Improving Pedestrian Safety Through ITS Solutions

University of South Florida
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<td>2</td>
<td>Designated Agency</td>
<td>Florida Department of Transportation (FDOT)</td>
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<td>Sponsoring Agency</td>
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<td>Concepts of Operations</td>
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<td>Project Title</td>
<td>Improving Pedestrian Safety Through ITS Solutions</td>
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<td>Performing Organisation Name and Address</td>
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<td>Rakesh Rangaswamy, University of South Florida <a href="mailto:rragaswamy@mail.usf.edu">rragaswamy@mail.usf.edu</a></td>
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</table>
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| 10 | Submission Date | April 30, 2019 |
| 11 | Abstract | Providing pedestrian safety and making facility much convenient and safer for pedestrian are the top most priorities and transportation goals in Florida. Our first solution will utilize a mobile function similar to the Emergency Alerts that will warn the pedestrian attempting to cross the intersection. This trigger will warn the pedestrian of the impending danger of crossing an intersection when the pedestrian cross signal is RED. The research team also proposes a second solution, namely an automated pedestrian detection system that utilizes sensors to detect pedestrian arrival at the crosswalk. In this situation, the pedestrian is not required to press the push-button as the sensor detects their presence and alerts the signal system to activate the pedestrian crossing signal. Past iterations of this technology have utilized automated pedestrian detection systems only at mid-blocks but we propose to incorporate these solutions at signalized intersections. Future iterations of these solutions could also utilize the advancements in connected vehicle technologies to warn the drivers of impending danger while approaching intersections. We believe that the application of both the above-mentioned ITS solutions will produce drastic positive results that will reduce pedestrian fatalities in the state of Florida. |
| 12 | Original Problem Statement | Distracted pedestrians and drivers at intersections lead to a large share of crashes, fatalities, and even near misses. Our team has identified pedestrian safety at intersections to be of utmost priority and will propose ITS solutions with an aim to reduce pedestrian fatalities, crashes, and even near-miss encounters. |
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1. Background and Motivation

Providing pedestrian safety by making roadway facilities convenient and accessible for pedestrians and other road users are of most importance for the Florida Department of Transportation. According to Smart Growth America from 2008 to 2017, the state of Florida saw the highest average annual pedestrian fatality rate of any other state at 2.73 fatalities per 100,000 residents (1). The Florida DOT has identified pedestrians, bicyclists and distracted driving, as two of the 13 emphasis areas under the 2016 Strategic Highway Safety Plan (SHSP) (2). The Florida Department of Highway Safety and Motor Vehicles (DHSMV) releases an annual traffic crash fact report which summarizes crash rates for vulnerable road users such as, pedestrians and bicyclists. In 2017 alone, the state of Florida saw an increase in pedestrian crashes and fatalities from previous years to 9,420 crashes and 659 fatalities. In addition to this, the fact sheet gives information on crash location and driver actions. It was found there were 689 fatalities on local roadways and 559 fatalities due to drivers failing to yield the right of way (3). From this, it can be stipulated that a high volume of pedestrian fatalities occur at intersections when a driver fails to adhere to the pedestrian right of way while making a right-hand turn. In addition to this, the National Highway Traffic Safety Administration (NHTSA) released a nationwide pedestrian fact sheet that indicated in 2016, 45% on the weekday and 54% on the weekend of all pedestrian fatalities occurred between 6 pm and 9 pm (4). Other results also showed an alarmingly high rate of pedestrians (24%) crossing the intersection when the pedestrian crossing signals were flashing red, and a further 8% who crossed the intersection when the cross signal prohibited this maneuver.

2. Project Objectives

The overall objective of this project is to research and develop an accurate and reliable automated pedestrian detection system at signalized intersections with internally illuminated in-pavement markers (IIIPM) integrated with pedestrian detection technologies. This proposed project has three primary objectives:

- Research and review on pedestrian detection technologies, in-pavement markers and available pedestrian detection systems and obtain detailed information
- Integrate or develop a preliminary automated pedestrian detection system at signalized intersections with communication using currently deployed traffic controllers to adequately place a pedestrian call when a pedestrian is present and remove the pedestrian call when the pedestrian(s) leave the intersection.
- Finalize the development of an accurate automated pedestrian detection system and provide recommendations.

