APPENDIX B: PEDESTRIAN AND BICYCLE VOLUME DATA COLLECTION TOOLKIT

Purpose of the toolkit

Developing a systematic approach to collecting pedestrian and bicycle volume data is a complex process that requires a range of tools to address the unique characteristics of active transportation. Transportation agencies have already developed robust systems for monitoring vehicle travel along the highway system and it is useful to model pedestrian and bicycle data collection around these lessons. However, there are a number of factors that require special attention to adapt appropriate technologies to effectively collecting pedestrian and bicycle volume data.

The nature of bicycling and walking poses some unique challenges in terms of detection based on user behaviors and facility types. Motor vehicles are all designed within a vehicle code that governs size, weight and performance, while people and their bicycles varied in sizes, attributes and capabilities. Additionally, there are less often less defined travel ways for bicyclists and pedestrians. Bicycling and walking along a shared-use pathway is easy to define and monitor, but the mix of sidewalks, often on two sides of a roadway, and on-street bicycle facilities that range from being fully separated from motor vehicle traffic to shared traffic roadways. These varied conditions require a flexible approach to data collection and a solid understanding of which technology is appropriate for specific conditions

Because of these challenges, there is no single-solution count device that can address the needs of systematic pedestrian and bicycle volume data collection. Rather a combination of technologies will need to be utilized in tandem to provide effective coverage of the varied user and facility types in Colorado.

This toolkit provides an overview of current technology, as identified in the recent NCHRP 797 "Guidebook on Pedestrian and Bicycle Volume Data Collection." The following section describes the factors and considerations that help determine the best approach and appropriate technologies for planning and implementing an effective bicycle and pedestrian count system. The toolkit is not prescriptive, rather it is intended to provide a range of options to allow CDOT to best consider which tools and technologies will best suit the program needs moving forward.

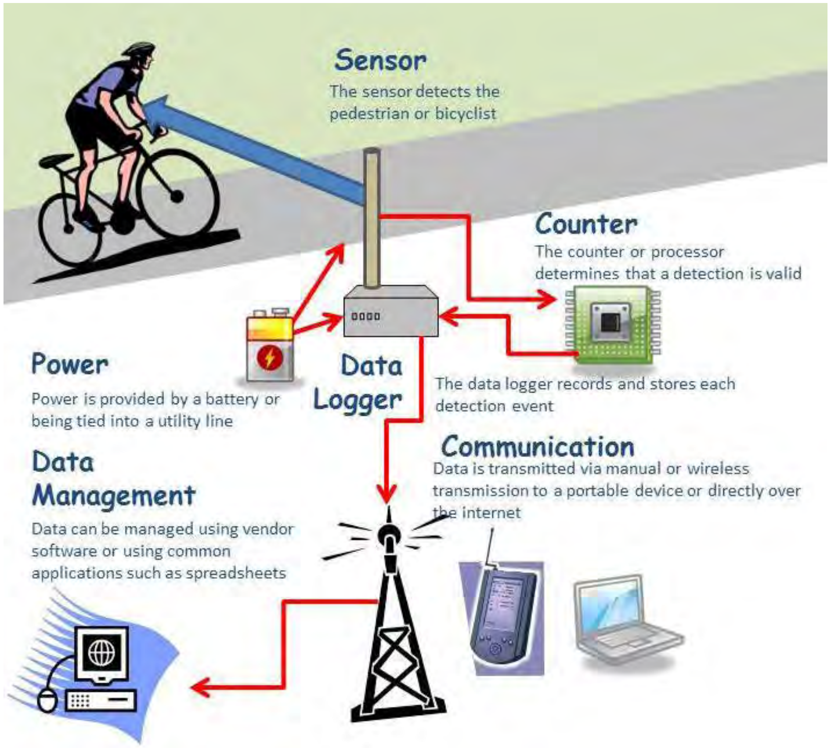
Understanding Count Technology

With the exception of manual counts (data collected manually by human observers in the field), all pedestrian and bicycle count technologies are comprised of components that sense, process, classify, store, and transmit data. Understanding these elements is helpful in evaluating the characteristics of various technologies and understanding the trade-offs associated with each.

