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Deliverable For:

Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project

Atlantic Blvd. / I-710 Corridor

Deliverable 2.5.1.4

System Detection Technology Analysis & Recommendation

Final

Submitted To:

Los Angeles County
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Submitted By:

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1. INTRODUCTION

The County of Los Angeles Department of Public Works Traffic Signal Synchronization, Operation and Maintenance (SOM) program has proven successful in creating an institutional infrastructure to coordinate the activities of the agencies responsible for traffic signal operations in the County. A key feature of this infrastructure is the Forums - groups of bordering agencies created to encourage and promote inter-agency cooperation. These Forums have enabled funding to be targeted at infrastructure improvements along arterial and arterial/freeway corridors in the County's sub-regions. Such projects are a critical part of what will eventually be a network of integrated ITS systems in Los Angeles County and in Southern California.

The Atlantic Blvd./I-710 Corridor is one such project which will result in arterial infrastructure improvements on north-south and east-west arterials along I-710 freeway in the Gateway Cities South-East LA County Forum.

As shown in Figure 1-1, the Atlantic Blvd./I-710 project area consists of 678 intersections in the following 15 different jurisdictions, comprising 13 cities, the County and Caltrans.

- Los Angeles County
- Caltrans
- City of Bell
- City of Bell Gardens
- City of Commerce
- City of Compton
- City of Cudahy
- City of Huntington Park
- City of Long Beach
- City of Lynwood
- City of Maywood
- City of Paramount
- City of Signal Hill
- City of South Gate
- City of Vernon

The objective of this project is to design, develop and deploy Advanced Traffic Management System(s) (ATMS) in the corridor so that the signals in the Project area can be synchronized across the jurisdictional boundaries. This project concentrates on the needs of the agencies in this corridor with respect to signal synchronization and recommends improvements to field infrastructure (including controllers, loops, detectors, and communications) and central traffic control systems to meet those needs.

When successfully completed, each of the agencies responsible for traffic signal operations in the Atlantic Blvd./I-710 Corridor will have full access to a ATMS that monitors and controls the traffic signals under their jurisdiction. Agencies will be able to synchronize their signals with neighboring agencies, and exchange traffic information in real-time. Agencies will also be able to exchange data with other agencies in the Gateway Cities region. This will allow the agencies to respond to recurrent and non-recurrent congestion in a coordinated fashion across the jurisdictional boundaries.

1.1. Purpose of the Report

This report presents an analysis of technologies available for system detection. The information presented in this report is based on the work done for a similar deliverable for I-5/Telegraph Rd.

corridor project. The information presented in the I-5/Telegraph Rd. corridor project report has been updated and augmented with new information as needed.

1.2. Referenced Documents

The following documents have been used as reference material in the preparation of this report:

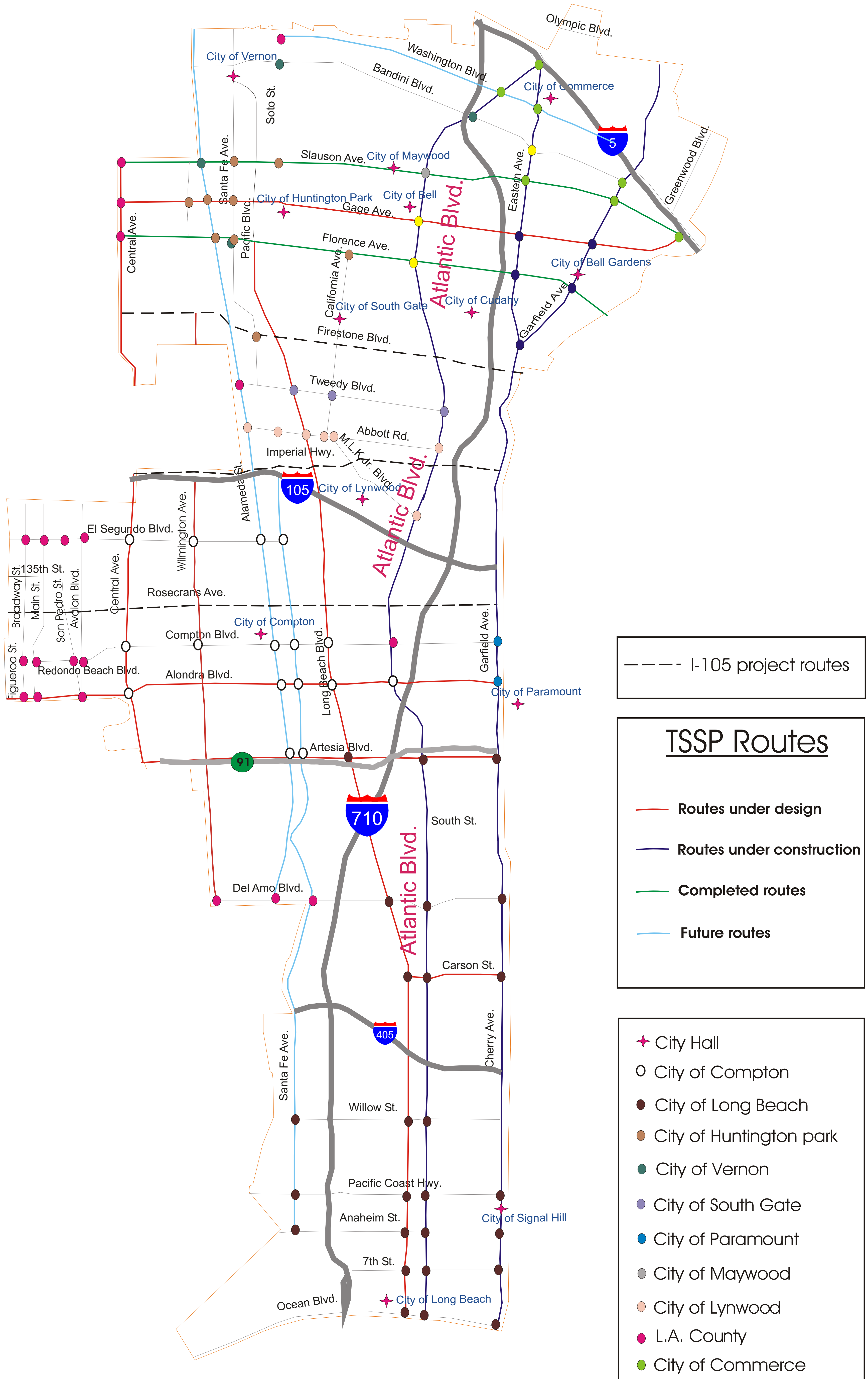
Atlantic Blvd. / I-710 Corridor Project

- Deliverable 2.1.1: Stakeholder's Operational Objectives and Individual City Reports

I-5/Telegraph Road Corridor Project

- Deliverable 3.6: Requirements Analysis
- Deliverable 4.1.2: High Level Design Definition Report Final (including Vehicle Detection Technology)

Figure 1-1: Atlantic Blvd. /I-710 Corridor Project Area



2. Vehicle Detection Systems

2.1. Background

In the Gateway Cities, there exists a need to collect traffic data for real-time traffic signal operations, to support transportation planning efforts, and to detect incidents in the corridor. Further, this information needs to be shared between the jurisdictions and agencies in the corridor. It is from the vehicle detection system that these needs and requirements are met.

Vehicle detectors are used as sensors to collect data for a number of system functions. They are in essence the surveillance subsystem that provides necessary data to the traffic signal system for such functions as, timing plan selection, critical intersection control, information for planning purposes, and incident detection.

2.2. Functions of Vehicle Detection at Traffic Signals

Vehicle detection at traffic signals is usually divided into the following three functional categories. For the purpose of this explanation, a "detector" is a loop or other on-road sensing device, or a detection zone configured in an off-road detector. Some detection technologies are unable to support some of these functions.

- *Stopline Detection:* Detection of vehicles moving or stopped while close to the stopline at a signalized intersection. The stopline detection area starts at the stopline and may extend to six to 60 feet before the stopline. Such detection is used by an actuated traffic signal controller for calling and extending a traffic signal phase. If stopline detection is absent, the signal will typically need to be set to automatically call the relevant signal phase in case vehicles are waiting to be served, and extend the green for a shorter or longer time than needed to serve the waiting vehicles. Stopline detection does not require monitoring of each traffic lane separately.

- *Advance Detection:* Detection of vehicles approaching a signalized intersection, usually in the area between 150 and 300 feet before the stopline. Such detection is used by an actuated traffic signal controller for calling and extending a traffic signal phase. If advance detection is absent, the signal will not be aware of an approaching vehicle until it is sensed by stopline detection, which may result in additional delay for vehicles approaching on red and wasted green extension after the last vehicle passes. Advance detection does not require monitoring of each traffic lane separately, but detectors used for advance detection are often separated by lane to enable their joint use for system detection.

