0	7	7	0.1163434
Extra push	0.2767857	0.6872038	0.0	0	4	4	0.0649347
No-Push	0.0535714	0.2952869	0.0	0	2	2	0.0279020
Left-turn Conflict	1.5357143	2.9283595	0.0	0	19	19	0.2767040
Right-turn Conflict	68.5089286	29.7763421	75.0	0	121	121	2.8135999
Through Conflict	0.1071429	0.5260278	0.0	0	4	4	0.0497050
Total Conflict	70.1517857	30.3867592	80.0	0	121	121	2.8712789
Pedestrian Yield	0.7053571	1.6746030	0.0	0	8	8	0.1582351
Vehicle Yield	69.5	30.2154426	78.0	0	121	121	2.8550910
Total Right-turn	313.4464286	79.3851189	317.5	118	574	456	7.5011887
Pedestrian Volume	481.625	297.1338803	485.0	28	1150	1122	28.0765126

The summary results of the after condition shows that there was no vehicle violation out of total 21 violations and most of the yielding maneuver during a conflicting situation were undertaken by the motorist instead of pedestrians. Most of the conflicts in the after condition was the right-turn conflict.

Table- 19: After Condition Summary of Location 4 from August 27-September 2, 2018

AFTER	8/27/2018	8/28/2018	8/29/2018	8/30/2018	8/31/2018	9/1/2018	9/2/2018	Sum
Pedestrian Violation	8	2	3	1	2	2	3	21
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	8	2	3	1	2	2	3	21
Extra push	1	1	0	0	0	1	1	4
No-Push	0	0	0	0	0	1	0	1
Left-turn Conflict	3	0	1	1	12	5	7	29
Right-turn Conflict	882	799	701	811	877	866	746	5682
Through Conflict	0	0	0	0	0	0	0	0
Total Conflict	885	799	702	812	889	871	753	5711
Pedestrian Yield	1	0	0	0	13	14	1	29
Vehicle Yield	884	799	702	812	876	857	752	5682
Total Right-turn	5224	4555	4642	5131	4752	4891	4338	33533
Pedestrian Volume	3682	3313	2803	3683	4606	4232	4571	26890

For the pedestrian volume the statistical summary shows that the mean and SD of the recorded data was 240.58 and 128.849, respectively. The summary result shows that there is a significant difference (241.045) between the mean pedestrian volume for before and after condition. Compared to before condition the SD of pedestrian volume is much lower for after condition, which suggest that the recorded data points are less dispersed.

Table- 20: Statistical Summary of After Condition of Location 4 from August 27-September 2, 2018

AFTER	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	0.1785714	0.4495100	0.0	0	2	2	0.0424747
Vehicle Violation	0.0000000	0.0000000	0.0	0	0	0	0.0000000
Total Violation	0.1785714	0.4495100	0.0	0	2	2	0.0424747
Extra push	0.0357143	0.1864109	0.0	0	1	1	0.0176142
No-Push	0.0089286	0.0944911	0.0	0	1	1	0.0089286
Left-turn Conflict	0.2589286	0.6113865	0.0	0	3	3	0.0577706
Right-turn Conflict	50.7321429	19.4625916	54.5	4	87	83	1.8390420
Through Conflict	0.0000000	0.0000000	0.0	0	0	0	0.0000000
Total Conflict	50.9910714	19.6264647	55.0	4	88	84	1.8545266
Pedestrian Yield	0.2321429	0.7100583	0.0	0	4	4	0.0670942
Vehicle Yield	50.7500000	19.4072059	55.0	4	87	83	1.8338086
Total Right-turn	299.4017857	62.0378350	302.0	111	443	332	5.8620244

Pedestrian Volume	240.5803571	128.8489330	246.5	28	512	484	12.1750798

This location is a T-type intersection with 2 crosswalks, serving the highest volume of pedestrians compared to other locations in this study. This high volume presented a unique opportunity to observe pedestrian's travel characteristics within a group environment. Noticeably **pedestrians crossing in large group walked slowly** whereas individual pedestrians or in small groups tried to cross speedily to give-way to the yielding motorist. This walking pattern (slow or fast) depend mostly on the presence yielding or traversing traffic at the intersection. The tendency to violate pedestrian signal was often observed when the traffic volume at the intersection was low or the headway between the successive traffic was much higher than usual. Notably, aggressive driving behavior was also observed where some of the motorists yield for the near-side pedestrians then rush through the gap during the crossing of far-side pedestrians.

While reviewing vehicle-pedestrian conflicts at location 4, 7,857 conflicts were recorded for 53,942 pedestrians during the before-condition. If this volume-conflict ratio is applied to the pedestrian volume during the after-condition period (26,890), the expected number of conflicts would be 3,916. However, the actual number of conflicts recorded during the after-condition was 5,711, **which is 45.83% higher than the expected conflicts**. Since majority of the conflicts were right-turn (7673), when compared with the recorded right-turning volume for before (35106) and after (33,533) condition showed decreasing trend, **a 22.47% decrease in the conflicts**. Averaging the conflict results with two factors (pedestrian volume and right-turning traffic volume) yields an overall increment of 11.68%.

For location 4, **violations decreased** during the after-condition study period. Before the YPB modules were installed, 89 violations were recorded for 53,942 pedestrians. Considering this ratio, the number of expected violations would be 44 for the after-condition study period. However, during the after-condition review, 21 violations were recorded for 26,890 pedestrians, **which is a 52.27% reduction** compared to the expected violations. Notably, majority (94.5%) the recorded violations during the entire study period including before and after condition were related to pedestrians.

The number of extra button pushes also reduced after the installation of the YPB modules. In the before condition, there were 31 extra button pushes for 53,942 pedestrians and for the after-condition the recorded extra button pushes was 4. Considering the ratio (button push / pedestrian) from the before condition a 73.33% reduction was observed for the after condition.

In most of the conflict events recorded for the before and after condition, the motorists yielded almost all the time during a conflict. For instance, out of 7857 recorded conflicts motorists yielded 7777 times (98.98%) during the before condition study and 5682 times (98.36%) out of 5711 conflicts during the after-condition study.