The following is a brief description of the key components of automated pedestrian and bicycle counters:

- **Sensor** – The sensor is the external detection element of the device. For pedestrian and bicycle counters sensors include active or passive beams, video, pneumatic tubes, or imbedded loops or strips. The sensor receives input as pedestrian and bicycle traffic encounters the detection zone.
- **Count Processor** – The processor is the brains of the technology that processes the detected information and classifies count events based on the parameters of the equipment. Some processors simply detect motion or movement and record events, while others use a series of algorithms to interpret the events and determine attributes to classify or dismiss the data.
- **Data Logger** – The data logger is the storage unit for the device where the count data. Data may be stored by time stamp or in bins of 15 minute, hourly, or daily data. The storage capacity of the logger and the type of data determine the capacity for storing data over time. Some devices have limits to the maximum number of events or length of time that data can be collected and stored.
- **Data Transmission** – All count devices need to be able to transmit the data collected, either by manual field data retrieval or by cellular (web-based) transmission. The type of

Figure A-1. Diagram of Basic Components of Automated Count Technology



data transmission is important in determining the schedule of maintenance and routine data collection that might be required for a device. A device that automatically transmits data to a web-host via cellular transmission will decrease the need to manually collect data in the field and allow for quality monitoring of daily activity to identify anomalies that may indicated device malfunctions. However, cellular transmission may also include costs for continuous transmission (similar to cellular phone plans) and contribute to battery fatigue for the device.

- **Power Source** – All detection systems require some form of power supply, which in most cases, is a battery with varied life based on the type of sensor, processing and transmission associated with the device. The type of power source, and longevity is a key consideration for longer-term and permanent count installations.
- **Data Management** – Many vendors include software and or web-based applications for managing the stored data. Data management and the available data formats is a key consideration in determining the appropriate technologies, particularly when combining numerous types of technologies, as required for systematic data collection.

Summary of Current Pedestrian and Bicycle Volume Data Collection Technologies

The following is a summary of currently available technologies and approaches for collecting pedestrian and bicycle volume data. Each includes a brief description and a table summarizing the various attributes and operational characteristics associated with the device. This summary is developed based on the technology and not specific vendor products.

There do exist some features and capabilities with each technology that is vendor specific, and due to the rapid pace of research in this field, many new innovations and features continue to be developed. CDOT should seek to update the data included in the toolkit every few years to include these developments.

	MODE TYPE					FACILITY TYPE			
TECHNOLOGY	PEDESTRIAN AND BICYCLE MIXED	PEDESTRIAN AND BICYCLE BY MODE	PEDESTRIAN ONLY	BICYCLE ONLY	BICYCLE IN MIXED MOTOR VEHICLE TRAFFIC	SHARED USE PATH	SIDEWALK	ON-STREET BIKE LANE	ON-STREET MIXED TRAFFIC
Passive infrared detectors	●		●			●	●		
Active infrared detectors	●		●			●	●		
Radio beam detectors	●	●	●			●	●		
Pneumatic tubes				●	●	●		●	●
Inductive loop detectors				●	●	●		●	●
Piezoelectric sensors				●		●		●	
Automated video	●	●	●	●	●	●	●	●	●
Combination inductive loop/ infrared detectors	●	●	●	●		●	●		
Manual field data counts	●	●	●	●	●	●	●	●	●

Passive Infrared Detectors

Passive infrared (IR) technologies detect bicyclists and pedestrians by use of heat signature associated with human body temperature (Ryus, et al., 2014). Passive IR sensors are small and generally quite portable being typically installed along exclusive bicycle and/or pedestrian facilities. The sensors record bicyclists and pedestrians as mixed traffic and are unable to distinguish one from the other without combining other sensor technologies, such as inductive loops or pneumatic tubes to extract the number of bicyclists from the mixed traffic total.

Passive IR detectors are fairly common in use (Ryus, et al., NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Data Collection, 2014), due to the relative low cost and out-of-the-box capability. Passive IR counters are subject to undercounting due to occlusion (two or more bicyclists and pedestrians travelling side-by-side counted as one) that can be adjusted using correction factors (Ryus, et al., NCHRP 797 Guidebook on Pedestrian and Bicycle Volume Data Collection, 2014).

