Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics

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Abstract. Video cameras and computer image processors have recently come into widespread use for the detection of vehicles at intersection stop lines for signal actuation purposes. These are considered direct replacements for traditionally used inductive loop detectors or similar in-ground sensing methods. While the task of simply detection the presence, or non-presence of a vehicle is straightforward, the image processing task is very challenging, particularly due the reliance upon ambient illumination of the processed scene, and the wide array of environmental conditions. In addition, the accuracy requirements are high, since, in the extreme case, a failure to detect may leave a vehicle stranded at a stop line, and false detections on a non-main arterial street could significantly reduce traffic flow efficiency. Manufacturer's accuracy and robustness claims vary in the metrics used and data reported, and are selective and inconsistent between competing products. The work reported herein is directed toward the establishment of and justification of a common set of performance metrics and test procedures for intersection traffic detection systems in general, with emphasis upon video-based detection systems. The application of these metrics and methods will be illustrated from direct experience in the evaluation of an early technology (1996) video detection product under an FHWA-sponsored field operational test.

INTRODUCTION

Video-based traffic detection systems for intersection signal actuation are generally characterized by one or more conventional CCD video surveillance cameras placed in elevated positions with views of each intersection approach, and a central processor usually located in the signal cabinet, which determines and reports to the signal controller the presence or non-presence of a vehicle at each stop line or advanced approach to the intersection. A typical system deployment is illustrated in Figure 1. The placement of a detection camera is shown in Figure 2, and a typical processor installation in a signal control cabinet is shown in Figure 3.

Video-based detection methods have a number of distinct advantages over traditional in-ground sensors. Among these are rapid and possibly temporary deployment, and installation at intersections in which the pavement may not be suitable for fixed ground detectors. Total cost may be attractive, in view of the expense and inconvenience required for the installation of in-ground detectors. This is especially true at larger intersections with as many as five or six lanes per approach. Life cycles have the potential to be favorable in comparison, considering the excessive pavement wear in area of intersection approaches and stop lines. And systems of this type can easily measure and record additional traffic performance metrics, such as vehicle counts, queue length, vehicles speeds, or vehicle classification.

However, video-based systems require the prior existence or supplementary installation of support structures for cameras, typically one camera per approach direction. Some intersection orientations may require the placement of cameras with fields of view directly into the sun or pavement glare during some hours of operation, or with detection zones in areas of inadequate illumination at night. Power to and signal routing from the cameras to common traffic control may be a design challenge in some cases. And routine camera maintenance, especially that associated with the optics, may be required.
The requirements for an intersection vehicle detection sensor, video or otherwise, are extremely demanding. Vehicle drivers rely upon the proper function of this system under all possible traffic conditions, at all times of the day, under all possible weather conditions. The system must also be adaptable for all possible camera placement configurations and all possible approach layouts. This degree of robustness and adaptability is especially important when considering deployment over a large network of intersections, since the cost of using different detection sensors at different intersections may defeat the economic advantages of the alternative sensor.

It is appropriate to contrast these requirements with those of more typical video-computer-vision-based systems designed to measure traffic flow metrics such as count, average speed, volume, average headway, or queue length (1,2). For this latter class of systems, camera placements can be much better specified in practice, without the a priori constraints of every possible intersection in a network. The ramifications of incorrect detection are typically only statistical errors, which tend to anneal over time and traffic volume. Compare this with the possibility of vehicle waiting indefinitely at a red light, the result of a failure to detect for an intersection detector.

Regardless, video-based vehicle presence detectors have been found to be suitable and sufficiently reliable in many situations and appear to be growing in popularity. Among the manufacturers of these systems are references (3,4,5,6,7,8,9).

![Figure 1. Typical deployment of a video-based vehicle detection system at an intersection, from [7].](image)

The accuracy and operational performance of advanced detection systems for intersections have been varied, and often vaguely defined metrics such as "detection accuracy" are reported in marketing materials and system specifications, there has been little consistency in the test conditions, methods and metrics used by each manufacturer, user, or independent testing group. Reported here is the result of an analysis of both what is
important for effective intersection vehicle detection, and what is possible within the constraints of the video sensing technology. The culmination is a suggested set of test procedures and measures of effectiveness (MOEs) applicable to the comparative testing of video-based and other advanced intersection detection technologies. These recommendations are not unique, and are not applicable for all possible deployments. But they represent a comprehensive effort to understand and quantify the effectiveness of vehicle sensing over a range of traffic scenarios and test conditions, and the actual impacts of correct or incorrect detection on traffic flow.

Figure 2. Typical camera position above intersection, with view of approach. Cameras are usually mounted on existing street light luminaires, as indicated by dotted circle.

