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16. Abstract

The foundation for several pedestrian safety measures is reliable and accurate detection of pedestrians. The main objective of this study was to evaluate sensors for use in a pedestrian safety test bed in College Station, TX. The following sensors were installed for use in the pedestrian test bed: 1) MS SEDCO SmartWalk 1400 (curbside detection) and SmartWalk 1800 (crosswalk detection); and 2) ASIM IR 201 (curbside detection) and IR 207 (crosswalk detection). Several other sensors designed for counting pedestrians and bicyclist on trails also were evaluated: 1) Jamar Scanner, 2) TrafX Infrared Trail Counter, and 3) Diamond Traffic TTC-4420.

The ASIM and MS SEDCO intersection sensors provided fair to mediocre results, with error rates ranging from 9 to 39 percent. The typical error rates were in the 20 to 30 percent range, which may not be sufficient accuracy for most pedestrian detection applications. The accuracy of the sensors appeared to be very location-specific, in that pedestrian detection can be more effective in certain situations in which the pedestrian travel area is constrained. The three trail sensors were able to accurately detect a single pedestrian at typical walking speed or a bicyclist at slow speed (5 to 10 mph). The Jamar sensor had difficulty counting bicyclists at typical bicycling speed. All three trail sensors did consistently undercount the actual ground truth counts, with the undercounting being more severe in situations with more pedestrian groups. This undercounting presents a problem on busy shared-use trails.

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TESTING AND EVALUATION OF PEDESTRIAN SENSORS

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EXECUTIVE SUMMARY

Introduction

The foundational element for several pedestrian safety measures is reliable and accurate detection of pedestrians. However, the tools and knowledge about these pedestrian safety measures and detection techniques are not widely tested nor utilized by traffic engineers. Thus, there is a need to develop a real-world, roadway-based test bed that can be used to evaluate pedestrian detectors and demonstrate a variety of pedestrian safety applications.

The primary objective of this study was to evaluate and refine pedestrian detection equipment for use in a pedestrian safety test bed in College Station, TX.

Background Information

A literature search was performed to identify relevant papers, articles, and reports on pedestrian sensing and detection. The literature review included the following findings:

- In several cities, pedestrian sensors have been used and evaluated in real-world applications. These cities include Los Angeles, CA, Phoenix, AZ, Rochester, NY, Portland, OR, Santa Monica, CA, and Berkeley, CA.

- There have been several accuracy evaluations of pedestrian sensors in which the accuracy of the sensors were verified against baseline or "ground truth" measurements. These evaluations have been conducted by Minnesota DOT, the University of Massachusetts, and researchers in the United Kingdom.

- Several other articles described the research and development of pedestrian sensing technologies. The Federal Highway Administration is developing a stereoscopic system for detecting and tracking pedestrians. The University of Washington has developed software that is capable of detecting and tracking pedestrians in ordinary video. Several other companies have developed applications to detect and track pedestrians, but these applications have not been extensively deployed or evaluated.

- There are several commercially available pedestrian sensors. The research team reviewed the features and past performance before selecting several pedestrian sensors for further testing.

Study Methodology

After considering several intersections, researchers selected the intersection of **University Drive at Spence Street**, College Station, TX for the pedestrian safety test bed. The following factors were considered in the selection of the pedestrian safety test bed location:
- Pedestrian activity throughout the daytime and nighttime hours;
- Access to high-speed communications infrastructure;
- Pedestrian safety (or lack thereof);

- Clear sight lines for future demonstration of vehicle infrastructure integration (VII) applications; and,
- Intersection geometry with simple or basic pedestrian patterns.

After reviewing previous evaluation results and discussing product features with the respective vendors, the following pedestrian sensors for installation at the pedestrian safety test bed were selected:
- **MS SEDCO SmartWalk 1400** (curbside detection) and **SmartWalk 1800** (crosswalk detection), based on microwave technology; and,
- **ASIM IR 201** (curbside detection) and **IR 207** (crosswalk detection), based on passive infrared.

In the course of investigating pedestrian sensors, the research team identified several low-cost, portable sensor units. These portable pedestrian sensors are typically used in a stand-alone mode, and are fairly simple in their operation and the features offered. The general idea with these sensors is that they monitor the passage of people through a detection area to determine the number of persons using a trail. The research team purchased the following pedestrian sensors to be used in developing a trail-based test bed:
- **Jamar Scanner**, based on passive infrared technology;
- **TrafX Infrared Trail Counter**, based on infrared technology; and,
- **Diamond Traffic TTC-4420**, based on pulsed infrared with a reflector.

The evaluation procedures for both types of sensors focused on accuracy and included these measures of effectiveness:
1. **Overall error rate** – the percentage of time in which the sensor reported the correct response;
2. **Missed detection error rate** – the percentage of time in which the sensor did not detect a pedestrian when one or more were present; and,
3. **False detection error rate** – the percentage of time in which the sensor detected a pedestrian when none were present.

These measures of effectiveness rely on reference or "ground truth" data that indicates the true and correct sensor response. In this evaluation, the reference data were obtained by recording video and manually verifying actual field conditions (i.e., the presence or absence of pedestrians).

The research team used slightly different evaluation procedures for the intersection-based pedestrian sensors and the trail-based pedestrian sensors. This was necessary because the intersection-based sensors report instantaneous pedestrian presence (i.e., a simple on/off switch that is activated at the sub-second level), whereas the trail-based sensors report an actual person count.

Findings and Conclusions

Intersection Sensors

Accurately detecting pedestrians with a low-cost sensor is a difficult task, particularly in a street environment in which pedestrian travel is unconstrained. Pedestrians may not walk into the detection zone when waiting to cross the street, and they may walk outside the crosswalk detection zone when crossing the street. Pedestrians may walk into the detection zone, but then stand still while waiting to cross the street. Pedestrians may walk into the detection zone without any intent to cross the street. All of these situations make it very challenging to accurately detect when pedestrians want to cross the street or when they may not be able to safely complete a street crossing.

The ASIM and MS SEDCO intersection sensors provided fair to mediocre results, with error rates ranging from 9 to 39 percent. The accuracy of the sensors appeared to be very location-specific, in that pedestrian detection is more viable in certain situations in which the pedestrian travel area is constrained and/or the pedestrian detection area is well-defined. The most promising error rates were at the southwest corner at 9 and 11 percent, which may not be sufficient accuracy for certain traffic safety applications. The typical error rates were in the 20 to 30 percent range, which is not sufficient accuracy for most pedestrian detection applications.

Trail Sensors

Another objective of this study was to determine the accuracy of three commercial trail counters and determine their strengths and weaknesses in different trail conditions. Although error rates in this study may show one counter to be more accurate than another, a potential purchaser of these counters should first analyze the intended location for installation and review what type of counts they desire. For instance, if a purchaser desires timestamps for each trail user, then the Diamond sensor would not be sufficient to meet this need. Conversely, if the purchaser desires only an hourly binned count each day, then the Diamond sensor is an option.

In general, all three trail sensors were able to accurately detect a single pedestrian at typical walking speed or a bicyclist at slow speed (5 to 10 mph). The Jamar sensor had difficulty counting bicyclists at typical bicycling speed. Although expected, all three counters had difficulty counting trail users who were closely spaced, but the required separation varied by counter. The Diamond sensor required the least amount of separation in a group, at about 2 ft.

The following paragraphs describe the strengths and weaknesses of each of the three trail sensors. The purchase price for all three sensors was comparable.

- **Jamar Scanner (larger infrared counter):** This sensor had difficulty with detecting bicyclists traveling faster than 10 mph. It also had average performance with group detection, typically requiring 3 ft or more of separation to detect individual users. The sensor functions and software interface were easy to use and the user's manual was adequate.

- **TrafX Sensor (small infrared counter):** This sensor performed well in group situations but also had difficulty detecting bicyclists traveling faster than 15 mph. This sensor was small and compact, and could be easily hidden from view. The sensor functions and software interface were easy to, use and the user's manual was adequate.

- **Diamond Trail Counter (break-beam with target):** This sensor performed well in single trail user and group situations. However, the sensor functions were limited to binned counts (not individual timestamps), the user interface was lacking, and the user's manual was very difficult to follow. Sensor setup also required additional time because of the target alignment and mounting.

All three trail sensors consistently undercounted the actual ground truth counts, with the undercounting being more severe on trails with more groups. This undercounting presents a problem on busy shared-use trails. It is possible to compensate for groups by adjusting the counts upward by a "group factor." However, this "group factor" to adjust raw counts would need to be determined on a site-by-site (and perhaps time-of-day) basis.

