TRAFFIC DETECTOR SELECTION PROCEDURE

(GUIDELINE DRAFT)

Prepared For:
Utah Department of Transportation Research and Development Division

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Traffic detection systems provide high quality real time and historical traffic data for a variety of traffic applications. Inductive loops, though they are the most widely deployed detector technology, have some limitations. They disrupt traffic flow during installation and maintenance, fail at a high rate under particular conditions, and are inflexible. Professionals are seeking alternative technologies to replace inductive loops.

A large number of traffic detector devices with different operation theories are currently available on the market. Manufacturers are constantly improving detector performance and capabilities. No single detector device is best for all applications. Each has its limitations, specializations, and individual capabilities. Because such a diversity of detector technologies and devices exists, it may be problematic to select the optimal detector technology and particular device to meet specific project requirements. To a large extent, successful application of detector technologies depends on proper device selection.

This guideline provides a systematic method for selecting detectors for permanent applications. The selection method considers many factors, including data type, data accuracy (within different environmental and traffic conditions), ease of installation and calibration, cost, reliability, and maintenance. A variety of detector technologies and devices are compared using these factors in order to help the user choose the best technology and device for his or her purposes. This guideline provides comparison matrixes for detector technologies and for specific detector devices. The technology matrixes provide general information about each detector technology, and the device matrixes offer specific information regarding each particular detector device. The matrixes need to be continuously updated to reflect new changes in the detector field.
1. INTRODUCTION

Traffic detection systems provide high quality real time and historical traffic data for a variety of traffic applications. Inductive loops, though they are the most widely deployed detector technology, have some limitations. They disrupt traffic flow during installation and maintenance, fail at a high rate under particular conditions, and are inflexible. Professionals are seeking alternative technologies to replace inductive loops.

A large number of traffic detector devices with different operation theories are currently available on the market. Manufacturers are constantly improving detector performance and capabilities. No single detector device is best for all applications. Each has its limitations, specializations, and individual capabilities. Because such a diversity of detector technologies and devices exists, it may be problematic to select the optimal detector technology and particular device to meet specific project requirements. To a large extent, successful application of detector technologies depends on proper device selection.

This guideline provides a systematic method for selecting detectors for permanent applications. The selection method considers many factors, including data type, data accuracy (within different environmental and traffic conditions), ease of installation and calibration, cost, reliability, and maintenance. A variety of detector technologies and devices are compared using these factors in order to help the user choose the best technology and device for his or her purposes. This guideline provides comparison matrixes for detector technologies and for specific detector devices. The technology matrixes provide general information about each detector technology, and the device matrixes offer specific information regarding each particular detector device. The matrixes need to be continuously updated to reflect new changes in the detector field.
The technologies discussed in this guideline are inductive loop, magnetic, active infrared, passive infrared, microwave radar, ultrasonic, passive acoustic, and Video Image Processing (VIP).
2. TRAFFIC DETECTION SELECTION FOR PERMANENT APPLICATIONS

Figure 1 shows the traffic detector selection procedure for permanent applications.

- Understand project requirements
  - Applications, primary data needs, required data accuracy, traffic condition, traffic closure impact, geometric condition, budget, data retrieval, power supply, etc.

- Can detector device provide required data types?
  - No: Exclude those detectors that cannot provide required data types. Reference: Table 1 and Table 2.
  - Yes:
    - Can detector device be used for required application?
      - No: Exclude those detector devices that cannot be used for the required applications, including highway traffic data collection and intersection signal control. Reference: Table 3
      - Yes:
        - Can detector device be suitable for installation conditions?
          - No: Exclude those detector devices that cannot meet general installation rules: pavement, supports, field of view, traffic control, light supply, noise, frequency conflicts, horizontal curves,... Reference: Table 3, Table 4 and Table 5
          - Yes:
            - Can the cost of detector devices meet budget?
              - No: 1. Exclude those detector devices that the capital cost and maintenance cost cannot meet budget.
                * Capital cost - unit cost, detector number decided by data type, site, and number of lanes monitored. Reference: Table 6
                * Installation cost Reference: Table 8
                * Maintenance cost and system life Reference: Table 7 and Table 8
              - Yes: 2. Prioritize the remaining detector devices by life-cycle costs

- Reconsider project requirements
Exclude those detectors that cannot meet requirements on reliability and ease of installation & maintenance.
Reference: Table 13 and 14

Exclude those detectors that cannot meet requirements on power and data communication.
Reference: Table 3

Consider environmental and traffic conditions.

Consider other issues:
(1) Additional data types
(2) Integration with the existing system
(3) Technician skill level
(4) Others

Make initial decision.

Is there a short list with priorities?
Yes
Field experience information collection
Make a final decision

No

Can detector device meet requirements on reliability and ease of installation & maintenance?
Yes

Can detector device meet requirements on power and data communication?
Yes

Can detector device meet data accuracy requirements?

Exclude those detectors that cannot meet data accuracy requirements.
Reference: Table 9 and Table 11 for highway data collection, Table 10 for intersection signal control, Table 12 for environmental and traffic impacts

Exclude those detectors that cannot meet requirements on reliability and ease of installation & maintenance.
Reference: Table 13 and 14

Exclude those detectors that cannot meet requirements on power and data communication.
Reference: Table 3

Make a final decision.

Figure 1: Traffic Detector Selection Procedure for Permanent Applications
2.1 Understand Project Requirements

Before going through the selection procedure, it is necessary to understand the requirements and conditions of the project for which the traffic detection system will be used. Several questions should be answered in advance:

1. What are application detectors used for?
   - Highway traffic data collection
   - Intersection signal control

2. What are primary data needs?
   - Count
   - Speed
   - Occupancy
   - Presence
   - Classification (axle or length)
   - Others

3. What is the detection accuracy level required for the specific project?

4. What is the budget for the project?
   - Capital budget (device and installation)
   - Maintenance budget

5. Are there stop-and-go traffic conditions at application sites?

6. Is it possible to close traffic lanes for installation and what impact will installation have on traffic flow?

7. Is the temperature at the site frequently extremely hot or cold? Are there often heavy snow, rain, fog, and/or wind?

8. Are there supportive infrastructures at application sites? Are they overhead or sidefire? What are the maximum heights?
9. Is the pavement in good condition? Has there been a recent pavement rebuild plan?

10. What are the geometric conditions of application sites? It is beneficial to have a geometric sketch map for application sites.