Figure A-2. Example of Passive IR Device Mounted at Sidewalk Location

Figure A-3. Field Data Collection from a Passive IR Counter

Table A-7. Passive Infrared Detectors

USER TYPES	
All Users	YES
Pedestrian Only	YES (Sidewalk locations)
Bicycle Only	
Pedestrian vs. Bicycle	
Bicycle vs. Motor Vehicle	
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	YES
On-Street Bicycle Lane	
On-Street Mixed Traffic	
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	longer duration (2 weeks to continuous)
Portability	High
Site Preparation	Minimal (possible post installation)
Detection Width	up to 20’
Installation	Quick/some equipment mounting (hardware included)
Special Considerations	Sensitive to ambient background temperatures (uses human heat signature for detection)
	Install on an exclusive pedestrian walkway for “pedestrian-only” data
	Sensor should be mounted at the edge of path about between 30 to 40 inches above ground (some overhead models available)
	Sensor should be directed perpendicular to the path of travel
Things to avoid	Directing sensor at doors, windows, or metallic surfaces in direct sunlight
	Directing sensor at vegetation or objects prone to movement
	Locations where pedestrians are likely to linger (bus stops, entryways, kiosks, etc.)
	Locations where snow storage or debris may block sensor

Active Infrared Detectors

Active infrared (IR) devices operate similar to Passive IR, with the exception that the sensor beam is sent between two devices (sender and receiver), sensing bicyclists and pedestrians when the beam transmission is broken. Like, Passive IR devices, Active IR detectors can collect bicycles and pedestrians as mixed traffic, but cannot distinguish mode classification without the use of second detectors, and are subject to undercounts due to occlusion.

Table A-8. Active Infrared Detectors

USER TYPES	
All Users	YES
Pedestrian Only	YES (Sidewalk locations)
Bicycle Only	
Pedestrian vs. Bicycle	
Bicycle vs. Motor Vehicle	
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	YES
On-Street Bicycle Lane	
On-Street Mixed Traffic	
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	longer duration (2 weeks to continuous)
Portability	High
Site Preparation	Minimal (possible post installation)
Detection Width	up to 20’
Installation	Quick/two mounting locations perpendicular to path of travel
Special Considerations	Sender receiver mounted perpendicular to path of travel
	Install on an exclusive pedestrian walkway for “pedestrian-only” data
Things to avoid	Locations where any motorized traffic can travel between the sender/receiver
	Locations where pedestrians are likely to linger (bus stops, entryways, kiosks, etc.)
	Locations where animals are likely to encounter the sensor
	Locations where snow storage or debris may block sensor

Radio Beam Detectors

Radio beam devices use radio wave signals sent between devices (sender and receiver) mounted on opposite sides of a walkway or path. The operational characteristics are similar to the Active IR, in terms of recording events based on breaks in the beam. Radio beam detectors are only capable of classifying direction when a multiple frequency model is used, which reduces the maximum detection distance from 20 to 13 feet (Ryus, et al., NCHRP 797 Guidebook on Pedestrian and Bicycle Volume Data Collection, 2014).

Table A-9. Radio Beam Detectors

USER TYPES	
All Users	YES
Pedestrian Only	YES (Sidewalk locations)
Bicycle Only	
Pedestrian vs. Bicycle	Some two-frequency models
Bicycle vs. Motor Vehicle	
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	YES
On-Street Bicycle Lane	
On-Street Mixed Traffic	
ADDITIONAL CHARACTERISTICS	
Direction of Travel	Some two-frequency models
Duration of Count	longer duration (2 weeks to continuous)
Portability	Moderate (requires sender and receiver mounting)
Site Preparation	Minimal (possible post installation)
Detection Width	Up to 20' (single frequency) 13' (multiple frequency)
Installation	Quick/two mounting locations perpendicular to path of travel
Special Considerations	Sender receiver mounted perpendicular to path of travel
	Install on an exclusive pedestrian walkway for "pedestrian-only" data
	Use of multi-frequency models can allow for distinguishing pedestrians from bicycles and travel direction
Things to avoid	Locations where any motorized traffic can travel between the sender/receiver
	Locations where pedestrians are likely to linger (bus stops, entryways, kiosks, etc.)
	Locations where animals are likely to encounter the sensor
	Locations where snow storage or debris may block sensor