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INTRODUCTION

Pedestrians account for about 11 percent of all traffic fatalities[1] yet receive less than 1 percent of Federal transportation spending and no dedicated safety funding. Increased attention and funding for pedestrian safety will help to create a more balanced transportation system with safe and convenient places to walk. Given the appropriate equipment that demonstrated acceptable accuracy, a variety of pedestrian safety measures could be implemented at signalized intersections and other uncontrolled pedestrian street crossings. These pedestrian safety measures include:

- Automated provision of longer walk times for pedestrians still crossing at onset of green vehicle signal;
- Automated provision of lead pedestrian walk intervals based on pedestrian presence;
- Dynamic restriction of right-turn-on-red based on pedestrian presence;
- Automated warning for motorists based on pedestrian presence in the roadway;
- Automated warning for pedestrians based on vehicle probe information (VII); and
- Automated pedestrian counting for crash exposure calculations.

Problem Statement

The foundational element for nearly all of these pedestrian safety measures is reliable and accurate detection of pedestrians. However, the tools and knowledge about these pedestrian safety measures and detection techniques are not widely tested nor utilized by traffic engineers. Thus, there is a need to develop a real-world, roadway-based test bed that can be used to evaluate pedestrian sensors and demonstrate a variety of pedestrian safety applications.

Research Objective

The primary objective of this study was to evaluate and refine pedestrian detection equipment for use in a pedestrian safety test bed in College Station. At the end of this project, the research team anticipated having one or more working pedestrian detectors that could be used to demonstrate various pedestrian safety applications.

Overview of this Report

This report is organized into the following sections:
- *Introduction:* provides a brief statement of the problem and the research objectives;
- *Background Information*: summarizes a literature review and commercially available technology for pedestrian sensing and detection;
- *Study Methodology:* describes the procedures used to test and evaluate the pedestrian detectors;
- *Study Findings:* summarizes the major study findings; and,
- *Conclusions and Recommendations:* summarizes the study conclusions and recommendations.

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[1] National Highway Traffic Safety Administration. *Traffic Safety Facts, 2005 Data: Pedestrians*. Report DOT HS 810 624.

BACKGROUND INFORMATION

This section summarizes the literature review, a review of current practices, and commercially available technology and products for pedestrian sensing and detection. This section begins by introducing a concept of operations for pedestrian detectors.

Concept of Operations

Accurate and reliable pedestrian detection forms the foundation for several intersection-based pedestrian safety applications. Several vendors offer pedestrian detectors but these products are mostly untested; thus, reliability and accuracy must be verified to satisfy concerns of public agencies wishing to install pedestrian detection. Multiple pedestrian detectors need to be tested to determine which one(s) deliver the desired information most accurately and consistently. Examples are microwave and passive infrared detectors. Items to be evaluated include point of detection, walk speed and trajectory, whether detectors continuously monitor pedestrian position, user interface, communication capabilities, and detector response to anomalous events. Figure 1 illustrates a microwave detector at a signalized intersection, which can detect pedestrians both at curbside and within the crosswalk. Detection within the crosswalk in this particular application can result in additional pedestrian clearance time at the signalized intersection.
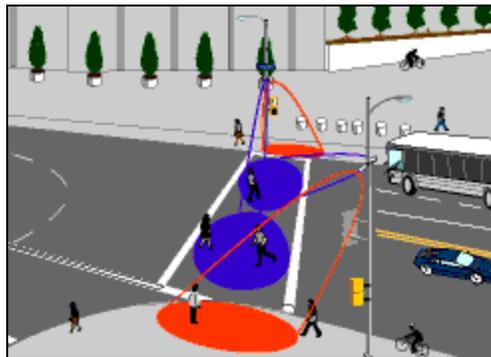
Source: http://www.walkinginfo.org/pedsmart/nookit.htm, accessed June 10, 2005.
Figure 1. Example of Microwave Detection Zones at Signalized Intersections

Another technology for pedestrian detection is passive infrared. Portland, OR is using this technology to monitor pedestrians as indicated in Figure 2. The figure illustrates that curbside detections trigger a call to the controller while detection within the street area extends the pedestrian walk phase. ASIM and Sentrol are two manufacturers of passive infrared pedestrian detectors.

Figure 2. Example of Passive Infrared Detection Zones at Signalized Intersections

The minimum requirements for a pedestrian detector subsystem are to detect movement within the specified areas of the curbside and along the crosswalk and to distinguish which area the movement is in. More desirably, the system should be able to detect pedestrians at curbside and measure walk speed and trajectory of individuals or groups of pedestrians within the crosswalk. Outputs from the minimal system are detection at curbside and within the crosswalk. Outputs from the advanced system would be detection at curbside, and walk speed and trajectory within the crosswalk.

A detector subsystem has the following basic needs: a sturdy mounting structure, source of power, communications infrastructure for sending output to a processor or other subsystems, and technical expertise for installation and calibration. The best structure is an existing pole immediately adjacent to the crosswalk to be monitored. It will already have power and some of the conduit and other infrastructure needed. It is expected that in most cases the output from simpler devices will be binary—detection or no detection along with the location of the detection (curbside or crosswalk). For more complex systems, the outputs from each device will be unique and unknown to installers, so manufacturer cooperation will expedite any custom use of output code. Use of pedestrian speed and trajectory will require more processing, but provides the possibility of greater accuracy in projecting pedestrian locations with time to compare with the vehicular subsystem. The basic idea for aiming either type of detector is to place it high enough and of such orientation as to cover both curbside areas and the full length of the crosswalk.

The accuracy of the example microwave and passive infrared detectors is measured in terms of presence detection. Neither is a complex system and both can generate errors from missed detections (detected something besides a pedestrian or missed a pedestrian) and false positives (sent a call when no pedestrian was there). Results of recent tests of the latest versions of these two examples were unavailable, but their accuracies are expected to be in the 80 to 90 percent range. In other words, they were anticipated to either miss pedestrians or will detect something besides a pedestrian 10 to 20 percent of the time. More complex systems are anticipated to be more accurate in addition to providing more features (e.g., walk speed and trajectory). Accuracies in the 85 to 95 percent range were expected.

Literature Review

A literature search was performed to identify relevant papers, articles, and reports on pedestrian sensing and detection. The literature search included the following sources:
- World Wide Web (Google and other meta-searches);
- National Transportation Library;
- Transportation Research Information Services (TRIS); and,
- Other online electronic databases and journal indexes.

The results of the literature search and review are summarized in the following paragraphs.

Real-World Applications

In several cities, pedestrian sensors have been used and evaluated in real-world applications. For example, the Federal Highway Administration sponsored an evaluation of automated detection in Los Angeles, Phoenix, and Rochester in the late 1990s.[2,3] This study evaluated the effects of passive pedestrian detection on vehicle-pedestrian conflicts, as well as evaluating the accuracy of the pedestrian detection equipment. The study concluded that "improvements are needed in detection accuracy so that the number of false actuations and missed calls can be reduced."

The city of Portland, OR has been experimenting with pedestrian detection since the mid-1990s.[4,5] The Portland evaluations included pedestrian sensors based on passive infrared, ultrasonic, and microwave radar technologies. The evaluation results were satisfactory, and the microwave radar sensors recently have been installed at several new pedestrian crossings.

The city of Santa Monica, CA has installed video detection at an in-pavement flashing crosswalk.[6] Engineers also considered an infrared pedestrian sensor but instead installed a solar-powered video detector.

Most recently, researchers at California PATH have installed passive pedestrian detection in a vehicle infrastructure integration (VII) test bed in Berkeley, CA.[7,8] The test bed utilizes a microwave pedestrian sensor to detect when pedestrians are crossing a side street. In this

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[2] Hughes, R., H. Huang, C. Zegeer, and M. Cynecki. Automated Detection of Pedestrians in Conjunction with Standard Pedestrian Push Buttons at Signalized Intersections. In *Transportation Research Record 1705*, 2000, pp. 32-39.

[3] Hughes, R., H. Huang, C. Zegeer, and M. Cynecki. *Evaluation of Automated Pedestrian Detection at Signalized Intersections*. Publication FHWA-RD-00-097. FHWA, U.S. Department of Transportation, 2001.

[4] Beckwith, D.M., and K.M. Hunter-Zaworski. Passive Pedestrian Detection at Unsignalized Crossings. In *Transportation Research Record 1636*, 1998, pp. 96-103.

[5] Kloos, W.C. Innovative Intermodal Solutions for Urban Transportation Award: Developing Intermodal Traffic Signal Solutions for Portland, OR, USA. *ITE Journal*, December 2005, pp. 28-30.