EVALUATION AND TEST METHODOLOGY

We segregated our test procedures along the lines of two objectives: raw vehicle detection accuracy under a range of traffic scenarios, and extrapolated effects on traffic control efficiency. We defined nine detection event classes for each scenario, and assessed potential impacts on intersection traffic flow in six phase actuation classes. A range of lighting, camera placement, environmental and traffic conditions are possible and ideally, should be evaluated. These may vary according to the geographic region, intersection size or configuration, and expected traffic density (e.g., urban, suburban, or rural). A list of some possible test conditions, applicable to warmer climates (snow and sleet conditions are excluded), is shown in Table 1. For practical reasons, not all event classes can be examined under all combinations of these test conditions. Instead, a representative and balanced sample of test conditions is sought, constrained by expected conditions during the allowable test period. Data for all event classes are sought (but not always obtained) under each testable combination of conditions. One possible set of testable combinations of these conditions for a Southern California urban deployment is listed in Table 2. Each combination of conditions defines a particular test sequence,
Figure 3. Typical installation of central video processor in signal control cabinet. Processor is indicated by a dashed square.

Table 1: List of some possible test conditions applicable to southern California urban intersection.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Environmental</td>
<td>2. Axial camera position</td>
</tr>
<tr>
<td></td>
<td>a. Clear</td>
</tr>
<tr>
<td></td>
<td>b. Fog</td>
</tr>
<tr>
<td></td>
<td>c. Rain</td>
</tr>
<tr>
<td></td>
<td>a. Directly above traffic lane</td>
</tr>
<tr>
<td></td>
<td>b. Roadside, approximately 20 degrees off traffic axis</td>
</tr>
<tr>
<td>a. Overhead, full sun</td>
<td>a. None</td>
</tr>
<tr>
<td>b. Steep incidence angle, transverse</td>
<td>b. Wind-induced vibration (horizontal, sway)</td>
</tr>
<tr>
<td>c. Steep incidence angle, into sun</td>
<td>c. Ground-induced vibration (vertical, due to heavy vehicle)</td>
</tr>
<tr>
<td>d. Steep incidence angle, away from sun</td>
<td>d. Electromagnetic interference (auto ignition)</td>
</tr>
<tr>
<td>e. Low light (dusk/dawn)</td>
<td>e. Compromised power quality (power line noise)</td>
</tr>
<tr>
<td>f. Night</td>
<td>f. Degraded video signal (ohmic connection or line)</td>
</tr>
<tr>
<td></td>
<td>g. Optical degradation (dust on window)</td>
</tr>
<tr>
<td></td>
<td>h. Optical degradation (water drops on window)</td>
</tr>
<tr>
<td>5. Traffic Level of Service (LOS)</td>
<td>6. Number of Lanes</td>
</tr>
<tr>
<td>a. LOS A-B</td>
<td>a. 1</td>
</tr>
<tr>
<td>b. LOS C-D</td>
<td>b. 2</td>
</tr>
<tr>
<td>c. LOS E-F</td>
<td>c. 3</td>
</tr>
<tr>
<td></td>
<td>d. 4</td>
</tr>
<tr>
<td>7. Camera angle (steepness)</td>
<td>8. Camera height</td>
</tr>
<tr>
<td>a. Shallow (&lt;10 degrees)</td>
<td>a. high (&gt;8 meters)</td>
</tr>
<tr>
<td>b. Steep (&gt;10 degrees)</td>
<td>b. medium (5-8 meters)</td>
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<tr>
<td></td>
<td>c. low (&lt;5 meters)</td>
</tr>
</tbody>
</table>
that are recorded on high-resolution (e.g., S-VHS, DV, Super 8) video tape from actual camera feeds for a fixed sample duration, typically one half to one hour, not including a setup and "warm up" period (for image registration) prior to the actual start of the test sequence. The collection of test sequences, representative of obtainable combinations of test conditions, constitutes a video test suite. Actual system tests are conducted, with the system or systems under test sourced from the video test suite tapes, and the detection results for each system concurrently recorded for manual verification off line.

Camera placement and field of view are critical requirements for the proper operation of any video-based detection system. The cameras must be placed with an adequate lateral field of view to permit coverage of required detection zones, and sufficiently above the road surface to avoid obscuration of detection zones by cross-traffic. Detection zones are defined graphically, usually as an overlay on top of the traffic video display, during the setup and calibration of the system; some systems require hookup to a PC to run setup software, while others are self-contained. Detection zones are general located at the stop line for each lane of an approach, but upstream detection zones may optionally be defined (within the camera field of view) for signaling queue length or vehicle approach for adaptive intersection control algorithms.
Table 2: Sample combinations of test conditions, used to form basis of video test suite.