Pneumatic Tubes

Pneumatic tubes are appropriate for bicycle-only data collection, as they do not detect foot traffic. The pneumatic tubes used to collect bicycle data operate similar to traditional pneumatic tubes for motor vehicles, whereby two tubes are stretched across the travel way and detect the pulse of air pressure caused by traveling over the tube. There are additional types of pneumatic tube technology appropriate for collecting bicycle data in mixed-vehicle traffic situations, where data is processed based on force of the pulse and rate between two tubes to classify bicycles from motor vehicle traffic.

Pneumatic tubes can be ideal for short duration counts, as they are portable and relatively easy to deploy. Due care should be used to avoid damage from vandalism or routine maintenance, such as street-sweeping or snow plowing. Pneumatic tubes are not appropriate for data collection during the snow season.

Figure A-4. Pneumatic Tube Installation

Figure A-5. Pneumatic Tube Installation on a Bicycle Lane

Table A-10. Pneumatic Tubes

USER TYPES	
All Users	
Pedestrian Only	
Bicycle Only	YES
Pedestrian vs. Bicycle	
Bicycle vs. Motor Vehicle	YES
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	
On-Street Bicycle Lane	YES
On-Street Mixed Traffic	YES
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Short duration (several days to a month)
Portability	High
Site Preparation	Minimal
Detection Width	up to 20’
Installation	Quick/some equipment mounting; staking tubes
Special Considerations	Surface of detection area should be relatively flat and perpendicular to travel flow
	Specific procedures for shared roadways vs. bike lanes or shoulders
	Not appropriate for use during snow season
	Sometimes prone to vandalism, or avoidance where tubes are installed conspicuously. Additional installation equipment (tools) needed
Things to avoid	Locations where stopping may occur (intersections, traffic control locations, etc.)
	Locations where vehicles may park or trucks may load/unload (parking areas, bus stops, loading zones, etc.)
	Locations where vehicles may park or trucks may load/unload (parking areas, bus stops, loading zones, etc.)
	Installation in locations or in ways that may cause bicyclists to navigate around the tubes

Inductive Loop Detectors

Inductive loops are also a bicycle-specific data collection technology. Like traditional loop detectors used for signal detection and volume data collection, inductive loops are imbedded into the travel way using diamond-shaped pavement cuts. The sensors detect the presence of metal parts of a bicycle to classify count events. Many inductive loops can work in both shared-use path and on-street mixed traffic situations. Inductive loops are not re-usable so only suitable for permanent count locations. Because the loops use magnetic fields for detection they are sensitive to utility lines, either overhead or buried, so careful planning is needed to avoid installation in locations where the devices will not function properly.

Figure A-6. Installing an Inductive Loop Detector in Minneapolis, MN

Figure A-7. Example of Inductive Loop on Shared Use Path

Table A-11. Inductive Loop Detectors

USER TYPES	
All Users	
Pedestrian Only	
Bicycle Only	YES
Pedestrian vs. Bicycle	
Bicycle vs. Motor Vehicle	YES
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	
On-Street Bicycle Lane	YES
On-Street Mixed Traffic	Sometimes depending on site conditions
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Continuous permanent counts
Portability	None (One-time permanent installation)
Site Preparation	Surface and utility considerations (requires pavement cut)
Detection Width	Up to 20’
Installation	Requires work crew to install (pavement cutting; manhole for logger)
Special Considerations	Best in locations with predictable path of travel for bicycle traffic (bike lane; path, etc.)
	Presence of overhead or buried utilities may interfere with the inductive loop
	May require permitting
	Temporary or “surface Loops” are available to avoid cuts where needed (less permanent installation)
Things to avoid	Locations with overhead or buried utilities
	Locations where bicyclists may ride outside of the loop detector

Piezoelectric Sensors

Piezoelectric devices consist of two strips imbedded in the pavement perpendicular to travel that emit pulses that are altered as bicycle pass over the two sensors. The devices are capable of measuring bicycle volume, direction and travel speeds. The technology is not widely used in North America, possibly due to the complexity of installation that includes high precision cuts and installation of a utility box to house the processing and data storage equipment. The sensors are limited to detecting bicyclists and not appropriate for on-street mixed traffic locations.