[6] Suter, M.M. Alternative Passive Detection Methods & Applications for In-pavement (In-road) Flashing Crosswalks, City of Santa Ana, California. ITE 2002 District Meeting, Palm Desert, California July 14 to 17, 2002.

[7] Chan, C., J.A. Ko, S. Kuang, T. Lian, and D. Nelson. A Transit-Bus Experimental Platform and Testing of Vehicle-Infrastructure Integration for the Application of Pedestrian Detection. March 23, 2004.

[8] Chan, C. A Vehicle-Infrastructure Integration (VII) Approach for Pedestrian Detection. *Intellimotion*. Volume 11, No. 3. California PATH, 2005, pp. 2-5.

application, a turning vehicle (in this test bed, a transit bus) is given an in-vehicle warning when pedestrians are present in the side street crosswalk.

Equipment Evaluations

There have been several accuracy evaluations of pedestrian sensors in which the accuracy of the sensors were verified against baseline or "ground truth" measurements. The Minnesota DOT sponsored evaluations of several pedestrian and bicycle sensors as part of a larger project to evaluate non-intrusive traffic detector technologies.[9] The evaluation test was conducted on a shared-use path, and inductance loops and video were used as ground truth. The pedestrian detectors included several technologies, including the Autoscope Solo, MS SEDCO Smartwalk 1400, ASIM DT272, and the Diamond trail counter. One hundred passes were made by the evaluation personnel, and the first three sensors exhibited 100 percent accuracy, with the Diamond trail counter at 93 percent accuracy. The authors noted that the results may not be indicative of performance with real-world conditions, since only individual pedestrians walked through the detection zone.

The University of Massachusetts has also evaluated automated detection of pedestrians and bicyclists.[10,11] A preliminary review identified video imaging and active infrared as promising technologies for differentiating between pedestrians and bicyclists, and the latter technology (i.e., Autosense II) was chosen for test bed evaluations. The evaluation found that 92 percent of the pedestrians were detected and 77 percent of the bicyclists were detected. Further research and development of detection and classification algorithms improved the performance with 92 percent of the bicyclists and pedestrians being classified correctly.[12]

Researchers in the United Kingdom have also experimented and evaluated an infrared sensor capable of detecting and tracking pedestrians.[13] The IRISYS infrared sensor is capable of tracking pedestrian trajectory, from which density, flow rate, walking speed and pedestrian counts can be derived. An exhibit hall demonstration at the Transportation Research Board's 2005 Annual Meeting highlighted the pedestrian tracking capabilities of this sensor.

Emerging Technologies and Products

Several other articles describe the research and development of pedestrian sensing technologies. The FHWA is sponsoring the research and development of a computerized stereovision system

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[9] SRF Consulting Group, Inc. *Bicycle and Pedestrian Detection: Final Report*. Minnesota Department of Transportation, February 27, 2003.
[10] Noyce, D.A, and R. Dharmaraju. An Evaluation of Technologies for Automated Detection and Classification of Pedestrians and Bicycles. Report UMTC-02-01, University of Massachusetts May 2002.
[11] Dharmaraju, R., D.A. Noyce, and J. Lehman. *An Evaluation of Technologies for Automated Detection and Classification of Pedestrians and Bicycles*. Institute of Transportation Engineers Annual Meeting, 2001.
[12] Noyce, D.A., A. Gajendran, and R. Dharmaraju. Development of Bicycle and Pedestrian Detection and Classification Algorithm for Active-Infrared Overhead Vehicle Imaging Sensors. In *Transportation Research Record 1982*, 2006, pp. 202-209.
[13] Kerridge, J., S. Keller, T. Chamberlain, and N. Sumpter. *Collecting, Processing, and Calculating Pedestrian Flow Data in Real-Time*. Paper No. 05-0191. Presented at the 2005 TRB Annual Meeting, Washington, DC, 2005.

for detecting and tracking pedestrians.[14] Preliminary testing of the system has shown significant potential for detecting pedestrians in crosswalks, and further research will focus on pedestrians waiting at the curb to cross.

Cambridge Consultants is developing a three-dimensional radar sensor called SPOT that is designed to detect pedestrians in crosswalks.[15] The system will also be capable of replacing inductance loop detectors for vehicle traffic. A production-ready system was expected to be available in 2007.

Bosch is developing video content analysis to analyze pedestrian movement in video surveillance.[16] Their technology has been demonstrated to detect, track, and store pedestrian movements. More specifically, their video content analysis was mainly geared toward security applications, such as identifying suspicious behavior.

Nissan is developing a program to track pedestrians and vehicles using cellular phone signals.[17] The ultimate goal of their research and development is to provide in-vehicle warnings to drivers of certain hazardous situations involving pedestrians.

The University of Washington has developed software that is capable of detecting and tracking pedestrians in ordinary video.[18] Preliminary results indicate that about 80 percent of pedestrians could be properly detected and tracked.

Other Pedestrian Sensor Information

A survey of pedestrian and bicycle data collection identified several pedestrian sensors that were being used in the United States.[19] For example, the city of Cheyenne, WY is using an infrared laser to count pedestrians and other shared-use path users. A passive infrared sensor is used to count pedestrian and bicyclist trail users in Licking County, OH. Researchers at the University of Massachusetts have tested an active infrared sensor to detect and classify pedestrian and bicyclist traffic along a path.

Commercially Available Technologies and Products

The literature search also identified several commercially available technologies and products for pedestrian sensing and detection (Table 1). This listing of commercially available products was used in later tasks of the project to identify the most promising and suitable pedestrian sensors for testing and evaluation.

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[14] Gibson, D.R.P., B. Ling, M. Zeifman, S. Dong, and U. Venkataraman. *Multipedestrian Tracking*. Public Roads, Vol. 69, No. 5, March/April 2006, available at http://www.tfhrc.gov/pubrds/06mar/08.htm.
[15] Sight Unseen. *ITS International*, January/February 2006, pp. 57-58.
[16] Toonders, R. Do You See What I See? *Traffic Technology International*, June/July 2007.
[17] Keeble, L. Pedestrians crossing. *Traffic Technology International*, June/July 2007.
[18] Malinovskiy, Y., J. Zheng, Y. Wang. *A Simple and Model-Free Algorithm for Real-Time Pedestrian Detection and Tracking*. Paper presented at the 2007 TRB Annual Meeting, Washington, DC, 2007.
[19] Schneider, R., R. Patton, J. Toole, and C. Raborn. *Pedestrian and Bicycle Data Collection in United States Communities: Quantifying Use, Surveying Users, and Documenting Facility Extent*. Pedestrian and Bicycle Information Center, Federal Highway Administration, January 2005.

Table 1. Summary of Commercially Available Pedestrian Sensors

Manufacturer	Detector and Type of Technology	Website	Comments
MS SEDCO	**SmartWalk 1400** (curbside presence) **SmartWalk 1800** (crossing occupancy detection) Microwave	http://www.mssedco.com/traffic-pedestrian.html	Used in PATH VII test bed, Mn/DOT test (SRF), and FHWA/Hughes test in Phoenix
ASIM Technologies Ltd	**DT 272** (passive infrared and active ultrasonic) **IR 207** (corner mounting) and **IR 208** (centre mounting) – both are passive infrared	http://www.asim.ch/e/traffic/index.htm	Used in Mn/DOT test (SRF)
AGD Systems Ltd	**AGD 220** (crossing occupancy detection) and **AGD 620** (curbside presence) AGD 220: Doppler radar; AGD 620: digital vision	http://www.agd-systems.com/systemhome.html	Used in UK for PUFFIN pedestrian crossings
Traficon, Inc.	**TrafiCam and VIP detector boards**	http://www.traficon.com/index.jsp	Used in Los Angeles Smart Crosswalk
OSI LaserScan (formerly Schwartz Electro-Optics, Inc.)	**AutoSense II** Active infrared	http://www.osilaserscan.com/pdfs/ASII_UsersGuide_Rev_G-Feb_2004.pdf	Used in UMass test (Noyce)
Image Sensing Systems, Inc.	**Autoscope Solo Pro** Video imaging	http://www.autoscope.com/solopro.htm	Used in Mn/DOT test (SRF)
Diamond Traffic Products	**Millennium Trail Counter, #TTC-4420** Portable infrared	http://www.diamondtraffic.com/M_Trail_Traffic_Counter.pdf	Used in Mn/DOT test (SRF)
JAMAR Technologies, Inc.	**Scanner** Portable passive infrared	http://www.jamartech.com/scanner.htm	
TRAFx Research Ltd.	**TRAFx Infrared Trail Counter** Portable passive infrared	http://www.trafx.net/products.htm#infrared	Used by Licking County Ohio (FHWA Case Studies)
IRISYS InfraRed Integrated Systems	**IRISYS IRC1004** Indoor/outdoor people counter	http://www.irisys.co.uk/products/index.htm	Used by Jon Kerridge (see TRB paper)
Cognex Corporation	**CPS-1000 PeopleSensor** Indoor stereovision video imaging	http://www.cognex.com/products/ExpertSensors/PeopleSensor.asp	No information on usage in US
PAT America (distributor)	**Publicount** Indoor/outdoor people counter	http://www.publicount.de/hauptseite/e_index.htm	Not used in the US
SenSource, Inc.	Variety of inexpensive indoor and outdoor people counting sensors	http://www.sensourceinc.com/peoplecounters.htm	
TrafSys People Counting Systems	**Thermal Imaging Camera** Indoor/outdoor people counter	http://www.trafsys.com/index.html	