Table- 21: Before and After Comparison for Location 4

LOCATION 4	Conflict / Pedestrian Volume	RT Conflict / RT Traffic Volume	Extra Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
Change in Percentage (%)	**+45.83%**	**-22.47%**	**-73.33%**	**-52.27%**	**-0.62%**

Location 5: Fairmount / Sao Paolo Avenue (Albany)

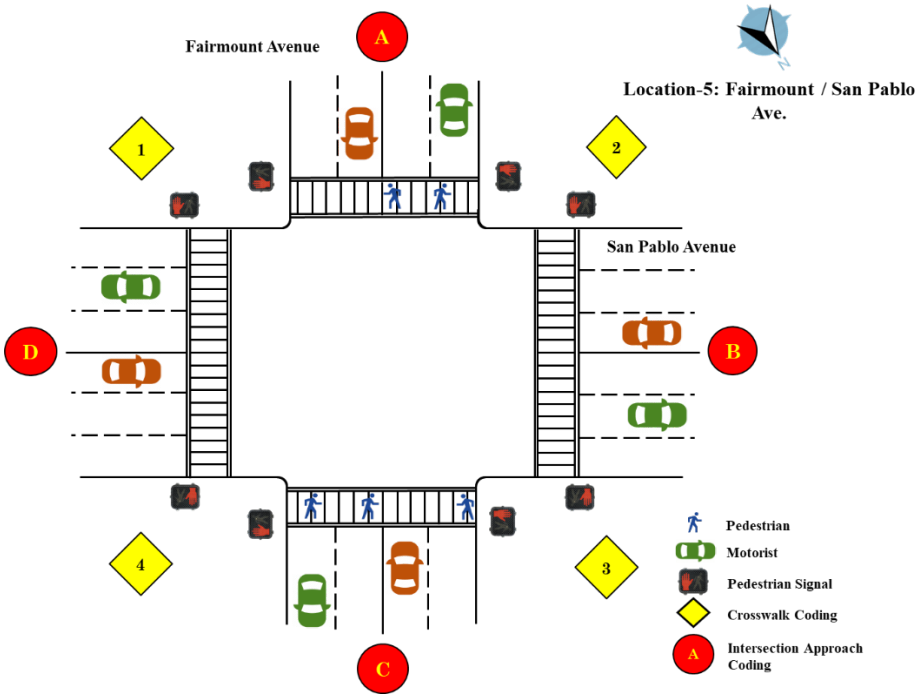


Figure 20: Schematic Coding of Location 3 (Redwood Ave / Main St., Fort Bragg) for Data Recording

The video data for the before-condition was recorded for seven consecutive days, from August 31-September 6, 2018. The YPB modules were installed on later that week and turned on after the before study period. Due to schedule delay and location shift, the learning period was shortened to about 2 weeks for the motorists and pedestrians to become accustomed with the new feature of the installed YPB modules. The after-condition video data was recorded from September 18-24, 2018.

Table- 22: Before Condition Summary of Location 5 from August 31-September 6, 2018

BEFORE	8/31/2018	9/1/2018	9/2/2018	9/3/2018	9/4/2018	9/5/2018	9/6/2018	Sum
Pedestrian Violation	21	41	24	18	24	8	23	159
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	21	43	22	18	25	9	23	161
Extra Push	14	15	16	13	11	12	9	90
No Push	44	53	49	58	66	136	43	449

Left-turn Conflict	7	13	4	6	6	12	2	50
Right-turn Conflict	80	65	33	46	78	121	25	448
Through Conflict	4	0	1	0	1	0	1	7
Total Conflict	91	78	38	52	85	133	28	505
Pedestrian Yield	4	4	5	5	3	13	2	36
Vehicle Yield	87	74	33	47	82	120	26	469
Pedestrian Volume	1395	1417	1252	1086	1272	1686	1151	9259

The summary results of the before condition shows that there was no vehicle violation and most of the yielding maneuver during conflicting situations were undertaken by the motorist instead of pedestrians.

Table- 23: Statistical Summary of Before Condition of Location 5 from August 31-September 6, 2018

BEFORE	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	1.4196429	1.5861926	1.0	0	8	8	0.1498811
Vehicle Violation	0.0000000	0.0000000	0.0	0	0	0	0.0000000
Total Violation	1.4375000	1.5756094	1.0	0	8	8	0.1488811
Extra Push	0.8035714	1.0469973	0.0	0	4	4	0.0989319
No Push	4.0089286	4.3277765	3.0	0	31	31	0.4089364
Left-turn Conflict	0.4464286	0.8257051	0.0	0	5	5	0.0780218
Right-turn Conflict	4.0000000	3.5615565	3.0	0	15	15	0.3365355
Through Conflict	0.0625000	0.2777402	0.0	0	2	2	0.0262440
Total Conflict	4.5089286	4.0514607	4.0	0	17	17	0.3828271
Pedestrian Yield	0.2142857	0.4732211	0.0	0	2	2	0.0447152
Vehicle Yield	4.1875000	3.7597471	3.0	0	14	14	0.3552627
Pedestrian Volume	82.6696429	44.9601201	84.0	3	266	263	4.2483320

The statistical summary of the before condition shows that the mean and SD of the pedestrian volume is 82.67 and 44.96, respectively. Also, the maximum recorded volume within an hour is 266.

Table- 24: After Condition Summary of Location 5 from September 18-24, 2018

AFTER	**9/18/2018**	**9/19/2018**	**9/20/2018**	**9/21/2018**	**9/22/2018**	**9/23/2018**	**9/24/2018**	**Sum**
Pedestrian Violation	36	48	53	55	47	71	52	362
Vehicle Violation	0	0	0	0	0	0	0	0
Total Violation	40	53	55	60	47	72	53	380
Extra Push	27	19	7	5	11	14	4	87
No Push	46	56	48	83	37	70	30	370