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</tr>
</thead>
<tbody>
<tr>
<td>1. clear ovhd sun</td>
<td>A-B</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. clear ovhd sun</td>
<td>C-D</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. clear ovhd sun</td>
<td>E-F</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. clear ovhd sun</td>
<td>A-B</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. clear ovhd sun</td>
<td>C-D</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. clear ovhd sun</td>
<td>E-F</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. clear transverse</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. clear transverse</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. clear into sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. clear into sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. clear low light</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. clear low light</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. clear night</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>above</td>
<td>7-9 m</td>
<td>steep</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. clear night</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. rain day</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. rain night</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. fog day</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. fog night</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>wind vib</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>grnd vib</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>local EM</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>dust</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. clear night</td>
<td>B-E</td>
<td>2-4</td>
<td>dust</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. rain day</td>
<td>B-E</td>
<td>2-4</td>
<td>droplets</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. rain night</td>
<td>B-E</td>
<td>2-4</td>
<td>droplets</td>
<td>roadside</td>
<td>7-9 m</td>
<td>steep</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>shallow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. clear into sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>7-9 m</td>
<td>shallow</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>&gt;9 m</td>
<td>steep</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. clear ovhd sun</td>
<td>B-E</td>
<td>2-4</td>
<td>none</td>
<td>roadside</td>
<td>&lt;7 m</td>
<td>shallow</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. From cameras located at very high traffic urban intersection.
2. Fog density sufficient to diffuse image or cause headlight backscatter.
3. Auto ignition noise, unshielded, 0.5 meter from system enclosure.
4. Light dust coating on camera enclosure window.
5. Raindrops on camera enclosure window.
6. Sun at approximately 10 degree incidence angle to road surface.
7. Maximum camera height available.
8. Camera height set at threshold of vehicle obscuration.
VEHICLE DETECTION TEST PROCEDURES

We identified nine possible vehicle detection event classes:

1. Correct Detection
   A vehicle is detected when it enters a detection zone, stays continuously detected while in the zone, and detection ceases when it leaves the zone.

2. Detection with Latch
   A vehicle is detected when present in a detection zone, stays continuously detected while in the zone, but detection remains on indefinitely after it leaves the zone.

3. Multiple Detections
   A vehicle is detected when present in a zone, but while in the zone detection ceases and repeats at least once, including the possibility of a final latch condition.

4. Failure to Detect
   A vehicle is not detected at all when present in a detection zone.

5. Drop After Detection
   A vehicle is initially detected after entering a zone, but later dropped (and not redetected) while stationary in the zone.

6. Tailgate
   Detection remains on for the second and possibly later vehicles following the leader in a platoon. (Detection correct for presence purposes such as signal actuation, but not for count or queue length determination purposes.)

7. Tailgate with Latch
   Tailgate event, but detection remains on indefinitely after last car in platoon leaves.

8. False Detection
   Detection reported when no vehicle present or near detection zone. Detection ceases when either the causal image artifact is no longer present or after five seconds.

9. False Detection with Latch
   False detection which stays on indefinitely.

In the detection event class samples that follow in Figures 4.1 through 4.9, an active detection is indicated by the illumination of the four corners of the detection window in the captured video screen image. The box in each site plan indicates where the event occurred.
Figure 4.1. Event Class 1: Correct Detection

Figure 4.1. Event Class 2: Detection with Latch

Figure 4.3. Event Class 3: Multiple Detection

Figure 4.4. Event Class 4: Failure to Detect
Figure 4.5. Event Class 5: Dropped After Detection

Site Plan:

Figure 4.6. Event Class 6: Tailgate (Failure to count subsequent vehicles)

Site Plan:

Figure 4.7. Event Class 7: Tailgate with Latch After Final Vehicle

Site Plan:

Figure 4.8. Event Class 8: False Detection

Site Plan:
Test results are reported as the number of occurrences of each detection event class, during each test suite condition. A sample result listing for Test Sequence 2 (clear, overhead sun, no noise, traffic LOS C-D) is shown in Table 3. In this table, **Total Detections** refers to the sum of the left column, which are all vehicle detections reported by the system, either correctly or incorrectly. Detection event class results shown in *bold italics* represent actual vehicles that were either detected (left column) or not detected (right column) by the system under test. Detection class results in the left column which are not shown in bold italics represent non-existent vehicles falsely detected by the system. The raw detection event data from which Table 3 is constructed are shown in Table 4.

**Table 3. Sample results for Test Sequence 2 (clear, overhead sun, LOS C-D), 15 minutes, 210 actual vehicles**

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Correct Detection</strong></td>
<td>173</td>
</tr>
<tr>
<td><strong>Detection with Latch</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Dropped After Detection</strong></td>
<td>1</td>
</tr>
<tr>
<td>Multiple Detections</td>
<td>2</td>
</tr>
<tr>
<td>False Detection</td>
<td>20</td>
</tr>
<tr>
<td>False Detection with Latch</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Detections</strong></td>
<td>201</td>
</tr>
<tr>
<td><strong>Failure to Detect</strong></td>
<td>14</td>
</tr>
<tr>
<td><strong>Tailgate</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Tailgate with Latch</strong></td>
<td>2</td>
</tr>
</tbody>
</table>
Table 4. Raw detection event data for Test Sequence 2 (clear, overhead sun, LOS C-D).

