



APPENDIX K

Bicycle & Pedestrian Count Technology White Paper



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Re: Cupertino ATP: Bicycle and Pedestrian Count White Paper

Introduction

This memorandum outlines the key steps and considerations for establishing a bicycle and pedestrian count program in the City of Cupertino. Reference memo [sources](#) for additional details on concepts discussed, and the California Active Transportation Safety Information Pages ([CATSIP](#)) for more resources. Key takeaways include:

- Thorough planning is essential for selecting a count product that meets all potential program purposes and uses technology that can be deployed at desired count locations.
- All long-term, continuous count programs need to incorporate short-term counts for baseline data validation and should plan regular short-term counts to validate data, as part of a QA/QC protocol.
- There are many different products and staff time costs associated with starting a bicycle and pedestrian count program. Comprehensive life cycle budgetary planning will reduce unexpected and preventable costs.

Bicycle and Pedestrian Count Planning

During the bicycle and pedestrian count planning stage, program staff should identify all possible count purposes and locations to select the most appropriate count method. One component of identifying the count purpose(s) is establishing the count duration (short-term versus long-term) and which users (bicyclists and/or pedestrians) the program aims to count. Count duration, user compatibility, and location compatibility are three considerations that differentiate between the count technology (outlined **Table 1** and **Table 2**).

Count Purpose

There are several potential purposes for conducting bicycle and pedestrian counts, including but not limited to (Hugh, Davis, Voros, O'Toole, & Piper, 2016):

- Establishing a baseline for bicycle and pedestrian volume
- Determining locations where there is the greatest demand for bicycle and pedestrian facilities
- Analyzing changes over time in bicycle and pedestrian facility utilization
- Quantifying utilization when prioritizing resources and competing for funding

Establishing a baseline bicycle and pedestrian volume is an example of a count purpose where short-term, temporary count methods can be utilized. However, if the count program also aims to analyze changes over time, that is an example of a count purpose where long-term, permanent counting methods can be utilized. The Federal Highway Administration (FHWA) Traffic Monitoring Guide (TMG) recommends collecting a two-week, short-term count before installing permanent, continuous counting equipment. As a result, all long-term counts should include baseline data collection as a program purpose.

Count Location

The FHWA TMG recommends that bicycle and pedestrian count locations be representative of the network, aiming for geographic diversity and encompassing a range of low, medium, and high volumes of bicycle and pedestrian traffic. The short-term count, conducted in advance of installing continuous counting equipment, validates assumptions about traffic volume and supports the notion that these locations are representative of geographic and volume diversity. In a study of Municipal Planning Organizations (MPOs) piloting bicycle and pedestrian count programs, some MPOs selected count locations where they previously completed manual counts (Federal Highway Administration, 2016). This data may be sufficient for validating geographic and volume diversity.

Other factors that MPOs considered when selecting count locations include:

- **Stakeholder Input:** MPOs considered input from their local agencies, a university, a bicycle and pedestrian advisory committee, and interested parties. Coordination across agency departments was particularly crucial for identifying the specific locations where continuous count products would be installed and obtaining the necessary permissions for installation.
- **Recently completed projects:** Some MPOs used counts to assess the impact of recently completed projects on bicycle and pedestrian volumes. Alternatively, some collected a baseline volume for planned projects in advance of project completion.

A final consideration when selecting count locations is proximity to a power source. When identifying potential count locations, it is helpful to note in advance which locations are near a power source and which locations would require a battery-operated product.

Selecting a Count Method

In their report on bicycle and pedestrian counting technology, Ozan et al. (2021) provide a high-level overview of the different counting methods, their typical application, and the type of locations where they can be implemented. While not included in **Table 1** and **Table 2**, Ozan et al. (2021) also suggest **manual entry** as a very portable and expensive count method due to training and staff time. Manual entry is most often cited in the literature as a short-term method for validating automated count technology.