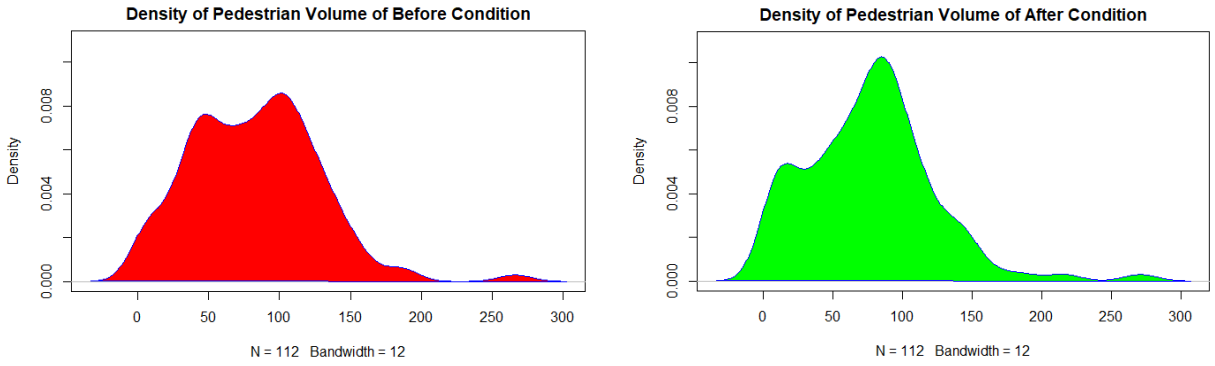
Left-turn Conflict	8	7	6	2	5	4	6	38
Right-turn Conflict	20	62	48	51	29	28	15	253
Through Conflict	10	8	3	9	4	8	3	45
Total Conflict	38	77	57	62	38	40	24	336
Pedestrian Yield	3	7	2	3	7	11	5	38
Vehicle Yield	24	66	50	46	31	29	21	267
Pedestrian Volume	1084	1643	1243	1473	1319	892	928	8582

The summary results of the after condition shows that there was no vehicle violation and most of the yielding maneuver during conflicting situations were undertaken by the motorist instead of pedestrians.

Table- 25: Statistical Summary of After Condition of Location 5 from September 18-24, 2018

AFTER	MEAN	SD	MEDIAN	MIN	MAX	RANGE	SE
Pedestrian Violation	3.2321429	2.4346676	3.0	0	14	14	0.2300545
Vehicle Violation	0.0000000	0.0000000	0.0	0	0	0	0.0000000
Total Violation	3.3928571	2.4654629	3.0	0	14	14	0.2329643
Extra Push	0.7767857	1.1366921	0.0	0	5	5	0.1074073
No Push	3.3035714	2.4708728	3.0	0	11	11	0.2334755
Left-turn Conflict	0.3392857	0.5781856	0.0	0	2	2	0.0546334
Right-turn Conflict	2.2589286	2.4263773	2.0	0	16	16	0.2292711
Through Conflict	0.4017857	0.7647625	0.0	0	4	4	0.0722633
Total Conflict	3.0000000	2.6610301	3.0	0	17	17	0.2514437
Pedestrian Yield	0.3392857	0.5935626	0.0	0	2	2	0.0560864
Vehicle Yield	2.3839286	2.4723536	2.0	0	17	17	0.2336155
Pedestrian Volume	76.6250000	46.1894113	79.5	2	271	269	4.3644891

The statistical summary of the before condition shows that the mean and SD of the pedestrian volume is 72.625 and 46.189, respectively. Also, the maximum recorded volume within an hour is 271. The difference in mean pedestrian volume for before and after condition is very small (6.044).



(a) (b)

Figure 21: Density plot of the pedestrian volume for (a) before and (b) after condition

In this case the density plot (*Figure 21*) of pedestrian volume shows that the shape of the distribution for both cases is quite analogous with dissimilar peak and identical tail distribution. The before-condition data has a lower peak and the after-condition distribution has most of the observations in between 0 to 150.

In the before-condition 505 conflicts were recorded for 9259 pedestrians. Applying this ratio to the number of pedestrians counted during the after-condition period (8582), the expected number of conflicts would be 468. However, the actual number of conflicts recorded during the after-condition was 336, **which is 28.21% lower than the expected conflicts**. Thus, in comparison to pedestrian volume, the number of conflicts were lower than expected at this location.

At this location, pedestrian violations increased during the after-condition study period. Before the YPB modules were installed, 159 violations were recorded for 9259 pedestrians. Considering this ratio, the number of expected violations would be 147 for the after-condition study period. However, during the after-condition review, 362 violations were recorded for 8582 pedestrians, **which is 46.26% higher than the expected violations**. Notably, all the recorded violations during the entire study period including before and after condition were related to pedestrians. According to the violation distribution over the crosswalks of the study location, the crosswalk coded as 34 and 21 had the highest number of violations during the after-condition period. These two crosswalks connect the minor approach (Fairmount Avenue), **where the traffic volume was much lower during off-peak period compared to the major connection** (San Pablo Avenue). Possibly the higher number of violations in this location can be attributed to the **shorter crosswalks** which tend to have more pedestrian compliance issues, specifically during non-peak hours when the traffic volume is low.

Table- 26: Violation Events Distributed according to the crosswalks for before and after condition

Crosswalk Movement Direction*	31-Aug	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep
12	11	19	18	23	16	44	15	24	27	32	50	33	38	35

14	24	17	12	19	19	14	8	6	13	10	12	1	1	4
21	34	30	26	25	22	53	23	34	26	41	59	36	44	44
23	22	29	14	16	27	45	12	21	51	21	24	20	48	2
32	13	28	16	24	26	52	9	20	36	22	25	19	40	4
34	24	26	8	8	24	25	15	7	16	11	12	8	9	4
41	22	23	9	9	28	22	9	9	10	13	17	10	5	8
43	20	17	22	17	25	25	12	13	17	13	6	6	1	9
Sum	170	189	125	141	187	280	103	134	196	163	205	133	186	110

* movement direction coding is provided in the schematic drawing

The number of extra button pushes also reduced after the installation of the YPB modules. In the before condition, there were 90 extra button pushes for 9259 pedestrians. However, for the after-condition the recorded extra button pushes was 87, a 4.82% increase than the expected value of 83 when compared to the ratio (extra button push / pedestrian volume) of before condition.

The video data showed that the crossing for most of the pedestrians on the minor (Fairmount Avenue) approach crosswalks without pushing the call button was a common event. Since the intersection was a major-minor connecting type, the pedestrian signal time is more available for the two crosswalks across the Fairmount Avenue (minor) compared to that on the San Pablo Avenue (major). For this reason, the number of no-push events for this location was noticeable for before and after condition. The number of no-push events recorded during the before condition were 449 for 9259 pedestrians. Applying this ratio, the expected no-push events during the after condition would be 416. However, the actual recorded number was 370 for the after-condition period, **which is a 11% decrease**.