STUDY METHODOLOGY

Selection of Test Bed Location

Several intersections were considered for the pedestrian safety test bed. Table 2 outlines the advantages and disadvantages of these candidate intersections. The following factors were considered in the selection of the pedestrian safety test bed location:
- Pedestrian activity throughout the daytime and nighttime hours;
- Access to high-speed communications infrastructure;
- Pedestrian safety (or lack thereof);
- Clear sight lines for future demonstration of VII applications; and,
- Intersection geometry with simple or basic pedestrian patterns.

The intersection selected for the pedestrian safety test bed was **University Drive at Spence Street** (Figure 3) in College Station, TX. This signalized intersection is used by many pedestrians crossing University Drive, which is located along the northern edge of the Texas A&M University campus. In the past several years, there have been several vehicle-pedestrian crashes at this intersection.

The research team obtained three years (2003 to 2005) of vehicle-pedestrian crash data from the city of College Station. This crash data was used to identify high-crash locations which have the largest potential for safety improvements. As shown in Figure 4, University Drive and Wellborn Road near campus had the largest concentration of vehicle-pedestrian crashes. Nearly all of the intersections considered in Table 2 had several vehicle-pedestrian crashes in the past three years.

Selection of Test Bed Sensors

To identify commercially available pedestrian sensors, the research team searched and reviewed the literature and available product summaries. Table 1 lists pedestrian sensors that could be used in the pedestrian safety test bed.

After reviewing previous evaluation results and discussing product features with the respective vendors, the research team selected the following pedestrian sensors for installation at the pedestrian safety test bed intersection:
- **MS SEDCO SmartWalk 1400** (curbside detection) and **SmartWalk 1800** (crosswalk detection), based on microwave technology; and,
- **ASIM IR 201** (curbside detection) and **IR 207** (crosswalk detection), based on passive infrared.

As indicated above, these detectors represent two different types of non-intrusive detection technology. Thus, their evaluation in the pedestrian test bed should provide a reasonable cross-section of the pedestrian detection capabilities that currently exist in commercially-available products.

Table 2. Considerations for Location of Pedestrian Safety Test Bed

Intersection	Advantages	Disadvantages
University Drive at Spence (near Zachry/ McDonalds)	• Several vehicle-pedestrian crashes in this area in the past three years • Has median refuge island on east crosswalk but only two-way left turn lane on the west crosswalk	• May be outside the range of wireless communications to connect with Wellborn fiber communications infrastructure
Wellborn Road at Old Main (near Albritton Tower)	• Heavy pedestrian activity between center campus and west campus • Little to no pedestrian travel along Wellborn—most pedestrians are crossing Wellborn • Clear line of sight for wireless VII communication • Easy access to fiber communications infrastructure along Wellborn corridor • Several vehicle-pedestrian crashes at this intersection in the past three years	• Less pedestrian activity during nighttime hours • Little to no pedestrian travel along Wellborn—most pedestrians are crossing Wellborn
University Drive at College Main/North Houston (Northgate)	• Heavy pedestrian activity crossing and along University Drive • Already has accessible pedestrian signal • Several vehicle-pedestrian crashes at this intersection in the past three years	• Sidewalk clutter on Northgate side may complicate pedestrian detection • Limited line-of-sight along University Drive for VII applications • Wireless communications would be necessary to connect with Wellborn fiber communications infrastructure
University Drive at Tauber/Asbury (near Aggieland Credit Union/Church)	• Nearby Northside parking garage provides ideal vantage point for research data collection	• Tree canopy could be problematic for detection or remote video monitoring • No marked crosswalk on east side of intersection
University Drive at Nagle/Ireland (near Blocker/North Side Parking Garage)	• Heavy pedestrian activity crossing and along University Drive • Nearby Northside parking garage provides vantage point for research data collection • Several vehicle-pedestrian crashes in this area in the past three years	• Wireless communications would be necessary to connect with Wellborn fiber communications infrastructure
George Bush Drive at Olsen (near Callaway House)	• Clear line of sight for wireless VII communication	• Potentially affected by Wellborn/Bush Drive underpass construction in the future • Pedestrian traffic sporadic between classes • Wireless communications would be necessary to connect with Wellborn fiber communications infrastructure
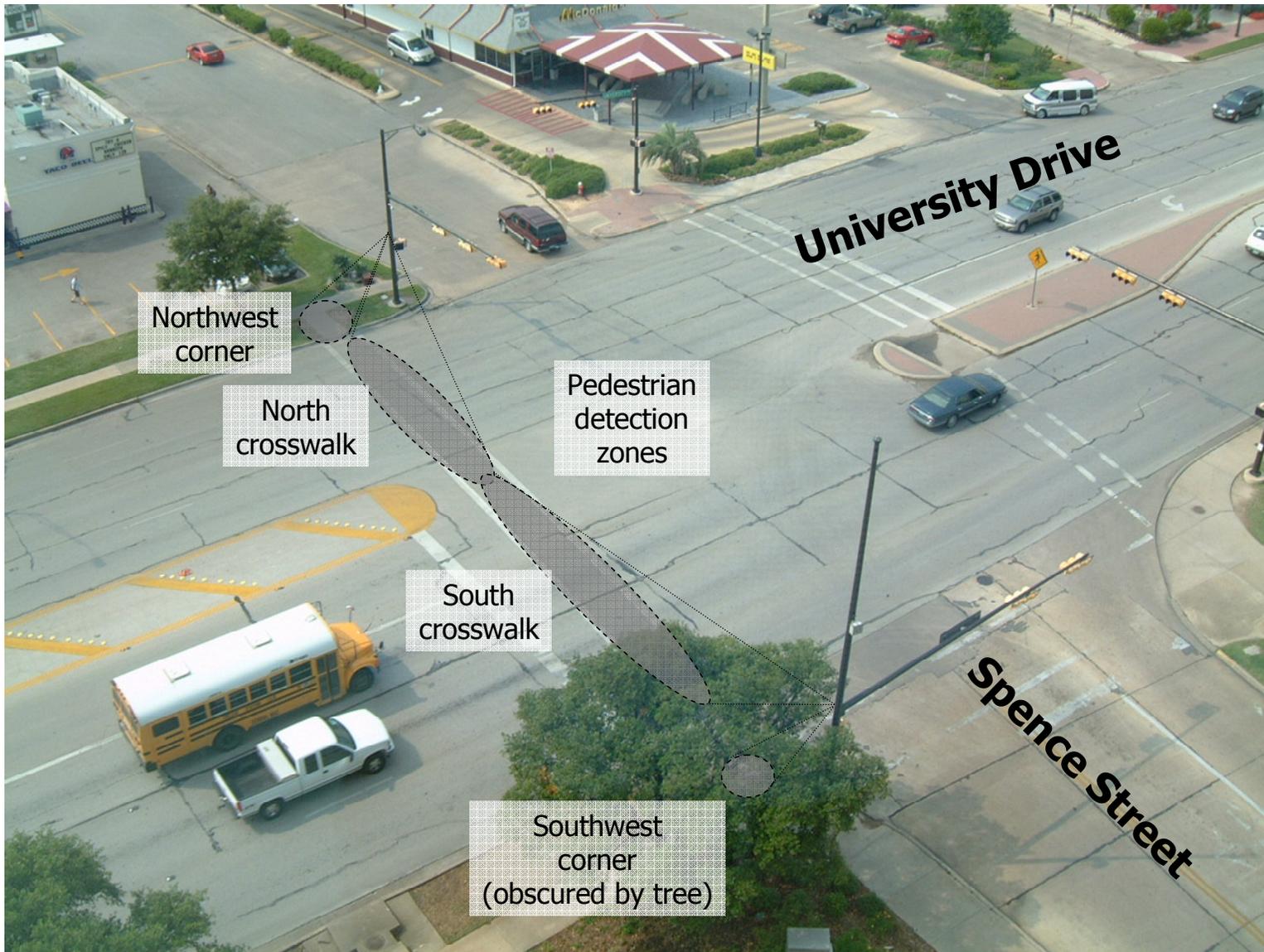
Figure 3. TTI Pedestrian Safety Test Bed: University Drive at Spence Street

Figure 4. Vehicle-Pedestrian Crashes in College Station, 2003 through 2005

In addition to the two pedestrian sensor systems, the intersection test bed required several support components. These support components included an industrial computer, a pan-tilt-zoom camera (for live video and to be used as a future video feed for the Autoscope video imaging system), and equipment to make video and data available to TTI's TransLink® Lab.