When used singularly, automated counting technologies have various limitations. Some can't be placed near vehicles, or they can't differentiate between bicyclists and pedestrians. However, when companies combine count technologies, their products are more flexible, can differentiate between user types, and can be deployed at a variety of location types. This memo prioritized discussing products that are either compatible with multiple user types or multiple location types. Below is a general description of each technology utilized in the products outlined in **Table 3** and **Table 4**.

Passive infrared sensors detect humans based on their heat signatures and cannot differentiate between bicyclists and pedestrians. The technology also captures individuals when they are in vehicles, making it unsuitable for collection near roadways. Passive infrared sensors can be used on trails or shared-use paths separated from traffic. They are best suited for either temporary or permanent counts where bicyclists and pedestrians do not need to be separately classified.

Pneumatic tubes use pressure sensors to detect when a bicycle passes over the tubes on a shared path, bike lane, or shared street lane. This technology is only used for short-term, temporary counts due to product wear and tear over time. When in combination with passive infrared sensors, as is the case with the Eco-Counter Mobile MULTI, bicyclists and pedestrians can be classified separately. Pedestrians are identified on sidewalks using passive infrared sensors, and bicyclists are identified using pneumatic tubes.

Inductive loops are a long-term, permanent alternative to pneumatic tubes. They use electric currents embedded under the pavement to detect magnetic objects. When in combination with passive infrared sensors, as is the case with the MULTI Evo, bicyclists and pedestrians can be classified separately. Pedestrians are identified on sidewalks using passive infrared sensors, and bicyclists are identified using inductive loops. A downside to inductive loops is that they do not capture bicycle traffic that does not pass over the loop (i.e., on the sidewalk or in the vehicle travel lane).

Piezoelectric sensors emit electric signals when a bicycle or pedestrian passes over the surface. The MetroCount RidePod BP is the only piezoelectric product on the market that can classify bicyclists separate from pedestrians. It is a long-term, permanent count technology, as the sensors are slotted into the pavement under a resin cover.

Radar sensors detect users based on reflected electromagnetic pulses and cannot differentiate between bicyclists and pedestrians combined. Radar sensor products can be used for temporary or permanent counts. The Smartmicro Traffic Radar uses radar sensors in combination with AI to distinguish between bicyclists and pedestrians.

Camera and AI uses videos or imagery to classify bicyclists and pedestrians separately. Products can be used for temporary or permanent counts. One technical specification that differentiates between products is whether video or images are saved. The Telraam S2 and Eco-Counter CITIX-AI explicitly state that images are not recorded – other products require further inquiry to determine their privacy policies.

Equipment Installation

As previously described, some count methods are more portable and can be used for either temporary or permanent counts. Other methods have a more intensive and permanent installation process, and may require special equipment or training. For example, Ozan et al. (2021) stated that installing a piezoelectric strip was the most time-intensive and challenging count method to install. The level of precision may require hiring a consultant, depending on current staff training. Installing permanent count methods may also require additional time and coordination across city agencies to validate site location permissions and installation logistics. As a result, installation equipment and staff time should both be considered in the program budget.

Count Program Management

According to the FHWA TMG, after installation, traffic monitoring equipment should be periodically calibrated and validated to ensure accurate reporting. In the study of MPOs piloting bicycle and pedestrian count programs, when validating their automatic count data, some MPOs identified instances of over- and under-counting due to factors like counter positioning. Count programs should establish quality assurance and quality control (QA/QC) protocols for testing count equipment, as well as establish a procedure for inputting data in the event of counter malfunction. Equipment maintenance, including battery checks and changes, as well as sensor cleaning, should also be incorporated into QA/QC protocols. Count products vary with regards to battery life (2 years to up to 10 years) and sensor sensitivity. Some vendors, such as Eco-Counter, offer subscriptions that detect inconsistencies in data collection and send alerts when issues arise with counters. QA/QC protocol costs, including additional monitoring subscriptions and/or staff time, should be incorporated into count budgeting and count product selection considerations.

