Passive Pedestrian Detection at Unsignalized Crossings

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INTRODUCTION

Millions of Americans regularly walk or bicycle for exercise, sport, relaxation, and enjoyment of the outdoors. According to the 1990 National Personal Transportation Study, approximately 7.2 percent of all travel trips are made by walking in the U.S. One job of city and state agencies is to provide facilities that are safe for crossing streets and walking along roadways (Zegeer, June 1995).

The City of Portland, Oregon is researching ways to improve pedestrian safety at unsignalized pedestrian crossings. Experience has shown that installing standard signing and markings provide limited safety improvements for pedestrians. Pedestrians may also tend to develop a false sense of security from these warning devices. Over time, motorists who travel the areas with these crossings tend to become conditioned (ignore) the signs and markings, therefore providing no increase in safety for pedestrians. One possible solution to this is a warning device that operates only when a pedestrian is present. Such a device may be a yellow beacon activated by the pedestrian using a push button and a reflective pedestrian crossing sign. This type of device would catch the attention of the motorist that has become conditioned to the crossing by presenting something that is not present at all times such as the yellow beacon. However, if one observes a crossing with push buttons, it can be seen that not all pedestrians use the push buttons. Whether this is due to the push button being hard to find, poorly located, not expected, or the pedestrian has a seeing impairment, it would be beneficial to have the warning devices activated without having to rely on the pedestrian to push a button. A better approach to triggering the device may be passive detection of the pedestrian.

This report includes a discussion of a project conducted by the City of Portland to evaluate available sensor technologies for passive pedestrian detection, design of a crossing to utilize these sensor technologies, and a preliminary evaluation of how well the sensors operate once installed at the crossing.

BACKGROUND

Passive Pedestrian Detection - *to detect the presence of pedestrians in a stationary or moving state at the curbside of and/or in a pedestrian crossing by means other than those requiring physical actuation by the pedestrian. These means may be by using infrared, ultrasonic, microwave radar, video imaging, or piezometric sensors.*

Passive pedestrian detection may be one solution to help make unsignalized pedestrian crossings safer in Portland, Oregon. Currently, many sensors are being developed and in use by different industries that may be used to passively detect pedestrians. Some of these sensor technologies include the following: video imaging, infrared, ultra sonic, piezometric, and microwave radar. The intended use of these sensors is to detect a pedestrian waiting in the landing areas of a crossing (passive detection). Once a pedestrian is detected, a warning device, such as a yellow beacon, would be actuated to warn oncoming motorists of the pedestrian's presence. To insure pedestrians can clear the crossing once they have entered it, another sensor can be positioned to detect pedestrians within the crossing itself and prolong the yellow beacon or flashing pedestrian crossing sign until the pedestrian clears the crossing.

SUMMARY OF EXISTING TECHNOLOGIES

In determining what type of detection devices could be used for passive pedestrian detection, reviews of literature and telephone interviews with sensor manufacturers were conducted. The following two sections sum up what was found.

A literature review provided insight into what types of technologies are being used for detection devices in general. However, the literature on passive pedestrian detection devices is scarce except for a few articles on "PUFFIN" (Pedestrian User Friendly Intelligent Signals) and "Pussycat" (Pedestrian Urban Safety System and Comfort at Traffic Signals) crossings that use a combination of devices such as piezometric pads and Doppler radar or passive infrared sensors in detecting the presence of pedestrians in Great Britain and the Netherlands. For further information, see references (Tan, C., November 1995, King, W., November 1993, Davies, H.E.H., 1992, and the Department of Transport, March 1993).

Contacts with different sensor manufacturers and suppliers were made to obtain information on detection devices. These sources were helpful in providing information on the limitations and effectiveness of sensors in various environmental conditions.

The literature search and industry contacts identified five types of technologies that have been used in detection systems and that could possibly be used for passive pedestrian detection. These technologies include the following:

- **Passive Infrared** (PIR) - detects a change in the thermal contrast within a defined field of vision.

- **Ultrasonic** - emits an ultrasonic sound and listens for an echo bouncing off an object that is found within its field of view. Temperature and humidity changes can affect sensor operations.

- **Doppler Radar** - as an object moves, a radio wave bounced off that object will change in frequency. Doppler radar emits a radio wave and analyzes the change in frequency of that radio wave as it is bounced back from an object moving within its detection range. This change in frequency is known as the Doppler Effect.

- **Video Imaging** - video imaging is the analysis of the change in pixels of a video image in order to detect movement within a defined zone. Lighting and shadows can affect a video imaging systems detection capabilities.

- **Piezometric** - senses a change of pressure on a material subjected to hydrostatic pressure.

PORTLAND PASSIVE PEDESTRIAN PROJECT

Of the technologies found in the previous section, a passive infrared, microwave radar, and two ultrasonic sensors were chosen to be tested in the Portland Passive Pedestrian Project. Sensors were chosen by using a decision matrix in the form of the Quality Function Deployment Method (QFD Method) to evaluate how well each sensor met the needs of the project. Performance, maintenance, and cost requirements were all analyzed as part of the QFD Method. Once sensors that met the needs of the project were found, preliminary and secondary testing were conducted on each of them.

Quality Function Deployment Method

The Quality Function Deployment Method was employed in this project to help evaluate sensors and better understand the scope of the project before development and testing began. It also provided a structure of the information for future development of similar systems (Hunter-Zaworski, 1992). The following six steps comprise the QFD Method (Ullman, 1992):

- Identification of the customer using the product.
- Determination of customer requirements.
- Determination of the importance of each requirement to the customer.
- Bench marking the existing products.
- Translation of customer requirements into measurable engineering requirements.
- Setting engineering targets for the product.