- *System Detection:* Detection of vehicles for the purpose of measuring the volume (count) and density (average occupancy) of traffic at a roadway location over a period of time typically in the range of one to five minutes. Some traffic signal controllers may also use system detection to calculate average vehicle speed. After the end of each data accumulation period, the data for that time period are stored in the controller, or more typically, transmitted to a field master or central computer, where they are stored and used in traffic responsive plan selection and other applications. Vehicle detectors used for advance detection, if suitably configured, may also provide system detection. More rarely, detectors used for stopline detection can be configured to also provide system detection. It is common to install separate detectors just for system detection, and such separate detectors are often located downstream of the intersection (on the departure side) in the area extending from the intersection up to about 300 feet away. To obtain the most useful and accurate data, detectors used for system detection need to monitor each traffic lane separately and separate data need to be reported for each lane for the purposes of measuring the system performance.

Figure 2-1 is a schematic that illustrates typical detector locations for these three types of detection. Traffic responsive and traffic adaptive control require system detection to provide timely information on current traffic conditions and trends so that the timing plans can be changed automatically as conditions warrant. For example, as it lies parallel to the I-710 Freeway, Atlantic Blvd. has a function as a freeway alternate. It is necessary to know the traffic conditions on this arterial either before assigning this as an alternate or in order to know which signal timing plan would be the most appropriate for accommodating the additional traffic.

A separate program is being implemented by the County DPW to address the design and provision of stopline and advance detection. The Atlantic Blvd. /I-710 Corridor Project is focusing on system detection, to be accommodated either by dedicated system detectors or dual-use advance detectors, or both.

2.3. User Needs for System Detection

Within the Gateway Cities (Project) area, agencies originally identified a number of traffic management needs requiring vehicle detection including:

- Improved mobility through improved traffic signal timings.
- Improved traffic signal operations.
- Information sharing.
- Traffic condition monitoring.
- Automated notification of congestion and incidents.
- Automated data collection and timing plan generation.

In addition, a desire was expressed to replace inductive loops with a technology not susceptible to failure with pavement deterioration, while one city preferred to continue with its use of loops.

Later an additional need was identified, that of security, in the form of identifying stopped vehicles. This is contributory to enhancing the security of the transportation network as well as a potential rapid identification of incidents that could cause non-recurring traffic congestion.

These identified needs have corresponding requirements for Advanced Traffic Management System (ATMS) functionality which require system detectors to provide information. System detector stations collect real time data on roadway traffic flow. The data are used for traffic management functions such as detecting incidents, traffic flow information, and archiving for planning and historical analysis. System detection provides the capability to monitor and manage both recurring and non-recurring congestion. For example, the latter would trigger the congestion alarm; the former may be used in conjunction with traffic responsive plan selection.

The following types of data, collected on a per-lane basis, can be useful in addressing these needs:

- Volume
- Occupancy
- Speed

Volume and occupancy data are typically collected by traffic signals controllers and transmitted to the central ATMS. The ATMS typically estimates vehicular speed from these two measures. Even if the traffic signal controller is capable of measuring or calculating speed, standard center-to-field communication protocols for traffic signals do not accommodate speed data.

At present, system detection in the Atlantic Blvd./I-710 Corridor Project area is addressed by advance detectors on some major approaches to signalized intersections. Previous studies, along with this project, have identified a need to provide additional system detection in the Project area.

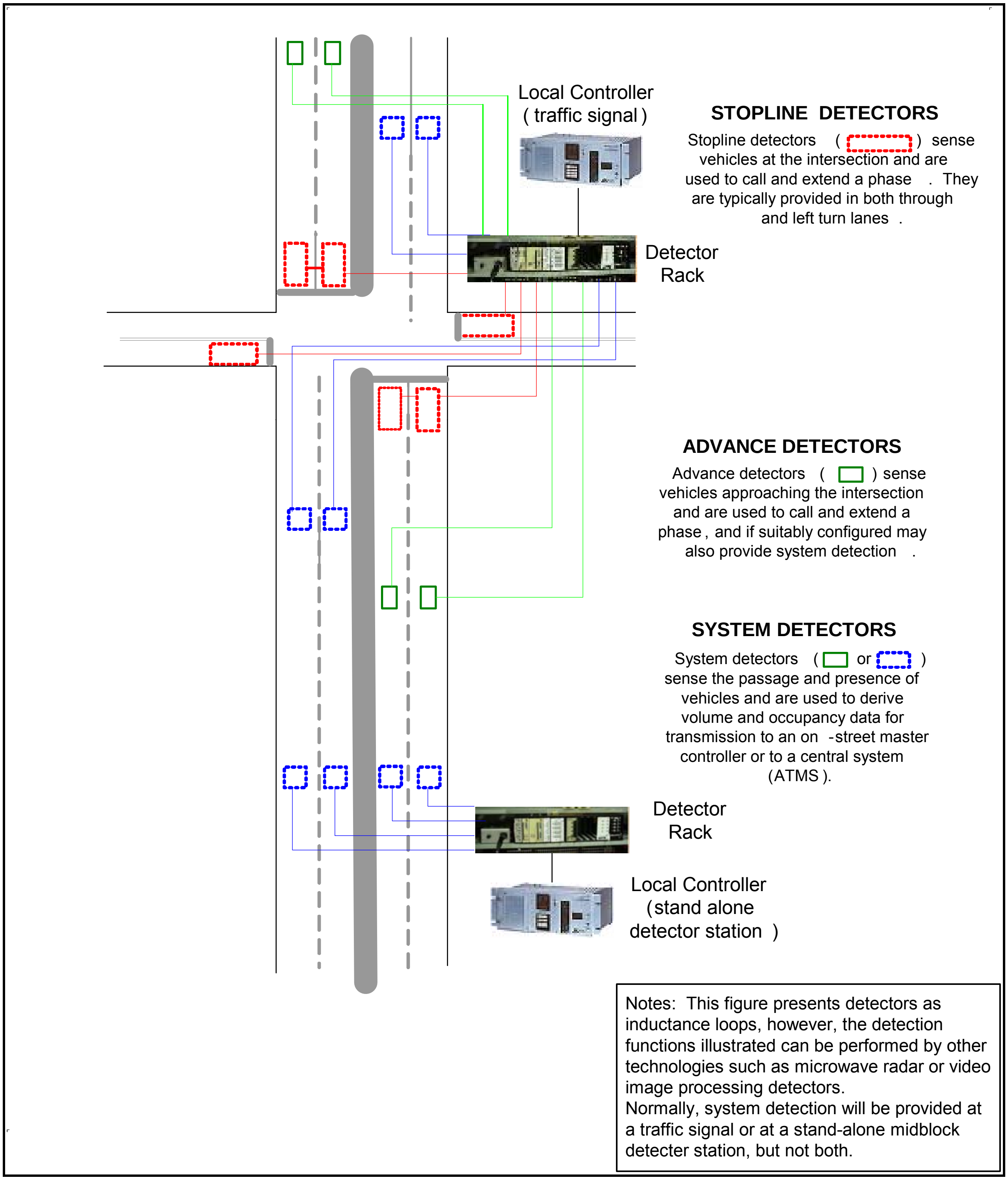


Figure 2-1: Detector Functional Types

2.4. Detector Placement

Paramount to successful system detection is the placement of the detection device along the roadway. Basic guidelines that apply to longitudinal placement include:

- Detection should be placed outside of any “weaving” areas along the roadway.
- For non-intersection areas, detectors should be placed away from lane-drops, acceleration/deceleration lane introductions, and other similar features.
- Placement of side-fire microwave detectors and Video Imaging Detection System (VIDS) (on poles) must be in a location that allows any new pole to be placed outside of the safety clear zone if breakaway pedestal bases are not used, and is good practice even with breakaway bases.
- Placement should be such that they can be made accessible for maintenance vehicles including bucket trucks for pole-mounted detectors.

System detection can make use of existing traffic signal controllers, or can be provided away from traffic signals by installation of a separate controller and communications link to the ATMS. Such a separate installation is referred to here as a “stand alone detector station”. Some detection products offer an integral controller and communications interface, thereby avoiding the need for a traffic signal controller at a stand alone installation. However, the ATMS may not support communications with, and integration of data from, these proprietary controllers, in which case a controller with traffic signal software, the same as used at adjacent traffic signals and therefore compatible with the ATMS, will need to be installed at a stand alone detector station. This greatly increases the cost of a stand alone detector station. Stand alone detector stations also forego the opportunity to save costs by dual use of advance detectors at a traffic signal. If the ATMS supports a detector product’s direct interface, stand alone stations should be considered, but in general it will be more economical to use existing traffic signals for system detection data collection and transmission. The following analysis is focused on system detection at traffic signals.