Other additional costs with regard to the count program management may include data storage and transmission. Setting up an internal and/or publicly accessible dashboard (**Figure 1**) may also come at an additional cost. These costs vary by vendor and product. Costs included in the analysis from Ozan et al. (2021) are summarized in **Table 5** – obtaining estimates for other costs may require communicating directly with vendors.

Cupertino's Current Approach

There has been increasing community interest in Cupertino adopting a more robust data collection approach for transportation management. In response to these comments and those heard from the Bicycle Pedestrian Commission during the ATP Phase 1 outreach, Cupertino staff presented various counting technologies and methods to the Cupertino Bicycle Pedestrian Commission on July 17, 2025. During this meeting, staff solicited feedback on a potential program the City should consider. Although the Commission did not recommend a single method or technology, it reiterated its support for ongoing data monitoring to understand transportation trends.

Currently, the City has nine intersections capable of collecting bicycle and, in some circumstances, pedestrian counts. Expanding this network would require the City to consider the associated capital, staffing, and maintenance costs related to a count program. Both increasing the number of City-owned permanent counters and the scheduling of routine vendor counts would require additional City resources.

Permanent Counters

As Cupertino has upgraded its traffic control cabinets, signals, and general hardware, these upgrades have also come with new technology to detect bicycles and pedestrians. Inductive loops are being phased out and upgraded to video systems for improved vehicle detection and signal coordination. These modern systems now include features to collect bicycle movement data. This technology exists at the following intersections:

- Stevens Creek Boulevard/Mary Avenue
- Stevens Creek Boulevard/SR-85 northbound ramp
- Stevens Creek Boulevard/SR-85 southbound ramp
- Stevens Creek Boulevard/Wolfe Road
- De Anza Boulevard/Homestead Road
- De Anza Boulevard/I-280 northbound ramp
- De Anza Boulevard/I-280 southbound ramp
- De Anza Boulevard/McClellan Road/Pacifica Drive
- De Anza Boulevard/Stevens Creek Blvd

Historically, data from these locations has been collected on an as-needed basis, as exporting and validating the counts requires significant staff time.

While Cupertino could establish a formal bicycle and pedestrian count program, doing so would require additional resources to purchase technology, maintain the equipment, and review the data for accuracy.

Vendor Performed Counts

Cupertino has previously contracted with vendors to conduct citywide bicycle counts. Most recently, in 2018, the City conducted counts at 47 locations for a cost of \$40,000.

These contractor-facilitated counts are costly and may not accurately represent typical travel patterns because they capture data over short periods. Variables such as weather, holidays, school schedules, and special events can influence results, leading to undercounts or overcounts of walking and biking activity. Therefore, when conducting temporary counts, it is critical that they occur during periods that reflect a typical day, when patterns are likely representative of normal conditions.

Conclusion

Primary Recommendation

Based on the factors discussed in this memo, we recommend using the Eco-Counter MULTI Evo Nature on shared-use paths and the Eco-Counter Urban MULTI Evo on sidewalks or roadways for conducting long-term and/or continuous counts at a permanent location. Eco-Counter utilizes a dynamic combination of technologies that is rated as highly accurate. Additionally, Eco-Counter has additional products like the Eco-DISPLAY Classic+ (**Figure 2**) and the online dashboard (**Figure 1**) which can be used for communicating bicycle and pedestrian counts to the public.

Per Ozan et al. (2021), these specific products come at a high cost when combining equipment, software, data transmission, and installation (**Table 6**). Ozan et al.'s (2021) estimates for staff time to conduct site selection, installation, maintenance, and validation are also conservative, as the wage/hour rates are based on assumptions from North Carolina wages in 2020. Accounting for an estimated 10% increase in costs due to wage/hour differences, a bicycle and pedestrian counter could cost between \$14,000-\$28,000 per location, depending on the number of inductive loops used and the type of product (Evo Nature has a lower cost per unit compared to the Urban MULTI Evo).