The QFD Method has been in use since 1972 by companies such as Toyota, Ford, Hewlett-Packard, and AT&T (Hauser, 1988). Use of this method in the transportation engineering field has been limited. A further and beneficial explanation of the QFD Method and its use in the

Portland Passive Pedestrian Project can be read in a paper entitled, *Passive Pedestrian Detection Sensor Selection Using the Quality Function Deployment Method* (Beckwith, 1997).

A large portion of the information used in the evaluations of the various sensor technologies came from the manufacturers that typically had never tested or used the sensors in applications involving detection of pedestrians in external environments. This required that preliminary (short term) tests on the sensors be performed to see how well pedestrians could be detected in an external environment. Secondary (long term) tests were then conducted on sensors that performed well in the initial testing to see how well they functioned at an actual crossing.

Preliminary (Short Term) Testing

With the initial group of sensors identified as possible candidates for use in the passive pedestrian project, each needed to be tested for accuracy in detecting pedestrians. The main goals here were to determine if the detectors could detect pedestrians, what types of detection zones could be expected, location requirements, and if there were an excessive number of false calls. A few false calls from the sensors are acceptable and can be compensated for through various methods where as not detecting pedestrians can be fatal. Therefore, if a sensor could not consistently detect a pedestrian, it was automatically excluded from consideration to be used with the passive detection project. If sensors were found that could consistently detect pedestrians, they were further tested to determine if false calls were being made and could be reduced.

Performing the preliminary testing at an actual intersection was not necessary since similar conditions could be produced where higher pedestrian volumes were present. This reduced the time required to conduct a complete test, short of testing the sensors under varying weather conditions. For this project, a location that showed a high level of pedestrian traffic adjacent to a bus stop was chosen to conduct the preliminary testing of each sensor.

Each sensor was mounted on a pedestrian signal and positioned to detect pedestrian traffic passing by on the sidewalk. The sensors were then connected into a type 170 controller at the location. The controller cabinet was retrofitted with two lights mounted on top that illuminated each time a pedestrian entered the detection zone of the sensor. This permitted two sensors to be tested at once. At this point, adjustments were made for aiming, delay settings, and size of detection zones.

The intersection chosen for preliminary testing was equipped with video cameras and a video cassette recorder that allowed for monitoring of the sensors over extended periods without having an observer present at all times. The cameras were set to monitor the lights mounted on the controller cabinet and the detection zones of each sensor. This made it possible to ensure that the detection zones were not fluctuating due to environmental changes and that pedestrians outside the zones, animals, or wind blowing through trees, were not causing false detections.

Each sensor's zone of detection was marked on the ground. This allowed the analyst to determine if a pedestrian was detected, not detected, or a false call was received. Determination of detection was accomplished by watching to see if a pedestrian was within a detection zone and observing whether or not the lights on the controller cabinet were illuminated. The intersection was video taped at various times during the day. This gave various conditions at different temperatures throughout the day that could affect sensor operations. The sensors also needed to be tested under various weather conditions which for the Portland area include: rain, freezing rain, snow, sleet, hail, fog, warmest day, and coldest day. Testing of sensors during dark and light hours does not need to be considered here since lighting has no effect on the operation of the chosen sensors.

With the preliminary testing complete, ways to reduce the number of false calls were also researched. Most often, the way false calls are reduced is dependent on the type of sensor. Each type of sensor has its own operating characteristics and adjustments. Some were equipped with delay or sensitivity adjustments. Many other sensors had no adjustment methods other than physically moving them from one position to another. Still, others are adjusted through a software package sold with the sensor. The company that develops and manufactures each sensor can provide insight on the best methods for sensor adjustments to reduce false calls.

Preliminary Test Results

Of the detectors chosen using the QFD Method, three were tested. These included the passive infrared, Doppler Radar, and one ultrasonic sensor. Selection of these three sensors were based on them effectively meeting performance, maintenance, and cost requirements (Beckwith, July 1997). The ultrasonic and passive infrared sensors had the greatest limitations on detection distances and had been used very little in applications involving pedestrian detection in an external environment. They were therefore tested at close and extended ranges with the latter showing how well they operated at their maximum ranges. The Doppler radar however, which was designed and tested specifically for pedestrian detection was only tested at medium and extended ranges in anticipation that it would be used as an extended range sensor. Table 1 shows preliminary test results.

Sensor Characteristics

The following section discusses the unique characteristics found for each type of sensor tested and expands upon the results found in Table 1. These characteristics may or may not be desirable and are presented here to show what may be expected when dealing with different sensor technologies.

Ultrasonic - Ultrasonic sensors have been used in various applications involving pedestrian and traffic detection. Usually they can detect up to a distance of 30 feet. However, documentation is scarce concerning applications involving pedestrians.

An important characteristic of the ultrasonic sensor is the need to aim it in a horizontal (side fired) or vertical position to the target (see Figure 1). In a position other than these two, the sensor can lose signal bounce back (echo). This increases the possibility of pedestrians not being detected. It also restricts the number of sites that can use this type of sensor. The need for specific vertical placement directly above a landing means mast arms would need to be added to a crossing. This can increase installation costs for new and upgraded facilities. These extra costs can easily make use of a sensor of this type uneconomical when compared with a device such as a push button. Horizontal placement or the side fired position can also become a problem. When placed in this position, the sensor is at a level easily reached by pedestrians, increasing the chances for vandalism. They can also easily be blocked by objects set in front of them.