<table>
<thead>
<tr>
<th>Vehicle Detection</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
<th>Lane 4</th>
<th>Lane 5</th>
<th>All Lanes</th>
<th>All Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Detection</td>
<td>29</td>
<td>76</td>
<td>55</td>
<td>10</td>
<td>3</td>
<td>173</td>
<td>82.4%</td>
</tr>
<tr>
<td>Detection w/ Latch</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td>5</td>
<td>2.4%</td>
</tr>
<tr>
<td>Multiple Detections (Additional</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>detections of correctly detected vehicle)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure to Detect</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>14</td>
<td>6.7%</td>
</tr>
<tr>
<td>Dropped after Detection</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Tailgate</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>15</td>
<td>7.1%</td>
</tr>
<tr>
<td>Tailgate w/ Latch</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1.0%</td>
</tr>
<tr>
<td>False Detection</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>20</td>
<td>9.5%</td>
</tr>
<tr>
<td>False Detection w/ Latch</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total Detections</td>
<td>30</td>
<td>77</td>
<td>61</td>
<td>16</td>
<td>17</td>
<td>201</td>
<td>95.7%</td>
</tr>
<tr>
<td>Actual Vehicles</td>
<td>40</td>
<td>82</td>
<td>63</td>
<td>11</td>
<td>14</td>
<td>210</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

PHASE ACTUATION TEST PROCEDURES

The impact of the detection system's performance on the actual traffic flow through the intersection is assessed by MOE's related to the actuation of signal phases. Six phase actuation event classes are identified, consistent with standard terminology (10). Phase detection event classes are recorded only once for each main phase for the selected approach. For a simple intersection, this would be the red and green phases. Note that test results against these metrics are highly dependent on the traffic encountered during the test sequence, as well as the intersection configuration and control cycle. Therefore, test results are deemed only applicable for comparison of two or more systems using the same video test quite.

Assuming that all lanes of a particular intersection approach are monitored by the detection system, we treat all through lanes in one set, and if present, all protected left turn lanes in another set. Similarly for protected right turn lanes if present. Non-exclusive left or right turn lanes are treated as part of the through set. All lanes in each set are logically OR'ed together for data collection purposes. This means that a detection event is recorded whenever a vehicle is reported by the system in any detection zone in the set.

We subdivide the six phase actuation events into three types for each of the two main signal intervals possible for each approach set (usually through or protected left). Each phase actuation event is defined below and illustrated in Figures 5.1 through 5.6, each with a sample video frame.

Red Interval (Effecting Actuation of Red/Green Transition)

1. Correct actuation (Correct).
   During red interval, detection within one second of arrival of first vehicle, and detection held constant by logical OR of all lanes until observed R/G transition.

2. Failure to actuate correctly (Fail).
   During red interval, first vehicle not detected within one second of arrival or, after initial detection, logical OR of detection zones for all waiting vehicles FALSE at any time prior to observed R/G transition.
3. False actuation (False).
During red interval, when no vehicles are present in any detection zone, detection occurs, either continuous or intermittent.

Note that both (2) and (3) (Fail and False) can occur during the same interval.

Green Interval (Effecting Actuation of Green/Red Transition)

4. Correct green extension.
   During green interval, every vehicle or platoon* is detected and no false detections occur.

5. Potential failure to extend green.
   During green interval, one or more vehicle(s) or platoon(s)* was not detected.

6. Potentially false green extension.
   During green interval, detection occurred when no vehicle or vehicles was/were present.

* A platoon is defined for this purpose as a set of vehicles separated by less than one second, even if the vehicles are in different lanes within the same approach set.
Figure 5.3. Phase Actuation Class 3: Red interval (call for R/G transition) potential false actuation.

Figure 5.4. Phase Detection Class 4: Green interval (green extension) correct extension.

Figure 5.5. Phase Detection Class 5: Green interval (green extension) potential failure to extend green.

Figure 5.6. Phase Detection Class 6: Green interval (green extension) potentially false green extension.
Phase actuation test results as the number of occurrences of each phase actuation event class, during each test suite condition. A sample result listing for Test Sequence 2 (clear, overhead sun, no noise, traffic LOS C-D) is shown in Table 5. The raw detection event data from which Table 5 is derived are shown in Table 6.

Table 5. Sample phase actuation results, test sequence 2 (clear, overhead sun, LOS C-D), 15 minutes.
Total of 7 through cycles and 6 left turn cycles.

<table>
<thead>
<tr>
<th>Correct Actuation</th>
<th>Failure to Actuate</th>
<th>False Actuation</th>
<th>Fail and False</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Interval</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Green Interval</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Left Turn

<table>
<thead>
<tr>
<th>Correct Actuation</th>
<th>Failure to Actuate</th>
<th>False Actuation</th>
<th>Fail and False</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Interval</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Green Interval</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 6. Sample phase actuation raw test results, test sequence 2 (clear, overhead sun, LOS C-D), 15 minutes.
Total of 7 through cycles and 6 left turn cycles.