In most of the conflict events recorded for the before and after condition, the motorists yielded almost all the time during a conflict. For instance, out of 505 recorded conflicts motorists yielded 469 times (92%) during the before condition study and 267 times (79.46%) out of 336 conflicts during the after-condition study.

Table- 27: Before and After Comparison of Location 5

LOCATION 5	Conflict / Pedestrian Volume	No Push / Pedestrian Volume	Extra Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
Change in Percentage (%)	**-28.21%**	**-11%**	**+4.82%**	**+46.26%**	**-12.5%**

RESULT SUMMARY

The five locations around California studied as part of this study presented a unique opportunity to record and observe a variety of pedestrian and vehicle interaction situations while determining the effectiveness of the YPB module. From traditional four-way intersection to a T-intersection in

a tourist spot, the study locations were selected based on their maintenance under Caltrans and potential for pedestrian-vehicle conflicts that could benefit from the experimental device. The following table summarizes the study results for all five locations:

Table- 28: Cumulative Percent Change for Before and After Comparison

	Conflict / Pedestrian Volume	LT* Conflict / LT Traffic Volume	RT* Conflict / RT Traffic Volume	Conflict / Turning Traffic Volume	Extra Push / Pedestrian Volume	No Push / Pedestrian Volume	Violation / Pedestrian Volume	Vehicle Yielding
LOCATION 1	-57.47	-43.67	-56.3	-50	+43.39	-45.46	-59.75	+0.84
LOCATION 2	-8.67	+28.8	+15.29	+21.41	-40	-29.83	-4.29	+5
LOCATION 3	+66.67	-40.73	-14.81	+5	-54.5	-	-78	+0.5
LOCATION 4	+45.83	-	-22.47	-	-73.33	-	-52.27	-0.62
LOCATION 5	-28.21	-	-	-	+4.82	-11	+46.26	-12.5
Cumulative Average	3.630	-18.533	-19.573	-7.863	-10.359	-25.133	-29.610	-1.356

***LT- Left-turn, *RT- Right-turn**

The cumulative results show a minor increase in pedestrian-vehicle conflicts with respect to total pedestrian volume. However, that is not the case when the conflicts were considered with respect to turning vehicular traffic volume. The conflicts showed a moderate decrease when turning traffic volumes were considered. Averaging these conflicts results for the two base categories (pedestrian volume and turning traffic volume) yields an overall 4.23% decrease. Pedestrian violations showed a more significant reduction of 29.61%, and the no-push events showed reduction of 25.13%. An overall reduction was also observed for the number of extra button pushes. Though the expected benefit would be related to the increment of vehicle yielding to the pedestrians for safe interactions, the study results showed a minor decrease. However, this would not be a major issue since in some of the study locations, the vehicles yielded almost at all the conflicting situations recorded during the study period. There were multiple factors which may have contributed to the broad range of results in this study. Based on field observations and data recording events, the following factors were identified as having some influence on the variation of results among the five locations:

Visibility and Orientation of the Pedestrian Signal

The primary factor is the visibility of the pedestrian signal indications during daylight. Since the installed LED border light on the experimental pedestrian signal is small and most visible during low light conditions, it becomes difficult for the motorists to notice the ring of yellow border readily at daylight, especially when the sunlight is shining directly into the signal face. In some locations, west facing pedestrian signals can be washed out when the afternoon sun is low enough to shine directly into the device. Similar occurrence can occur for the east facing pedestrian signals during morning.

Geometry of the Intersection

Geometry of the intersection also plays a role, since pedestrian signals are farther away and less noticeable to vehicle traffic at large intersections, especially during bright daylight conditions. Notably, at smaller intersections, the shorter crosswalks tend to have more pedestrian compliance issues, specifically during non-peak hours when the traffic volume is low. The crosswalks studied at the five locations varied in length from 36 ft. to 102 ft.

Extent of the learning period

Even after adopting an adequate learning period to get pedestrians and motorists accommodated with the experimental device, local motorists could have driven through the study location multiple times a day and missed the device in operation. In case the motorists encounter a pedestrian using a crosswalk parallel to their travel direction, they would know the presence of the excremental device. The longer the YPB modules were installed and operational prior to recording the after-condition data, the greater the opportunity for the road users to observe and determine the intended safety purpose. For the five study intersections, the learning period ranged from 14 to 60 days.

Traversing Traffic Composition

All the five study locations were on State routes and maintained by Caltrans. In these routes, there was a considerable amount of non-local traffic along with high percentage of local commuting traffic. Because the experimental devices were installed at five locations around California, motorists apart from the local commuters were less likely to have an understanding even after any encounter with the devices during the study period.

Pedestrian Behavior

For the studied crosswalks, a range of pedestrian activity was observed throughout the study period. Since some of the study locations were in the place of tourist attraction, some crosswalks served large groups of pedestrians crossing almost every cycle during peak times whereas the other crosswalks were used less often by individuals or small groups. The characteristics of the pedestrians varied between different locations, which could have contributed to the range of results in the study. Notably, the younger pedestrians seemed impatient and usually push the call button multiple times. However, they were more careful to wait for pedestrian signal before crossing the intersection. On the other hand, most of the violation caused by pedestrians can be attributed to the adult, such as homeless people in Location 2. The difference in pedestrian characteristics affected the violation, pushbutton results between the locations and influenced the driver behavior. Since some pedestrians are also drivers, the recording of different locations throughout the after-condition period showed that over time some of the motorists notice the YPB signals and actively search for the waiting pedestrians at the near-side or far-side to cross mostly during the nighttime.

PEDESTRIAN QUESTIONNAIRE SURVEY

A 5-point questionnaire survey with 5 questions was carried out at the study locations during the after-condition study adopted from the previous study at District 2, Caltrans. The five questions were based on five attributes of the experimental pedestrian signal: (i) visibility; (ii) reliability; (iii) ensure compliance; (iv) conflicting resolution; (v) safety. Details of the survey questions are presented below. 77 responses from the pedestrians were recorded from face-to-face interview at the study locations. Review of the survey responses show that the overall public response to the YPB signals is positive. Almost 85% of the respondents agree or strongly agree that the yellow border on the pedestrian signal is noticeable and about 64% agree or strongly agree that it is effective in confirming the call when the button is pushed. Nearly 60% of the respondents agree or strongly agree that the purpose of the additional ring of lights is easy to understand. However, about 86% of the respondents were neutral or disagreed that the yellow border influenced motorists to drive more cautiously when pedestrians were crossing. Given the already high percentage of motorists who yield to pedestrians when there is a conflict observed in the five locations, this response is not surprising. Finally, for the last response, 75% of the respondents agree or strongly agree that the yellow border lights are an effective addition to pedestrian signals.