The detection zone of the ultrasonic sensor also requires adjustment so the end of it stops above the ground. This can have negative and positive impacts. If the sensor is not adjusted properly, false calls can be received by signal bounce back from the ground. On the other hand, if detection of small animals is not wanted, then the zones can be adjusted to a height allowing animals to pass below the detection zone of the sensor.

Another characteristic of the ultrasonic sensor is that temperature and humidity changes can increase or decrease the size of the detection zone. This is usually insignificant, but in highly sensitive applications, this can cause difficulties with sensor operation.

Finally, clothing type effects how easily a pedestrian is detected. Pedestrians wearing nylon or synthetic clothing were easily detected, but pedestrians wearing cotton or natural fiber were often not detected. This may be due to clothes made of natural fiber being more absorbent to sound waves than clothes made of synthetic fiber which would effectively reduce the amount of signal bounce back.

In reference to Table 1, the ultrasonic sensor tested in the Portland project did not do well with a 45% no detection rate in the long range application (approximately 25 feet). This in part may be due to the sensor being placed at a 67º angle rather than perpendicular to the pedestrian allowing for signal loss. In the close range applications (approximately 14 feet), the no detection rate dropped to about 3%. Here, the sensor was placed at a 40º angle rather than perpendicular to the pedestrian which again could account for part of the 3% no detection rate (see Figure 2). It was also found that during rainy weather, the sensor would continuously receive false calls.

It may be questioned why the ultrasonic sensor was not tested at the optimum operating angle. One requirement of this project is to find a sensor that is not just economical and reliable, but that can easily be adapted to existing facilities. This means attaching sensors to existing poles that require the sensor to be at an angle to provide detection for the crossing. The versatility for placement of a sensor is an important evaluation factor.

Other ultrasonic sensors will share many of the same characteristics as the one tested here. These characteristics will include: the need for a specific angle of placement, sensitivity to temperature and humidity change, and a maximum detection range.

Passive Infrared Sensor (PIR) - The passive infrared sensor (PIR) tested was manufactured to operate in temperature ranges between -40° to 120° Fahrenheit. With this range, the warmest and coldest temperatures experienced within Portland, Oregon area should be within the sensors operating range. This is an important characteristic to keep in mind. Not all PIR sensors are designed to operate at these temperature extremes.

During the preliminary testing of the PIR sensor, occasional rain showers were present. These rain showers did not affect sensor operations.

The passive infrared sensors use a Fresnel lens to provide various detection patterns. The lens found to work best was a vertical barrier lens that allows for operations up to 45 feet and provides a continuous detection zone (see Figure 3). The vertical lens extends the detection zone from just below the sensor outward to a given distance dependent on sensor height and angle. These lenses however, are made of plastic and ultraviolet light will eventually degrade them. Therefore, replacing these lenses every five to seven years is necessary.

The detection zone of the passive infrared sensor is well defined at close and extended ranges. This makes it easily adjustable in the field without the use of special equipment. The widest detection zone for the PIR sensor was achieved when the sensor was tested at extended ranges of approximately 45 feet. The largest detection zone is approximately 3 feet in width at these extended distances. This requires that three to four sensors be used to fully cover a crossing 10 to 12 feet in width. From a maintenance view point, this can be problematic. Having as little equipment as possible at a crossing reduces the number of breakdowns and preventive maintenance hours. At close range testing of approximately 13 feet, the detection zone was 1.5 feet in width. This makes this sensor ideal at the landing of a crossing where small detection zones are wanted. With this sensor, a one inch change in detection zone width is experienced with each foot change in the distance from the sensor.

The PIR sensor can be placed at any angle with no loss in the sensor's operation. This means it can be mounted in an unlimited number of locations to existing hardware.

One limitation that needs to be considered with the PIR sensors is that it looks for a change in the temperature contrast of the area it is monitoring. If a pedestrian is moving directly into the sensors field of view at a very slow pace, the pedestrian may not be picked up by the sensor since the rate of change in the temperature contrast is sometimes less than the sensor can detect. This effect can become greater as the distance from the sensor increases. Also, it is theoretically possible for no detection to occur if the ambient temperature and the body temperature of a pedestrian were the same. However, this is unlikely to occur since clothing and physical activity of the pedestrian causes the body temperature to vary from the ambient temperature.

Again referring to Table 1, the passive infrared sensor worked well in close and extended range applications. In the close range applications, there was a no detection rate of 0%. In the extended range application, a no detection rate of 1.5% was observed. This may have been due in part to the detector being tested at the maximum range where a change in temperature contrast experienced at the end of the detection zone farthest from the sensor may have been too small or slow to detect.

Many different types of infrared sensors being developed today operate using the same principles. However, operational variations do exist and include: detection zone sizes, effective detection distances, operational temperature ranges, and types of focusing devices such as Fresnel lenses. Infrared sensors have been effectively adapted to various needs of the manufacturing industry. However, the use and testing in external environments has been limited until now and care needs to be taken when choosing one to fit the needs of a project of this type.

Doppler Radar Sensor - The Doppler radar sensor can provide a detection zone of 20 feet in width and can extend up to 49 feet in length (see Figure 4). With adjustment this length can be extended. This makes the Doppler radar a candidate for use at extended ranges of up to 49 feet with detection zones wide enough to cover a crossing 10 to 12 feet in width.