3. Approach

To address our project objective, two solutions were developed, and the general approach to each part of the solution is summarized below:

1. The research team will propose a solution, namely an automated pedestrian detection system that utilizes sensors to detect pedestrian arrival at the crosswalk. In this situation, the pedestrian is not required to press the push- button as the sensor detects their presence and alerts the signal system to activate the pedestrian crossing signal. Past iterations of this technology have utilized automated pedestrian detection systems only at mid-blocks, but we propose to incorporate these solutions at signalized intersections.
2. Our second solution is for the future iterations of the integrated automated pedestrian detection with IIIPMs and also utilize the advancements in connected vehicle technologies to warn the drivers of impending danger while approaching intersections. We believe that the application of both the above-mentioned ITS solutions will produce drastic positive results that will reduce pedestrian fatalities in the state of Florida.

4. Problem Statement

Distracted pedestrians and drivers at intersections lead to a large share of crashes, fatalities, and even near misses. Our team has identified pedestrian safety at intersections to be of utmost priority and will propose ITS solutions to reduce pedestrian fatalities, crashes, and even near-miss encounters.
### 5. Description of the Solution

#### 5.1 Automated Pedestrian Detection

Table 1: Summary of Existing Automated Pedestrian/Bicycle Detection Technologies [16-30]

<table>
<thead>
<tr>
<th>Technology Used</th>
<th>Duration</th>
<th>User Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Laser Scanner            | Short or long |          | • High accuracy  
• Easy installation  
• Laser scanners can differentiate according to height information  
• Larger coverage area | • Different model setup application used to monitor pedestrians and vehicles  
• More than one scanner plane needs to compensate vehicle pitch motion  
• More complex in signal processing  
• Limits detection in severe weather condition |
| Active Infrared Sensor    | Short or long |          | • Portability  
• Relatively low cost  
• Easy installation  
• High accuracy and high precision | • Subject to interference in outdoor settings  
• Occlusion effects |
| Passive Infrared Sensor   | Short or long |          | • Low cost  
• Commercially widely available  
• Not affected by wet or foggy weather  
• Can be mounted perpendicular to pedestrian movement and can track the direction of movement  
• Multiple sensor arrays can distinguish pedestrians walking in groups | • Single or double sensor counter cannot differentiate between individual or pedestrians in group  
• Temperature can affect counter performance  
• Limited coverage area  
• The tendency to undercount groups or side-by-side travelers  
• Possible undercounting due to occlusion  
• Differences between products |
| Microwave Radar Sensors   | Long     |          | • Great precision  
• Insensitive to inclement weather at relatively short ranges encountered in traffic management applications  
• Direct measurement of speed  
• Multiple lane operations available | • Continuous wave, Doppler sensors cannot detect stopped vehicles |
| Computer Visioning        | Long     |          | • Easy installation  
• Data verification  
• Automated process  
• Ideal for crowded environments  
• Large coverage area  
• Potential to count accurately in various conditions (crowded pedestrians, different lighting conditions)  
• Possible to review to collect pedestrian characteristics  
• Video can be recorded for manual review | • Most products intended for indoor settings  
• Development complexity  
• Non-standard and non-transferable approaches  
• Malfunctions after installation of equipment  
• The difficulty of counting pedestrians in crowded environments not yet resolved  
• Poor weather conditions can affect product performance if device not adequately designed |
5.1.1 Description of the device

Automated pedestrian detection uses thermal technology, which is a combination of passive and automated image processing. Thermal cameras operate similar to passive infrared sensors and generate images by detecting body temperature. They are mounted above the detection zone (as shown in the figure 4) which allows both detection and movement monitoring functions. This detection device is connected to the traffic signal controller via dry contact outputs or TCP/IP network communication which will allow for enhanced dynamic control of traffic signals based on presence or volume information. A significant advantage of thermal sensors is that they are not affected by variations on ambient light. It is also capable of thermal detection in complete darkness, through shadows, and under sun glare and, therefore, can provide real-time detection and monitoring regardless of time. The summary of technical specifications for the proposed device are located in the APPENDIX.