11. What are the requirements of data communication and data storage?

12. What are the requirements of data aggregation?

13. Are there any other requirements from existing traffic systems?

2.2 Select by Data Type

Exclude those detector technologies and detector devices that cannot provide required data types. Table 1 and Table 2 provide reference information.

Five primary data types measured by detectors are count, speed, presence, occupancy, and classification. Vehicle classification is based on vehicle length and/or height. VIP systems can provide additional data in the categories of density, queue length, headway and incident number. Vehicle probes can directly measure travel time, but travel time can also be calculated from average speed, which is inversely proportional to travel time. Detector devices typically have varied interval settings for data aggregation, such as twenty-second, five-minute, and fifteen-minute settings.

2.3 Select by Applications

Exclude those detector devices that cannot be used for the required applications. Table 3 provides reference information.

Two primary detector applications are highway traffic data collection and intersection signal control. Highway traffic data collection typically detects traffic flow, speed, occupancy and classification. Vehicle presence is the primary data for traffic signal control; speed is needed for
dilemma zone protection. Traffic signal control requires higher data accuracy, as undetected vehicles may result in signal violation and accident consequence.

### 2.4 Select by General Installation Conditions

Aside from experience and product manual information, there are some general rules to follow regarding detector applications:

1. Poor pavement is not suitable for intrusive detectors.

2. Inductive loops cannot be installed at some sites, including bridge decks and railroad crossings.

3. Horizontal curves can create a problem for inductive loops when vehicles do not travel in the center of a lane.

4. Application sites should have supportive infrastructures if considering non-intrusive detectors. Otherwise, the necessary supportive infrastructures should be counted into the capital costs.

5. Installation sites should have good fields of view for non-intrusive detectors. No obstacles should exist between detectors and detection zones.

6. Most non-intrusive detectors commonly require installation within certain heights and offset distances (for sidefire installation) to perform at their best. Make sure that selected installation sites meet the requirements of installation. Table 6 provides reference information. Table 4 provides the minimum camera height needed to reduce the adjacent-lane occlusion of VIP detector signal control applications.
7. Consider the impacts of closing traffic lanes for installation and the potential costs for the closure at application sites. This will influence decisions regarding whether to use intrusive or non-intrusive detectors and whether to use overhead installation or sidefire installation for non-intrusive detectors.

8. VIP detectors need streetlights in order to work properly at night, so VIP application sites should have an adequate light supply.

9. VIP detectors should be cautiously used to provide dilemma zone protection (12,15). Table 5 provides minimum camera height for advanced detection of VIP detectors.

10. Acoustic noise in the audible or ultrasonic ranges can interfere with the operation of acoustic and ultrasonic detectors. The installation sites should have no acoustic noise and relatively small and focused fields of view should be used to reduce the impacts.

11. When the same frequency as SPVD (Wireless data transmission on 47MHz) exists in the installation area, it may result in intermittent “false calls.” Therefore, it is necessary to determine whether the particular frequency is already in use in the area by another entity.

12. Electromagnetic interference may occur when microwave radar detectors operate in the sites where other radar waves transmit at close frequencies. Microwave radar frequencies are regulated to be near 10.5, 24.0 or 34.0 GHz.

13. Sidefire calibration is difficult for passive infrared.
2.5 Select by Project Budgets and Cost Comparison

**Capital cost**

Capital cost is dependent on unit device cost and on the quantity of devices used. Data type and geometric conditions determine the number of devices needed. Using intrusive detectors to collect speed commonly requires dual configuration. A typical intersection site requires that four approaches be monitored while a typical freeway site requires that only two approaches be monitored. To monitor multiple lanes, multiple-lane detector technologies are commonly used because of their low device cost, ease of installation and maintenance, and high reliability. Single-zone multiple-lane detectors are limited to monitoring a zone composed of several lanes without lane discrimination while multiple-zone detectors can cover several zones simultaneously.

Table 6 provides reference information.

**Installation cost**

Installation cost is relative to the material used in installation and the ease of installation and calibration. Traffic control cost should be considered for detector technologies that require lane closures during installation as traffic control for a single lane closure can cost one thousand to fifteen thousand dollars in large urban areas (8). The actual average installation cost may be similar for devices with similar difficulties of installation and calibration.

Table 8 provides reference information.

**Maintenance cost**

Because the application periods of most non-intrusive detectors are short, the average maintenance cost related to long-term performance is difficult to obtain. Table 7 provides reference information with estimated values.
**Life cycle cost**

Life cycle cost is also dependent on system life – the longer the system life of a detector device, the lower the life cycle cost. Table 8 provides the system life of each detector technology.

Exclude detector devices when their capital cost and maintenance cost are not within budget.

Make a priority list on remaining detector devices by life cycle costs. The following equation is used to calculate life cycle cost:

\[
\text{LifeCycleCost} = \left( \text{DeviceCost} \times \text{Quantity} \right) + \text{InstallationCost} \times \frac{(1 + i)^{OY}}{(1 + i)^{OY} - 1} + \text{AnnualMaintenanceCost}
\]

Where:

- \( \text{LifeCycleCost} \) = Life-cycle cost, ($)
- \( \text{DeviceCost} \) = Unit device cost, ($)
- \( \text{Quantity} \) = the quantity of devices required for the application,
- \( \text{OY} \) = Operation year, which can be system life or designed operation life, (year)
- \( \text{InstallationCost} \) = Installation cost, including labor, materials, etc. ($)
- \( \text{AnnualMaintenanceCost} \) = Annual maintenance cost ($/year).

Estimated life cycle costs of detector devices for a typical freeway application and a typical intersection application are shown in Tables 15 and 16.

Other cost issues, including quantity discount and pavement rebuild plans, should be considered. A quantity discount is often associated with a large number of units purchased. James Bonneson et. al (15) mentioned that at a typical intersection, when the pavement will be reconstructed in
less than three years, the replacement of all inductive loops will exceed the cost of installing the VIP detectors.

2.6 Select by Data Accuracy

Data detection accuracy should be within error tolerances. Field test results by third parties can provide reference information on data accuracy.

Tables 9 and 11 show highway traffic data collection.

Table 10 shows intersection signal control. Several detector technologies, including inductive loop, magnetic, true-presence microwave radar, passive infrared, ultrasonic, and VIP systems, are used for intersection signal control.