In the preliminary testing, the Doppler radar performed well. It operates at approximately 10.5 GHz which offers a negligible loss of performance due to adverse weather conditions. During the preliminary testing two adverse weather conditions were experienced: high temperatures from 95 to 100 degree Fahrenheit and heavy summer rain showers. The high temperatures did not have an effect on the sensor operation. The heavy rains however were detected by the sensor. This allows for false calls to occur during these and possibly other types of adverse weather conditions. As discussed earlier, a few of these false calls are acceptable since they would extend a detection call to a controller rather than cut a detection call short during times of adverse weather conditions.

Ideal detection is achieved when a pedestrian is walking at some angle other than perpendicular toward or away from the sensor. A pedestrian crossing perpendicular to the sensor may not be detected. This happens because Doppler radar analyzes the change in received radio frequencies bouncing off an object moving toward or away from the sensor. This change in frequency is known as the “Doppler Effect.” If the pedestrian moves perpendicular to the sensor, there is no change in the received radio frequencies.

The Doppler radar sensor has a minimum rate a target needs to be moving to be detected. Field measurements of the sensor tested showed a minimum average walking speed of 0.85 ft/s for pedestrians to be continuously detected by the sensor. Walking speeds as low as 0.65 ft/s also provided detection, but on an intermittent basis. At a minimum, the sensor tested had been designed to detect a minimum walking speed of at least 1.65 ft/s which falls well below the 4 ft/s suggested by AASHTO for design of pedestrian facilities.

Table 1 shows that the Doppler radar sensor had a 7% no detection rate. This is higher than the other detectors except the ultrasonic at long range. Although the no detection rate was higher, it had the greatest detection distance and can cover a wider area than the other sensors. It was felt that this was the best option available for extended range sensors and that the no detection rate could be reduced to an acceptable level by using a controller-based logic sequence and a multiple long and short range sensor array.

With Doppler radar sensors, operating frequencies, detection zones, and minimum threshold (walking speed) values may be unique for each sensor. The general operating principles however remain the same.

Error Sources - As with any piece of equipment, there are various sources that can induce error into the operational characteristics of the sensors tested. To sum these error sources, they can be divided into two categories. The first of these are error sources specific to each sensor. The second are general error sources that can be characteristic of all sensors.

Error sources specific to each sensor have been covered in the previous section on “Sensor Characteristics.” General error sources however, include sensor sampling rates and electronic components. Sample rates were briefly discussed regarding the passive infrared sensor operation. However, sample rates can affect each of the sensor’s abilities to detect pedestrians. If a sensor does not sample the signal it is designed to analyze, frequently enough, then pedestrians can pass through the detection zone without being detected. Electronic components can also induce error. For example, the Doppler radar could have a noise diode that could make it more sensitive to small moving objects such as rain that would normally not be detected by the sensor.

Secondary (Long Term) Testing

From the preliminary testing, two of the three types of sensors were chosen for further testing at an existing pedestrian crossing. The infrared sensor was chosen for monitoring the landing areas of the crossing and the Doppler radar was chosen for monitoring the area within the crossing itself.

As discussed in the previous section, the infrared sensors had a very good detection rate and was versatile regarding sensor positioning. This allows the detector to be installed in many different types of applications with minimum upgrading required to existing facilities and also low installation time and cost.

The Doppler radar sensor was the only sensor that effectively detected pedestrians at a distance of 30 feet or greater and had no maximum operating angles. It also had a detection zone that was wide enough to cover the width of a standard crossing. Therefore, only one to two sensors is needed to effectively monitor a crossing keeping installation time and cost at a minimum.

Installation Site

The intersection of SW Naito Parkway and Couch Street was chosen as the installation site to perform secondary testing on the passive infrared and Doppler radar sensors. At this intersection, the passive infrared sensors were used to detect pedestrians at the landings and the Doppler radar detected pedestrians within the crossing. The crossing is approximately 74 feet in length with a 13 foot wide pedestrian island in the middle. The sensors actuate yellow beacons placed above reflective yellow pedestrian crossing signs suspended above the crossing. There are advanced warning signs on each approach along Naito Parkway and the intersection is stop sign controlled on the Couch Street approach.

This crossing poses three problems for applying the given sensors:

- The long crossing length means sensors monitoring the crossing, not the landings, must detect for greater distances. This means less overlapping of detection zones for these sensors.

- The pedestrian median allows the pedestrian an opportunity to stop at a half way point in the crossing. This can allow for the pedestrian detection to be lost.

- Traffic is not required to stop. Since the sensors do not sense a difference between pedestrians and automobiles, both will be detected which potentially means the beacons may be actuated even when the pedestrians are not present.

A four-sensor configuration was designed to help address these problems and provide the safest possible crossing for the pedestrian using existing facilities (see Figure 5).

Four Sensor Configuration

The four sensor crossing consists of two passive infrared (1 and 4) and two Doppler radar (2 and 3) sensors. As discussed previously, the infrared sensors were positioned above each landing of the crossing. The Doppler radar sensors were positioned to detect pedestrians within the crossings with overlapping detection zones at the half way point.