Both pedestrian sensors—the ASIM IR 201/207 and the MS SEDCO SmartWalk—are capable of sending information over a local network by using an Ethernet switch and a terminal server. A wireless system could be available for future tests which require communications between vehicles on the street and the intersection. Most of the future off-site monitoring could then occur at TTI's TransLink® Lab.

In the course of investigating pedestrian sensors, the research team identified several low-cost, portable detector units. These portable pedestrian detectors are typically used in a stand-alone mode and are fairly simple in their operation and the features offered. The general idea with these detectors is that they monitor the passage of people through a detection area to determine the number of persons using a trail. The research team purchased the following pedestrian sensors to be used in developing a trail-based test bed:

- **Jamar Scanner**, based on passive infrared technology;
- **TrafX Infrared Trail Counter**, based on infrared technology; and,
- **Diamond Traffic TTC-4420**, based on pulsed infrared with a reflector.

Researchers envisioned that these low-cost sensors (essentially motion detectors with a counter) could be tested and used on several shared-use trails in College Station, including Bee Creek Trail (in Lemontree and Bee Creek Park) as well as the Wolf Pen Creek trails.

Physical Design and Configuration of Test Bed

Figure 3 shows the general location of the detection zones that were configured at the test bed intersection. Figure 5 shows the pedestrian sensors mounted at the northwest corner (for both the northwest corner and the north crosswalk detection zones). Figure 6 shows the pedestrian mounted sensors at the southwest corner (for both the southwest corner and the south crosswalk detection zones). The test bed surveillance camera can also be seen in Figure 6.

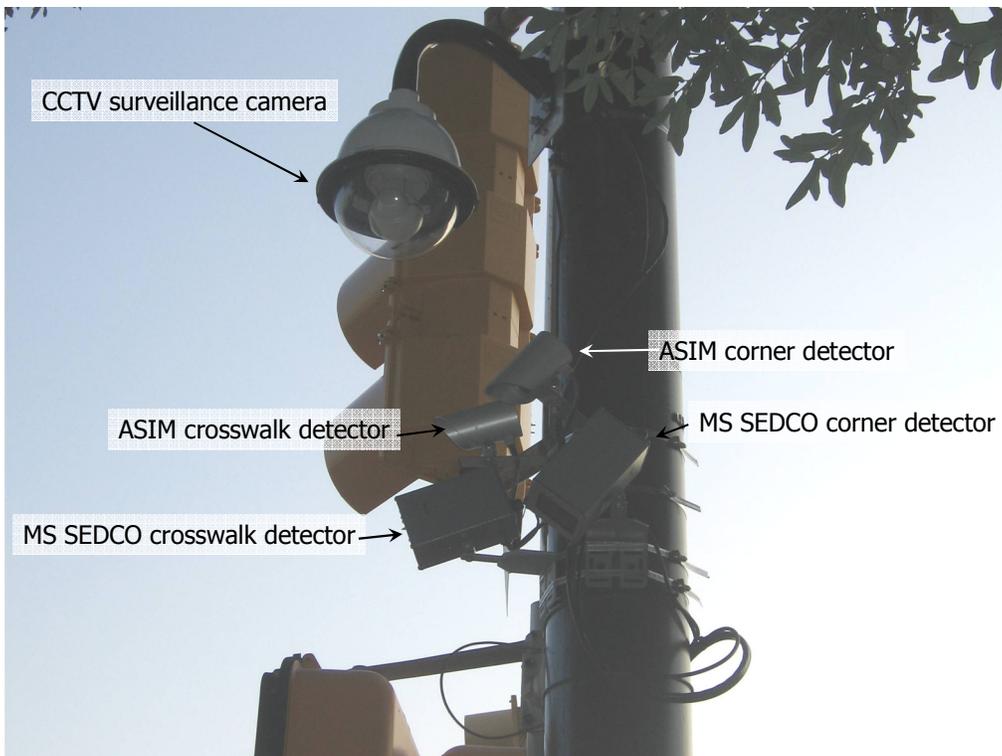**Figure 5. Pedestrian Sensors at the Northwest Corner of Test Bed**

Figure 6. Pedestrian Sensors at the Southwest Corner of Test Bed

Evaluation of Intersection-Based Pedestrian Sensors

The research team used slightly different evaluation procedures for the intersection-based pedestrian sensors and the trail-based pedestrian sensors. This was necessary because the intersection sensors report instantaneous pedestrian presence (i.e., a simple on/off switch that is activated at the sub-second level), whereas the trail sensors report an actual person count.

The evaluation procedures for both types of sensors focused on accuracy and included these measures of effectiveness:
1. **Overall error rate** – the percentage of time in which the sensor reported the correct response;
2. **Missed detection error rate** – the percentage of time in which the sensor did not detect a pedestrian when one or more were present; and,
3. **False detection error rate** – the percentage of time in which the sensor detected a pedestrian when none were present.

These measures of effectiveness rely on reference or "ground truth" data that indicate the true and correct sensor response. In this evaluation, the reference data were obtained by recording video and manually verifying actual field conditions (i.e., the presence or absence of pedestrians).

The intersection pedestrian sensors used different sensors to monitor the pedestrian waiting area at the corner and the marked pedestrian crosswalk in the street. Therefore, the evaluation procedures considered four different locations:
- Northwest corner/waiting area of University and Spence Street.
- Southwest corner/waiting area of University and Spence Street.
- North crosswalk as viewed from the northwest corner of the intersection.
- South crosswalk as viewed from the southwest corner of the intersection.

In order to first estimate the detection zone, the research team followed the instructions for calibrating the detectors. The first step identified where the detectors should be aimed, and took height and distance measurements from that point. This step required finding the angle of the detector and estimating the areas of detection of the detectors. The crosswalk zone was estimated using an approximate angle and height to avoid taking detailed measurements in the middle of a busy street.

The starting point was the northwest corner of University and Spence. Based upon the estimated area of the detection zone, the researchers outlined a zone that would emulate what the detector should see. To avoid conflicts with another subsequent zone, this zone became the "yellow zone." The timestamp on the video served as the record of times that people were in the zone of detection. This timestamp provided the necessary comparison for the data that had been recorded by the sensor.

The uncertainty of the actual sensor detection zone required defining a second smaller detection zone for the northwest corner called the "red zone." The red zone was a narrower field of

detection. The red zone resulted in improved detection over the yellow zone, which may have been wider than the actual sensor detection zone.

The camera on the southwest corner provided the video necessary for recording and verifying detections. Correlating detections between the recorded video and test detectors required the use of timestamps and counting in the same manner as the northwest corner was counted.

The north and south crosswalk detection zones were established using each manufacturer's estimates based on approximate mounting height and angle. Two elongated ovals approximated the crosswalks, which were verified by counting the times that pedestrians crossed into the detection zone. The recorded video did not show a timestamp, so researchers had to relate the crosswalk video to the north corner video. This correlation required finding a car that passed a point and synchronizing the video time counter on the crosswalk video to the timestamp on the corner video. These results provided an accurate timestamp to measure and compare the reference data with the sensor data.

Unlike the corner detectors, crosswalk detector zones have cars crossing them constantly. Compensating for these unwanted detections required disregarding the data when cars were present. Only the longer gaps between cars were used to establish detector accuracy, but the data with cars were stored for subsequent checks using a spreadsheet to verify that the sensor data and the reduced data were the same. If they were different, researchers checked which type of error occurred and recorded it. Finding cars in the zone during this time caused the data to be disregarded.

The data from the sensors, as well as the reference data, was available in one-second time increments. Analysts placed the reduced data into a chart form using a binary system where "1" represented "on" and "0" represented "off." For the northwest and southwest corners, the researchers simply looked in the sensor data spreadsheet and checked to see if the values were the same as the reference data. If the data were not the same as the reference data, the researchers checked to see which type of error occurred (i.e., missed detection or false detection). The two types of errors were kept separate in order to better see which types of errors were occurring with each sensor. An overall error rate was calculated by combining the two types of errors.