Detection accuracy is affected by environmental and traffic conditions. Primary environmental factors are precipitation, wind, temperature, and shadow and light. Rain and snow can reduce visibility and may also hinder the short-length wave produced by infrared and other detectors. Wind may change the detector position or cause detector vibration, especially when detectors are installed near the end of the mast arm or high pole. The movement can reduce the accuracy of detection. And, extremely low or high temperature can reduce the accuracy of some detectors. The VIP detectors may suffer from poor light, sunlight, vehicle headlight reflection, and shadows caused by buildings or vehicles. High traffic volume can cause stop-and-go congestion and low vehicle speed and can lead to poor detection by some detector technologies. Table 12 provides information about environmental and traffic impacts on detector performance.

2.7 Select by Reliability and Ease of Installation & Maintenance

Tables 13 and 14 provide reference information.
2.8 Select by Power and Data Communication

Power requirements are of most concern in remote areas where power sources are unavailable. Table 3 provides reference information.

2.9 Select by Other Issues

Projects should also consider the following issues in addition to other project-specific issues:
1. The detector devices’ provision of additional data types.
2. The detection system’s ability to integrate with existing systems.
3. The skill level of maintenance personnel.
5. Capability for remote adjustment of calibration parameters and for trouble-shooting.

2.10 Make Initial Decision

If after following the selection steps no detector devices remain, project requirements should be reconsidered and possibly altered. If several options remain, a priority list should be made and the detector options reconsidered.

2.11 Field Information Collection

To select the best detector for their purposes, buyers should contact vendors for detailed information, contact other users for experience, and conduct field tests if necessary. Vendors can provide detailed information about products and company services. It is important to know a company’s history in order to ensure that it has a good reputation and a commitment to the industry. This minimizes the risk that a product will be abandoned shortly after an agency invests in it. Buyers should ensure that the company has an ISO 9001 certification, or credentials that a manufacturer has implemented a process of constant improvement and has the maturity to
reliably manufacture products. Finally, the warranty period of a detector device should also be considered.

It is strongly recommended that a field test be carried out to guarantee that a detector is appropriate for a project. In addition, manufacturers may be unaware of or reluctant to discuss certain aspects of their products, so it is wise to contact actual users about their experience prior to purchasing a new device. Although products are continuously being improved, they may show problems in field tests. Buyers should pay close attention to recurring problems and ask vendors how they should deal with these problems.

**2.12 Make a Final Decision**

The preceding steps will help buyers narrow their detector device selection and select the product appropriate for their needs.
### 3. REFERENCE TABLES

#### Table 1: Data Types of Detector Technologies

<table>
<thead>
<tr>
<th>Detector Type</th>
<th>Volume/Count</th>
<th>Speed</th>
<th>Classification</th>
<th>Occupancy</th>
<th>Presence</th>
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<tr>
<td>Inductive Loop</td>
<td>✓</td>
<td>✓(1)</td>
<td>✓(2)</td>
<td>✓</td>
<td>✓</td>
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<td>Magnetic</td>
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<td>✓(3)</td>
<td>✓(3)</td>
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<td>×</td>
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<td>Microwave Radar True Presence</td>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note:
1. Speed can be measured by using dual-loops with a known distance apart, or by algorithms with a single-loop covering the length of the detection zone and vehicle.
2. Advanced detector cards using “vehicle signature” can measure Classification.
3. Speed and classification measurement by magnetic detectors requires two units.
4. Passive infrared detectors with multi-detection-zone capability can measure speed.
✓ - Can provide the data type, × - Cannot provide the data type.
<table>
<thead>
<tr>
<th>Device</th>
<th>Volume</th>
<th>Speed</th>
<th>Classification (length)</th>
<th>Occupancy</th>
<th>Presence</th>
<th>Other data</th>
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<td>✓(4)</td>
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</table>

Note:
(1) – Speed can be measured by dual-loops with a known distance apart, or by algorithms with a single-loop covering the length of the detection zone and vehicle.
(2) – Advanced detector cards using “vehicle signature” can measure Classification.
(3) – Requires two units.
✔ - Can provide the data type, × - Cannot provide the data type.
<table>
<thead>
<tr>
<th>Technology/Sensor</th>
<th>Traffic Data Collection/Signal Control</th>
<th>Supply Voltage</th>
<th>Communication</th>
<th>Data Storage</th>
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</tr>
<tr>
<td>3M Microloop</td>
<td>Both</td>
<td>Powered off amplifier 10.8v – 39v</td>
<td>Dual communications – front panel to laptop or modem or pin 19-21 off back panel</td>
<td>16K additional memory available</td>
</tr>
<tr>
<td>SPVD</td>
<td>SC</td>
<td>Detector: 13.5V 17Ah battery pack; Receiver: 10 –25VDC</td>
<td>Wireless data transmission on 47MHz</td>
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</tr>
<tr>
<td>ASIM IR 254</td>
<td>Both</td>
<td>8mA@12VDC</td>
<td>RS485</td>
<td>20 vehicles</td>
</tr>
<tr>
<td>Siemens PIR-1</td>
<td>Both</td>
<td>115VAC 10.5-26VDC</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Eltec Model 842</td>
<td>SC</td>
<td>95-135VAC</td>
<td>N/A, relay output</td>
<td>None</td>
</tr>
<tr>
<td><strong>Microwave Radar</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuwave 150LX</td>
<td>SC</td>
<td>95-125VAC</td>
<td>RS232</td>
<td>?</td>
</tr>
<tr>
<td>RTMS</td>
<td>Both</td>
<td>12-14VDC</td>
<td>RS232/RS485</td>
<td>?</td>
</tr>
<tr>
<td>TC 26B</td>
<td>TDC</td>
<td>12-24VDC/AC</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>TDN-30</td>
<td>TDC</td>
<td>12-14VDC</td>
<td>RS232</td>
<td>?</td>
</tr>
<tr>
<td>Loren</td>
<td>TDC</td>
<td>?</td>
<td>RS232</td>
<td>?</td>
</tr>
<tr>
<td><strong>Ultrasonic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Lane KingTM SC</td>
<td>115±20VAC</td>
<td>RS422/RS485</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>TC-30 SC</td>
<td>12-24VAC/DC</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

| **Passive Acoustic** | | | | | |
| --- | --- | --- | --- | --- | |
| SmartSonic TSS-I Rural road data collection (a free flow road with speeds greater than 35 mph) | 12VDC with solar charging or AC power | RS232 | 64K memory | |
| SmarTek SAS – I Both | 0.125 mA at 12 VDC (1.5 watts) | RS-232 or RS-422, Ethernet, opto-isolated relay | 60 days storage of 5 lanes of data | |

| **Video Image Processing** | | | | | |
| --- | --- | --- | --- | --- | |
| Autoscope 2004\(^{(1)}\) Both | 115/230VAC | RS232/RS485/RJ45 | ? | |
| Autoscope solo Both | 24VAC, 12-18VDC | RS485 | ? | |
| VideoTrak 900\(^{(1)}\) Both | Camera 110V-40W max dissipation, four camera unit draws quiescent current of 0.5 amp | RS232/RS485 | 4MB memory | |
| Traficon Both (different VIP detector cards) | 10.8-26.5VDC | RS232/RS485/RJ45 | VIP/presence: 10 days VIP/data: 4 days | |