The occupancy measurement obtained from a system detector is used to detect slow moving traffic at a location where it should be free flowing. If the queue from a traffic signal routinely backs up beyond the detector location, the average occupancy output will have limited value, but it can still provide a useful traffic count (volume). The most useful location for a system detector is therefore out of the area of routine queuing.

Advance detectors at traffic signals are often located within the area of routine queuing, and therefore are not ideal for dual use as system detectors. However they are better than nothing, and still quite useful in providing the traffic volume.

The preferred location for system detectors at a traffic signal is on the departure side of the intersection, monitoring traffic as it leaves the intersection. In this area, it is desirable to locate the detectors at least 150 feet from the intersection, as vehicles turning in the intersection may take some distance to become established in a lane. It is sometimes convenient to locate departure detectors adjacent to advance detectors in the other direction, to enable shared use of conduit.

System detection is needed on main roadways, but is of little value on side streets. The one exception is use of system detectors to provide turning movement counts at an intersection. This use of system detection is often not feasible due to shared lanes or the large number of detector inputs needed, is not a requirement of this project, and is not considered further here.

However, it should be pointed out that video detection is the preferred technology for system detection if turning movement counting is required, as it allows detection zones to be placed optimally and can output a count pulse on a single input to the controller when any of multiple zones register a vehicle passage. A video detection camera located optimally for turning movement counting may not be able to provide occupancy data suitable for other applications, and may not be optimal for shared use for stopline and advance detection.

2.5. Traffic Signal Cabinet and Controller

If the system detectors are connected to a traffic signal controller, the limitations and characteristics of the controller need to be considered. Each detector input to a controller, regardless of detector technology, appears to the controller as simply on or off – a binary input. This is true in all cabinet types, including Model 332, NEMA TS1, NEMA TS2, and the ITS cabinet. Some controllers provide a serial communications interface to stand alone detector stations to enable numerical data to be obtained directly, but this is not yet common and is not assumed to be an option for this project.

In a typical configuration, 28 binary detector inputs can be accommodated in a Model 170 controller and the Model 332 cabinet, but the controller software will further limit the number of inputs that can be configured as system detectors. NEMA cabinets can be configured to accommodate more detector inputs, but again, the controller will have limits, which often includes a maximum of 16 system detectors. Some controller software used in Model 2070 controllers allows larger numbers of system detectors, but such software is not anticipated in this project.

The controller checks the state of each detector input every tenth of a second, and when it sees a system detector input change state it increments the vehicle count and/or occupancy accumulators for that system detector, as appropriate. At the end of the specified data collection period, which is typically in the range of one to five minutes, the controller captures the total count and occupancy values for all such system detectors, converts the occupancy values to “percentage of time the detector was occupied during this time period”, resets the accumulators to zero, and transmits the new count and occupancy percentage data to the ATMS when next asked for such data.

3. Alternative Detection Technologies

3.1. Candidate Detection Technologies

An analysis of current detection technologies was conducted in the I-5/Telegraph Road Corridor Project and presented in the report*: "Deliverable 3.2.1; ATMS Functional And Local Traffic Control Center Requirements*". That analysis led to a recommendation of three detector technologies: Inductive loops (in-pavement), microwave radar (above-pavement), video image detection systems (VIDS, above-pavement) and wireless magnetometers (in-pavement). The recommendations were based upon compliance to the functional specifications, requirements of Gateway Cities' agencies, technological maturity, reliability, ease of implementation, and cost. These candidate detection technologies are the focus of this analysis.

3.2. Inductive Loop Detectors

3.2.1. System Detector Configuration / Layout

Inductive loops are typically installed in the pavement as single loops to collect volume and occupancy data (Figure 3-1). If accurate speed data are necessary, the communications protocol supports transmission of speed data, and the controller supports its collection, the loops need to be configured in a "trap" configuration; two loops spaced at a consistent distance apart (typically 16-ft) leading edge to leading edge to collect speed data (Figure 3-2). Speed can also be estimated from the time a vehicle occupies a single loop, assuming an average vehicle length, but this is less accurate.

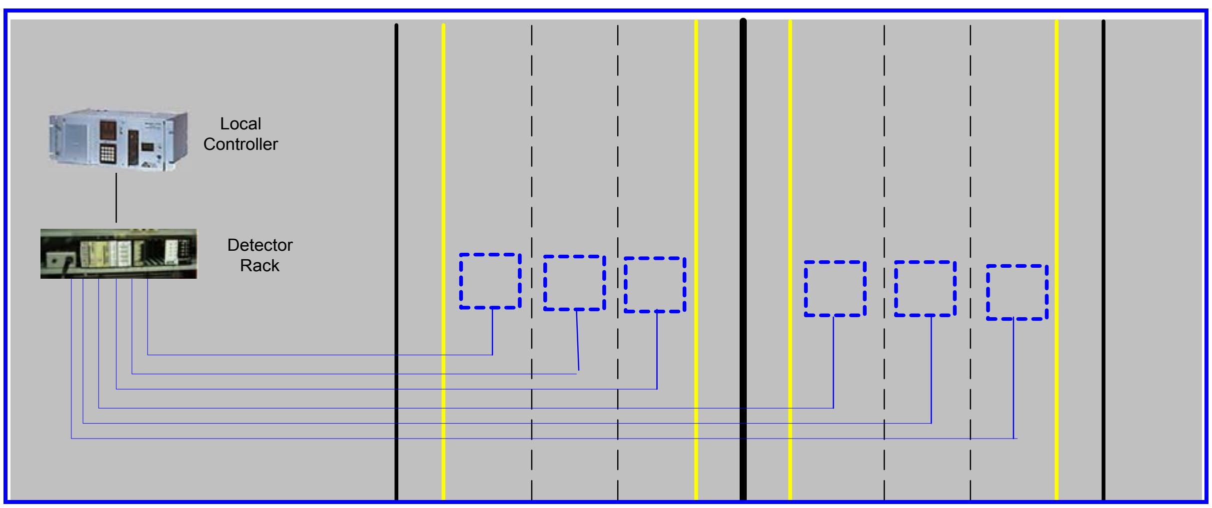


Figure 3-1: Loop Configuration for Volume and Occupancy

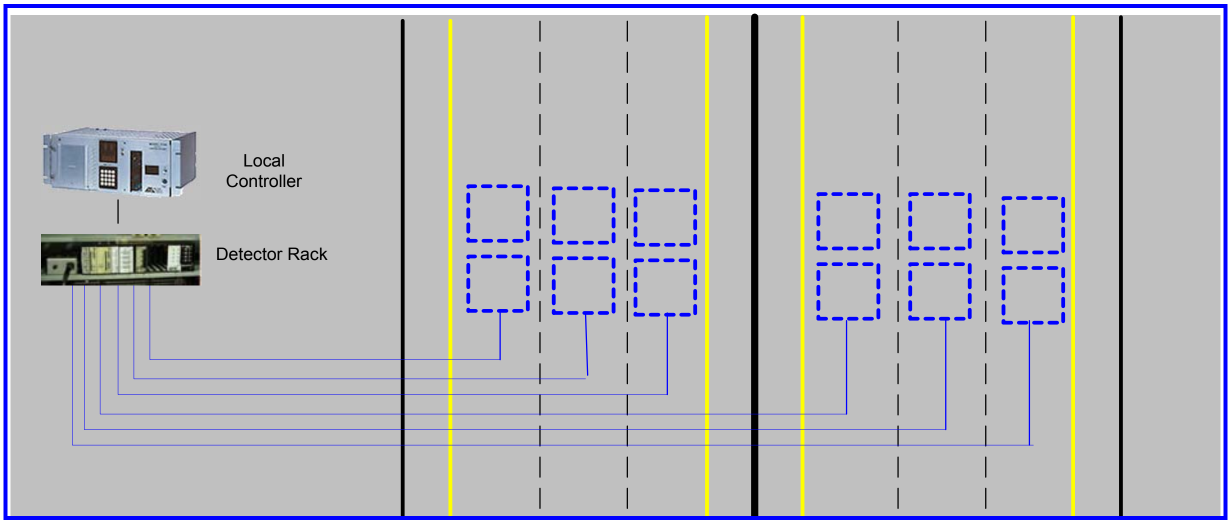


Figure 3-2: Loop Configuration for Accurate Speed Data

Each loop is connected to a sensor unit housed in a controller cabinet via a lead-in cable between the loop and the cabinet. Each sensor unit, or loop amplifier, typically accommodates two separate detector inputs to the controller. Each input may be the result of one or more loops. If multiple loops are wired together prior to the sensor unit, a vehicle occupying any one of them will cause the sensor unit to output a “detector on” condition.