The error rate was determined by comparing the units of time that the detector had an error to the units of time that it had available to be correct. The errors were reported separately. In the case of the northwest and southwest corners, the amount of time available was 45 minutes. In the case of the crosswalk errors, the total time available for evaluation was about 15 minutes (i.e., the total time less the time that cars were present.

Evaluation of Trail-Based Sensors

The evaluation procedures for the trail-based pedestrian sensors used slightly different procedures because the trail-based sensors captured a count (pedestrian, bicyclist or other non-motorized trail user), whereas the intersection-based sensors measured instantaneous presence.

Other differences in evaluation procedures were the use of several sites (since the trail sensors are intended to be portable), as well as controlled testing to evaluate sensor performance in a variety of conditions. Table 3 summarizes the study sites used in the evaluation of the trail sensors. The following sections provide a description of each study site.

Table 3. Summary of Trail Sensor Study Sites

Site Number	City	Location	Date of Study Period	Time of Study Period
1	College Station	Wolf Pen Creek Trail (controlled testing)	July 6, 2006	8:00 am – 12:00 pm
2	College Station	Texas A&M University Student Recreation Center	September 15, 2006	7:30 am – 11:30 am
3	Austin	Town Lake Pedestrian Bridge	October 13, 2006	7:30 am – 11:30 am

Wolf Pen Creek Study Site

The first study site at the Wolf Pen Creek Trail (Figure 7) laid the foundation for the pedestrian trail counter study. Researchers conducted a series of baseline tests using predefined pedestrian traffic simulated by research personnel. The Wolf Pen Creek Trail is part of a system of multi-use trails in the city of College Station that link parks, residential areas, and commercial districts. This section of the trail provided an abundance of convenient mounting locations with multiple park benches and light poles. The trail has relatively low volumes compared to the other two locations. The low volumes were ideally suited to the controlled testing at this location.

The controlled testing at Wolf Pen Creek evaluated the effects on trail sensor performance of the following factors: 1) target speed, 2) group spacing, 3) target distance, and 4) sensor mounting height. Each test consisted of 15 passes in front of the counters in each direction of the trail for each test measurement. Figure 8 shows an example of testing group spacing. To test target speed, researchers traveled in front of the counters at five different speeds: "stopping to talk," walking, jogging, running, and traveling by bicycle. To test group spacing, pairs of researchers walked in front of the counters side-by-side and at spacings of 1-ft increments from 1 to 5 ft. To measure target range, researchers walked in front of the counters at distances of 30, 40, and 50 ft. Finally, researchers adjusted the mounting height of each counter from its original height of approximately 3 ft to test accuracy at 4 ft, 4.5 ft, and 5 ft.

Figure 7. View of Study Site at Wolf Pen Creek

Figure 8. Controlled Test for 5 ft Spacing at Wolf Pen Creek Study Site

Recreation Center Study Site

The second trail sensor study site was located on the Texas A&M University campus.
Researchers observed two locations on the walkways between the Student Recreation Center, the
West Campus Parking Garage, and the Wellborn Road pedestrian underpass. This is a high-
traffic area as students travel throughout the day between their parked vehicles, the Recreation
Center, and their classes on the main campus. Figure 9 shows one of the walkways at this site.

Figure 9. View of Study Site at Texas A&M Recreation Center

Town Lake Study Site

In an attempt to use the counters in heavy trail traffic, the Town Lake Pedestrian Bridge
(Figure 10) in Austin was selected for the third trail sensor study site. This site provided not
only higher traffic volumes but also more consistent traffic throughout the study period. The
variety of modes of transportation at this site (i.e., bicyclists, joggers, walkers with baby
strollers) provided the sensors with a testing scenario that was unavailable at either the Wolf Pen
Creek or Recreation Center locations. At this location, a large proportion of groups (two or more
pedestrians traveling together) accounted for almost half of the total pedestrian traffic.

Figure 10. View of Study Site at Town Lake

Trail Sensor Equipment Setup and Data Collection

Prior to collecting data, researchers synchronized the equipment time and adjusted the timestamp settings on each counter using the configuration programs supplied by the vendors. At each location, the trail counters were mounted on one or more fixed objects and aimed across the trail or walkway under observation. In addition, researchers installed one or more tripod-mounted camcorders to create a video recording of traffic at the site; a camcorder point-of-view is shown in Figure 11. The purpose of timestamp videotaping the detection zone is to provide a "ground truth" count of the actual trail user traffic. During data reduction and comparison of results, researchers used the video to determine the ground truth counts at each site. Reducing video data in an office is more advantageous than reducing data in the field, as a video can be reviewed multiple times to reduce the human error in counting. The ground truth data allowed for multiple viewings and created an error-checking procedure that reduced the subjective human error in the timestamp recording portion of the data reduction. The clock on the camcorder was synchronized with the counter clocks to ensure an accurate reproduction of the observed traffic.

Figure 11. Camcorder Point of View at Town Lake Study Site

At Wolf Pen Creek, all three counters were mounted on a light pole (Figure 12); the camcorder tripod was positioned near the edge of the sidewalk a short distance away. At the Texas A&M Recreation Center, the counters were installed at two locations. At the Texas A&M Recreation Center location (Figure 9), two counters were mounted on bollards and angled at a wall, limiting the distance of detection to the bounds of both detectors. Due to mounting constraints, the target-based counter was moved to a nearby second location between two trees. Researchers mounted video cameras on top of the West Campus Parking Garage to provide the ground truth volume count at each location. At Town Lake, all three counters were mounted to a light pole, similar to Wolf Pen Creek.

Figure 12. Counter Installation at Wolf Pen Creek Study Site

Data Collection at the Recreation Center and Town Lake

After installing the counters at the Texas A&M Recreation Center site, researchers relocated to the top of the adjacent parking garage to observe conditions from a distance. The high volumes of pedestrians provided a sufficient sample for the first field test. The first location (Jamar and TrafX sensors) had 470 walkway users, and the second location (Diamond sensor) had 327 sidewalk users. Researchers had some concerns with heavy shade at the second location, but it did not pose a problem. Although conspicuity and vandalism were not formally tested, informal observations of pedestrians also indicated that the counters were inconspicuous enough to be undetected or ignored by the average pedestrian.

At the Town Lake site, researchers remained within sight of the counters and trail users, so that any needed changes or adjustments could be identified and implemented quickly. Group spacing and the ability to count groups seemed to be the greatest challenge when attempting to calibrate these sensors. The TrafX sensor had an adjustment feature allowing the user to change the delay between readings. This feature seemed to be more focused on preventing the counter from counting the same person twice (i.e., double-counting). The Jamar sensor documentation suggested angling the detector at a 45-degree angle to reduce the number of pedestrians missed in a group of trail users. After some manipulation, the detectors were set and appeared to be operating normally. Placing the detectors in an appropriate location to record traffic on the bridge required that the detectors be in direct light; however, this did not appear to affect performance based on site observations.

Data Reduction

Data reduction for the trail sensors consisted of reviewing the video tapes of each study site and the corresponding data that were downloaded from each counter. Prior to the actual reduction of the video data, equivalent zones of detection, specified by engineering judgment and vendor specifications, were identified on the viewing monitor for each trail counter. Each time a subject passed through the detection zone, a ground truth timestamp was recorded. The researchers reducing the data utilized two independent counts in which they reviewed and verified all timestamps for accuracy to reduce human error in recording. The ground truth volumes were then compared to the volumes recorded by each detector and evaluated for counter accuracy. The results were summarized first by travel mode to determine if each counter was consistently under- or over-counting a particular mode. Overall count totals were then aggregated for easy comparison of the overall performance of the counters.

Defining Groups vs. Individual Pedestrians. In many instances, pedestrians or joggers will run side-by-side or within several feet of one another. From the early study site at Wolf Pen Creek, the researchers realized that a detector would identify a group of two or more closely-spaced pedestrians as one trail user. Considering this, groups of two or more were noted in the analysis as "passing through as a group" rather than several single persons. This allowed researchers to quantify the sensitivity of the individual counters, with a goal of obtaining an accurate count containing each person passing through the study area. The important consideration is that the detectors cannot differentiate what type of trail user passed through the detection line. If a single pedestrian crossed the line alone, the researchers had confidence that the actual detection picked up by the sensor was indeed the walking pedestrian. If, however, a jogger and a walker (pedestrian walking and a pedestrian jogging) crossed paths within the detection zone, there was some doubt as to which person the trail counter detected. Researchers made one important assumption: a person pushing a stroller would count as two people for purposes of this analysis. The only site affected by this assumption was the Town Lake Bridge study site.