Note: (1) – Autoscope 2004 is being replaced by the new version Autoscope 2020; VideoTrak 900 is being replaced by a new version. TDC – Highway Traffic Data Collection, SC – Intersection Signal Control.
Table 4: Minimum Camera Height to Reduce Adjacent-Lane Occlusion

<table>
<thead>
<tr>
<th>Camera Location</th>
<th>Lateral Offset&lt;sup&gt;(1)&lt;/sup&gt;, feet</th>
<th>No Left-turn Lanes Through+Right Lanes&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>One Left-turn Lane Through+Right Lanes&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>Two Left-turn Lanes Through+Right Lanes&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side of Approach</td>
<td>-75</td>
<td>54</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>-65</td>
<td>47</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>-55</td>
<td>39</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>-45</td>
<td>32</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>-35</td>
<td>24</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>-25</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>-15</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>-5</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Center</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Right Side of Approach</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Note:
(1) – Lateral offset of the camera measured from the center of the approach traffic lanes, including turn lanes. Cameras to the left of the center have a negative offset.
(2) – Total number of through and right-turn lanes on the approach.
(3) – Based on a vehicle height of 4.5 feet and a vehicle width of 6.0 feet.
(4) – Underlined values in each column correspond to typical lateral offsets when the camera is mounted within ten feet of the edge of the traveled way.

Source: Video Detection For Intersection and Interchange Control (15).
Table 5: Minimum Camera Height for Advance Detection

<table>
<thead>
<tr>
<th>Distance Between Camera and Stop Line&lt;sup&gt;(1)&lt;/sup&gt;, feet</th>
<th>Approach Speed Limit&lt;sup&gt;(2)&lt;/sup&gt;, mph</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Minimum Camera Height&lt;sup&gt;(3)&lt;/sup&gt;, feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>24</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>24</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>25</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>25</td>
<td>28</td>
<td>30</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>26</td>
<td>28</td>
<td>31</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>27</td>
<td>29</td>
<td>31</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>27</td>
<td>30</td>
<td>32</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>28</td>
<td>30</td>
<td>32</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>28</td>
<td>31</td>
<td>33</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>29</td>
<td>31</td>
<td>34</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>30</td>
<td>32</td>
<td>34</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Distance to Furthest Zone&lt;sup&gt;(4)&lt;/sup&gt;, feet</td>
<td>353</td>
<td>392</td>
<td>431</td>
<td>470</td>
<td></td>
</tr>
</tbody>
</table>

Note:
(1) – Distance between the camera and the stop line, as measured parallel to the direction of travel.
(2) – Approach speed limit is assumed to equal the eighty-fifth percentile speed.
(3) – Based on distance-to-height ratio of 17:1.
(4) – Distances based on 5.0 seconds travel time at the ninety-fifth percentile speed.

Source: Video Detection For Intersection and Interchange Control (15).
Table 6: Cost Comparison of Detector Devices

<table>
<thead>
<tr>
<th>Technology/Sensor</th>
<th>Device cost</th>
<th>Lanes</th>
<th>Mounting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inductive loop</strong></td>
<td>$500-$1000/loop (including installation)</td>
<td>S</td>
<td>Under pavement</td>
</tr>
<tr>
<td>Magnetic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M Microloop</td>
<td>Canoga Detector C822F(2 channel): $546; Canoga Detector C824F (4 channel): $704; 702 Microloop Probe: $160; 701 Microloop Probe: $138; Installation Kit: $114; Carriers: $355/package. Cable: $0.39/foot</td>
<td>S</td>
<td>Under pavement (inserted in a 3-inch non-metallic conduit placed 21±3inch under the roadway)</td>
</tr>
<tr>
<td>SPVD</td>
<td>$395/unit</td>
<td>S</td>
<td>Under pavement (core drilling an 8 inch hole or using a jack hammer to cut a 6 inch square by 8 inch in depth)</td>
</tr>
<tr>
<td><strong>Active Infrared</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autosense II</td>
<td>$6000-$7500/unit</td>
<td>S</td>
<td>O (20 – 25ft)</td>
</tr>
<tr>
<td><strong>Passive Infrared</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASIM IR</td>
<td>IR 224: $1300/unit</td>
<td>S</td>
<td>O (18 ft)</td>
</tr>
<tr>
<td></td>
<td>IR 254: $700/unit</td>
<td>S</td>
<td>O/S (13-33 ft)</td>
</tr>
<tr>
<td>Siemens PIR-1</td>
<td>$1100/unit</td>
<td>S</td>
<td>O (18 ft)</td>
</tr>
<tr>
<td>Eltec Model 842</td>
<td>$1360/unit</td>
<td>S</td>
<td>O/S</td>
</tr>
<tr>
<td><strong>Microwave Radar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuwave 150LX</td>
<td>$975; An interface panel for two detectors: $150</td>
<td>M</td>
<td>O</td>
</tr>
<tr>
<td>RTMS</td>
<td>$3300/unit</td>
<td>M</td>
<td>O (17-22 ft)</td>
</tr>
<tr>
<td></td>
<td>M (8 separate detection zones)</td>
<td></td>
<td>S (&gt; 17 ft)</td>
</tr>
<tr>
<td>TC 26B</td>
<td>$735/unit</td>
<td>M</td>
<td>O (14-18ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S (14-18 ft, near the immediate area adjacent to desired coverage area)</td>
</tr>
<tr>
<td>Model</td>
<td>Price</td>
<td>System Type</td>
<td>Lane Type 1</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>TDN-30</td>
<td>$995/unit</td>
<td>S</td>
<td>O</td>
</tr>
<tr>
<td>Loren</td>
<td>?</td>
<td>M (4 lanes)</td>
<td>S (19-39 ft)</td>
</tr>
</tbody>
</table>