<table>
<thead>
<tr>
<th>TIME</th>
<th>Thru</th>
<th>R-G Correct</th>
<th>R-G FALSE</th>
<th>G-R Correct</th>
<th>G-R FALSE</th>
<th>Left R-G Correct</th>
<th>Left R-G FALSE</th>
<th>Left G-R Correct</th>
<th>Left G-R FALSE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:45:17</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:47:42</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:50:04</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:52:23</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:54:46</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:56:58</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>0:59:25</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>7</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Tot Correct</td>
<td>17</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>% Correct</td>
<td>63.0%</td>
<td>14.8%</td>
<td>22.2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OVERALL PERFORMANCE ASSESSMENT

Any vehicle detection sensor or system must function continuously, 24 hours per day, 365 days per year, over a wide range of environmental and traffic conditions. Test conditions represented in any given test suite do not map linearly to year-long performance, since test conditions are not equally weighted over the course of a day or year. A composite metric of performance may be desirable, with a realistic mapping to the long-term overall performance of the system. Normalized overall scores may be generated for each detection event class using appropriate weightings of each test condition, reflective of average annual climatic and average daily traffic conditions.
The weighting factors are applied to each of the test conditions, such that common conditions of medium traffic, overhead sun light and regular night illumination predominate, while less common conditions such as transitional lighting, rain, and wind are less emphasized. Since the weighting factors applied cannot be entirely objective in their derivation, and not all conditions might not be included in the test suite, any overall score derived from available data and weighting factors should be considered only one view of the data, subject to multiple interpretations.

The general idea is to assess and fairly weight a range of conditions, representative of both time-dependent changes and the diversity of traffic conditions, intersection configurations, and camera placements possible within the study area. For example, normal daylight and night conditions predominate, transitional and glare lighting occurs a smaller percentage of the time, while rain and wind conditions are rare. Also, light-to-moderate traffic conditions dominate, especially at night, while heavy traffic occurs only for limited daily periods. Since EM noise, alternative camera use, and large wires in the field of view represent problems that would probably be corrected in the deployment, they may be discarded in the overall assessment at the discretion of the evaluator. Some test conditions in the test suite may be redundant, or excessively dominant. Therefore, a composite result may be based on a significantly reduced subset of the test scenarios in a given test suite.

Table 7 shows one possible set of daily weighting factors for each test condition, and indicates which test condition, in each of three categories (illumination, traffic, and environment), is represented in each Test Sequence (TSx). The specifications category is a gating factor - 100% for ideal and 0% for non-deal operational conditions. The product of each of the four factors becomes the composite weighting factors for each Test Sequence in the Test Suite (note that not all Test Sequences are included.)

| Table 7. Derivation of Weighting Factors for Composite Metrics |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Illumination** | **Available Test Data** | **Total** |
| Day, overhead/diffuse | 7 | 29.17% | X | X | X | X | X | X | X | X | X | X | X |
| Night | 9 | 37.50% | X | X |
| Transverse | 4 | 16.67% | X |
| Dawn/Dusk | 3 | 12.50% | X |
| Glare | 1 | 4.17% | X |
| **Traffic** | **Total** |
| Light (LOS A-B) | 8 | 33.33% | X |
| Moderate (LOS C-D) | 2 | 8.33% | X |
| Heavy (LOS E-F) | 2 | 8.33% | X |
| Varied (LOS B-E) | 12 | 50.00% | X | X | X | X | X | X | X | X | X | X | X |
| **Environment** | **Total** |
| Calm (clear or overcast) | 310 | 84.93% | X | X | X | X | X | X | X | X | X | X |
| Rain (possibly with wind) | 30 | 8.22% | X | X |
| Wind (without rain) | 20 | 5.48% | X | X |
| Other (no TC data) | 5 | 1.37% | X | X |
| **Specifications** | **Total** |
| Ideal | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Non-ideal | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Composite % | 8.26% | 2.06% | 7.08% | 1.77% | 5.31% | 15.92% | 1.20% | 1.54% | 0.80% | 0.00% | 0.00% | 0.00% | 43.94% |

The weighting factors are observed estimates only, since the time of transition between dawn/day, day/dusk, dusk/night, etc., are not rigorously established. Also, the annual percentage of time that windy conditions above a certain threshold might prevail, or rain is expected, cannot be readily determined from published weather data, which is reported in terms of days in which thresholds were exceeded or total volume (i.e., rainfall) rather than net hours in which the condition was observed. However, the exactness of this hourly distribution is probably not
critical to the validity of the conclusion. For comparative purposes, we define an *average test day* based upon the distribution in Table 7 and summarized in Table 8 below.