A loop sensor unit may be configured to output a brief pulse when a vehicle first occupies the loop, and then to ignore the further presence of the vehicle. It is possible, with special cabinet wiring, to combine the outputs of multiple sensor units so configured, to effectively provide a single detector input to the controller that fairly accurately counts traffic in multiple lanes. It is still possible for two vehicles to arrive on two loops simultaneously and be viewed as only one vehicle, but the pulse output minimizes this risk. This technique can be useful if the maximum number of detector inputs to the controller, or maximum number of system detectors supported by the controller, would otherwise be exceeded. Occupancy data from sensor units configured in this way are not useful. Some manufacturers offer sensor units with two outputs, one a pulse for counting purposes and the other a sustained output for occupancy measurement.

3.2.2. Miscellaneous Issues

As Inductive loops are in the pavement, their installation and maintenance are the most disruptive to the traffic stream of any devices currently being used. This is a major weakness, along with their high failure rate (about 10% per year) generally caused by poor installation techniques or installation in poor quality pavement. In the event of failure of the loop, the only remedy is replacement of the whole loop. In addition, when the road system “footprint” changes the investment into cutting the loops is lost.

3.3. Microwave Detector

Microwave detectors are above-ground units mounted either over a traffic lane (e.g., on a bridge overpass or sign structure), or along the side of the arterial mounted on a pole in a “side-fire” (see Figure 3-3) configuration approximately 15 feet high. For microwave detectors mounted over a traffic lane, speed can be measured directly, whereas via side-fire configuration, the speed parameter is calculated.

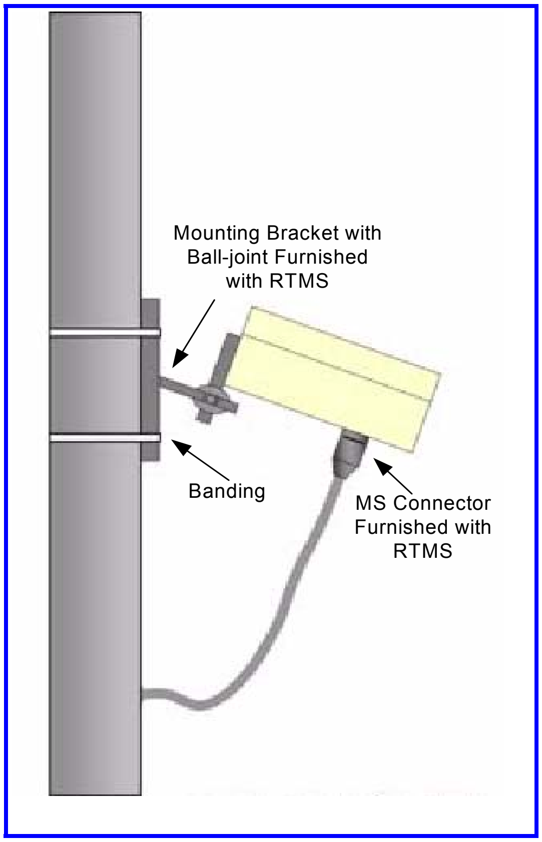


Figure 3-3: Typical RTMS Mounting Configuration

The RTMS unit (Remote Traffic Microwave Sensor) from EIS Systems Inc. is a general-purpose, all-weather traffic sensor, which detects presence, and measures traffic parameters in multiple independent lanes. The RTMS is a traffic detector providing presence, volume, occupancy, and speed and classification information in up to 8 discrete user-defined detection zones (e.g., one per lane) up to 60 m (200 ft.) away (see Figure 3-4). It is possible to provide the output information from a RTMS unit either to the controller or directly to the traffic control system. Output information is provided to existing controllers via contact closure and to central systems via an RS-232 serial communications port with RS-485 and TCP/IP as options. The RTMS is designed for side-fire operation. It is usually mounted on existing side-of-the-road poles for ease of installation and is programmable to support a variety of applications. The manufacturer claims that the RTMS unit and its operation are unaffected by any type of weather.

3.3.1. System Detector Configuration / Layout

The RTMS Microwave detectors utilize a 12-pair cable between the detection unit and the controller cabinet. One microwave detector cable is required for each RTMS unit. A Model 170-style controller cabinet, in a typical configuration, can accept 28 detector inputs, where each input corresponds to a detection “zone”. In a side-fire configuration collecting data for 3 lanes, the single microwave detector unit captures three zones, and thereby requires three inputs in the controller cabinet. For bi-directional detection involving 6 total lanes, one RTMS unit can usually serve both directions, but depending on geometry, it may be necessary to install two microwave detector units, two microwave detector cables (1 per unit), and 6 inputs in the controller cabinet. The microwave detector units should be placed within 800 feet of the controller cabinet.

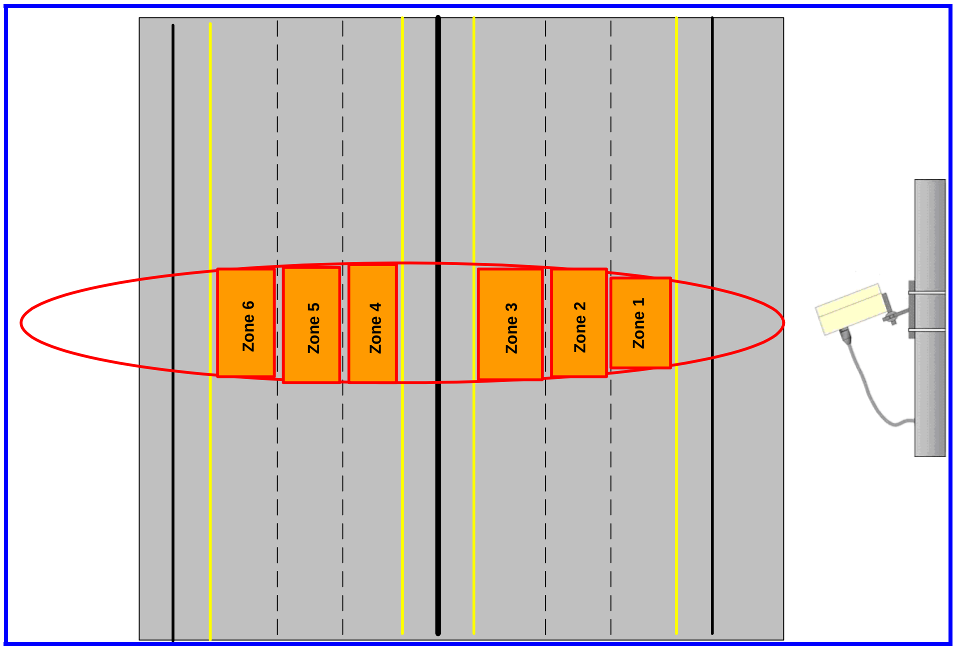


Figure 3-4: Typical RTMS Configuration for a Three-Lane Roadway

It is possible to connect the RTMS unit directly to a wireless communication device (e.g., GPRS modem) and transmit Vehicle Speed, Occupancy and Volume data back to an ATMS located in the TMC. In one popular configuration, the field RTMS unit communicates directly with a wireless transceiver that provides a link to the Internet or other wide area network (WAN).. On the TMC side, the traffic volume, occupancy and speed data are usually retrieved via a wired connection to the Internet or WAN, although it too could use a wireless link.

3.3.2. Miscellaneous Issues

The RTMS speed accuracy in sidefire mode is approximately ± 10 percent, but its accuracy mounted over a lane and facing approaching traffic is claimed by the manufacturer to be much better. Concrete median barriers sometimes limit RTMS performance on the far side of a highway. Each RTMS unit can handle up to eight lanes. The manufacturer claims that maintenance on the RTMS is minimal once the detector is set and calibrated. The RTMS unit needs 12-24V AC/DC power. A wireless transceiver may need a different DC voltage, but usually comes with a 110 VAC to DC converter.

RELIABILITY: Mean Time between Failures 10 years

WARRANTY: 2 years

3.4. Video Image Detection System (VIDS)

Video Image Detection Systems (VIDS) are above-ground units mounted over (Figure 3-5) or along side (Figure 3-6) the arterial to collect volume, occupancy and speed data. Representative information about the VIDS systems is provided here. The features and specifications of individual

VIDS systems may vary. Traditional VIDS, such as Autoscope, Vantage and Traficon are configured with the cameras in the field and control receivers located in the controller cabinet. This typically requires more space in the controller cabinets than loop detectors or RTMS Interface Units.