**Ultrasonic**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
<th>System Type</th>
<th>Lane Type 1</th>
<th>Lane Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane King™</td>
<td>?</td>
<td>Single/Dual (2 separate detection zones)</td>
<td>O (28 ft)</td>
<td>S (12-18 ft)</td>
</tr>
<tr>
<td>TC 30</td>
<td>$475/unit</td>
<td>S</td>
<td>O (12-18 ft)</td>
<td>S (3-5 ft)</td>
</tr>
</tbody>
</table>

**Passive Acoustic**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
<th>System Type</th>
<th>Lane Type 1</th>
<th>Lane Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SmartSonic TSS-I</td>
<td>$5000/unit; A controller card for four sensors: $800.</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>SmarTek SAS – I</td>
<td>$3500/unit</td>
<td>M (5 lanes)</td>
<td>S (25-40 ft)</td>
<td></td>
</tr>
</tbody>
</table>

**Video Image Processing**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
<th>System Type</th>
<th>Lane Type 1</th>
<th>Lane Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoscope</td>
<td>Autoscope solo (2) - Single direction: $4900 Entire intersection: $18000</td>
<td>M (32) (5)</td>
<td>O/S</td>
<td></td>
</tr>
<tr>
<td>VideoTrak</td>
<td>$14000/VIP processor; Camera, cable, housing, cable: $1700 (3)</td>
<td>M (32) (5)</td>
<td>O (recommended) S (possible not good as O)</td>
<td></td>
</tr>
<tr>
<td>Traficon</td>
<td>$4000 per camera (camera, VIP, housing, lens, cables, surge protection, set-up and training) (4)</td>
<td>M (24) (5)</td>
<td>O/S (25-45 ft)</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
Prices listed here may change, and the vendor-authorized dealers should be contacted for a final price.
(1) – The price of JARMAR TRAX-II
(2) – Autoscope solo includes a camera and a processor
(3) – Recommended camera is a Our Philips BW camera with integrated IR filter. Use of non-recommended camera may introduce optical artifacts that reduce system performance.
(4) – A high resolution CCD black/white or color camera. The video camera should provide detailed video without lag, image retention, or geometric distortion.

(5) – Maximum number of detection zones per camera
<table>
<thead>
<tr>
<th>Detector Technology</th>
<th>Operation/Maintenance (SK/year)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Inductive loop on corridor</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Inductive loop at intersection</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Video image processing on corridor</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Video image processing at intersection</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Passive acoustic on corridor</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Passive acoustic at intersection</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Remote Traffic Microwave Sensor</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Sensor on corridor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote Traffic Microwave Sensor</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Sensor at intersection</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: the operation/maintenance costs could be similar for devices with similar difficulties of installation and calibration.

Source: ITS Unit Costs Database (13)
Table 8: Device Cost, Installation Cost and System Life of Detector Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Unit Device cost</th>
<th>Installation cost</th>
<th>System Life (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive loop</td>
<td>$5 – 15</td>
<td>(7)</td>
<td>5 – 15 (4)</td>
</tr>
<tr>
<td>Magnetic</td>
<td>$15</td>
<td>(8)</td>
<td>15 (5)</td>
</tr>
<tr>
<td>Active infrared</td>
<td>$200</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Passive infrared</td>
<td>$200</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Microwave radar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doppler</td>
<td>$200</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>True Presence</td>
<td>$200</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td></td>
<td>$200</td>
<td>7</td>
</tr>
<tr>
<td>Passive acoustic</td>
<td></td>
<td>$400-$500</td>
<td>7</td>
</tr>
<tr>
<td>VIP</td>
<td></td>
<td>$1000 - $1500</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: (1) – Traffic control cost is not considered. Traffic control for a single lane closure can be $1000 - $1500/hr in large urban areas. Intrusive detectors and non-intrusive detectors with overhead installation may require traffic control.
(2) – Installation costs are estimated values, taken from the report, “Vehicle Detection Workshop” by Dan Middleton and Rich Packer.
(3) – It is difficult to decide system life for most detector technologies since they were only applied for a short period. The data in the table is average system life, based on ITS Unit Costs Database (13) and vendor survey results.
(4) – The average failure rate of inductive loops within a district decides the average system life.
(5) – SPVD requires replacing the battery to renew the life every four years.
(6) – Staff time to setup and calibrate a six-lane freeway system is estimated to be $1000 - $1500. Other material costs are included in the unit cost of VIP systems shown in Table 6.
(7) – Installation cost of an inductive loop is included in the unit device cost in Table 6.
(8) - According to the survey on Brian Hagan, State of Idaho Transportation Department, on four highway sites with a total of 16 lanes and 32 probes, the total cost of 3M microloops is $35000, including devices and installation.
? – unknown, □ – Low (< $1000), ■ – Medium ($1000 – $2500), □ – High (> $2500).
Table 9: Error Rates of Detector Devices in Freeway Field Tests

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Mounting Location</th>
<th>Count</th>
<th>Speed</th>
<th>Evaluation Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inductive loop</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saw-cut</td>
<td>Pavement</td>
<td>3%</td>
<td>1.2% - 3.3%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Saw-cut</td>
<td>Pavement</td>
<td>2%</td>
<td>5% - 10%</td>
<td>TTI (8)</td>
</tr>
<tr>
<td>Preformed</td>
<td>Pavement</td>
<td>2%</td>
<td>2% - 5%</td>
<td>TTI (8)</td>
</tr>
<tr>
<td>2. Magnetic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M microloop</td>
<td>Pavement</td>
<td>2.5%</td>
<td>1.4% - 4.8%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>3M microloop</td>
<td>Bridge</td>
<td>1.2%</td>
<td>1.8%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>3M microloop</td>
<td>Pavement</td>
<td>5%</td>
<td>µ : -0.25 mph, σ : 3.6 mph</td>
<td>TTI (3)</td>
</tr>
<tr>
<td>SPVD</td>
<td>Pavement</td>
<td>1%</td>
<td>(Phoenix) 5% - 12% (Florida)</td>
<td>HAC (4)</td>
</tr>
<tr>
<td>4. Active Infrared</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autosense I</td>
<td>Overhead</td>
<td>2.4%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Autosense II</td>
<td>Overhead</td>
<td>0.7%</td>
<td>5.8%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>5. Passive Infrared</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASIM IR 224</td>
<td>Overhead</td>
<td>1%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>ASIM IR 254</td>
<td>Overhead</td>
<td>10.0%</td>
<td>10.8%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Siemens PIR - 1</td>
<td>Overhead</td>
<td>10%</td>
<td></td>
<td>TTI (8)</td>
</tr>
<tr>
<td>6. Microwave Radar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuwave 150LX</td>
<td>Overhead</td>
<td>10%</td>
<td></td>
<td>TTI (8)</td>
</tr>
<tr>
<td>TDN 30</td>
<td>Overhead</td>
<td>2.5% - 13.8%</td>
<td>1%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Overhead</td>
<td>2%</td>
<td>7.9%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Sidefire</td>
<td>5%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Sidefire</td>
<td>3% - 5%</td>
<td></td>
<td>ODOT (6)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Sidefire</td>
<td>3%</td>
<td></td>
<td>SDDOT (5–10)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Sidefire</td>
<td>2.4% - 13.6%</td>
<td>2.6% - 5.9%</td>
<td>TTI (9)</td>
</tr>
<tr>
<td>7. Ultrasonic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC 30</td>
<td>Overhead</td>
<td>2%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Lane King</td>
<td>Overhead</td>
<td>1.2%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
</tbody>
</table>
### 8. Passive Acoustic