**Table 8. Summary of time-dependent weighting factors for composite performance metrics.**

<table>
<thead>
<tr>
<th>Test Cond No. (i)</th>
<th>Condition Description</th>
<th>Yearly Avg Hrs / Day</th>
<th>Normalized Weighting Factor (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>overhead sun, light traffic</td>
<td>4</td>
<td>0.1879</td>
</tr>
<tr>
<td>2</td>
<td>overhead sun, moderate traffic</td>
<td>4</td>
<td>0.0470</td>
</tr>
<tr>
<td>4</td>
<td>transverse sun, varied traffic</td>
<td>4</td>
<td>0.1611</td>
</tr>
<tr>
<td>5</td>
<td>sun glare, varied traffic</td>
<td>1</td>
<td>0.0403</td>
</tr>
<tr>
<td>6</td>
<td>dawn/dusk, varied traffic</td>
<td>2</td>
<td>0.1208</td>
</tr>
<tr>
<td>7</td>
<td>night, varied traffic</td>
<td>8</td>
<td>0.3624</td>
</tr>
<tr>
<td>8</td>
<td>rain, mid-day, varied traffic</td>
<td>0.25</td>
<td>0.0273</td>
</tr>
<tr>
<td>9</td>
<td>rain, night, varied traffic</td>
<td>0.25</td>
<td>0.0351</td>
</tr>
<tr>
<td>12</td>
<td>wind, mid-day, varied traffic</td>
<td>0.50</td>
<td>0.0182</td>
</tr>
<tr>
<td>14</td>
<td>EM noise, mid-day, varied traffic</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>wires in view, mid-day, varied traffic</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>color camera, mid-day, varied traffic</td>
<td>N/A</td>
<td>0</td>
</tr>
</tbody>
</table>

The *yearly average hours per day* column represents the average number of hours per day, over a typical year, during which the test condition is assumed to be valid. The *normalized weighting factor* divides the average number of hours per day for each condition by 24 hours. All possible daily conditions may not be represented, due to the restrictions of the experimental site, and seasonal and traffic limitations.

A formula representative of overall performance based upon the above sample weighting factors is:

$$\text{Composite Score} = \sum a_i c_i$$

$$= 0.1879c_1 + 0.0470c_2 + 0.1611c_4 + 0.403c_5 + 0.1208c_6 + 0.3624c_7 + 0.0273c_8 + 0.0351c_9 + 0.0182c_{12}$$  \hspace{1cm} (1)

where $c_i$ are the percentage data for a given detection metric during the $i^{th}$ test condition.

**Overall Vehicle Detection Results**

This formula may then be applied to the vehicle detection event class results or the phase actuation event class results, to help to emphasize the relative importance of each result to the practical overall performance of the detection system. For example, Table 9 below is a reduction of the vehicle detection event class data (*Vehicle Detection*) data utilizing the above to arrive at composite performance metrics appropriate to answer several typical questions about the overall system performance.
With these overall detection event class results, it is now possible to postulate and attempt to answer several practical questions, and address realistic MOEs for the detection system:

1. **As a percentage of all vehicles flowing through detection windows at an intersection, how many are correctly individually detected, just as they would be detected by a properly working loop detector?**

To answer this question, we consider here the ability of the system under test to report the presence of a vehicle when actually present in a detection window, and to not report a vehicle present when no vehicle is actually present in the detection zone. The gap between subsequent vehicles in a platoon must be correctly detected, so that the system would correctly count vehicles passing through a detection window. For this metric, $C_i$ for each of the $i$ test conditions is just the percentage of vehicles passing through each detection window that were logged in the “Correct Detection” vehicle detection event class. Note, however, that although this metric assesses the percentage of vehicles that would be correctly added to a count, it is not a metric of the accuracy of the counting ability of the system, since the count can be incorrect in both an additive and subtractive sense, i.e., false detections and multiple detections can contribute to higher-than-actual count results.

2. **As a percentage of all vehicles flowing through detection windows at a signalized intersection, how many are detected adequately for purposes of proper actuation of the signal phases?**

For proper actuation of signal phases, it is only necessary for the system to correctly identify the presence or proximity of vehicles relative to the detection zone. The system is not penalized for inability to distinguish between a sequence of closely spaced vehicles. Therefore $C_i$ for each condition is the total of the “Correct Detection” and the “Tailgate” detection event classes.

3. **As a percentage of the total number of actual vehicles flowing through detection windows at a signalized intersection, how often are vehicles “missed” such that proper actuation of the red/green signal phase transition might not occur?**

At the test intersections in Anaheim, the signal controllers do not latch the presence signal from a vehicle detected during the red interval. This assures against wasting a green phase when a vehicle may have already turned right during the red, or left the approach for some reason such as running the light. Therefore, a “miss” can occur if a vehicle is either not detected, or is initially detected and then dropped while waiting in the detection window. Not included in this total are vehicles not individually detected in platoons in platoons (Tailgate event class) or following latched detections (Detection with Latch, False Detection with Latch, or Tailgate with Latch classes) since these do not represent vehicles waiting during a red interval. $C_i$ for each condition is the total of the “Failure to Detect” and the “Dropped After Detection” event classes.

### Table 9. Vehicle Detection Event Class results for sample data, weighted via equation (1), and normalized to number of actual vehicles.