5.2 Internally Illuminated In-Pavement Markers (IIPM)

**Background:** Internally illuminated in-pavement markers (IIIPM), also known as in-road warning lights (IIIRWL) or recessed pavement markers (IIRPM) have seen an increase in roadway applications throughout the United States. Initially, IIIPMs was developed for airport runway and taxiways. However, they have had more frequent use for pedestrian crosswalks, school and construction zones and highway-rail crossings. (Nambisan, Pulugurtha, & Karkee 2006) (Hofer and Yim 2018). Studies have found that crosswalks with active IIIMPs, compared to those with no additional pedestrian safety features outside of what is required, have seen an increase in driver yield compliance by 70-100 percent (Hamood et al. 2015). At signalized intersections, IIIPMs have also been used to increase driver compliance to red lights by locating the IIIPMs just before the stop bar. A previous study in Houston, Texas, collected data from multiple sites between 2006 and 2009 that implemented an IIIPM system which operated in a continual red burn mode when the signal was also red. The study identified over a 90 percent decrease in the number of right turn on red violations after installing the IIIPM system (Tydlacka 2010).

5.2.1 Description of the device

IIIPMs consists of a light-emitting diodes (LED), a power source and a system controller that are all housed in a compact, durable shell. The color of the LED can come in blue, red, amber, or white, and depending on the vendor, it can be bi-colored. IIIPMs power source is comprised of buried low voltage, parallel DC currents, but have sometimes utilized solar power (NCHRP S-380). Solar powered IIIPM devices have had luminosity constrictions, to which when there is an external power source available, hardwired IIIPMs are preferred (Baker 2002). An example of an IIIPM and its specifications are displayed in Figure 5, in the Appendix.
5.3 Integration of Automated Pedestrian Detection and IIIPMs

Although studies have proven the usefulness of IIIPM systems for stop bar reinforcement and pedestrian yield compliance, there has not been a system which links a pedestrian automated detection system to an IIIPM at an intersection. Moreover, the IIIPMs have only displayed one color that either indicates to stop or yield. It is for this reason that the University of South Florida Team 1 is proposing to link the existing IIIPM systems and the automated pedestrian detection systems together to provide a physical, visible, bi-colored indicator to the roadway users. The placement of the IIIPM system will be located at the right-hand turn stop bar of each approach in the intersection, due to most pedestrian crashes at intersections occurring at the right-hand turn movement.

6. Functional Architecture

The functional architecture, displayed in Figure 1, demonstrates how the system will operate. To prompt the system, pedestrians must remain in the sensor’s view for more than 4 seconds. The minimum 4-second wait time will ensure that unnecessary pedestrian phases do not occur when no pedestrians are present. After 4 seconds has incurred, a signal will be sent to the traffic controller indicating a pedestrian phase needs to be initiated. When the pedestrian phase occurs, the conflicting right-hand turn approaches will have their IIIPMs glow red, which is shown in the “yes” flow line to the in-pavement markers in Figure 1, reinforcing the stop bar and promoting the drivers to make a complete stop in order to increase their awareness of pedestrians in the intersection. In addition to this, the parallel, right-hand turn approaches, will have their IIIPMs glow amber indicating that there is a pedestrian in the crosswalk, and that the pedestrians have the right of way, regardless if the traffic light is green, since the movement is considered permissive as seen in phases 2, 6, 4 and 8 in Figure 2.

Figure 1: Functional Architecture
Figure 2: Typical Intersection Phase Diagram with Right-Turn Overlap

7. Physical Architecture

Figure 3: Physical Architecture

[1 and 3] Automated pedestrian detectors physical locations
[2] Dedicated short range communication (DSRC) (discussed later)
[4] Pedestrian detection zone
[5] Internally illuminated in-pavement marker location
[6] Connected vehicle transmission to the DSRC (discussed later)
[7] Traffic control cabinet, housing the signal system controller and the IIIPM controller
### 8. Cost Estimate