Uploading the Detector Files. The researchers became familiar with each of the detectors' user interface, configuration software, and input/output software to assure that the data were correctly uploaded. Both the Jamar and TrafX sensors required the vendor-supplied software to upload the detector data into spreadsheet files for each study site. The hourly counts from the Diamond sensors were read from the user interface and were recorded into field notebooks.

Comparing the Timestamps. A spreadsheet was created to organize the counter data. Timestamps were matched with corresponding ground truth timestamps as shown in Table 4. In the case where there was no detector timestamp for a ground truth timestamp (the counter did not detect a person present in the detection zone), the cell in the worksheet would remain blank. Extra false detection timestamps were highlighted in red for ease in counting later. Tan-colored timestamps in the "Ground Truth" column of the spreadsheet represent timestamps of a group of two or more in which case the identical time values are repeated. Researchers reviewed the video twice to verify that the ground truth timestamps and volume counts were correctly observed and recorded in the spreadsheet.

Table 4. Trail Sensor and Ground Truth Timestamp Comparison

Timestamp Comparison		
Counter 2	Counter 1	Ground Truth
8:01:31	8:01:30	8:01:32
		8:01:32
8:01:36	8:01:35	8:01:37
		8:01:37
8:02:33	8:02:32	8:02:33
		8:02:33
	8:02:43	8:02:43
	8:02:13	
8:02:46	8:02:46	8:02:45
8:02:49	8:02:48	8:02:52
8:02:53	8:02:52	8:02:53
	8:02:55	8:02:53
8:02:56	8:02:55	8:02:55
		8:02:55
		8:02:55
8:03:23	8:03:21	8:03:22
8:03:30	8:03:29	8:03:30
8:03:42	8:03:40	8:03:41
		8:03:41
8:04:39	8:04:38	8:04:39
		8:04:39
8:04:43	8:04:42	8:04:42
8:04:59	8:04:58	8:04:58
8:05:10	8:05:10	8:05:09
		8:05:09
8:05:15	8:05:14	8:05:14
8:06:19	8:06:18	8:06:19

(red)	Signifies a false detection
<blank cell>	Signifies a missed detection
(tan)	Signifies a group of two or more

Calculation of Error Rates

Error rates can be analyzed in many different ways. The most common error rate that customers of these products are interested is the overall error rate (Equation 1). None of the detectors can classify the mode of the person traveling (short of mounting the detectors at different heights to change the height of detection) and the overall error rate can summarize the detectors' accuracy with a single number. With the overall error rate, missed detections and false detections can potentially cancel each other out, leaving an overall error rate of zero. A negative difference indicates an overall undercount of the ground truth count.

Equation 1 $$\text{Overall Error Rate (\%)} = \frac{(\text{test device count} - \text{ground truth count})}{\text{ground truth count}}$$

Missed detection errors (Equation 2) were defined in this study on an individual count basis (i.e., a detector that did not detect one walking pedestrian would have one missed detection).

Equation 2 $$\text{Missed Detection Error Rate (\%)} = \frac{\text{count of missed detections}}{\text{ground truth count}}$$

Similarly, false detections (Equation 3) were any unexpected detections that a trail counter recorded in addition to the expected counts. Occasionally, slow pedestrians or pedestrians who happen to stop immediately in front of the detection zone will trigger a counter multiple times.

Equation 3 $$\text{False Detection Error Rate (\%)} = \frac{\text{count of false detections}}{\text{ground truth count}}$$

The error rate for different users (walking pedestrian, jogging pedestrian, bicyclists, strollers, etc.) was calculated using only single individuals. Since researchers could not determine from the counters' output which of the persons in the group were counted by the detectors, groups were not included.

STUDY FINDINGS

The findings and conclusions for this study are first presented for the intersection sensors, then for the trail sensors.

Intersection Sensors

Table 5 summarizes the evaluation results for the ASIM and MS SEDCO intersection sensors. The error rates ranged from 9 to 39 percent, with most error rates in the 20 to 30 percent range. Both intersection sensors performed comparably, with the ASIM sensor having a slightly lower error rate in most scenarios.

Table 5. Summary of Evaluation Results for Intersection Sensors

Test Location	Number of Samples	Overall Error Rate (%)		Missed Detection (%)		False Detection (%)	
		ASIM	SEDCO	ASIM	SEDCO	ASIM	SEDCO
Northwest corner: red zone	2,752	25%	30%	17%	22%	8%	7%
Northwest corner: red & yellow zone	2,752	25%	31%	22%	31%	3%	0%
Southwest corner	2,752	9%	11%	7%	10%	2%	1%
North crosswalk	750	22%	23%	10%	14%	13%	9%
South crosswalk	750	32%	39%	17%	27%	16%	13%

The sensors mounted at the southwest corner had the lowest error rate, at 9 percent for ASIM and 11 percent for MS SEDCO. This result may have been due to the better defined waiting area for pedestrians, in that waiting pedestrians were limited to an area that coincided with the sensor detection zone.

The sensors mounted for the southern portion of the crosswalk had the highest error, at 32 percent for ASIM and 39 percent for MS SEDCO. This high error could have been due to mounting difficulties, in that the sensors for the south crosswalk were mounted at a high skew angle to the crosswalk.

There were several issues that confounded reliable and accurate detection at the intersection corners and the crosswalks:
- Pedestrians did not always walk clearly through the detection zones.
- The actual pedestrian detection zone cannot be clearly established for each sensor.

There were several issues that confounded accurate and reliable detection at the intersection corners only:
- Pedestrians that did not intend to cross the street were counted as detections.
- Pedestrians standing still in the detection zone could not be detected.
- Pedestrians standing close to the edges of the detection zone made it difficult to judge whether they were in the detection zone.

There were also several issues that confounded accurate and reliable detection in the marked crosswalk:
- Cars turning westbound onto University during the time when pedestrians crossed the road triggered the pedestrian sensors.
- Cars would stop on the crosswalk detection zone, causing a prolonged detection during the pedestrian walk phase.

Trail Sensors

Controlled Tests at Wolf Pen Creek

Table 6 summarizes the controlled tests at Wolf Pen Creek. The following bullets summarize the findings for each test condition:

- **Baseline:** For a single walking pedestrian, all three counters had no errors in the 30 trial passes. For a single bicyclist, the Jamar sensor consistently missed detecting the bicyclist while the TrafX sensor had no errors (the Diamond sensor was not tested for bicyclists).

- **Group Spacing:** As was expected, all three counters had difficulty accurately detecting pedestrians walking close to each other. The Diamond sensor required about a 2 ft separation before it could detect separate pedestrians, whereas the Jamar sensor required 4 ft or more of separation to detector single individuals in a group. It appears that the time delay between detections on the TrafX sensor was high, as it had difficulty separating pedestrians even with a spacing of 5 ft.

- **Pedestrian Speed:** All three trail sensors had difficulty detecting pedestrians that stopped at or near the detection zone, as well as detecting pedestrians who were running. All three trail sensors were effective at detecting pedestrians who were jogging.

- **Bicyclist Speed:** The Jamar sensor had high error rates for bicyclists that were traveling 10 mph or faster. The TrafX sensor had no error for bicyclists at 10 mph, but did have high error rates for bicyclists at 15 mph or faster. The Diamond sensor was not tested for bicyclists.

- **Detection Range:** The Diamond sensor performed best at longer distances, most likely because of the break-beam technology used. In general, all three trail sensors worked satisfactorily for single pedestrians traveling within the respective manufacturer's recommended range.

- **Mounting Height:** A mounting height in the range of 3 to 5 ft appeared to have little effect on the error rates. Each manufacturer recommends a mounting height of 3 to 4 ft, such that the detection zone is near the torso of a typical adult pedestrian.