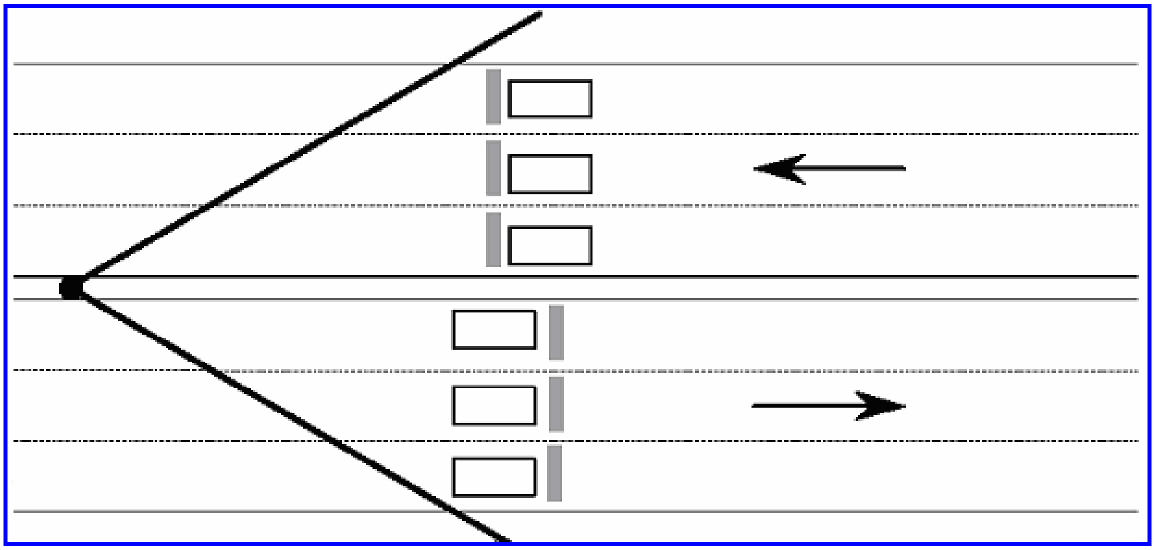


Figure 3-5: Video Image Detection System - Median Mounted

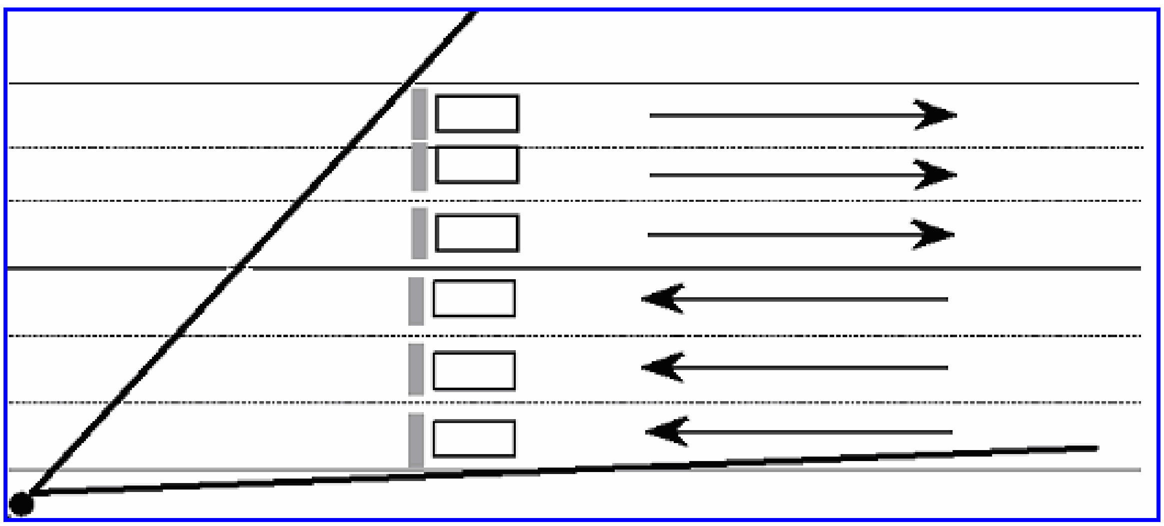


Figure 3-6: Video Image Detection System - Side-Fire Mounted

3.4.1. System Detector Configuration / Layout

VIDS cameras are mounted on street lighting mast arms or poles. A "10ft to 1ft" rule is commonly used to identify the maximum VIDS monitoring distance. This rule states that maximum distance increases 10ft for every 1ft increase in camera height. Normally, it is not practical to monitor vehicle presence at distances greater than 300ft.

In traditional VIDS systems, video and power cables are run from the cabinet to each camera. The VIDS Processor in the controller cabinet connects directly to coax cabling from each camera. Newer systems provide the option to process the video at the camera, and communicate the status of each detection zone to a transceiver in the controller cabinet, using twisted wire pairs or wireless data communication. Some systems allow the video to be transmitted to the cabinet or other locations as a compressed digital video stream using any IP link over cable or a wireless system. Isolation amplification is included in the VIDS Processor, eliminating the need to buy extra equipment to protect against transients or compensate for coax cable losses.

Typically, programming of the VIDS unit requires a separate PC/laptop. However, more and more venders are integrating full programming capability into the VIDS processor and eliminating the need for a separate PC. Usually a programming menu is displayed as an overlay on the video image from each camera. Detectors are drawn on the camera video image using a mouse. Once vehicle detectors are saved in memory the detection starts immediately.

3.4.2. VIDS Systems Products

VIDS are available from several manufacturers including Econolite, Iteris, Traficon, Peek Traffic, Nestor Traffic Systems, and Transformation Systems. The characteristics of several VIDS products are listed in Table 3-1.

Table 3-1: Overview of Several VIDS products

Characteristics	Product Name		
	Autoscope	Vantage	Traficon
Manufacturer	Image Sensing Systems	Iteris	Traficon NV
Model	Solo Pro II, RackVision and 2020	Vantage One, Plus and Edge2	VIP3.x, VIP3D.x, VID/D/I
Available Video output	Analog/Digitized Video	Analog	Analog/Digitized Video
Communication media between camera and processor	Solo Pro II: TWP RackVision and 2020: Coax Cable	Coax Cable	Coax Cable
Communication media between processor and central system	Ethernet/IP addressable or Analog	Ethernet/IP addressable or Analog	Ethernet/IP addressable or Analog

3.4.3. Miscellaneous Issues

Manufacturers claim VIDS systems will accurately measure individual vehicle speed with more than 95% accuracy under all operating conditions for vehicles approaching the sensor (viewing the front end of vehicles), and 90% accuracy for vehicles receding from the sensor (viewing the rear end of vehicles). In a standalone system detection application (gathering count, occupancy and speed data) the traffic data can be polled every 20 seconds and a video snapshot sent every 2-3 minutes. As with other detection technologies, the field-to-central communication link can be wired or wireless, and can use the Internet or other wide area network.

RELIABILITY: Mean Time between Failures 10 years

WARRANTY: 2 years (extended warranty available to 5 years)

3.5. Wireless Magnetometers

Magnetometers are small metal detectors that can be placed in the roadway pavement to detect vehicles passing above. Recent advances in miniaturization, low power consumption, wireless transmission techniques, and battery life have enabled the development of a wireless magnetometer for vehicle detection. These units are functionally similar to loop detectors, except that they are a point sensor and the area of detection cannot be increased as with a loop or video detector. However, they are relatively inexpensive and numerous point detectors can be deployed to cover the area of interest.

The magnetometer transmits a signal to a roadside access point when a vehicle moves into or out of the detection zone. The access point can accumulate data for periodic transmission to a central computer, or can immediately inform a roadside controller of the change in detection state in a loop emulation mode.

The types of data that can be provided by a wireless magnetometer include the following:

- Vehicle speed;
- Vehicle count (volume);
- Vehicle presence (occupancy) including stopped vehicles;
- Vehicle classification (length only, not type or axle count);
- Incident detection; and
- Queue length.

3.5.1. System Detector Configuration / Layout

The sensors are installed in a small hole drilled in the pavement, or can be affixed to the pavement surface in a temporary installation. No cabling is necessary between the sensor and the wireless access point. If the access point is installed in a roadside cabinet, an external antenna is needed. Multiple access points can be used to relay sensor outputs over long distances if needed. A loop emulation module can be wired to an access point to allow the magnetometers to be seen by a traffic controller as loops.

The in-pavement sensor is powered by a battery with a claimed life of 5 to 10 years or more, depending on traffic volume. The access point needs mains power, but as with any low-powered roadside equipment, could be solar powered.