Table- 29: Summary of Pedestrian Questionnaire Survey

	Question	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Average Score
1.	The yellow border lights are noticeable. (Visibility)	1	2	8	35	31	4.207792
2.	The yellow border lights are effective in confirming the push button worked and that the walk symbol is coming soon. (Reliability)	-	4	23	28	22	3.883117
3.	The purpose of the yellow border lights is easy to understand. (Ensure Compliance)	-	16	15	27	19	3.636364
4.	Cars notice the yellow border lights and drive more cautiously when pedestrians are crossing. (Conflicting Resolution)	2	36	30	5	4	2.649351
5.	Overall, the yellow border lights are effective and a good addition to pedestrian signal heads. (Safety)	-	5	14	38	20	3.948052

CONCLUSION

Pedestrian signals are installed to provide a safe crossing opportunity for the pedestrian. Generally, crosswalks parallel to the moving vehicular traffic are served simultaneously. However potential conflict situations arise when there is any turning movement involved. The YPB is designed in a way to ensure compliance for pedestrians and indicate motorists that pedestrians are waiting at the near-side or far-side to cross before starting the turning maneuver in order to reduce left or right-turning conflict and improve safety. On that note, the primary objective of this study was to determine whether the installation of YPB in place of traditional pedestrian signal improves the

interaction between pedestrian and motorist at signalized intersections in terms of conflicts, violation, extra call button push.

The cumulative average *(Table-27)* from the five study locations showed a slight increase in pedestrian-vehicle conflicts when the YPB modules were installed (3.63%). Notably, the cumulative average of total number of conflicts with respect to the total turning volume showed a decrease of 7.863 at Locations 1, 2, and 3. A weighted average of the conflict results with two factors (pedestrian volume and right-turning traffic volume) showed a fractional decrease of 0.35%, much lower than the expected outcome. The diversity of the pedestrian behavior, alternate intersection geometry, different learning period, and inadequate flyer information for different locations are possibly responsible for the diverse results. For instance, location 3 (Fort Bragg) and location 4 (Laguna) showed a sharp increase of conflicts, whereas the other three location showed a moderate decrease of conflicts for the after condition with respect to pedestrian volume.

For turning conflicts, the cumulative average for left-turn and right-turn conflicts with respect to the turning traffic volume showed a decrease of 18.533% and 19.573% in both cases. Since all the locations do not have same data points, a weighted average for the turning conflicts (left and right combined) showed an overall decrease of 19.127%.

Compared to the conflict situations, YPB signals had more cumulative impact on the pedestrians' behavior by reducing the overall no-push, extra-push, and violation events. The cumulative average (*Table-27*) of no-push, extra-push, and violation with respect to pedestrian volume showed a decrease of 21.563%, 34.4% and 45.08%, respectively. Though the expected benefit is related to the increment of vehicle yielding to the pedestrians for safe interactions, the study results showed a minor decrease. However, this is not a major issue since in all the study locations except one, the vehicles yielded more than 85% of the time for all the conflicting situations recorded during the study period. Thus, from the pedestrian safety perspective, addition of YPB significantly improves the pedestrian behavior.

The experimental results showed that YPB is a positive addition to a standard pedestrian signal since it is very effective in enhancing safety by ensuring compliance of the pedestrians. Moreover, the bright LED border serves as an additional visual cue for the motorist maneuvering any turning movement at the urban signalized intersection. Moreover, the visibility of the border will aid pedestrians and motorists during low light or inclement weather conditions when the potential for conflict is greatest.

The installation of YPB would be most beneficial on the coordinated urban corridor, where the main goal is to maximize the traffic throughput for mainline traffic; incurring delays for side street traffic and pedestrians waiting to cross. In this situation pedestrians may get impatient for extended waiting period and become confused whether the pedestrian signal / call button is operational, especially when there is little traffic on the mainline. This behavioral feature may lead to pedestrian signal violation, which can be mitigated or more likely controlled by installing the YPB.

REFERENCE

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APPENDIX-A: SPREADSHEET SUMMARY DATA

BEFORE CONDITION STUDY

LOCATION 1: ADAMS ST. / MAINS ST (NAPA VALLEY)

No.	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	10	0	10	0	9	3	1	0	4	0	4	110	212	47
2	7:00:00 AM - 8:00:00 AM	22	1	23	1	17	12	9	0	21	3	18	188	410	123
3	8:00:00 AM - 9:00:00 AM	31	0	31	1	36	33	20	0	53	0	53	369	662	251
4	9:00:00 AM - 10:00:00 AM	63	0	63	7	62	66	65	0	131	4	127	519	853	683
5	10:00:00 AM - 11:00:00 AM	88	0	88	4	104	135	98	0	233	7	227	620	966	1366
6	11:00:00 AM - 12:00:00 PM	83	0	83	3	98	148	131	0	279	15	265	658	1059	1873
7	12:00:00 PM - 1:00:00 PM	86	1	87	4	83	183	172	3	358	32	326	787	1061	2325
8	1:00:00 PM - 2:00:00 PM	93	1	94	6	101	176	139	0	315	32	283	704	1057	2603
9	2:00:00 PM - 3:00:00 PM	100	0	100	8	90	176	149	2	327	19	310	723	1034	2566
10	3:00:00 PM - 4:00:00 PM	107	0	107	7	95	164	119	0	283	16	269	724	1005	1947
11	4:00:00 PM - 5:00:00 PM	90	0	90	9	101	160	90	4	254	15	239	737	986	1727
12	5:00:00 PM - 6:00:00 PM	46	1	47	5	67	70	37	0	107	6	103	617	748	790
13	6:00:00 PM - 7:00:00 PM	26	0	26	2	44	23	15	0	38	4	34	404	527	329
14	7:00:00 PM - 8:00:00 PM	32	1	33	4	35	21	14	0	35	0	35	254	439	403
15	8:00:00 PM - 9:00:00 PM	23	0	23	0	25	2	1	0	3	0	3	152	325	145
16	9:00:00 PM - 10:00:00 PM	9	1	10	0	29	1	5	1	7	1	6	120	222	103