Table 6. Summary of Results for Controlled Test at Wolf Pen Creek Trail

Test Condition		Ground Truth Count		Overall Error Rate (%)			Missed Detection Error Rate (%)			False Detection Error Rate (%)		
		Jamar & Trafx	Diamond	Jamar	TrafX	Diamond	Jamar	TrafX	Diamond	Jamar	TrafX	Diamond
Baseline Walking	Walking	30	30	0%	0%	0%	0%	0%	0%	0%	0%	0%
Baseline Biking	10 MPH	30	-	-97%	0%	-	97%	0%	-	0%	0%	-
Group Spacing	Side-by-side	60	60	-53%	-50%	-50%	53%	50%	50%	0%	0%	0%
	1 ft length	60	60	-58%	-50%	-40%	58%	50%	40%	0%	0%	0%
	2 ft length	60	60	-47%	-50%	-2%	47%	50%	2%	0%	0%	0%
	3 ft length	60	-	-15%	-37%	-	15%	37%	-	0%	0%	-
	4 ft length	60	-	-2%	-38%	-	2%	38%	-	0%	0%	-
	5 ft length	60	-	0%	-22%	-	0%	22%	-	0%	0%	-
Pedestrian Speed	Stopped to talk	30	30	43%	-10%	7%	0%	43%	0%	43%	33%	7%
	Jogged	30	30	-7%	-7%	-3%	7%	7%	3%	0%	0%	0%
	Running	30	30	-67%	-20%	-40%	67%	20%	40%	0%	0%	0%
Bicyclist Speed	5 mph	30	-	-3%	0%	-	3%	0%	-	0%	0%	-
	15 mph	30	-	-100%	-87%	-	100%	87%	-	0%	0%	-
	20 mph	30	-	-100%	-60%	-	100%	60%	-	0%	0%	-
	25 mph	8	-	-100%	-100%	-	100%	100%	-	0%	0%	-
Detection Range	30 ft	30	30	-13%	-100%	0%	13%	100%	0%	0%	0%	0%
	40 ft	30	30	-27%	-100%	0%	27%	100%	0%	0%	0%	0%
	50 ft	31	30	-52%	-100%	3%	52%	100%	0%	0%	0%	3%
Mounting Height	3.0 ft	30	-	0%	-13%	-	0%	13%	-	0%	0%	-
	4.0 ft	28	-	0%	-32%	-	0%	32%	-	0%	0%	-
	4.5 ft	30	-	0%	-43%	-	0%	43%	-	0%	0%	-
	5.0 ft	30	-	0%	-63%	-	0%	63%	-	0%	0%	-

Field Tests at the Recreation Center and Town Lake

Tables 7 and 8 summarize the evaluation results and error rates from the two latter study sites. The following summarize key findings:

- At the Texas A&M Recreation Center Site, the TrafX and Diamond sensors performed fairly well, with overall count errors of -11 percent and -7 percent. The Jamar sensor missed more walkway users (mostly joggers and bicyclists), with an overall count error of -34 percent. At this study site, 15 percent of the walkway users were in groups of two or more.

- At the Town Lake Site, all three trail sensors had difficulty counting each person in a group. The TrafX and Diamond sensors had similar performance, with an overall error rate of -26 percent and -24 percent, respectively. The Jamar sensor had a higher error rate of -36 percent. At this study site, 47 percent of the trail users were in groups of two or more.

Table 7. Summary Evaluation Results from the Texas A&M Recreation Center Site

Test Condition		Ground Truth Count	Overall Error Rate (%)		Missed Detection Error Rate (%)		False Detection Error Rate (%)	
		Jamar & TrafX	Jamar	TrafX	Jamar	TrafX	Jamar	TrafX
Groups of 2 or more	Bike/ Ped	16	-63%	-44%	63%	44%	0%	0%
	Ped/ Ped	53	-43%	-49%	42%	47%	0%	0%
	Bike/ Bike	4	-50%	-25%	50%	25%	0%	0%
Pedestrians by walk speed	Walking	293	-13%	-3%	13%	4%	0%	1%
	Jogging	9	-56%	-33%	56%	33%	0%	0%
Non-Pedestrians	Bicycles	93	-84%	-8%	84%	8%	0%	0%
	Skateboarder	1	-100%	0%	100%	0%	0%	0%
	Golf cart	1	0%	0%	0%	0%	0%	0%
Totals		470	-34%	-11%	0%	0%	0%	0%

Note: In this test, the Diamond sensor could not be tested at the same location as the Jamar and TrafX sensors because an adequate mounting position was not available. The Diamond sensor was mounted at a nearby location that had similar types of sidewalk traffic. The results of this 3-hour test was that the Diamond sensor had an overall error rate of -7% (ground truth count was 327 sidewalk users).

Table 8. Summary Evaluation Results from the Town Lake Site

Test Condition		Ground Truth Count		Overall Error Rate (%)			Missed Detection Error Rate (%)			False Detection Error Rate (%)		
		Jamar & Trafx	Diamond	Jamar	TrafX	Diamond	Jamar	TrafX	Diamond	Jamar	TrafX	Diamond
Groups of 2 or more	Bicyclists, joggers, walkers, and/or strollers	450	-	-52%	-52%	-	52%	52%	-	0%	1%	-
Pedestrians by walk speed	Walking	273	-	-9%	-4%	-	9%	4%	-	0%	0%	-
	Jogging	181	-	-36%	-3%	-	36%	2%	-	0%	0%	-
Bicyclists	Bicyclists	63	-	-38%	-5%	-	38%	5%	-	0%	0%	-
Single Subtotal	Walkers/ Joggers/ Bicyclists	517	-	-22%	-4%	-	22%	4%	-	0%	0%	-
Totals		967	970	-36%	-26%	-24%	0%	0%	-	0%	0%	-

Note: The Diamond sensor is only capable of providing cumulative counts and does not have the ability to provide timestamps for individual trail users. Therefore, researchers were not able to determine the missed detector error rate, false detection error rate, or error rate by type of trail user.

CONCLUSIONS AND RECOMMENDATIONS

The following sections provide conclusions of this study and recommendations for future activities.

Intersection Sensors

Accurately detecting pedestrians with a low-cost sensor is a difficult task, particularly in a street environment in which pedestrian movement is unconstrained. Pedestrians may not walk into the detection zone at curbside when waiting to cross the street, and they may walk outside the crosswalk detection zone when crossing the street. Pedestrians may walk into the detection zone, but then stand still while waiting to cross the street. Pedestrians may walk into the detection zone without any intent to cross the street. All of these situations make it very challenging to detect pedestrians.

The ASIM and MS SEDCO intersection sensors provided fair to mediocre results, with error rates ranging from 9 to 39 percent. The accuracy of the sensors appeared to be very location-specific, in that pedestrian detection is more viable in certain situations in which the pedestrian travel area is constrained and/or the pedestrian detection area is well-defined. The error rates at the southwest corner were lowest at 9 and 11 percent, but even that error rate may not represent sufficient accuracy for certain traffic safety applications. The typical error rates were in the 20 to 30 percent range, which is not sufficient accuracy for most pedestrian detection applications.

Trail Sensors

Another objective of this study was to determine the accuracy of three commercial trail counters and determine their strengths and weaknesses in different trail conditions. Although error rates in this study may show one counter to be more accurate than another, a potential purchaser of these counters should first analyze the intended location for installation and review what type of counts they desire. For instance, if a purchaser desires timestamps for each trail user, then the Diamond sensor would not be sufficient to meet this need. Conversely, if the purchaser desires only an hourly binned count each day, then the Diamond sensor would be an option.

In general, all three trail sensors were able to accurately detect a single pedestrian at typical walking speed or a bicyclist at slow speed (5 to 10 mph). The Jamar sensor had difficulty counting bicyclists at typical bicycling speed. Although expected, all three counters had difficulty counting trail users who were closely spaced, but the required separation varied by counter. The Diamond sensor required the least amount of separation in a group, at about 2 ft.

The following paragraphs describe the strengths and weaknesses of each of the three trail sensors. That the purchase price for all three sensors was comparable.

- **Jamar Scanner (larger infrared counter):** This sensor had difficulty with detecting bicyclists traveling faster than 10 mph. It also had average performance with group detection, typically requiring 3 ft or more to detect individual users. The sensor functions and software interface were easy to use and the user's manual was adequate.

- **TrafX Sensor (small infrared counter):** This sensor performed well in group situations but also had difficulty detecting bicyclists faster than 15 mph. This sensor was small and compact, and could be easily hidden from view. The sensor functions and software interface were easy to use and the user's manual was adequate.

- **Diamond Trail Counter (break-beam with target):** This sensor performed well in single trail user and group situations. However, the sensor functions were limited to binned counts (not individual timestamps), the user interface was lacking, and the user's manual was very difficult to follow. Sensor setup also required additional time because of the target alignment and mounting.

All three trail sensors consistently undercounted the actual ground truth counts, with the undercounting being more severe on the trail with more groups. This undercounting presents a problem on busy shared-use trails. It is possible to compensate for groups by adjusting the counts up by a "group factor." However, this "group factor" to adjust raw counts would need to be determined on a site-by-site (and perhaps time-of-day) basis.