Secondary Recommendation

A secondary recommendation is to start with a small count program using a camera and AI product. This is a more flexible option for conducting long-term and/or continuous counts, which can be relocated easily.

Telraam S2 is the recommended product for a camera and AI product because it has a relatively low device and annual subscription cost (approximately \$500 combined). Additionally, no videos or images are saved to the device or cloud, addressing a data privacy concern that is often associated with some camera and AI products. The Telraam S2 is ideal for starting small, building momentum, and establishing support for a more sustained count program in the future. The primary challenge for a Telraam counter device is finding an available Wi-Fi source for data transmission.

Ozan et al.'s (2021) review of the Miovision Scout system, which utilizes standard video and algorithm processing, received high scores for accuracy but was penalized for its high cost (\$5,000 per unit, excluding data processing fees).

Appendix

Table 1. Technology Overview

Technology	Brief Description	Typical Application	Site Type			
			Shared Use Path	Sidewalks	On Street Bike Lanes	On Street Shared Lanes
Light/Optical						
Active Infrared	Detects users breaking an infrared light beam from transmitter to receiver.	Short-term or permanent counts; bicyclists and pedestrians combined.	X	X		
Passive Infrared	Detects infrared radiation given off by pedestrians and bicyclists passing the sensor.	Short-term or permanent counts; bicyclists and pedestrians combined.	X	X		
Laser Scanning	Emits laser pulses towards multiple directions and analyzes the reflections of the pulses to determine the characteristics of the device's surroundings, including the presence of pedestrians or bicyclists.	Short-term or permanent counts; bicyclists and pedestrians combined; object classification.	X	X	X	X
Radio/Radar						
Radar Sensors	Detect users based on reflected electromagnetic pulses.	Short-term or permanent counts; bicyclists and pedestrians combined.			X	
Radio Beams (single or multiple frequency)	Detect users breaking a radio beam from emitter to receivers.	Short-term or permanent counts; bicyclists and pedestrians combined.	X	X		
Microwave Radar	Classifies using a built-in microwave radar sensor to measure traffic at a one- or two-lane (opposite direction) road layout.	Short-term or permanent counts; bicyclists only.	X	X	X	X
Electromagnetic Detection						
Inductive Loops	Electric current running through a loop embedded in the pavement or placed on top of the pavement produces a magnetic field that detects magnetic objects, including bicycles.	Permanent counts; bicyclists only.	X	X	X	X
Magnetometers	Measure magnetism of magnetic objects, including bicycles.	Permanent counts; bicyclists only.	X		X	X
Pressure/Seismic Sensing						
Piezoelectric Strips	Emit electrical signals when strip is deformed as bicycle wheels pass over the surface.	Permanent counts; typically focused on bicyclists, but technology also available for counting pedestrians.	X		X	
Pneumatic Tubes	Detect pulses of air generated when tires pass over the tubes; includes standard pneumatic tubes and bicycle-specific versions.	Short-term counts; bicyclists only.	X		X	X

Source: (Ozan, et al., 2021)

Table 2. Technology Overview (continued)