Figure A-8. Piezoelectric Sensor in Arlington, VA

Table A-12. Piezoelectric Sensor

USER TYPES	
All Users	
Pedestrian Only	
Bicycle Only	YES
Pedestrian vs. Bicycle	
Bicycle vs. Motor Vehicle	
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	
On-Street Bicycle Lane	Only locations where vehicles cannot travel in lane
On-Street Mixed Traffic	
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Continuous permanent counts
Portability	None (permanent)
Site Preparation	Surface and utility considerations (requires pavement cut, and installation of utility box)
Detection Width	Up to 20’
Installation	Requires precision cut installation including utility box for storing logger
Special Considerations	Appropriate for locations where motor vehicles are prohibited
	May require permitting
	Install perpendicular to bicyclist path of travel
Things to avoid	Locations where motor vehicles may travel across sensor

Automated Video

Automated video is an emerging technology that utilizes algorithms to process video data and classify moving objects. Most market-available technology requires that video data be submitted to a vendor to be processed and returned as data based on hourly rates. Because of the proprietary nature and need for third party processing the full accuracy and effectiveness of the technology is unknown. However, there is strong potential for the use of video, particularly for short-duration data collection events or where specific attributes, such as user movements or characteristics are desired. The ability to maintain the video data for further observation is a benefit, and many agencies may find value in collecting video data to reduce manually for project specific data collection applications.

Figure A-9. Installing a Video Camera for Video Data Collection

Figure A-10. Video Cameras can be Mounted to Capture a Wide Area of Activity

Table A-13. Automated Video

USER TYPES	
All Users	YES
Pedestrian Only	YES
Bicycle Only	YES
Pedestrian vs. Bicycle	YES
Bicycle vs. Motor Vehicle	YES
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	YES
On-Street Bicycle Lane	YES
On-Street Mixed Traffic	YES
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Short Duration (up to 48 hours, depending on battery life and data storage of video equipment)
Portability	High
Site Preparation	Minimal/may require special mounting hardware and tamper resistant equipment
Detection Width	Up to 75' depending on quality of image
Installation	Quick/dependent on type of equipment used
Special Considerations	Mounts overhead at angle/ can be used for screenline or intersection counting
	High cost/hour of data collection, but with optimal attribution
	lighting and weather conditions can effect video image
	May be restrictions based on privacy concerns
Things to avoid	Locations with poor lighting conditions (glare, heavy shadowing, etc.)
	Locations where temporary obstructions may occlude data collection (delivery truck parking, etc.)

Combination Inductive Loop/Infrared Detectors

As mentioned previously with the description of the passive IR detectors, there are few devices capable of detecting bicycles and pedestrians and classifying by mode. One solution is the integration of multiple sensor devices, such as the Inductive loop and passive IR sensor at a single location. By integrating the two technologies the detector is able to obtain a total mixed traffic (bicycle and pedestrian) count and extrapolate the totals by mode by subtracting the bicycle only count from the loop detector. It is possible for agencies to deploy multiple devices to replicate this effort with post process analysis of data, but working with an integrated processor unit, it is possible to get the mode specific raw data from the count device. These are ideal solutions for shared use path locations.

Figure A-11. Combination Passive IR/Inductive Loop Detector in Delaware

Table A-14. Combination Device (Loop & Passive IR)

USER TYPES	
All Users	YES
Pedestrian Only	YES
Bicycle Only	YES
Pedestrian vs. Bicycle	YES
Bicycle vs. Motor Vehicle	
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	Where bicyclists use sidewalks
On-Street Bicycle Lane	
On-Street Mixed Traffic	
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Continuous permanent counts
Portability	None - Permanent
Site Preparation	Surface and utility considerations (requires pavement cut and post installation)
Detection Width	Up to 20’
Installation	Requires work crew to install (pavement cutting; post installation for passive IR sensor and logger)
Special Considerations	Best in locations with predictable path of travel for mixed traffic (pinch points or bridge approaches best)
	Presence of overhead or buried utilities may interfere with the inductive loop
	May require permitting
Things to avoid	Locations with overhead or buried utilities
	Locations where pedestrians and bicyclists may travel outside of the loop detector or sensor