The logic for this configuration is simple. Sensors 1 or 4 wait in a detect mode to be activated by a pedestrian entering one of their detection zones. Once activated, the yellow beacons turn on, sensors 2 and 3 will wait in a detect mode, and a minimum beacon activation timer (T1) plus a gap timer (T2) will be invoked. During the period the timer (T1) is active, the system checks to see if sensors 2 and 3 are detecting pedestrians. If pedestrians are detected, then the system continues to check if the timer (T1) has expired. If it has and pedestrians are still detected within the crossing, then the call to the yellow beacons will remain active if the gap timer (T2) time interval has not expired. If no pedestrians are detected, then the system checks to see if the gap time has been exceeded with no detection. If it has not, then the system continues to monitor for pedestrians. If there is still no detection of pedestrians, and the gap time expires, then sensors 2 and 3 are turned off, the beacons are turned off, and sensors 1 and 4 are reactivated (see the flow chart in Figure 6). The gap time (6 seconds) has been determined as the time it takes a person walking 3 ft/s (AASHTO design value for an elderly pedestrian) to cross the widest lane of vehicular travel that in this case is 21 feet. The minimum timer (T1) value was derived using the same method used for the gap timer value. It can be varied to an interval greater than or equal to the gap timer. This allows the minimum timer to be adjusted for specific needs of various applications.

The previously mentioned gap time is used to provide insurance against intermittent detection by sensors 2 and 3, or a pedestrian stopping on the pedestrian island for a small amount of time. If the sensors lose detection of the pedestrians while they are in the crossing or on the pedestrian island, then the gap time keeps sensors 2 and 3 active even if there is no pedestrian detected in the crossing. This crossing has sight distances well above the safe stopping sight distances on all approaches. The predetermined gap time exceeds the time it would take a vehicle traveling 35 mph to stop on wet pavements safely, which is 225 to 250 ft (AASHTO 1984, p 138).

Keep in mind that when sensors 2 and 3 are active, pedestrians and motor vehicles can be detected. This means during times of heavy traffic volumes, the beacons may stay illuminated for extended periods. This occurs because the gap time is not allowed to elapse due to the heavy traffic being detected by the sensors. Vehicles being detected by sensors 2 and 3 have two advantages. Since there is a pedestrian island at the half way point, pedestrians will tend to cross half way and then wait for a gap in traffic to finish crossing. This wait can be extensive during heavy traffic which means sensors 2 and 3 may lose detection of the pedestrians because they are not moving. However, since the motor vehicles are detected, the gap time is not allowed to elapse and once the pedestrians move again, they are again picked up by the sensors.

The four sensor configuration for this crossing becomes a problem if a pedestrian stops on the island for a period greater then the gap time and there is no vehicular traffic present for that same amount of time. In this case, the sensors will deactivate and the beacons will turn off. This means the pedestrian must finish the crossing with no supplementary warning.

Secondary Test Results

Initial secondary test results and observations have been obtained from the SW Naito Parkway and Couch Street location. The test site was observed to learn if detectors were reliably detecting pedestrians and the length of time the beacons remained active after the pedestrian left the crossing. Five items were recorded:

1. Weather Conditions: A record of which weather conditions the sensors have been tested under. This is one of the limiting factors for sensor operation.

2. Date: Different times of the year may show variations in pedestrian and motorist traffic patterns.

3. Time of Day: Recorded in 15 minute intervals. Different times of day will have different volumes of pedestrian traffic.

4. Detection Reliability: Each sensor was observed during a pedestrian's crossing to see whether it (F) false detected with no pedestrian present, (D) detected a pedestrian with no problems, (I) intermittently detected a pedestrian, or (L) lost detection of a pedestrian in the crossing.

5. System Shutdown Time: A record of how long after the pedestrian leaves the crossing the beacons remain activated. With cars and pedestrians

keeping the Doppler radar sensors activated, beacons can be extended long after the pedestrian has left the crossing.

Of sixty crossings observed, there were eight intermittent (I) detections with pedestrians present in the Doppler radar zones and one in the passive infrared zones. At no time during any of the observed crossings were pedestrians not detected or caught within the crossing when the system shut down after the gap time (T2) elapsed.

On the average, beacons would remain activated after the pedestrian left the crossing for 32 seconds. This is twice the time needed for a pedestrian walking at 4 ft/s (AASHTO design speed for an average pedestrian) to cross the 74 ft crossing. The maximum time recorded for beacons remaining on was 125 seconds with a minimum time of six seconds. Longer than average activation periods can be expected at this crossing during periods of heavy traffic volumes due to passing vehicles keeping sensors activated. The minimum time will not fall below six seconds since this is the time period set for the gap timer explained in the previous section.

During heavy rain fall, if the passive pedestrian detection system had been activated by a pedestrian, the Doppler radar sensors would remain active, keeping beacons illuminated. Once the rain subsided to a light rainfall, then the Doppler radar sensors would stop detecting. This can be viewed as either a benefit of the system or a failure. A failure due to the system operating even if no pedestrian is present at the crossing. A benefit because beacons would be activated during the adverse weather condition providing supplementary warning of a crossing with possible pedestrians present.

CONCLUSION

Passive pedestrian detection is a relatively new idea in the United States. It therefore requires careful studying and testing by agencies, such as the City of Portland that want to use this type of detection at pedestrian crossings. The information provided within this report has hopefully prompted questions and given insight into the complexity of the passive detection issue and what needs to be considered when developing passive pedestrian detection systems.

It was found that the Quality Function Deployment Matrix was helpful in unbiasedly selecting equipment. At the same time, it provided a structure or record of the information about the equipment that can be used in the current or similar future applications.

Many new devices are being developed and old ones improved for use in the detection of pedestrians. Through continued research, it is anticipated that the safety of unsignalized pedestrian crossings can be facilitated by using passive pedestrian detection systems. The infrared and Doppler radar sensors that passed the preliminary testing discussed in this report have shown encouraging initial secondary test results. With further analysis of these sensors applied to various crossing applications, it is anticipated that they will help in providing safe crossings.