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Range</th>
<th>Standard Deviation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAS – I</td>
<td>Sidefire</td>
<td>8% - 16%</td>
<td>4.8% - 6.3%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>SAS – I</td>
<td>Sidefire</td>
<td>4.0% - 6.8%</td>
<td>3.4% - 4.8%</td>
<td>TTI (9)</td>
</tr>
<tr>
<td>SAS – I</td>
<td>Sidefire</td>
<td>10%</td>
<td>µ : -0.5 mph</td>
<td>TTI (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>σ : 4.8 mph</td>
<td></td>
</tr>
<tr>
<td>Smartsonic TSS-1</td>
<td>Overhead</td>
<td>4%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Smartsonic TSS-1</td>
<td>Overhead</td>
<td>15%</td>
<td>µ : 4 mph</td>
<td>TTI (8)</td>
</tr>
</tbody>
</table>

### 9. Video Image Processing

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Range</th>
<th>Standard Deviation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoscope 2004 (1)</td>
<td>Sidefire</td>
<td>5%</td>
<td>Difference range: 5mph</td>
<td>ERAU (5)</td>
</tr>
<tr>
<td>Autoscope 2004</td>
<td>Overhead</td>
<td>2.2% - 10.6%</td>
<td></td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>Sidefire</td>
<td>5%</td>
<td>8%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>Overhead</td>
<td>5%</td>
<td>2.5% - 7%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>Sidefire</td>
<td>2.1% - 3.5%</td>
<td>0.8% - 3.1%</td>
<td>TTI (9)</td>
</tr>
<tr>
<td>VideoTrak 900 (1)</td>
<td>Overhead</td>
<td>1.6% - 4.8%</td>
<td>µ : +1.4 mph</td>
<td>TTI (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>σ : 6.9 mph</td>
<td></td>
</tr>
<tr>
<td>Traficon</td>
<td>Sidefire</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>µ : +1.4 mph</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>σ : 6.9 mph</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5% (45 feet)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10% - 15% (25 –30 feet)</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Traficon</td>
<td>Overhead</td>
<td>2.7% - 4.4%</td>
<td>3% - 7.2%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Traffic Vision</td>
<td></td>
<td>1.8% - 4.8%</td>
<td></td>
<td>TTI (8)</td>
</tr>
</tbody>
</table>

Note: The results in the table represent the tests under optimal operating conditions. 
(1) – Autoscope 2004 is being replaced by the new vision Autoscope 2020; VideoTrak 900 is being replaced by the new vision. 
µ – mean, σ – standard deviation.
MNDOT – Minnesota Department of Transportation, TTI – Texas Transportation Institute, ERAU - Embry-Riddle Aeronautical University, SDDOT – South Dakota Department of Transportation.
Table 10: Error Rates of Detector Devices in Intersection Field Tests

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Technology</th>
<th>Mounting Location</th>
<th>Count</th>
<th>Evaluation Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saw-cut</td>
<td>Inductive loop</td>
<td>Under pavement</td>
<td>3% - 9%</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Eltec Model 833</td>
<td>Passive infrared</td>
<td>Overhead</td>
<td>15%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>TC 30</td>
<td>Ultrasonic</td>
<td>Overhead</td>
<td>&gt; 10%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Lane King</td>
<td>Ultrasonic</td>
<td>Overhead</td>
<td>20%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>SAS-I</td>
<td>Passive Acoustic</td>
<td>Sidefire</td>
<td>0% for presence</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Smartsonic TSS-1 (1)</td>
<td>Passive Acoustic</td>
<td>Overhead</td>
<td>10%</td>
<td>MNDOT (2)</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>VIP</td>
<td>Overhead</td>
<td>18% in right turn lane, 19% in through lane</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Traficon (3)</td>
<td>VIP</td>
<td>Overhead</td>
<td>17% in right turn lane, 13% in through lane</td>
<td>MNDOT (1)</td>
</tr>
<tr>
<td>Vantage</td>
<td>VIP</td>
<td>Overhead</td>
<td>19% for non-proper actuation of signal phases, 8.3% for false detection.</td>
<td>CPSU (11)</td>
</tr>
<tr>
<td>RTMS</td>
<td>Microwave</td>
<td>Sidefire</td>
<td>Could detect the arrival of vehicles approaching the intersection as the inductive loops did</td>
<td>CUNY (14)</td>
</tr>
<tr>
<td>Autoscope, Vantage, (3)</td>
<td>VIP</td>
<td>Overhead/Sidefire</td>
<td>The average discrepancy call frequency is 5.3 calls/cycle and the error rate is about 1.8. The average duration of discrepant calls was about 2.1 seconds/call. During about 20% of the signal cycles, a phase experienced 4.1 missed or unneeded calls, and the total duration of these calls averaged 24.6 seconds per cycle.</td>
<td>TTI (15)</td>
</tr>
</tbody>
</table>

Note: (1) – Manual observations revealed that the device missed and double counted vehicles and that the daily results compensated errors. (2) – The vendor indicated that a different VIP card is designed for use in intersection applications and that the results would be improved by using this card. (3) – Discrepant calls refer to those calls that have discrepancy between the phase-call information provided by the VIPs and the true call information provided by a perfect detector. The discrepant call frequency is the number of discrepant calls per signal cycle and the error rate is the ratio of discrepant calls to true calls.