#### Table 2: Cost Estimate for the Automated Pedestrian Detection Sensor

<table>
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<table>
<thead>
<tr>
<th>Internally Illuminated Bi-Colored In-Pavement Marker (IPM)</th>
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<td>Category</td>
<td>Material</td>
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<td>Total Cost</td>
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<td>In-Pavement Markers</td>
<td>x10 Bi-Colored IPM</td>
<td>$100 - $250</td>
<td>$1600 - $4000</td>
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<td>IPM Controller</td>
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<td>X1 Electrical $21.89/lhr.</td>
<td>$1000 - $2000</td>
<td>$1050 - $3100</td>
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<td>Pavement Removal - Groove</td>
<td>Concrete/Asphalt Diamond Saw</td>
<td>X1 Saw Operator &amp; crew $40/hr</td>
<td>$100 - $320</td>
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<td>Pavement Removal - Core</td>
<td>Asphalt Milling x10, 7”x7” cores</td>
<td>Milling Crew $50/hr</td>
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<tr>
<td>Groove and Core Fill</td>
<td>Epoxy</td>
<td>General Laborer $11.71/hr</td>
<td>$154/Ga</td>
<td>$330</td>
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<td>x1 Electrical $21.89/lhr.</td>
<td>$3.30 LF</td>
<td>$396</td>
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**Cost Description:** Internally illuminated IPMs are typically estimated based on the entire cost of installation. The IPM controller is usually housed in the traffic control cabinet and thus needs to be installed by an electrician. One controller is capable of servicing all 10 IPMs. The groove pavement removal is to allow for the power source and fiber optic cables to connect from the IPM that is embedded in the pavement to the pull box. The core pavement removal is the imbedded placement of all 10 IPMs. Epoxy is needed to fill the groove and core. The power source and fiber optic cables are the distance from the strawberries IPM at each approach to the nearest pull box. In this case, we used a linear distance of 30 feet for each approach. Costs for Labor and Fiber optic cable were obtained from Wage Determinations which compiles federal wages and from the Florida Department of Transportation Yearly Basis of Estimate for Hillsborough County.

#### Table 3: Cost Estimate for the Internally Illuminated In-Pavement Bi- Colored Markers

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<td>$1650</td>
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**Cost Description:** The thermal sensors are estimates depending on the functionality of each sensor. The low end for each was identified as $500 and $4000 each for the more advanced versions available. The power source and fiber optic cables are assumed to be connected to local pull boxes at the intersection. The supplier vendor for the sensor often supplies the power cable, however, the fiber optic cable will need to be purchased and installed to which there will be an electrician needed to connect the sensor into the pull box. Lastly, brackets will be needed for each sensor to hang from existing Mast poles at each corner of the intersection. (It is assumed there will be a pole to hang the device from to not incur additional costs for fabrication and installation of another pole.) Costs for Labor and Fiber optic cable were obtained from Wage Determinations which compiles federal wages and from the Florida Department of Transportation Yearly Basis of Estimate for Hillsborough County.
Automated pedestrian detectors integrated with illuminated in-pavement markers can provide significant operational and safety benefits when installed, especially at signalized intersections. These pedestrian sensors are programmed in such a way that it would detect the pedestrian only in the assigned zone and assigned direction. For example, if a pedestrian enters the detection zone from the opposite side of the crosswalk, the sensors would not detect those pedestrians. There are cases where pedestrian using sidewalks tend to pass by the detection zone, for this scenario, the sensors are programmed to reject the pedestrian call be having an underlying directional awareness.

In some instances, there are false pedestrian triggers due to slow moving vehicles making right turns outside the detection zone. This can be solved by providing a proper setback (approx. 25-30 inches) between the curb and detection zone.

There might also be a case where pedestrian would intentionally stand outside the detection zone under a shade near a traffic signal while waiting to cross. This case is more observed in Florida especially during summer months where pedestrian would try to stay away from direct contact with the sun. This is a distinct instance where it becomes impossible for the sensors to detect the pedestrian since they have not presence in the detection zone. This is why, even though most individuals do not activate the push-button to cross the intersection should remain. If the pedestrian remains in close proximity to the intersection and does not receive the crossing phase, they will still have the option to physical institute the phase through the historic push-button.