Technology	Brief Description	Typical Application	Site Type			
			Shared Use Path	Sidewalks	On Street Bike Lanes	On Street Shared Lanes
Pressure/Seismic Sensing						
Fiber Optic Sensors	Suitable for high traffic volumes; not suitable for mixed traffic; detect pressure changes through detecting light changes passing through a cable.	Permanent counts; bicyclists only.	X	X	X	
Pressure Sensors/Mats	Count pressure signatures (changes in force) that pass over the device which is typically buried.	Permanent counts; typically used on unpaved trails or paths; bicyclists and pedestrians combined.	X			
Seismic Sensors (also called acoustic sensors)	Detect the passage of energy waves through the ground.	Short-term counts on unpaved trails; bicyclists and pedestrians combined.	X			
Mobile Device Signal Detection						
Passive Mobile Device Signal Sensing (Cellphone, Wi-Fi, or Bluetooth)	Detectors record unique identifiers of enabled devices passing by.	Short-term or permanent counts; bicyclists and pedestrians combined.	X	X	X	X
GPS Enabled Mobile App-Based Route Trackers	Uses Global Positioning System (GPS) and apps to track a mobile device's movements and to determine its location.	Short-term or permanent counts; bicyclists and pedestrians combined.	X	X	X	X
Sonic Sensors						
Ultrasonic Sensors	Transmit an ultrasound wave of a set duration and use the echo to measure distance.	Short-term counts; bicyclists and pedestrians combined.		X		
Video/Image Processing						
Video Imaging (machine learning-based or classical image processing algorithms)	Employs machine learning algorithms such as neural networks to detect and classify users from video frames.	Short-term or permanent counts; bicyclists and pedestrians separately.	X	X	X	X
Thermal Imaging	Combination of overhead passive infrared detection and automated imaging technology.	Short-term or permanent counts; bicyclists and pedestrians separately.	X	X	X	X
Depth Cameras	Dot matrix of infrared or visible light captured by a receptor to create a 3-D image of a scene.	Short-term or permanent counts; bicyclists and pedestrians separately.	X	X	X	X
Hybrid Technology						
Passive Infrared + Inductive Loop	Uses a combination of infrared and inductive loops to distinguish bicycles and pedestrians in mixed mode traffic scenarios.	Permanent counts; bicyclists and pedestrians separately.	X	X		
Multipurpose Sensor Networks	Synergistic use of citywide multi-sensor installations. Example: Array of Things project in Chicago.	Permanent counts; bicyclists and pedestrians combined.	X	X	X	X

Source: (Ozan, et al., 2021)

Table 3. Short-term and/or Recurring Counts

Vendor/Product	Technology	User Type	Location
N/A	Manual Count	Bicyclists and Pedestrians	All locations
Eco-Counter Mobile MULTI	Passive Infrared, Pneumatic tubes	Bicyclists and Pedestrians	Shared-use path, on-road
MetroCount RidePod BT	Pneumatic tubes	Bicyclists	Shared-use path, on-road
Miovision Scout	Camera and AI	Bicyclists and Pedestrians	Shared-use path, on-road

Table 4. Long-term and/or Continuous Counts

Vendor/Product	Technology	User Type	Location
Eco-Counter MULTI Evo	Passive Infrared, Inductive Loop	Bicyclists and Pedestrians	MULTI Evo Nature on shared-use path, Urban MULTI Evo on on-road
Eco-Counter CITIX-AI	Camera and AI	Bicyclists and Pedestrians	On-road
MetroCount RidePod BP	Piezoelectric	Bicyclists and Pedestrians	Shared-use path
Miovision TrafficLink	Camera and AI	Bicyclists and Pedestrians	On-road
Smartmicro Traffic Radar	Radar and AI	Bicyclists and Pedestrians	On-road
Telraam S2	Camera and AI	Bicyclists and Pedestrians	On-road
TRAFx Infrared Trail Counter	Passive Infrared	Bicyclists and Pedestrians (combined)	Shared-use path