MNDOT – Minnesota Department of Transportation, TTI – Texas Transportation Institute, CPSU - California Polytechnic State University, CUNY - City University of New York.
## Table 11: Detection Performance on Freeways

<table>
<thead>
<tr>
<th>Detector Technology</th>
<th>Count Accuracy</th>
<th>Speed Accuracy</th>
<th>Classification Accuracy (1)</th>
<th>Environmental Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Volume</td>
<td>High Volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive loop</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Magnetic</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>?</td>
</tr>
<tr>
<td>Pneumatic road tube</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>?</td>
</tr>
<tr>
<td>Active infrared</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Passive infrared</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td><strong>Radar</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doppler</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>True presence</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Passive acoustic</td>
<td>□</td>
<td>□</td>
<td>□/□</td>
<td>□</td>
</tr>
<tr>
<td>Pulse ultrasonic</td>
<td>□</td>
<td>□</td>
<td>□ (2)</td>
<td>□</td>
</tr>
<tr>
<td>VIP</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

Note:
- □ = Excellent (< 5%); □ = Fair (< 10%); □ = Poor (> 10%); ? = Unknown
- (1) – The classification accuracy rate refers to the project report: “Evaluation of Some Existing Technologies for Vehicle Detection” (10).
- (2) – Referred to (10).
Table 12: The Impacts of Environmental and Traffic Factors on the Performance of Detector Technologies

<table>
<thead>
<tr>
<th>Detector Type</th>
<th>Environmental Impact</th>
<th>Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Penetration</td>
<td>Wind</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive Loop</td>
<td>✓ (2)</td>
<td>✓</td>
</tr>
<tr>
<td>Magnetic</td>
<td>✓ (2)</td>
<td>✓</td>
</tr>
<tr>
<td>Pneumatic Road Tube</td>
<td>✓ (2)</td>
<td>✓</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Infrared</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>Passive Infrared</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Microwave</td>
<td>✓ (3)</td>
<td>✓</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Passive Acoustic</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>Video Image</td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>

Note: × - affected, ✓ - not affected

(1) The temperatures are extremely low or high and each detector device has its own operating temperature range.
(2) They may possibly be damaged by snow removal equipment.
(3) The RTMS vendor mentions that rain and snow smaller than ten millimeters should not hinder detection capabilities.
(4) Doppler microwave is not good at stop-and-go conditions.
(5) VIP systems are incorporating a variety of new features to reduce the impacts of environmental factors on detection accuracy, such as image stabilization algorithm, sun location algorithm, night reflecting algorithm, contrast loss detector, and advance detector.
### Table 13: The Ease of Installation and Reliability of Detector Devices

<table>
<thead>
<tr>
<th>Technology/Sensor</th>
<th>Ease of installation</th>
<th>Ease of calibration</th>
<th>Reliability&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive loop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M Microloop</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>SPVD</td>
<td>□ (3)</td>
<td>□ (3)</td>
<td>□ (3)</td>
</tr>
<tr>
<td>Pneumatic Road Tube</td>
<td>□ (3)</td>
<td>□ (3)</td>
<td>□ (3)</td>
</tr>
<tr>
<td>Active infrared</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Autosense I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autosense II</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Passive infrared</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Eltec Model 833</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>ASIM IR 224</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>ASIM IR 254</td>
<td>□</td>
<td>□ (1)</td>
<td>□</td>
</tr>
<tr>
<td>Semens PIR-1</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Microwave</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>TC-26 B</td>
<td>□</td>
<td>□</td>
<td>?</td>
</tr>
<tr>
<td>TDN-30</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>ECM Loren</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Accuwave 150LX</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>RTMS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Ultrasonic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane King</td>
<td>■</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC-30</td>
<td>□</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Passive acoustic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SmarTek SAS-1</td>
<td>■</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Smartsonic TSS-1</td>
<td>■</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td><strong>VIP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autoscope 2004</td>
<td>■</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Autoscope Solo</td>
<td>□</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VideoTrak 900</td>
<td>■</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Traficon</td>
<td>■</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Vantage</td>
<td>?</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

**Note:**
- ■ Denotes a sensor that performed satisfactorily in the stated condition.
- □ Denotes a sensor that meets some but not all the criteria for satisfactory performance in the stated condition.
- ■ Denotes a sensor that does not perform satisfactorily in the stated condition.
- ? Denotes a situation that could not be confirmed.
(1) – ASIM IR 254 was difficult to calibrate for sidefire installation because of alignment complications.
(2) – Reliability level is based only on the performance shown in the tests.
(3) – The evaluation is based on the information from survey responses or experience.
(4) – Autoscope 2004 is being replaced by the new vision Autoscope 2020; VideoTrak 900 is being replaced by the new vision.

**Source:** MNDOT tests (1, 2)
### Table 14: Ease of Installation and Maintenance of Detector Technologies

<table>
<thead>
<tr>
<th>Detector Technology</th>
<th>Ease of Installation</th>
<th>Ease of Calibration</th>
<th>Maintenance Requirement&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive Loop</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Magnetic</td>
<td>□</td>
<td>□</td>
<td>?</td>
</tr>
<tr>
<td>Pneumatic Road Tube</td>
<td>□</td>
<td>□</td>
<td>/</td>
</tr>
<tr>
<td>Active Infrared</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Passive Infrared</td>
<td>□</td>
<td>□∥□&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>□</td>
</tr>
<tr>
<td>Microwave Radar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doppler</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>True Presence</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Passive Acoustic</td>
<td>□</td>
<td>□</td>
<td>□∥□</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>VIP</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

Note: □ – Excellent/Low, □ – Fair/Medium, □ – Poor/High, ? – unknown, / - inapplicable.

<sup>(1)</sup> – Sidefire installation is difficult because of alignment complications