AFTER CONDITION STUDY

LOCATION 1: ADAMS ST. / MAINS ST (NAPA VALLEY)

No.	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	2	0	10	0	11	2	1	0	4	0	3	74	123	52
2	7:00:00 AM - 8:00:00 AM	15	0	23	2	38	3	3	0	24	0	6	175	313	176
3	8:00:00 AM - 9:00:00 AM	16	0	32	4	33	11	21	1	53	0	33	248	460	323
4	9:00:00 AM - 10:00:00 AM	33	0	51	5	28	26	24	0	146	2	48	312	515	635
5	10:00:00 AM - 11:00:00 AM	27	0	80	4	49	47	43	0	195	4	86	379	694	1101
6	11:00:00 AM - 12:00:00 PM	24	0	53	10	42	66	47	0	215	3	110	486	747	1649
7	12:00:00 PM - 1:00:00 PM	28	0	43	4	35	65	50	1	242	7	109	514	778	1614
8	1:00:00 PM - 2:00:00 PM	26	0	46	7	33	54	43	4	207	8	93	472	841	1939
9	2:00:00 PM - 3:00:00 PM	31	0	26	5	38	65	36	0	101	10	91	514	766	1801
10	3:00:00 PM - 4:00:00 PM	23	0	49	9	28	50	18	1	184	2	67	500	717	1545
11	4:00:00 PM - 5:00:00 PM	23	0	57	10	27	49	25	0	162	2	72	461	847	1517
12	5:00:00 PM - 6:00:00 PM	24	0	45	9	29	51	19	1	138	5	67	398	585	992
13	6:00:00 PM - 7:00:00 PM	14	0	44	3	16	18	14	2	142	2	32	341	496	483
14	7:00:00 PM - 8:00:00 PM	24	0	38	4	30	24	8	0	117	0	32	236	470	706
15	8:00:00 PM - 9:00:00 PM	10	0	27	0	20	4	4	1	65	2	7	122	382	314
16	9:00:00 PM - 10:00:00 PM	2	0	44	0	18	3	5	0	55	1	7	117	233	263

BEFORE CONDITION STUDY *(5/6/2018 - 5/12/2018)*

LOCATION 2: WEST 14 ST. / REDWOOD HWY (SR-101) (EUREKA)

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	2	0	2	0	9	1	1	0	2	1	1	445	330	71
2	7:00:00 AM - 8:00:00 AM	5	0	5	0	33	5	7	0	12	0	12	695	536	106
3	8:00:00 AM - 9:00:00 AM	11	0	11	0	14	11	6	0	17	6	11	880	725	147
4	9:00:00 AM - 10:00:00 AM	10	0	10	0	16	16	18	0	34	5	29	1020	1025	160
5	10:00:00 AM - 11:00:00 AM	9	1	10	1	14	24	28	1	53	12	41	1571	1136	231
6	11:00:00 AM - 12:00:00 PM	7	0	7	0	19	22	31	0	53	11	42	1840	1225	210
7	12:00:00 PM - 1:00:00 PM	6	1	7	1	16	10	36	2	48	10	38	1930	1216	220
8	1:00:00 PM - 2:00:00 PM	7	0	7	0	19	14	30	2	46	12	34	1834	1172	202
9	2:00:00 PM - 3:00:00 PM	9	1	10	1	22	14	29	0	43	10	33	1840	1232	166
10	3:00:00 PM - 4:00:00 PM	10	0	10	1	18	14	25	1	40	8	32	1835	1280	170
11	4:00:00 PM - 5:00:00 PM	15	3	18	1	20	12	33	1	46	14	32	1641	1197	144
12	5:00:00 PM - 6:00:00 PM	6	0	6	0	9	9	20	0	29	2	27	1302	916	134
13	6:00:00 PM - 7:00:00 PM	8	0	8	0	10	17	13	0	30	6	24	824	662	158
14	7:00:00 PM - 8:00:00 PM	8	1	9	0	18	20	8	0	28	2	26	650	670	140
15	8:00:00 PM - 9:00:00 PM	18	1	19	0	12	20	1	0	21	1	20	373	312	124
16	9:00:00 PM - 10:00:00 PM	8	0	8	0	18	4	5	0	9	0	9	254	262	62

AFTER CONDITION STUDY (7/1/2018 - 7/7/2018)

LOCATION 2: WEST 14 ST. / REDWOOD HWY (SR-101) (EUREKA)

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	10	0	10	0	15	3	1	0	4	1	3	232	252	69
2	7:00:00 AM - 8:00:00 AM	12	0	12	0	12	4	4	0	8	0	8	372	384	85
3	8:00:00 AM - 9:00:00 AM	8	0	8	0	12	7	7	1	15	0	15	697	537	107
4	9:00:00 AM - 10:00:00 AM	9	0	9	1	14	20	19	0	39	7	32	880	735	184
5	10:00:00 AM - 11:00:00 AM	9	0	9	1	21	28	26	0	54	6	48	1144	942	215
6	11:00:00 AM - 12:00:00 PM	16	0	16	0	14	26	33	1	60	13	49	1402	1106	245
7	12:00:00 PM - 1:00:00 PM	9	1	10	0	8	24	51	0	75	12	63	1567	1200	244
8	1:00:00 PM - 2:00:00 PM	15	0	15	0	7	19	34	0	53	7	46	1526	1199	235
9	2:00:00 PM - 3:00:00 PM	8	0	8	0	18	18	32	0	50	10	40	1455	1077	254
10	3:00:00 PM - 4:00:00 PM	11	1	12	1	11	17	26	0	43	5	38	1443	1027	222
11	4:00:00 PM - 5:00:00 PM	12	0	12	0	8	13	18	0	31	8	24	1170	1029	177
12	5:00:00 PM - 6:00:00 PM	9	0	9	0	7	6	23	1	30	3	27	1114	822	165
13	6:00:00 PM - 7:00:00 PM	9	0	9	0	15	11	5	0	16	1	15	866	709	125
14	7:00:00 PM - 8:00:00 PM	8	1	9	0	12	10	8	0	18	2	17	528	517	133
15	8:00:00 PM - 9:00:00 PM	7	1	8	0	20	8	5	0	13	5	8	470	363	132
16	9:00:00 PM - 10:00:00 PM	5	0	5	0	13	5	2	0	7	1	6	254	291	112