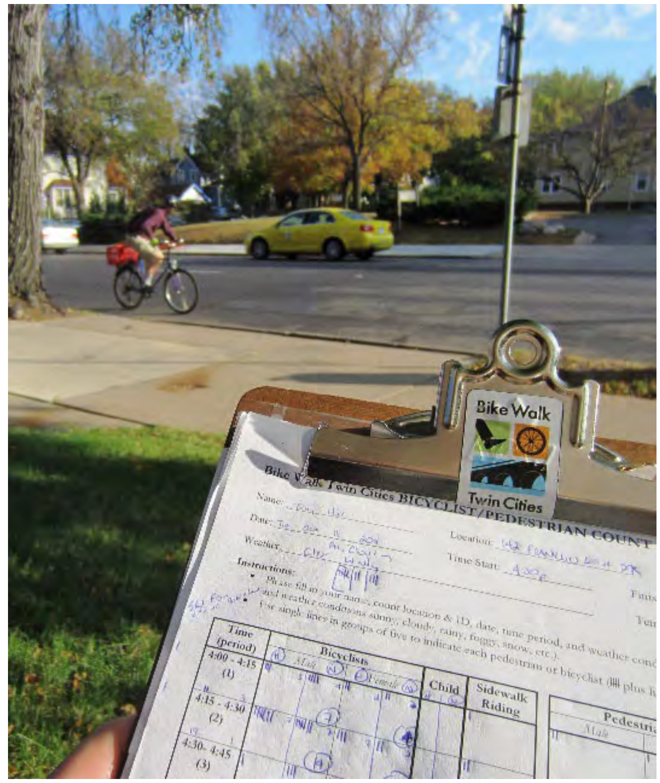
Manual Field Data Counts

While not actually a technology, Manual counts are an important tool for collecting pedestrian and bicycle volume data. Since the development of the ITE Bicycle and Pedestrian Documentation project[1], numerous agencies have initiated manual count programs as an entry point to developing a better understanding of bicycle and pedestrian travel in their respective communities. These efforts are conducted under a number of protocols for how to count, when to count and for what duration. Generally conducted in two to four hour intervals focused on peak travel hours and weekday traffic, manual counts are useful for developing baseline user information about pedestrian and bicycle travel.

Manual counts can be quite resource intensive when considering the training of field data collectors, observation time, and data entry. Additionally human factors can limit the accuracy and duration of counts (due to fatigue). Additionally it is important to consider the safety and comfort of manual observers when performing field counts.

Other benefits of manual counts are the ability to observe user behaviors and attributes (such as wearing helmets, using headlights, walking with aid of assistive devices, bicycling on sidewalks, etc.) that are not readily identified through automated technologies. While automated technologies are essential for collecting the long duration data and understanding the temporal and seasonal travel patterns, manual data remains an important tool for observing user behavior and even calibrating the automated count devices.

Figure A-12. Manual Count in Minneapolis,



1 http://bikepeddocumentation.org/

Table A-15. Manual Counts

USER TYPES	
All Users	YES
Pedestrian Only	YES
Bicycle Only	YES
Pedestrian vs. Bicycle	YES
Bicycle vs. Motor Vehicle	YES
FACILITY TYPES	
Shared Use Path	YES
Sidewalk	YES
On-Street Bicycle Lane	YES
On-Street Mixed Traffic	YES
ADDITIONAL CHARACTERISTICS	
Direction of Travel	YES
Duration of Count	Short (two to four hours)
Portability	High
Site Preparation	None
Detection Width	Varies based on sightline
Installation	None
Special Considerations	Locations where observer can safely and comfortably track travel
	Locations need to be clearly defined with imaginary screenline (should document with site map)
	Locations where bicycle and pedestrian travel paths are predictable
Things to avoid	Locations where conditions for observer may be unsafe (due to traffic or environmental conditions)
	Locations where pedestrians or bicyclists may be inclined to take short cuts or avoid screen line
	Locations where pedestrians are likely to linger (bus stops, entryways, kiosks, etc.)