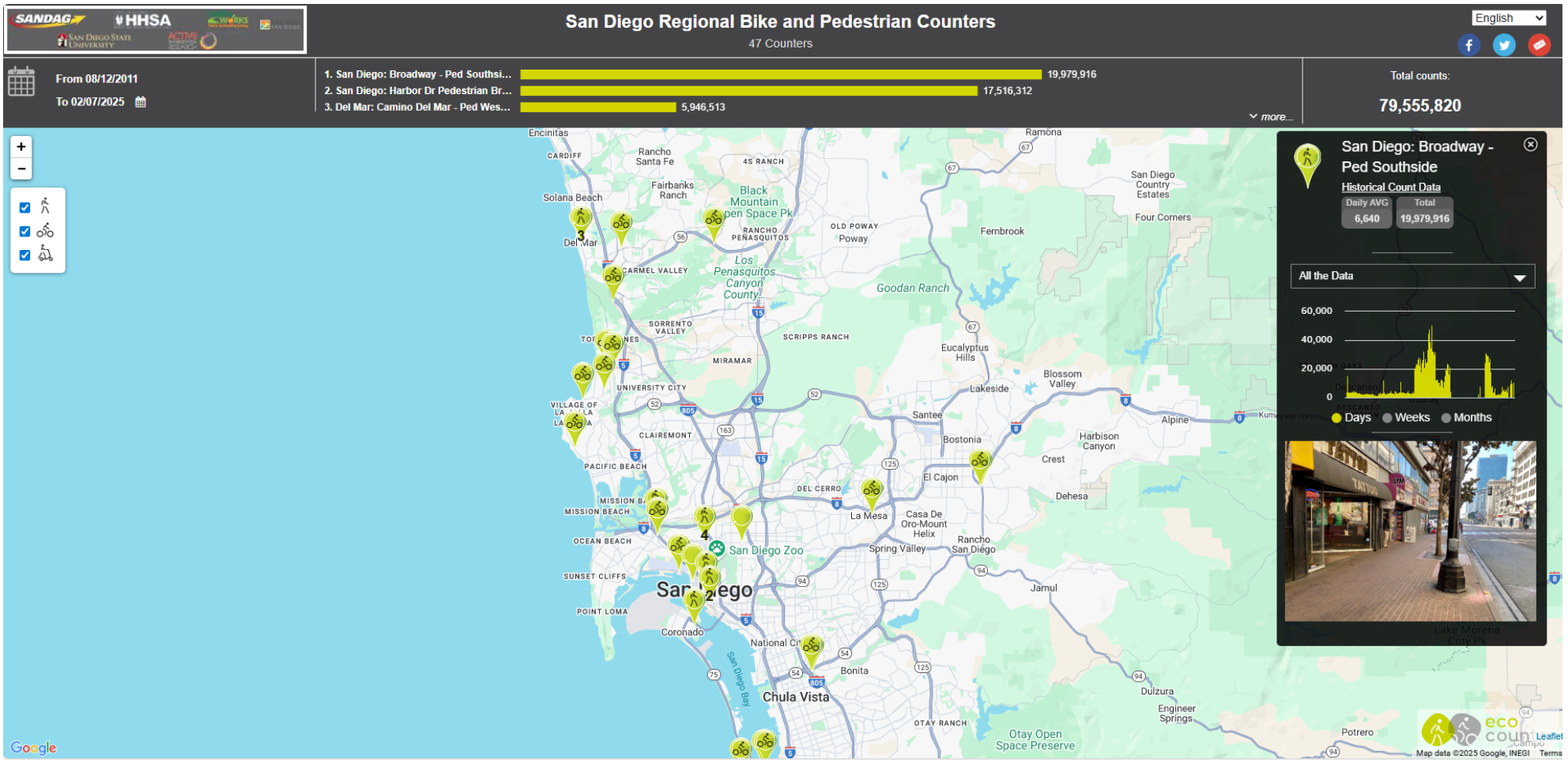


Figure 1. Publicly Accessible Bike and Pedestrian Count Dashboard

Table 5. Count Product Costs

Vendor/Product	Estimated Cost Per Unit	System Package Cost	Additional Fees
Eco-Counter Mobile MULTI	<i>Product not referenced in the literature or publicly available online. Requires contacting the vendor for a quote.</i>		
MetroCount RidePod BT	\$1,345		\$195 per tube install kit
Miovision Scout	\$5,000		\$198 processing fee for 6 hours of video footage
Eco-Counter MULTI Evo	\$5,545 - \$6,530 for shared-use path \$6,100 - \$7,320 for on-road		\$420 per counter per year for automatic data transmission and software subscription to access the data
Eco-Counter CITIX-AI	\$1,200 - \$8,000 on average		
MetroCount RidePod BP	\$4,400		
Miovision TrafficLink	\$1,200 - \$8,000 on average		\$198 processing fee for 6 hours of video footage
Smartmicro Traffic Radar			
Telraam	\$1,200 - \$8,000 on average		
TRAFx Infrared Trail Counter	\$490 - \$540	\$2,215	\$20 per security box supplies (electrical disconnect box, wire mesh, and hose clamp)