BEFORE CONDITION STUDY *(5/6/2018 - 5/12/2018)*

LOCATION 3: REDWOOD AVE / MAIN ST. (FORT BRAGG)

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	3	0	3	2	0	0	0	0	0	0	29	109	87
2	7:00:00 AM - 8:00:00 AM	0	0	0	0	2	1	0	3	0	4	58	279	273
3	8:00:00 AM - 9:00:00 AM	3	0	3	0	6	2	0	8	0	7	125	417	454
4	9:00:00 AM - 10:00:00 AM	4	0	4	3	2	2	0	4	0	10	172	520	639
5	10:00:00 AM - 11:00:00 AM	1	0	1	3	14	7	0	21	0	24	198	705	843
6	11:00:00 AM - 12:00:00 PM	2	0	2	3	16	10	0	26	0	23	208	757	951
7	12:00:00 PM - 1:00:00 PM	2	0	2	1	14	9	1	24	0	27	222	952	1024
8	1:00:00 PM - 2:00:00 PM	1	0	1	3	16	8	0	24	1	22	225	878	1054
9	2:00:00 PM - 3:00:00 PM	1	0	1	2	15	12	0	27	0	29	193	874	966
10	3:00:00 PM - 4:00:00 PM	1	0	1	1	21	13	0	34	0	34	217	1034	1120
11	4:00:00 PM - 5:00:00 PM	3	0	3	0	13	5	0	18	0	19	180	902	1058
12	5:00:00 PM - 6:00:00 PM	0	0	0	1	14	4	0	18	0	19	184	823	963
13	6:00:00 PM - 7:00:00 PM	1	0	1	0	7	4	0	11	0	11	134	546	668
14	7:00:00 PM - 8:00:00 PM	1	0	1	0	5	0	0	5	0	6	78	468	538
15	8:00:00 PM - 9:00:00 PM	0	0	0	0	1	4	0	5	1	5	75	372	502
16	9:00:00 PM - 10:00:00 PM	0	0	0	0	1	0	0	1	0	1	39	203	263

AFTER CONDITION STUDY *(6/17/2018 - 6/23/2018)*

LOCATION 3: REDWOOD AVE / MAIN ST. (FORT BRAGG)

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Left Turn	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	0	0	0	1	0	0	0	0	0	0	53	68	24
2	7:00:00 AM - 8:00:00 AM	1	0	1	0	1	0	0	1	0	1	144	139	44
3	8:00:00 AM - 9:00:00 AM	0	0	0	0	4	1	0	5	1	4	198	207	99
4	9:00:00 AM - 10:00:00 AM	0	0	0	1	7	3	0	10	0	10	288	336	285
5	10:00:00 AM - 11:00:00 AM	0	0	0	1	13	7	0	20	0	20	318	463	508
6	11:00:00 AM - 12:00:00 PM	0	0	0	0	25	6	0	31	0	31	419	548	606
7	12:00:00 PM - 1:00:00 PM	0	0	0	0	19	7	0	26	0	26	479	628	718
8	1:00:00 PM - 2:00:00 PM	1	0	1	0	19	7	0	26	0	26	406	570	735
9	2:00:00 PM - 3:00:00 PM	0	0	0	0	19	3	0	22	0	22	468	589	809
10	3:00:00 PM - 4:00:00 PM	1	0	1	1	18	5	0	23	0	23	435	606	711
11	4:00:00 PM - 5:00:00 PM	0	0	0	0	25	1	0	26	0	26	479	625	608
12	5:00:00 PM - 6:00:00 PM	0	0	0	0	13	1	0	14	0	14	352	514	466
13	6:00:00 PM - 7:00:00 PM	0	0	0	1	6	3	0	9	0	9	270	410	387
14	7:00:00 PM - 8:00:00 PM	0	0	0	0	6	1	0	7	0	7	214	343	334
15	8:00:00 PM - 9:00:00 PM	0	0	0	0	2	0	0	2	0	2	168	318	249
16	9:00:00 PM - 10:00:00 PM	0	0	0	0	2	1	0	3	0	3	124	191	115

BEFORE CONDITION STUDY *(8/3/2018 - 8/9/2018)*

LOCATION 4: COAST HWY (SR-1) / BROADWAY STREET

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	15	2	17	4	2	0	55	0	55	1	55	1107	257
2	7:00:00 AM - 8:00:00 AM	10	0	10	3	1	3	172	0	175	1	174	1526	489
3	8:00:00 AM - 9:00:00 AM	5	1	6	5	1	3	324	0	327	0	327	1864	995
4	9:00:00 AM - 10:00:00 AM	3	0	3	3	0	3	423	0	426	0	426	2368	1786
5	10:00:00 AM - 11:00:00 AM	0	0	0	3	0	8	515	0	523	7	516	2432	2319
6	11:00:00 AM - 12:00:00 PM	4	1	5	0	0	4	544	3	551	3	548	2441	3451
7	12:00:00 PM - 1:00:00 PM	4	0	4	1	0	12	565	0	577	9	568	2349	4231
8	1:00:00 PM - 2:00:00 PM	6	0	6	2	0	16	580	0	596	9	588	2549	4578
9	2:00:00 PM - 3:00:00 PM	7	1	8	1	0	23	606	0	629	6	624	2332	5070
10	3:00:00 PM - 4:00:00 PM	3	0	3	1	2	11	543	0	554	7	547	2523	4587
11	4:00:00 PM - 5:00:00 PM	6	0	6	3	0	13	623	2	638	9	631	2387	5200
12	5:00:00 PM - 6:00:00 PM	1	0	1	3	0	22	556	2	580	9	571	2598	4537
13	6:00:00 PM - 7:00:00 PM	4	0	4	2	0	25	579	4	608	6	602	2345	5072
14	7:00:00 PM - 8:00:00 PM	11	1	12	0	0	13	646	0	659	6	654	2368	5353
15	8:00:00 PM - 9:00:00 PM	3	0	3	0	0	14	591	1	606	5	601	2265	4166
16	9:00:00 PM - 10:00:00 PM	1	0	1	0	0	2	351	0	353	1	352	1652	1851