The sensors are placed in a four-inch diameter, two-inch deep hole in the pavement or glued on the pavement surface. Compared to loop detectors, the installation of sensors takes approximately 10 percent of the time with 10 percent of the crew. Installation of the sensors requires shorter lane closure times compared to the installation and maintenance of inductive loops.

The table below summarizes the relationship between the access point mounting height to the range from sensor node:

Access Point Height	Communication Range from Sensor to Access Point
8 feet	50 – 75 feet
16 feet	75 – 125 feet
24 feet	100 – 150 feet

Each magnetometer detects only a vehicle above it. Units can be located anywhere on a roadway, providing an access point is provided within about 150 feet to receive the transmitted data.

Caltrans is currently evaluating this new technology. Initial results suggest a good level of accuracy. Figure 3-7 and figure 3-8 shows the typical installation of these services in field for the various applications.

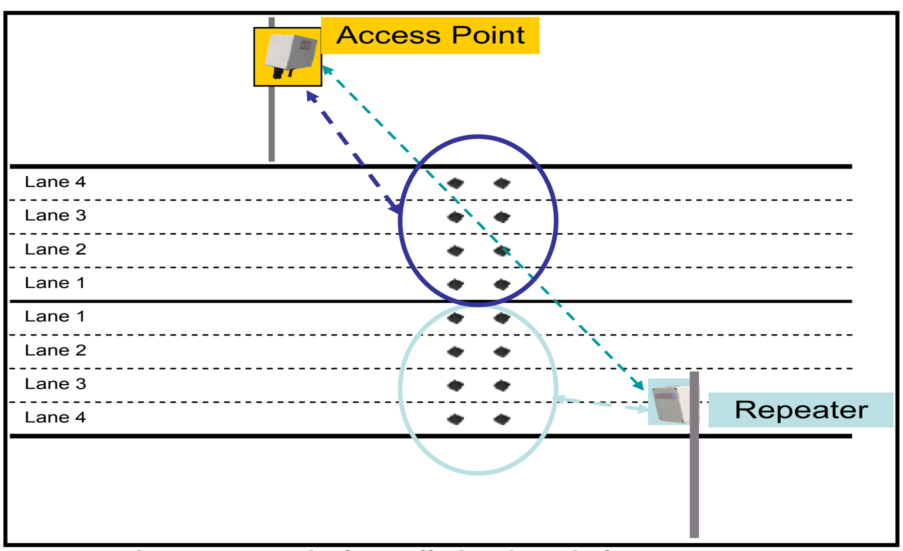


Figure 3-7: Typical Installation for Wireless Magnetometers

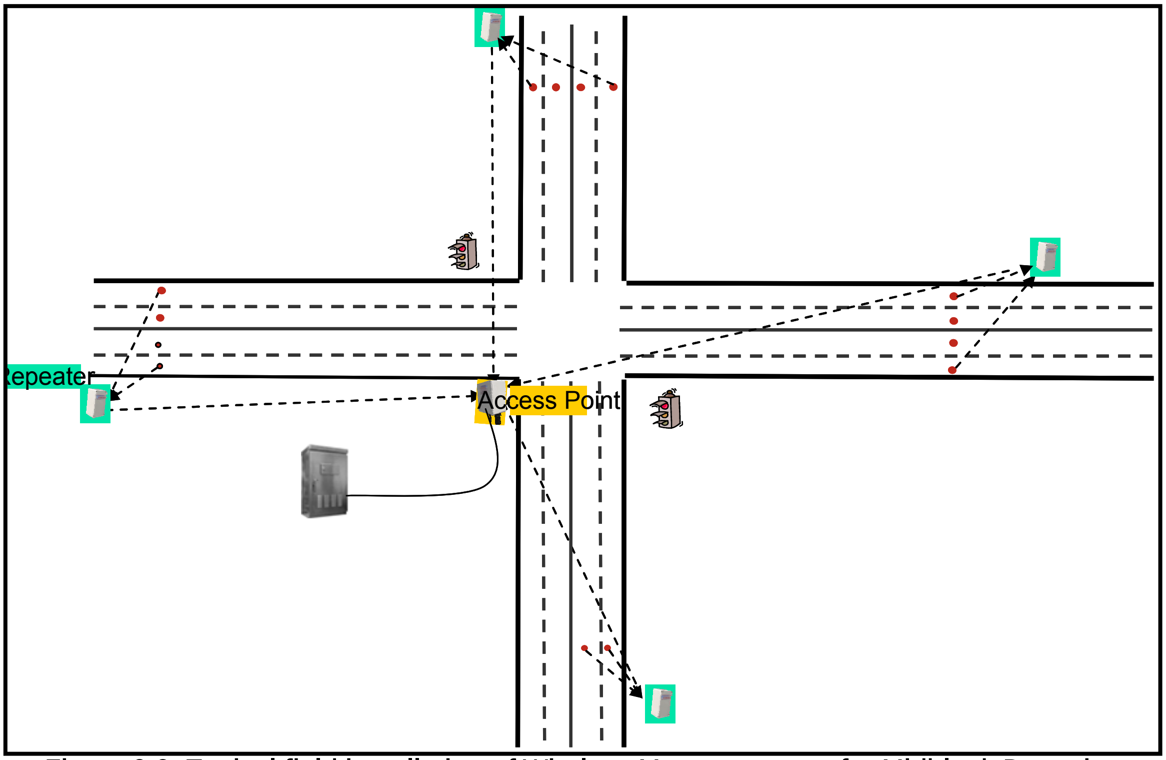


Figure 3-8: Typical field installation of Wireless Magnetometers for Midblock Detection

3.5.2. Miscellaneous issues

The sensor can be deployed in all weather and roadway conditions. The operating temperature ranges from -40°C to 85°C.

Routine pricing information is not available. Based on the amount of equipment involved, it should be a relatively inexpensive option. Maintenance costs are not known, as they will depend heavily on the actual battery and unit life.

Wireless magnetometers have been used for some time as a traffic census station (e.g., products by NuMetrics) where the data are stored at the device for later upload. They are only just beginning to be used for real-time vehicle detection, such as in needed for ATMIS. The only known product in production in this latter category is that by Sensys Networks, in Berkeley, California. Several test installations have been deployed around the US, including one by Caltrans.

3.6. Changes Needed for System Detection

In order to add system detection at a traffic signal, additional or modified equipment is often necessary. Upgrades (or modifications) that may be necessary regardless of the technology used include the following.

3.6.1. New Detection Zones

As discussed above, detectors (detection zones) located for local detection (phase calls and green extensions) at a traffic signal, are often not suitable for system detection (collecting count and occupancy data). Any of the following changes may be required:

- Replace a single detection zone spanning all lanes (including loops in each lane but wired together) with individual detection zones for each lane.
- Add detection zones in lanes not currently monitored.
- Provide new detectors (detection zones) at a different location, such as downstream of the intersection – on departure legs.

Such changes may be as simple as reconfiguring an existing sensor system, or may involve installation of new in-pavement or roadside equipment.

It is also possible to install stand –alone system detector stations, away from traffic signals, but this is usually more expensive and not warranted. The following discussion therefore focuses on the changes needed to implement system detection at a traffic signal.

3.6.2. New Sensor Units in Cabinet

The additional detection zones needed for system detection may require additional sensor units in the cabinet. If the existing card rack or shelf space is insufficient, this may include installation of an additional rack or shelf. In some cases, a new cabinet may be needed.

3.6.3. Additional Controller Inputs

The additional detection zones needed for system detection will require additional detector inputs to the controller. This may entail installation of an auxiliary wiring harness, rewiring existing harnesses, or reconfiguration of inputs in the controller firmware. In some cases, it may require a new controller or new controller firmware.

3.6.4. Electrical Service

In the case of microwave and VIDS, electrical service is necessary for the detector units themselves. For the purposes of this analysis it is assumed that the electrical service exists to the pole on which these devices would be mounted.

3.6.5. Communication

Some form of communication is necessary to communicate from the detectors to the controller. Examples are: loop lead-in cable, twisted wire pairs, coaxial cable, and wireless.

Communication interface units may be required as well.

3.6.6. Underground Infrastructure

This comprises:

- Conduit.
- Trenching and / or sawing for conduit or wires.

- Pull Boxes - the number is dependent upon the spacing. Typically, they should be spaced no greater than 200 feet. If a conduit run contains only one or two lightweight cables (e.g., loop lead-ins), this distance can be stretched to approximately 300 feet.

Note that existing conduit may have insufficient free space to accommodate new cables.