In the summer of 1997, PIR sensors found to be effective at the unsignalized crossing covered in this report were installed at a signalized crossing in Portland. They were used to replace existing push buttons.

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TABLES

Table 1
Preliminary Test Results

Sensor	False Calls	Detection	No Detection	Total Peds
Ultrasonic at long range	**8%** **(7)**	**47%** **(41)**	**45%** **(39)**	**87**
Ultrasonic at close range	**8%** **(8)**	**89%** **(86)**	**3%** **(3)**	**97**
Doppler Radar	**1%** **(1)**	**92%** **(116)**	**7%** **(9)**	**126**
Passive Infrared at close range	**4%** **(3)**	**96%** **(72)**	**–**	**75**
Passive Infrared at long range	**4.5%** **(6)**	**94%** **(126)**	**1.5%** **(2)**	**134**

The first number is the percent of pedestrain out of the total number of pedestrians observed at the crossing that falls within each category. The second number is the actual number of pedestrians that were observed that fell into each category. An empty cell means no pedestrians fell into that category..

FIGURES

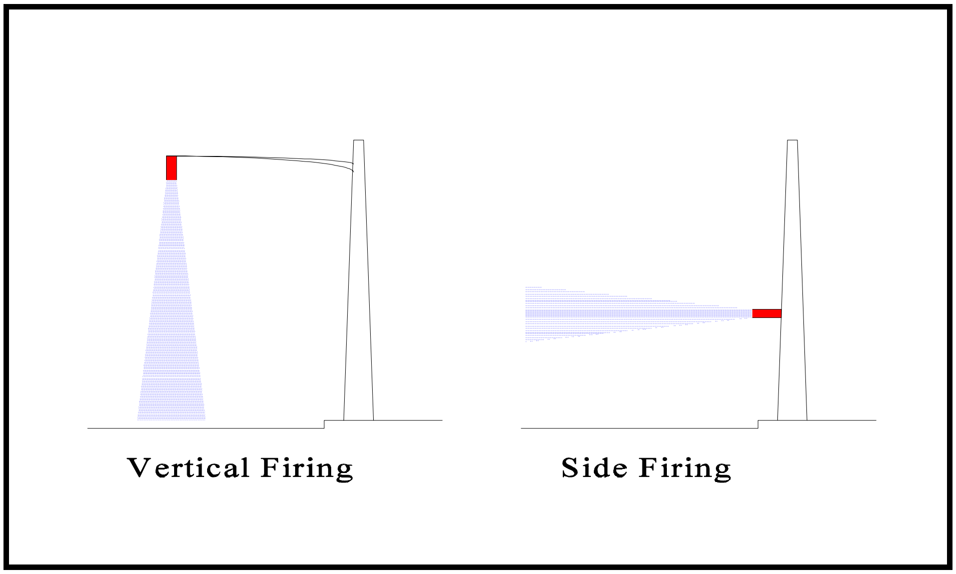

Figure 1: Profile View of Vertical and Side Firing Sensor Configurations.

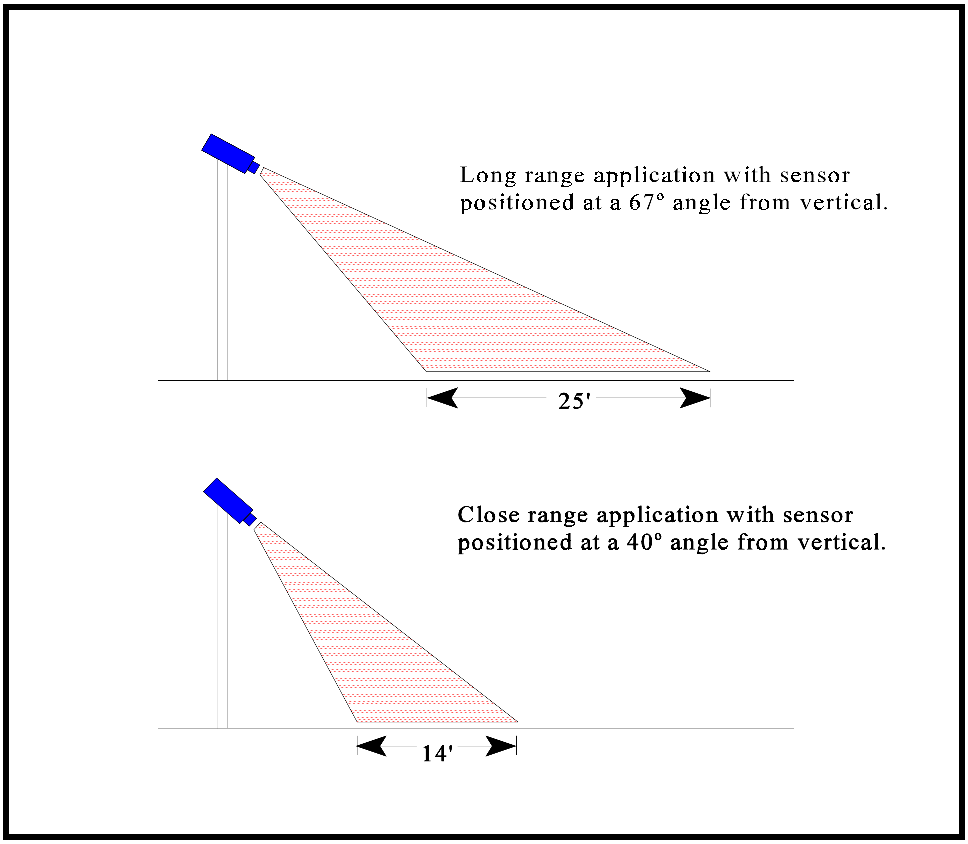

Figure 2: Profile View of Ultra Sonic Long and Close Range Configurations.