In terms of reducing traffic accidents and using transportation networks efficiently, it is essential to use wireless communication technologies such as Dedicated Short-Range Communication (DSRC) systems between connected vehicles and infrastructure via Intelligent Transportation System (ITS) applications [12]. DSRC is an active safety application which provides high-speed data transfer in two-way short to medium range wireless communications. For public safety and traffic management, the DSRC system provides many transportation applications such as intersection collision avoidance, blind spot warnings, and electronic toll payment [13]. Integrating the proposed technology (i.e., automated pedestrian detection with illuminated in-pavement markers) with Connected vehicle through DSRC would provide significant operational and safety benefits when installed especially on the signalized intersection. As it would be a vital role in triggering the presence of pedestrian on the crosswalk inside the vehicle would create a powerful impact on reducing the pedestrian crashes.

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[Diagram: Future Connected Vehicle Framework]
12. Stakeholders

City of Tampa

Traffic-related concerns such as traffic advisories, traffic signs, traffic signs repair, traffic signal timing concerns are taken care by city of Tampa with the involvement of other departments such as Florida department of transportation (FDOT).

Plan Hillsborough

The Planning Commission, the official local planning agency for all jurisdictions in Hillsborough County, provides consolidated planning services and makes independent recommendations to the Board of County Commissioners, Plant City Commission, Tampa City Council, Temple Terrace City Council and other agencies regarding smart growth and development of Hillsborough County.

Local and Regional Department of Transportation

The Florida Department of Transportation (FDOT or Department) is an executive agency, which means it reports directly to the Governor. FDOT’s primary statutory responsibility is to coordinate the planning and development of a safe, viable, and balanced state transportation system serving all regions of the state, and to assure the compatibility of all components, including multimodal facilities.

13. Conclusion

In the United States it is expected that development and refinement of automated pedestrian detection systems with connected in-pavement markers will continue due to the potential benefits of this technology to road users. Improvements are required in the accuracy of the detections to reduce the number of false alarms and missed calls at the interaction. The combination of an automated pedestrian detection system with illuminated in-pavement markers will result in positive changes in the driving behavior of drivers and thus decrease the negative statistics of pedestrian-motor vehicle incidents

Operational and Safety benefits: Since right-turns require the driver to pay attention to oncoming traffic, and the potential for there to be a pedestrian at two locations, one at each crosswalk, IIIPMs will provide a preemptive indication of pedestrians present in the crosswalk. This will give the driver an increased awareness of their presence in the crosswalk. The merged sensor system provides automation, which is conventionally done by manual efforts.

It is expected that the induction of IIIPMs and automated detection devices will reduce the number of incidents and near-misses for vehicle-on-pedestrian scenarios. The pedestrian would be safer when crossing the street as the sensors automatically detect them, and also the driver will have increased compliance of performing a complete stop at the stop bar. The advisory, amber scenario, will prompt users to be more cautious at an intersection because it will be made apparent there is a pedestrian attempting to use the crosswalk.

Mobility benefits: Since the Automated pedestrian detection sensors and IIIMP system is easy to install, it can be applied in a wider area, extending beyond places with high crash rates. Pedestrians themselves would travel in less time within crossings with less perceived risk and more road user awareness.

Environmental benefits: The systems have limited environmental impact – the markers and pedestrian detection devices are strong and easy to produce, last for a long time and the parts can be recycled for new systems. IIIPMs both physically and visually, it has a small footprint on the roadways. The system is appropriate for sensitive areas as causes less light pollution.
14. Acknowledgement

We are grateful to National Operations Center of Excellence (NOCoE) and the U.S.DOT program for giving us this opportunity to participate in this tournament. We would like to express our appreciation to Dr. Pei-Sung Lin, Program Director ITS, CUTR, USF, Dr. Nikhil Menon, Research Associate CUTR, USF, Pete Yauch, TSM&O Program Manager, Albeck Gerken, Inc. and Dr. Zhenyu Wang, Research Associate, CUTR, USF and Achilleas Kourtellis, Research Associate CUTR, USF for their kind support.