3.6.7. Roadside Infrastructure

In instances where structures are not available for installing microwave or VIDS detector units, poles and mast arms may be necessary.

4. Comparison of Candidate Detection Technologies

4.1. Candidate Technology Characteristics

Table 4-1 presents a summary of the relative merits of the candidate detector technologies. Factors such as installation, parameters measured, performance in inclement weather and variable lighting conditions, and suitability for wireless operation are considered.

For example, the RTMS and VIDS units have overhead sensors that are compact and not roadway invasive, making installation and maintenance relatively easy. On the other hand the Inductive loop installation and maintenance may require the closing of the roadway to normal traffic to ensure the safety of the installer and motorist. All the detector technologies discussed here operate under day and night conditions.

The strengths and weaknesses were compiled from various sources, and are representative of the technology in general; they may not be directly relevant to a specific vendor and product. A representative product from each of the detection technologies has been used here for comparison purposes only. For Microwave technology, a RTMS system manufactured by EIS Systems was used, and for Video (VIDS) an AUTOSCOPE Pro unit manufactured by Econolite was used for comparison purposes.

Table 4-1: Comparison of Detection Technologies

	STRENGTHS	WEAKNESS
Inductive Loops	▪ Flexible design to satisfy large variety of applications. ▪ Mature, well understood technology. ▪ Generally insensitive to inclement weather. ▪ Stopped vehicle detection. ▪ High accuracy if well maintained. ▪ Little or no repeated calibration or adjustment needed.	▪ Installation requires pavement cut. ▪ Decreases pavement life. ▪ Installation and maintenance require lane closure. ▪ Wire loops subject to stresses of traffic and temperature.
Microwave	▪ Generally insensitive to inclement weather. ▪ Multiple lane operation available at no extra cost over single lane operation. ▪ Relatively quick installation and calibration.	▪ Doppler sensors cannot detect stopped vehicles. ▪ Some inaccuracy due to occlusion ▪ Needs repeated calibration adjustment.
Video	▪ Multiple lane operation available at no extra cost over single lane operation. ▪ Easy to add and modify detection zones.	▪ Inclement weather, shadows, vehicle projection into adjacent lanes, occlusion, day-to-night transition, vehicle/road contrast, and water, salt

	STRENGTHS	WEAKNESS
Video Continued	▪ Stopped vehicle detection. ▪ Video can be brought back to the central for surveillance purposes.	grime, icicles, and cobwebs on camera lens can affect performance. ▪ Susceptible to camera motion caused by strong winds. ▪ Some inaccuracy due to occlusion and environmental conditions.
Wireless Magnetometers	▪ Easy to install with the least amount of disruption to traffic movement. ▪ Speed measurement, vehicle count, incident detection, stopped vehicle detection and queue length detection possible. ▪ Relatively quick installation and calibration. ▪ Insensitive to inclement weather.	▪ Relatively new technology. Has not been implemented at many locations. ▪ Pricing not available for the same. ▪ Not very accurate for vehicle classification type applications.

4.2. Equipment Cost Comparison

This Section contains the costs associated with the deployment of the three candidate technologies. Cost components taken into account in addition to the basic equipment supply costs include local communications, installation, maintenance and operational costs.

4.2.1. Assumptions

The following assumptions were made in developing the cost estimates:

1. System detection is being installed at an existing traffic signal.
2. System detection is being installed on only the main street, and that street has three lanes in each direction.
3. The system detection zones are placed approximately 100 feet downstream of the intersection, monitoring traffic departing the intersection.
4. RTMS units will be mounted on a new pole set back from the curb, to keep them independent of the street lighting system and to minimize the length of conduit and cable installation.
5. Video detection cameras will be mounted on existing signal poles or arms (signal or safety lighting arm) at the intersection, and will monitor traffic moving away from the camera (traffic departing the intersection).
6. Electrical power for the RTMS and video detection cameras is obtained from the traffic signal cabinet via the same cable used to transmit the detection zone status.

7. For RTMS and VIDS, it is assumed that one detection unit will be required for each of the two main street legs being monitored.

8. New cables can be accommodated in existing traffic signal conduits around the intersection.

4.2.2. Deployment Costs

Figure 4-1 presents the equipment layout for deploying inductive loop technology and Table 4-2 presents associated costs for deploying this option.

Figure 4-2 presents equipment layouts for deploying RTMS technology and Table 4-3 presents associated costs.

Figure 4-3 presents equipment layouts for deploying VIDS technology and Table 4-4 presents associated costs.

Table 4-5 presents a comparison of the 10-year cost analysis for the candidate technologies.

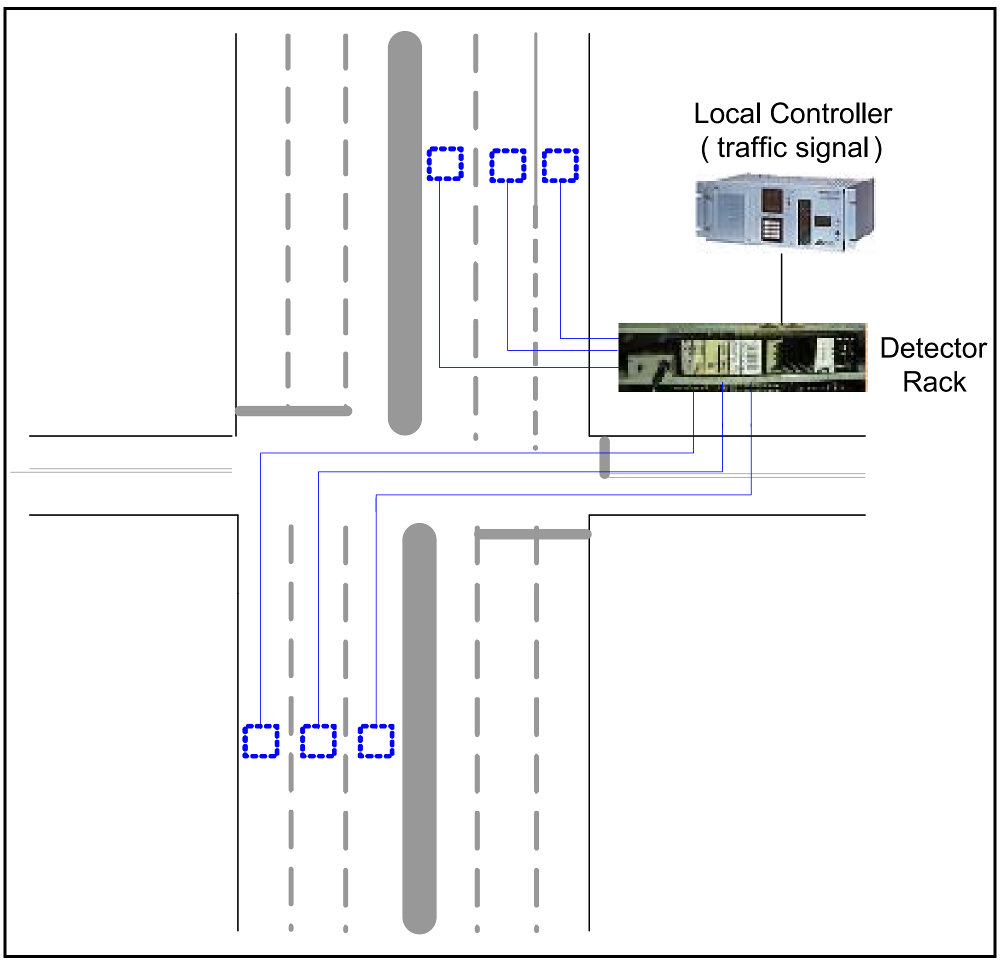


Figure 4-1: Inductive Loop Equipment Configuration

Table 4-2: Capital Cost for Deploying Inductive Loops Technology

Component	Cost	Unit	Total Cost
Inductive Loops Installation	$ 900	6	$ 5,400
Dual Channel Detector Cards	$ 300	4	$ 1,200
New Conduit	$30 / foot	200 feet	$ 6,000
Lead-in Cable from Inductive loops to Controller	$10 / foot	600 feet	$6,000
		Total	$ 18,600