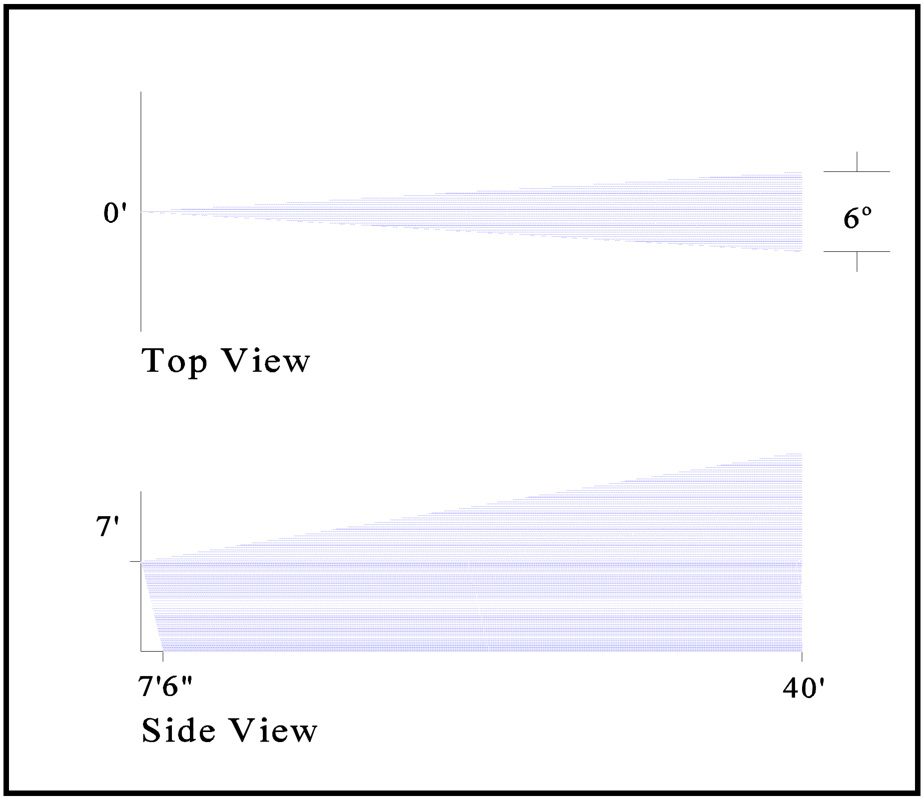

Figure 3: Vertical Curtain Fresnel Lens Detection Zone.

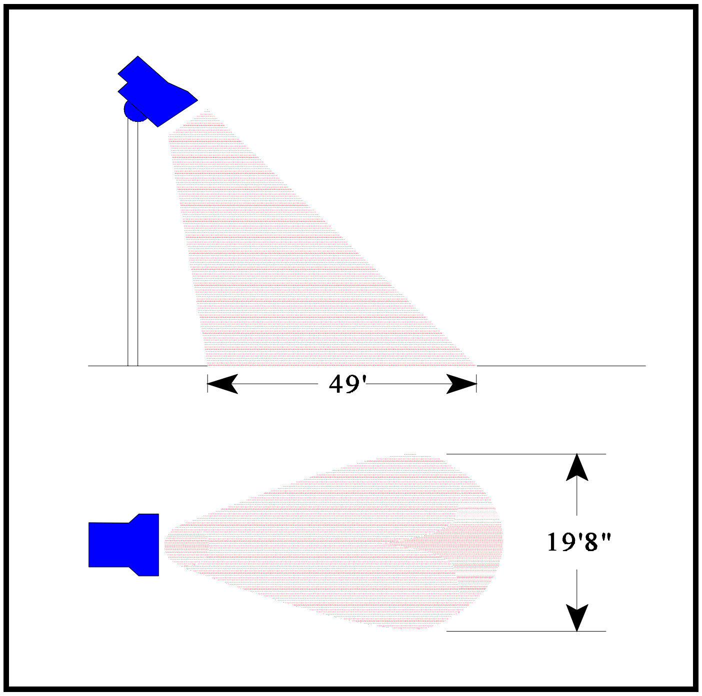

Figure 4: Profile and Plan View of Doppler Radar Detection Zone.