15. References

Table 4: Pedestrian Detection Sensor Specifications

<table>
<thead>
<tr>
<th>Input power</th>
<th>12 – 42 V AC/DC</th>
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<tr>
<td>Power consumption</td>
<td>3 Watt</td>
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<tr>
<td>Outputs</td>
<td>1 N/O and 1 N/C dry contacts direct, 16 N/C dry contacts via TI BPL2 interface</td>
</tr>
<tr>
<td>Ethernet</td>
<td>10/100 MBps</td>
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<tr>
<td>PoE</td>
<td>PoE A and PoE B</td>
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<td>Powerline communication</td>
<td>Up to 2 MBps via TI BPL2 interface</td>
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<td>Wi-Fi</td>
<td>IEEE 802.11</td>
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<td>NEMA TS2 specs</td>
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<td>IP67</td>
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<td>Temperature range</td>
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<tr>
<td>FCC</td>
<td>FCC part 15 class A</td>
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<td>Bracket</td>
<td>PA GF30 mounting clamps and aluminum tube</td>
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<td>Visual sensor resolution</td>
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<td>Visual sensor frame rate</td>
<td>30 fps</td>
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<td>HFOV 95°</td>
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<td>Visual sensor streaming Video</td>
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<td>Thermal sensor frame rate</td>
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<tr>
<td>Thermal sensor detector type</td>
<td>Focal Plane Array (FPA) uncooled VOx microbolometer LWIR sensor, 8 to 14 µm wavelength</td>
</tr>
<tr>
<td>Thermal sensor streaming video</td>
<td>RTSP</td>
</tr>
<tr>
<td>Visual sensor compression</td>
<td>H.264, MPEG-4, MJPEG</td>
</tr>
<tr>
<td># detection zones</td>
<td>8 vehicle presence zones, 8 pedestrian presence zones</td>
</tr>
<tr>
<td>Configuration</td>
<td>Web page via secure Wi-Fi or Ethernet</td>
</tr>
</tbody>
</table>
**Figure 5: Internally Illuminated In-Pavement Specifications**

<table>
<thead>
<tr>
<th><strong>Configuration</strong></th>
<th><strong>SPECIFICATIONS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Uni-Directional</td>
<td><strong>Technology</strong></td>
</tr>
<tr>
<td>Asphalt Bi-Directional</td>
<td><strong>Dimensions - LED Module</strong></td>
</tr>
<tr>
<td>Concrete Uni-Directional</td>
<td><strong>Dimensions - Housing, Including Junction Box</strong></td>
</tr>
<tr>
<td>Concrete Bi-Directional</td>
<td><strong>In-Road Profiles</strong></td>
</tr>
</tbody>
</table>

**DIMENSIONS**

- **Asphalt Installation, typical dimensions**
  - 7 in. [177mm] - 6 3/4 in. [170mm] - 9 LEDs per lane
  - 1 1/2 in. [38mm] - 9 LEDs per lane

- **Concrete Installation, typical dimensions**
  - 7 in. [177mm] - 6 3/4 in. [170mm] - 9 LEDs per lane
  - 1 1/2 in. [38mm] - 9 LEDs per lane

**IN-ROAD PROFILES**

- Snowplow Compatible: Yes, with flush mount installation
- Housing - LED Module: Stainless steel
- Housing - Base: Aluminium, sea water grade
- IP Code: IP68
- Load Rating: 5.5 tons [5,000 kg] compression
- Operating Temperature: -13°F to +167°F [-25°C to +75°C]
- LED Face: Uni-directional or bi-directional options
- LEDs Per Unit: 16
- LED Colour: Yellow, red, green, blue, white or bi-colour
- Light Intensity: Over 3,500,000 cd/m²
- Daytime Visibility: 3000 ft. [914m]
  Dimmable by PWM at night
- Operating Voltage: 24VDC or 36VAC
- Power Consumption: 2.5W (nominal)
- Wiring: 3-wire for VDC installation<br>2-wire for VAC installation<br>18 AWG direct burial or drain equipped conduit
- Controller: LaneLight MK4 or MK5 system controller
- Lens: Borosilicate glass
- MUTCD Compliance: YES
- Warranty: 5 year limited warranty for defects in manufacturing, factory assembly and materials only; excludes batteries and damage caused by vehicles or vandalism