<table>
<thead>
<tr>
<th>Event Class</th>
<th>Weighted Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Detection</td>
<td>65.0%</td>
</tr>
<tr>
<td>Detection w/Latch</td>
<td>0.42%</td>
</tr>
<tr>
<td>Multiple Detections</td>
<td>6.2%</td>
</tr>
<tr>
<td>Dropped After Detection</td>
<td>2.2%</td>
</tr>
<tr>
<td>False Detection</td>
<td>7.7%</td>
</tr>
<tr>
<td>False Detection w/Latch</td>
<td>0.1%</td>
</tr>
<tr>
<td>Failure to Detect</td>
<td>16.5%</td>
</tr>
<tr>
<td>Tailgate</td>
<td>15.9%</td>
</tr>
<tr>
<td>Tailgate w/Latch</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

9 Conditions Weighted, 135
Minutes, 1821 Actual Vehicles
4. As a percentage of the total number of actual vehicles flowing through detection windows at a signalized intersection, how many vehicles are “missed” in such a way that proper green extension might not occur?

In this case, we consider only vehicles not detected while in motion through a detection window. The system is not penalized for tailgates or latches since we are only concerned with the ability of the system to report the presence of any vehicles flowing through the detection window at the intersection. \( C_i \) for each condition comes only from the “Failure to Detect” event class.

5. As a percentage of the total number of actual vehicles flowing through detection windows at a signalized intersection, how many detections are incorrectly reported such that the green interval could possibly be incorrectly extended?

We consider here events in which no vehicle was ever present in the zone to warrant a detection reported by the system. Thus \( C_i \) includes the “False Detection” event class, and the three latch condition classes, but does not include the “Multiple Detection” event class, since this occurs only when an actual vehicle is stopped in a detection window, and is intermittently detected/not detected.

6. As a percentage of the total number of actual vehicles flowing through detection windows at a signalized intersection, how many detections are incorrectly reported such that actuation of the red/green phase transition might incorrectly occur?

We consider events in which no vehicle is present in the zone to warrant a detection reported by the system. Therefore, the criteria are the same as for the previous false green extension case. \( C_i \) includes the “False Detection” event class, and the three latch condition classes, but does not include the “Multiple Detection” or “Tailgate” event classes. Multiple detection is excluded since this occurs only when an actual vehicle is stopped in a detection window, and is intermittently detected/not detected. Tailgates are excluded because they are valid presence detections as discussed above. However, latches can leave a window in an actuated state when no vehicle is present. If the period of latch extends into the red interval, the presence of a non-existent vehicle may be reported.

7. What is the tendency of the system to overcount vehicles, as a percentage of the total number of actual vehicles flowing through detection windows?

This figure represents the extent to which a vehicle count provided by the system could be above the correct number. It is not mitigated by the concomitant tendency of the vehicle to undercount due to failures to detect vehicles. The case includes those event classes in which the vehicle count would be incorrectly incremented. Thus \( C_i \) includes the “False Detection”, “False Detection with Latch”, and “Multiple Detection” event classes only.

8. What is the tendency of the system to undercount vehicles, as a percentage of the total number of actual vehicles flowing through detection windows?

This figure represents the extent to which a vehicle count provided by the system could be below the correct number. It is not mitigated by the concomitant tendency of the vehicle to overcount due to false or multiple detections. The case includes those event classes in which the vehicle count would not be incremented when it should have been. \( C_i \) includes the “Failure to Detect”, “Tailgate” and “Tailgate with Latch” event classes only.

**Overall Phase Actuation Results**

We may also consider a reduction of the Phase Actuation Event results utilizing the weighting formula (1) in an attempt to answer four key questions associated with proper signal phase actuation listed below.

Since Phase Actuation accuracy is a property of the overall intersection and traffic, not solely a function of the detection device, the data is best reported as the number of elapsed signal phases that were correctly or incorrectly actuated using the detection system as the sensor. In reducing these totals to percentages, we divide by the total number of elapsed signal phases during the period of the test. Recall that four results are possible for each interval:
Red Interval (Effecting Actuation of Red/Green Transition):

1. Correct actuation (Correct).
2. Failure to actuate correctly (Fail).
3. False actuation (False).
4. Both Failure to actuate and false actuation during same interval.

Green Interval (Effecting Actuation of Green/Red Transition):

1. Correct green extension.
2. Potential failure to extend green.
3. Potentially false green extension.
4. Both potential failure to extend and potential false extension during same interval.

Note that all detectors on a given approach are considered to be logically OR’ed together for purposes of this assessment. This permits a red/green transition to be reported as correctly actuated, even if only a single vehicle out of several is detected waiting at the stop bar. However, it also increases the possibility of an incorrect red/green transition or an incorrect green extension if any of the detection windows on the given approach are falsely triggered during the respective phases. A “Correct Actuation” is reported for the interval only if no errors (Failure to Actuate or False Actuation) occurred at any time during the interval. If either a “Fail” or “False” (one or the other, not both) occurred at any time during the interval, this is reported in the respective category. A “Fail” and a “False” can occur during the same interval, since a false vehicle detection and a failure to detect a vehicle can occur during the duration of either a red or green single interval. If both a “Fail” and a “False” occurred during the same interval, this is reported in the “Fail and False” category. The sum of the “Fail”, “False” and “Fail and False” categories represents the total percentage of all elapsed cycles in which an error in detection could potentially lead to an incorrect control actuation.