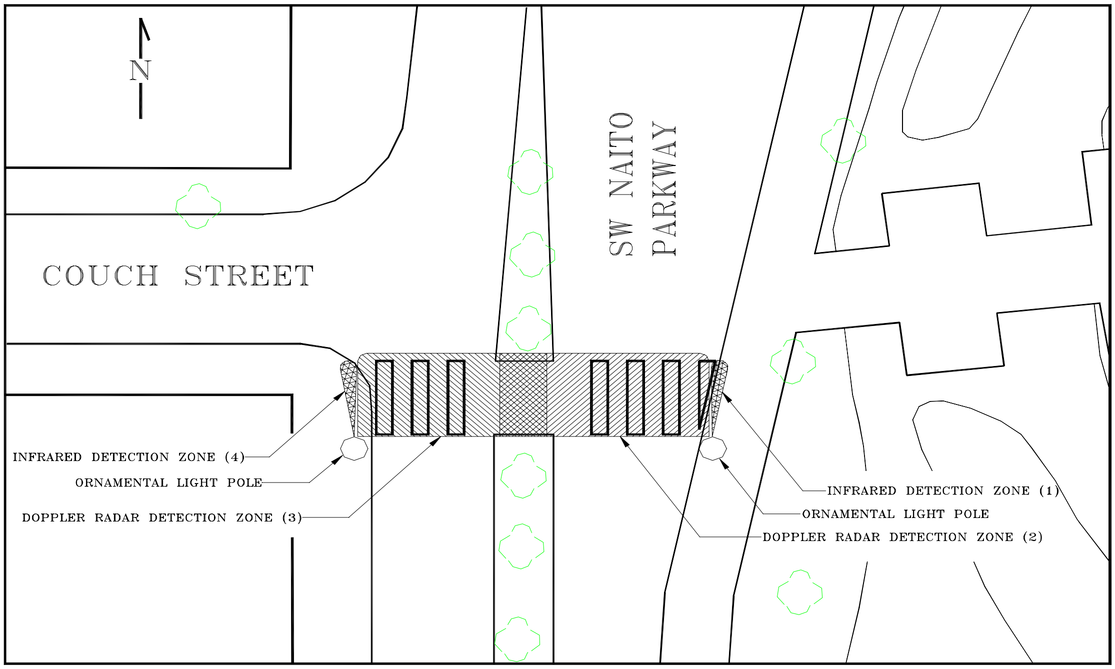

Figure 5: Plan View of Pedestrian Crossing at SW Naito Parkway and Couch Street.

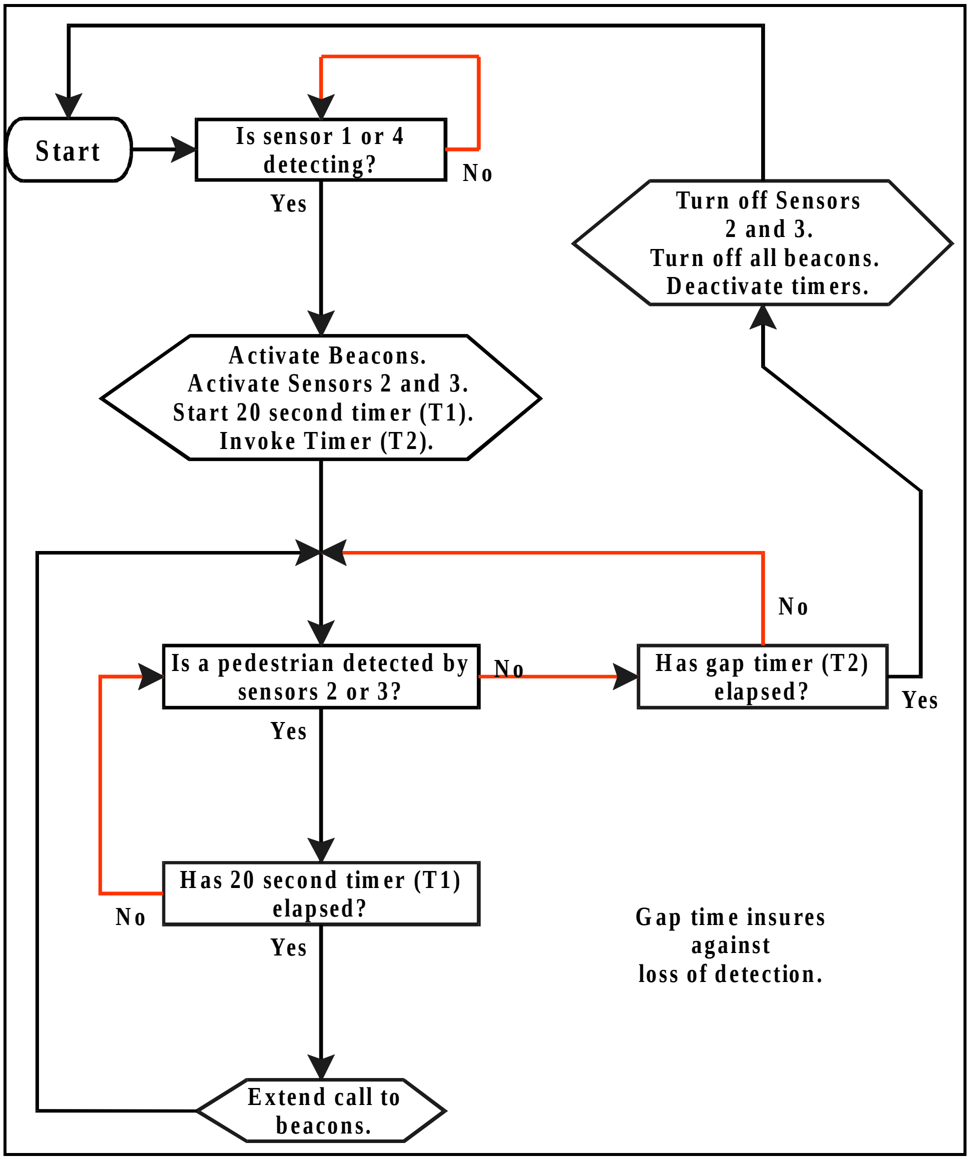

Figure 6: Sensor Logic Flow Chart.

List of Tables and Figures