<sup>(2)</sup> – The maintenance requirement refers to the project report: “Evaluation of Some Existing Technologies for Vehicle Detection” (10)
<table>
<thead>
<tr>
<th>Detector Device</th>
<th>Device</th>
<th>Unit Quantity</th>
<th>Cost</th>
<th>Installation</th>
<th>Annual Maintenance Cost</th>
<th>System Life (Year)</th>
<th>Life-Cycle Cost (per system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive loop</td>
<td>12 loops</td>
<td>$9000 (1)</td>
<td>/</td>
<td>$700</td>
<td>5</td>
<td>$2720</td>
<td></td>
</tr>
<tr>
<td>3M Microloop</td>
<td></td>
<td>$13125(2)</td>
<td></td>
<td>$200</td>
<td>15</td>
<td>$1380</td>
<td></td>
</tr>
<tr>
<td>Autosense II</td>
<td>6 Autosense II</td>
<td>$36000</td>
<td>O</td>
<td>$3200 (3)</td>
<td>$600</td>
<td>7</td>
<td>$7130</td>
</tr>
<tr>
<td>ASIM IR 254</td>
<td>6 ASIM IR 254</td>
<td>$4200</td>
<td>O</td>
<td>$3200 (3)</td>
<td>$600</td>
<td>7</td>
<td>$1832</td>
</tr>
<tr>
<td>Siemens PIR-1</td>
<td>6 Siemens PIR-1</td>
<td>$6600</td>
<td>O</td>
<td>$3200 (3)</td>
<td>$600</td>
<td>7</td>
<td>$2230</td>
</tr>
<tr>
<td>RTMS</td>
<td>One unit per direction</td>
<td>$6600</td>
<td>O</td>
<td>$2400 (3)</td>
<td>$200</td>
<td>7</td>
<td>$1700</td>
</tr>
<tr>
<td>TC 26B</td>
<td>One unit per direction</td>
<td>$1470</td>
<td>O</td>
<td>$2400 (3)</td>
<td>$200</td>
<td>7</td>
<td>$850</td>
</tr>
<tr>
<td>TDN 30</td>
<td>One unit per direction</td>
<td>$5970</td>
<td>O</td>
<td>$3200 (3)</td>
<td>$600</td>
<td>7</td>
<td>$2130</td>
</tr>
<tr>
<td>SmarTek SAS-1</td>
<td>One unit per direction</td>
<td>$7000</td>
<td>S</td>
<td>$800</td>
<td>$400</td>
<td>7</td>
<td>$1980</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>One camera per direction</td>
<td>$9800</td>
<td>O</td>
<td>$3000 (3)</td>
<td>$400</td>
<td>10</td>
<td>$1730</td>
</tr>
<tr>
<td>VideoTrak 900</td>
<td>One camera per direction</td>
<td>$17400</td>
<td>O</td>
<td>$3000 (3)</td>
<td>$400</td>
<td>10</td>
<td>$2920</td>
</tr>
<tr>
<td>Traficon</td>
<td>One camera per direction</td>
<td>$8000</td>
<td>O</td>
<td>$3000 (3)</td>
<td>$400</td>
<td>10</td>
<td>$1760</td>
</tr>
</tbody>
</table>

Note: A typical freeway location has two directions, and three lanes at each direction. Data needs are traffic count and speed.
Cost information is based on Tables 6, 7 and 8.
1. The average loop cost is $750, including installation cost.
2. According to the survey on Brian Hagan, State of Idaho Transportation Department, on four highway sites with a total of sixteen lanes and thirty-two probes, the total cost of 3M microloops is $35000, so the estimation cost including devices and installation of six lanes and twelve probes is calculated proportionately.
3. Overhead installation considers traffic control, assumed as $1000 per direction.
4. Siemens PIR-1 cannot provide speed data.
## Table 16: Estimated Life-cycle Costs for a Typical Intersection Application

<table>
<thead>
<tr>
<th>Detector Device</th>
<th>Device</th>
<th>Unit Quantity</th>
<th>Cost</th>
<th>Installation Cost</th>
<th>Annual Maintenance Cost</th>
<th>System Life (Years)</th>
<th>Life-Cycle Cost (per system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive loop</td>
<td>32 loops, 3 loops for one through lane, and 2 loops for one left turn pocket</td>
<td>$24000</td>
<td>/</td>
<td>$1300</td>
<td>5</td>
<td>$6700</td>
<td></td>
</tr>
<tr>
<td>SPVD</td>
<td>16 SPVD detectors, 16 batteries, 4 receivers, 1 pole mounted antenna, 1 receiver multi-coupler</td>
<td>$9700</td>
<td>$12000 (1)</td>
<td>$360 (1)</td>
<td>15</td>
<td>$2310</td>
<td></td>
</tr>
<tr>
<td>ASIM IR 254</td>
<td>12 ASIM IR 254</td>
<td>$8400</td>
<td>O</td>
<td>$6400 (2)</td>
<td>$200</td>
<td>7</td>
<td>$2670</td>
</tr>
<tr>
<td>Siemens PIR-1</td>
<td>12 Siemens PIR-1</td>
<td>$13200</td>
<td>S</td>
<td>$2400</td>
<td>$200</td>
<td>7</td>
<td>$2800</td>
</tr>
<tr>
<td>Eltec Model 842</td>
<td>12 Eltec Model 842</td>
<td>$16320</td>
<td>O</td>
<td>$6400 (2)</td>
<td>$200</td>
<td>7</td>
<td>$4000</td>
</tr>
<tr>
<td>RTMS</td>
<td>4 RTMS</td>
<td>$13200</td>
<td>O</td>
<td>$4800 (2)</td>
<td>$100</td>
<td>7</td>
<td>$3100</td>
</tr>
<tr>
<td>TC-30</td>
<td>12 TC30</td>
<td>$5700</td>
<td>O</td>
<td>$6400 (2)</td>
<td>$200</td>
<td>7</td>
<td>$2220</td>
</tr>
<tr>
<td>SmarTek SAS-1</td>
<td>4 SmarTek SAS-1</td>
<td>$13000</td>
<td>S</td>
<td>$1600</td>
<td>$300</td>
<td>7</td>
<td>$2740</td>
</tr>
<tr>
<td>Autoscope solo</td>
<td>4 Autoscope solo</td>
<td>$18000</td>
<td>O</td>
<td>$8000 (2)</td>
<td>$200</td>
<td>10</td>
<td>$3400</td>
</tr>
<tr>
<td>VideoTrak 900</td>
<td>4 cameras</td>
<td>$20800</td>
<td>O</td>
<td>$8000 (2)</td>
<td>$200</td>
<td>10</td>
<td>$3750</td>
</tr>
<tr>
<td>Traficon</td>
<td>4 cameras</td>
<td>$16000</td>
<td>O</td>
<td>$8000 (2)</td>
<td>$200</td>
<td>10</td>
<td>$3160</td>
</tr>
</tbody>
</table>

Note:
A typical intersection has four approaches, with two through lanes and one left-turn pocket at each approach. The signal phases are four phases, with two through phases and two left-turn protected phases.
Cost information is based on Tables 6, 7 and 8.
1. Including battery replacement every four years.
2. Overhead installation considers traffic control, assumed as $1000 per approach.
3. It is estimated at $3000 per approach.
4. REFERENCE


3. Dan Middleton and Rick Parker, Initial Evaluation of Selected of Detectors to Replace Inductive Loops on Freeway, FHWA/TX-00/1439-7, April 2000.