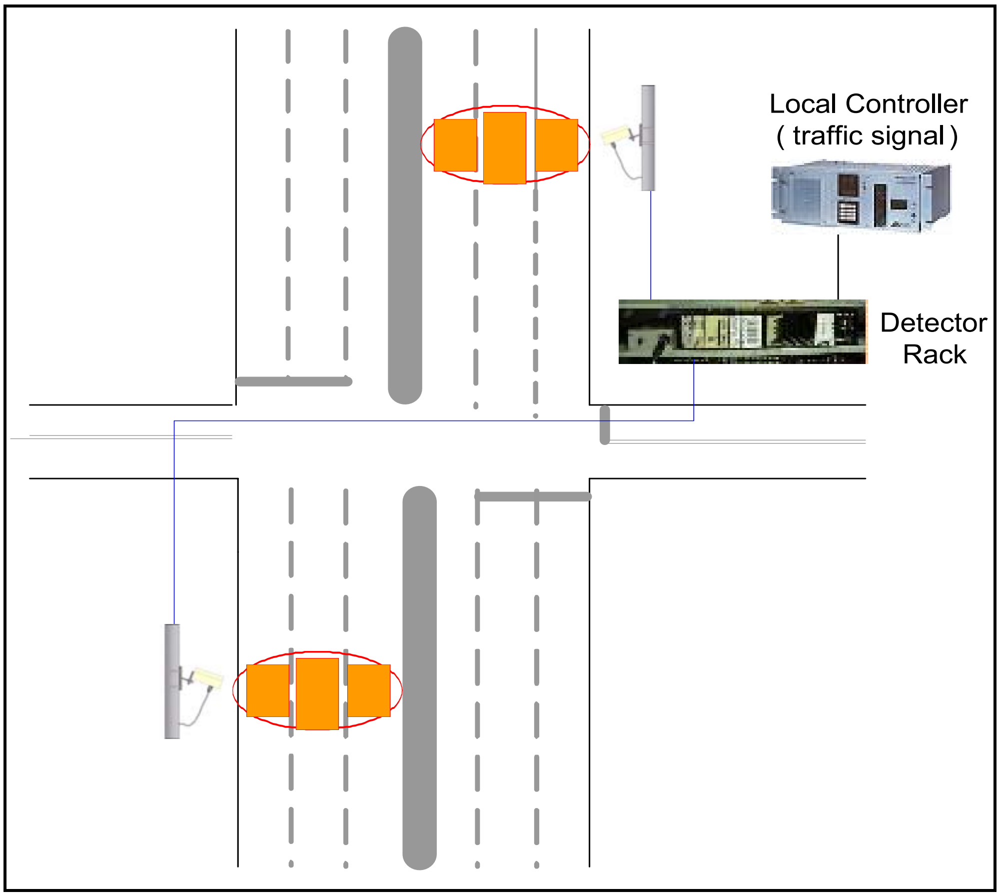


Figure 4-2: RTMS Equipment Configuration

Table 4-3: Capital Cost for Deploying Microwave Technology (RTMS by EIS Systems)

Component	Cost	Unit	Total Cost
RTMS Unit with mounting bracket and cable connector	$ 6000	2	$ 12,000
Install Pole and RTMS unit	$ 7000	2	$ 14,000
2 Channel DC Isolator Card	$150	4	$ 600
New Conduit	$30 / foot	200 feet	$6,000
Power and Detection TWP Cable from RTMS to Controller	$10/ foot	400 feet	$ 4,000
		Total	$36,600

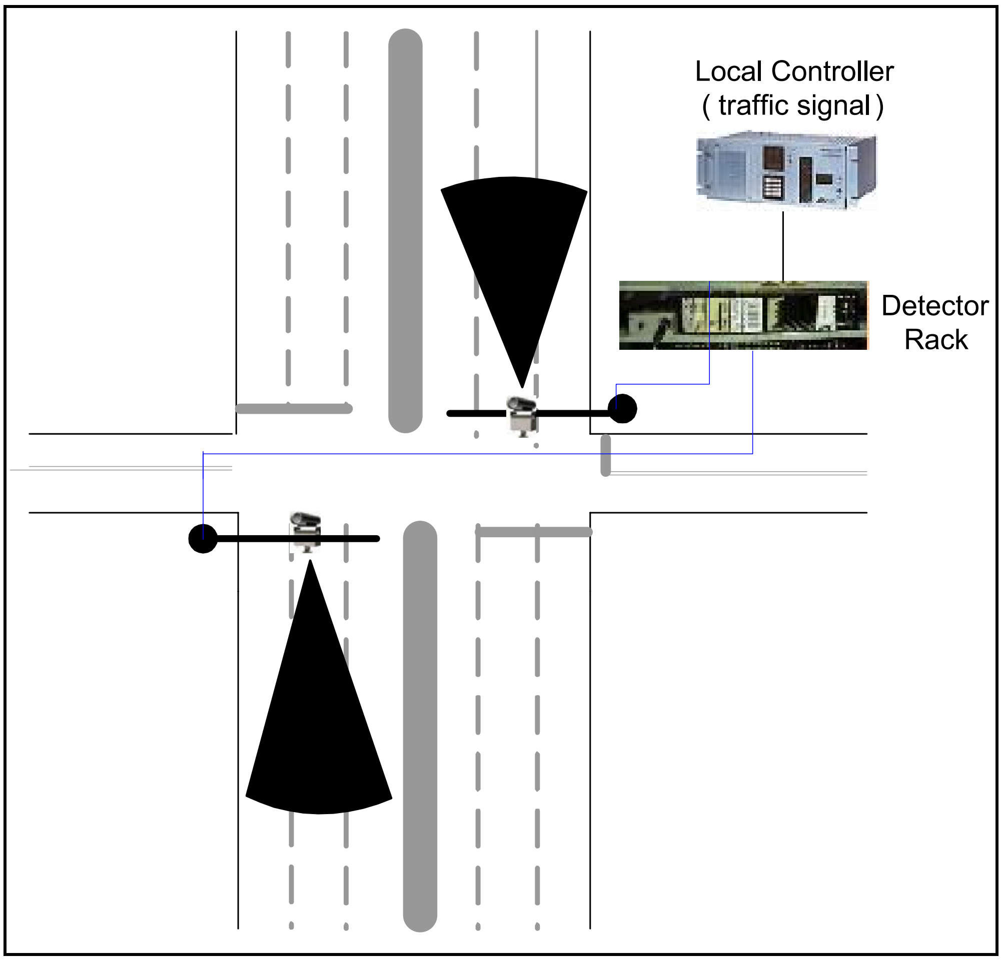


Figure 4-3: VIDS Equipment Configuration

Table 4-4: Capital Cost for Deploying Video Image Detection Systems (VIDS)

Component	Cost	Unit	Total Cost
VIDS Camera and Processor (Assume two Autoscope Solo Pro II unit)	$6,500	2	$ 13,000
Communication Interface Panel (Assume ACIP4/E with Ethernet option)	$2,000	1	$2,000
Modular Cabinet Interface Unit (Mini Hub II or Mini Hub TS2)	$1000	2	$2,000
Cable – VIDS to Controller Cabinet	$2 /foot	250 feet	$500
Install all of the Above	$5,000	1	$5,000
		Total	$22,500

Table 4-5: 10-Year Cost Analysis Summary Table

	LOOPS	RTMS	VIDS
Initial Cost	$18,600	$36,600	$22,500
10-year Maintenance Cost (e.g. Inspect, Adjustment, Clean and Repair)	$10,000	$4,000	$4,000
Total Cost for 10 years	$28,600	$40,600	$26,500

4.3. Analysis and Recommendation

This report analyzed the functionality and costs of three system detection technologies –inductive loops, side-fire radar (e.g., RTMS), and video detection – against the Project requirements. As far as functionality is concerned, loops provide the most accurate measurements of volume and occupancy, but all three technologies are considered sufficiently accurate for use as system detectors.

Video detection allows the video feed to be transmitted to the TMC for viewing. A fiber network will provide high–quality streaming video while a wireless or twisted-pair modem will enable lower quality streaming video or snapshot images. However, the recommended location of system detection zones is on the departure side of the intersection, and video detection cameras would face away from the intersection, thus limiting the value of such video feeds.

The preferred method for system detection is to install separate detection zones downstream of the intersection. If installation of new detection in this preferred location is not feasible, it is possible to use existing advance detection loops to collect approximate traffic volume data, but not occupancy data. This assumes the advance loops on each main street approach have all lanes wired to a single controller input and set in the pulse mode, and that the advance loops is each travel direction are monitored as separate inputs to the controller. If two or more vehicles enter the combined loops simultaneously, they will be counted as only one vehicle. Although less accurate and missing usable occupancy data, using advance loops in this way as system loops is better than nothing and may be sufficient for some applications.

The cost comparison shows that there are no significant differences between the 10 year costs for the three alternative technologies. Loops have a somewhat lower initial cost, but due to the higher failure rate and higher repair cost, they incur higher maintenance costs.

All in all, there is little to distinguish between the three alternative detection technologies in the role of system detection at an existing traffic signal. It is recommended that the adoption of a technology be based on the agency's familiarity and comfort with each of the alternative technologies.