Source: (Ozan, et al., 2021)



Table 6. Total Cost for Eco-Counter Products

Cost Type	Cost Frequency	Per Screenline Counting Location (values reported in 2020 USD)			
		Trail (Bikes & Peds) ¹	Sidewalk (Peds) / Bike Lane (Bikes) - 2 loop ²	Sidewalk (Peds) / Bike Lane (Bikes) - 4 loop ³	Sidewalk (Peds) Only ⁴
Equipment (Hardware)	One-Time	\$7,093	\$15,704	\$19,499	\$10,571
Software and Data Transmission	Annual	\$420	\$840	\$840	\$840
Replacement Batteries	Biennial	\$125	\$450	\$900 ⁵	\$250
Site Selection	One-Time	\$500	\$500	\$500	\$500
Installation	One-Time	\$1,350	\$1,350	\$1,350	\$1,350
Maintenance and Validation ⁶	Annual	\$1,140	\$1,140	\$1,140	\$1,140
Data Management	Annual	\$1,420	\$1,420	\$1,420	\$1,420
Total (One-Time/Initial Hardware, Site Selection, and Installation)		\$8,943	\$17,554	\$21,349	\$12,421
Total (Recurring Annual Software and Data Transmission, Maintenance and Validation, and Data Management)		\$2,980	\$3,400	\$3,400	\$3,400
Total (Recurring Biennial Replacement Batteries)		\$125	\$450	\$900	\$250
Grand Total (First Year - One-Time/Initial Hardware, Site Selection, and Installation; Annual Software and Data Transmission, Maintenance and Validation, and Data Management)		\$11,923	\$20,954	\$24,749	\$15,821

Assumptions	
Intern Wage/Hour (Fully Loaded)	\$13
Staff Wage/Hour (Fully Loaded) - Maintenance Technician	\$51
Staff Wage/Hour (Fully Loaded) - Data Technician	\$60
Staff Wage/Hour (Fully Loaded) - Planner/Researcher	\$70
Mileage/Trip (Per Mile Cost)	\$0.59
Average Roundtrip Mileage from ITRE	228

¹ Costs assume (1) Eco MULTI system with passive infrared sensor and 2 inductive loops; original purchase price = \$6,580 in 2016 USD

² Costs assume (2) Urban MULTI systems with 15-minute interval data recording with PYRO (passive infrared) sensor and 2 ZELT (inductive) loops – (1) system on each side of the roadway to capture the combined screenline across two sidewalks and two bike lanes; original purchase price = \$14,568 in 2016 USD

³ Costs assume (2) Urban MULTI systems with 15-minute interval data recording with PYRO (passive infrared) sensor and 4 ZELT (inductive) loops – (1) system on each side of the roadway to capture the combined screenline across two sidewalks and two bike lanes; original purchase price = \$18,088 in 2016 USD

⁴ Costs assume (2) Wooden Posts with PYRO (passive infrared) sensors and 15-minute interval data recording – (1) system on each side of the roadway to capture the combined screenline across two sidewalks; original purchase price = \$9,806 in 2016 USD

⁵ 4 loop systems require the battery to be replaced each year

⁶ Costs assume (2) field visits per year per screenline counting location to conduct maintenance and validation

Source: (Ozan, et al., 2021)



Figure 2. Eco-DISPLAY Classic +

Sources

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