AFTER CONDITION STUDY *(8/27/2018 - 9/2/2018)*

LOCATION 4: COAST HWY (SR-1) / BROADWAY STREET

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Critical Right Turn	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	1	0	1	2	0	0	53	0	53	0	53	1339	249
2	7:00:00 AM - 8:00:00 AM	4	0	4	1	0	2	164	0	166	0	166	1698	338
3	8:00:00 AM - 9:00:00 AM	2	0	2	0	0	0	294	0	294	2	292	1997	654
4	9:00:00 AM - 10:00:00 AM	3	0	3	0	0	2	356	0	358	0	358	1929	1138
5	10:00:00 AM - 11:00:00 AM	0	0	0	1	0	0	353	0	353	2	351	2253	1331
6	11:00:00 AM - 12:00:00 PM	0	0	0	0	0	3	424	0	427	1	428	2516	1851
7	12:00:00 PM - 1:00:00 PM	1	0	1	0	0	5	494	0	499	7	490	2597	2598
8	1:00:00 PM - 2:00:00 PM	0	0	0	0	0	3	438	0	441	0	441	2525	2414
9	2:00:00 PM - 3:00:00 PM	0	0	0	0	0	4	438	0	442	4	438	2258	2291
10	3:00:00 PM - 4:00:00 PM	0	0	0	0	0	2	443	0	445	0	445	2150	2292
11	4:00:00 PM - 5:00:00 PM	0	0	0	0	0	1	368	0	369	3	365	2211	2202
12	5:00:00 PM - 6:00:00 PM	1	0	1	0	0	3	409	0	412	1	411	2101	2091
13	6:00:00 PM - 7:00:00 PM	1	0	1	0	0	0	455	0	455	4	451	2241	2270
14	7:00:00 PM - 8:00:00 PM	2	0	2	0	0	1	470	0	471	1	470	2197	2800
15	8:00:00 PM - 9:00:00 PM	4	0	4	0	1	2	356	0	358	0	358	2025	1588
16	9:00:00 PM - 10:00:00 PM	2	0	2	0	0	1	167	0	168	1	167	1496	838

BEFORE CONDITION STUDY *(8/31/2018 - 9/6/2018)*

LOCATION 5: SAO PAOLO AVENUE (R123) / FAIRMOUNT AVENUE

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	0	0	0	0	13	0	2	0	2	0	2	76
2	7:00:00 AM - 8:00:00 AM	8	0	8	3	17	1	11	0	12	1	11	229
3	8:00:00 AM - 9:00:00 AM	18	0	18	7	24	2	21	0	23	0	22	461
4	9:00:00 AM - 10:00:00 AM	8	0	8	7	26	4	16	0	20	1	18	364
5	10:00:00 AM - 11:00:00 AM	8	0	5	9	31	3	30	1	34	1	33	536
6	11:00:00 AM - 12:00:00 PM	14	0	14	6	27	4	42	0	46	3	43	653
7	12:00:00 PM - 1:00:00 PM	12	0	11	6	16	11	44	0	55	5	50	695
8	1:00:00 PM - 2:00:00 PM	4	0	4	6	27	3	33	1	37	3	34	632
9	2:00:00 PM - 3:00:00 PM	16	0	16	12	28	4	39	1	44	1	42	856
10	3:00:00 PM - 4:00:00 PM	12	0	13	9	24	9	50	0	59	2	55	848
11	4:00:00 PM - 5:00:00 PM	12	0	12	4	51	2	52	0	54	5	49	863
12	5:00:00 PM - 6:00:00 PM	12	0	12	10	39	3	31	2	36	1	32	871
13	6:00:00 PM - 7:00:00 PM	10	0	13	7	48	2	39	1	42	0	39	902
14	7:00:00 PM - 8:00:00 PM	9	0	9	4	32	1	23	1	25	0	24	653
15	8:00:00 PM - 9:00:00 PM	6	0	7	0	26	1	13	0	14	1	13	351
16	9:00:00 PM - 10:00:00 PM	10	0	11	0	20	0	2	0	2	0	2	269

AFTER CONDITION STUDY *(9/18/2018 - 9/24/2018)*

LOCATION 5: SAO PAOLO AVENUE (R123) / FAIRMOUNT AVENUE

No	Time Interval	Pedestrian Violation	Vehicle Violation	Total Violation	Extra Push	No Push	Left Turn Conflict	Right Turn Conflict	Through Conflict	Total Conflict	Pedestrian Yield	Vehicle Yield	Total Pedestrian
1	6:00:00 AM - 7:00:00 AM	5	0	5	1	8	0	0	0	0	0	0	54
2	7:00:00 AM - 8:00:00 AM	23	0	26	5	12	1	3	6	10	1	4	214
3	8:00:00 AM - 9:00:00 AM	28	0	28	5	11	3	11	2	16	1	12	336
4	9:00:00 AM - 10:00:00 AM	36	0	39	9	24	1	17	2	20	3	12	427
5	10:00:00 AM - 11:00:00 AM	26	0	28	8	28	5	15	5	25	4	15	474
6	11:00:00 AM - 12:00:00 PM	22	0	22	7	34	3	25	3	31	5	25	538
7	12:00:00 PM - 1:00:00 PM	19	0	19	3	33	2	16	2	20	0	20	544
8	1:00:00 PM - 2:00:00 PM	29	0	30	5	29	6	17	4	27	5	18	772
9	2:00:00 PM - 3:00:00 PM	40	0	41	6	38	3	22	5	30	2	24	792
10	3:00:00 PM - 4:00:00 PM	30	0	32	9	24	3	10	6	19	2	13	727
11	4:00:00 PM - 5:00:00 PM	20	0	20	8	28	3	22	1	26	5	20	769
12	5:00:00 PM - 6:00:00 PM	25	0	27	13	21	4	24	4	32	5	27	863
13	6:00:00 PM - 7:00:00 PM	26	0	26	5	29	3	34	2	39	3	36	869
14	7:00:00 PM - 8:00:00 PM	15	0	15	3	19	1	19	1	21	2	20	670
15	8:00:00 PM - 9:00:00 PM	8	0	8	0	14	0	10	0	10	0	10	301
16	9:00:00 PM - 10:00:00 PM	10	0	14	0	18	0	8	2	10	0	11	232