Table 10. Normalized and weighted overall Phase Actuation Accuracy Results based on sample data.

<table>
<thead>
<tr>
<th></th>
<th>Correct</th>
<th>Fail</th>
<th>False</th>
<th>Fail and False</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Through</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>67.1%</td>
<td>16.7%</td>
<td>14.2%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Green</td>
<td>51.2%</td>
<td>25.6%</td>
<td>8.5%</td>
<td>14.7%</td>
</tr>
<tr>
<td><strong>Left Turn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>62.6%</td>
<td>28.8%</td>
<td>4.1%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Green</td>
<td>76.8%</td>
<td>18.1%</td>
<td>1.9%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

* For the Left Turn Phase calculations, the normalized weighting factors were corrected to compensate for the lack of a left turn phase during TC1. This was accomplished by removing TC1 from the overall test basis and re-normalizing all factors based upon the remaining test conditions.

The overall concerns of traffic engineering personnel can often be reduced to the general question “Do the signal controls at the intersection actuate properly using the video detection system?” In other words: As a weighted average percentage of all elapsed cycles during the test periods, how many cycles would have been assured to be actuated correctly? Conversely, how many cycles could possibly be incorrect due to incorrect detection at one or more times during a signal interval. Note that it is possible that the cycle may still be actuated correctly, even if vehicle detection was not correct in all cases over the interval.
Overall phase actuation accuracy questions may therefore be answered in terms of four basic actuation concerns effecting traffic regulated by the signal control at the intersection. For the sample data, the percentage results are shown in Table 11.

Table 10. Normalized and weighted overall phase actuation accuracy results based on sample data.

<table>
<thead>
<tr>
<th>Situation</th>
<th>% Cycles with Completely Correct Actuation</th>
<th>% Cycles Actuated, either correctly or due to false detection.</th>
<th>% Cycles with Possible Incorrect Actuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Basis:</td>
<td>% Correct</td>
<td>% Correct + % False</td>
<td>% False + % Fail &amp; False</td>
</tr>
<tr>
<td>1. Vehicle(s) waiting at red for green; proper actuation of green.</td>
<td>64.9%</td>
<td>77.1%</td>
<td>-----</td>
</tr>
<tr>
<td>2. No vehicle(s) waiting at red; possible unjustified actuation of green.</td>
<td>-----</td>
<td>-----</td>
<td>24.4%</td>
</tr>
<tr>
<td>3. Vehicle(s) flowing on green; proper extension of green.</td>
<td>64.0%</td>
<td>78.2%</td>
<td>-----</td>
</tr>
<tr>
<td>4. No vehicle(s) flowing on green; possible unjustified green extension.</td>
<td>-----</td>
<td>-----</td>
<td>14.2%</td>
</tr>
</tbody>
</table>

CONCLUSIONS AND DISCUSSION

One possible systematic approach to the performance evaluation of video-based or other advanced intersection presence detection systems is presented. Test and data reduction methodologies are derived from an analysis of "what is important" in intersection signal control, as well as "what is possible" for the technology. The ramifications of correct and incorrect sensing on the efficient control of intersection traffic can be inferred from elemental detection accuracy tests, in which nine detection event classes are defined. Daily and annualized weighting strategies are derived as an aid to deriving overall performance MOEs and conclusions from elemental test results.

There appears to be a lack of evaluation standards for intersection video detection and similar advanced detectors and sensors, such that system-to-system comparisons based upon tests performed by different entities are extremely difficult. Simple statements of any single metric such as cumulative count accuracy, percent correct detections, percent overcount, percent undercount, or percent false detections alone can be very misleading to the potential user. Reports of indirect metrics such as "phase actuation (or phase detection accuracy) alone can obscure the actual accuracy of the detection system beneath the circumstances of the traffic patterns and signal controller programming encountered at the intersection(s) during the test.

Phase actuation tests add the influence of factors unrelated to the function of the detection system alone. This or any other video-based detection system is just a sensor, intended to replace the function of another sensor, inductive loops, as an input to a traffic signal controller. We feel that the Phase Actuation tests are valid as a means for extrapolating how a typical intersection control might respond using the given sensor system. However, if different traffic conditions prevail during the tests, Phase Actuation results can be significantly different. Note, for example, that "perfect" results would be reported for any interval in which there was no traffic, and that in general, the less traffic per cycle, the greater the chance that all detection events occurring during that cycles will be correct. We therefore feel that, due to the strong dependency upon external factors unrelated to the basic function of the detection system, Phase actuation test results are interesting but should not be used as a primary metric of evaluation for detection systems of this kind.
REFERENCES


7. The EVA is a dual-purpose product, intended for both freeway data collection and intersection actuation. Video compatibility is PAL (Phase Alternating Line) European standard, but NTSC compatibility is apparently available on request. Deployment in the USA has been limited.

