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16. Abstract

Video imaging vehicle detection systems (VIVDSs) are becoming an increasingly common means of detecting traffic at intersections and interchanges in Texas. This interest stems from the recognition that video detection is often cheaper to install and maintain than inductive loop detectors at multi-lane intersections. It is also recognized that video detection is more readily adaptable to changing conditions at the intersection (e.g., lane reassignment, temporary lane closure for work zone activities). The benefits of VIVDSs have become more substantial as the technology matures, its initial cost drops, and experience with it grows.

This handbook is intended to assist engineers and technicians with the design, layout, and operation of a VIVDS. This assistance is provided in three ways. First, the handbook identifies the optimal detection design and layout. Second, it provides guidelines for achieving an optimal or near-optimal camera location and field of view. Third, it provides guidelines for laying out the VIVDS detectors such that they will provide safe and efficient operation. Finally, guidance is provided on the need for, and schedule of, VIVDS maintenance activities.

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INTERSECTION VIDEO DETECTION FIELD HANDBOOK

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NOTICE

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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CHAPTER 1. INTRODUCTION

OBJECTIVE

This handbook is intended to assist engineers and technicians with the design, layout, and operation of a video imaging vehicle detection system (VIVDS). This assistance is provided in three ways. First, the handbook identifies the optimal detection design and layout. Second, it provides guidelines for achieving an optimal or near-optimal camera location and field of view. Third, it provides guidelines for laying out the VIVDS detectors such that they will provide safe and efficient operation. Finally, guidance is provided on the need for, and schedule of, VIVDS maintenance activities.

Some of the guidance provided in this document was obtained from a review of the literature and from interviews with TxDOT staff. Some guidance was also developed using the geometric relationships of camera optics and the principles of detection design. The report by Bonneson and Abbas (*1*) documents these development activities. In particular, it describes the rationale underlying the guidance and the validation of some guidelines based on simulation or field data.

SCOPE

The guidelines provided in this handbook address the use of a VIVDS to provide vehicle presence detection at a signalized intersection or interchange in Texas. The facility can be new or existing. It can be in an urban or rural environment and on a collector or arterial roadway. To the extent practical, the guidelines are applicable to all VIVDS products. They are applicable to detection designs that use one camera (for each intersection approach monitored) to provide detection at the stop line and, if needed, detection in advance of the stop line.

The guidelines are developed for intersections and interchanges that use one signal controller. The research does not explicitly address the use of a VIVDS to facilitate coordinated signal operation, beyond that needed to affect stop-line detection in support of such operation. The research does not address the use of a VIVDS for measuring vehicle count, speed, headway, occupancy, or other traffic characteristics beyond that needed for basic intersection (or interchange) control using presence-mode detection.

The terms "detection design," "detection layout," and "detection zone" are used frequently in this handbook. *Detection design* refers to the selection of camera location and the calibration of its field of view. *Detection layout* refers to the location of detection zones, the number of detection zones, and the settings or detection features used with each zone. A *detection zone* is defined to be one or more VIVDS detectors that are configured (or linked) to act as one detector and that are separated from upstream and downstream detection zones by at least the effective length of a vehicle.

CHAPTER 2. DESIGN GUIDELINES

OVERVIEW

This chapter addresses several important VIVDS design elements. These elements include camera mounting location and field-of-view calibration. Design considerations include the camera's height, offset, distance from the stop line, pitch angle (relative to a horizontal plane), and lens focal length. The first three considerations refer to "camera location" and the last two considerations refer to the "field-of-view calibration." The variables associated with these considerations are illustrated in Figure 1. Lens focal length refers to the degree to which the field of view is magnified (or "zoomed"). Intersection lighting is also an important design consideration as it relates to VIVDS performance. It is also discussed in this chapter.

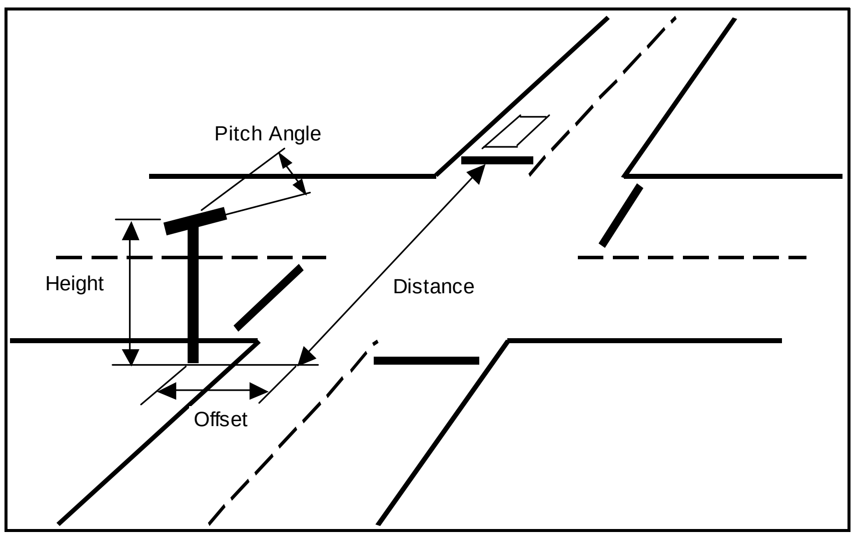
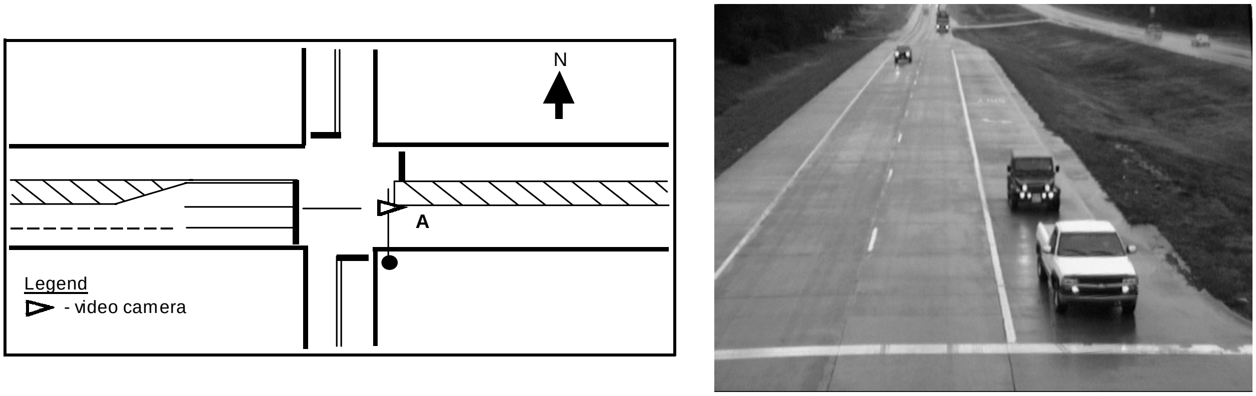


Figure 1. Variables Defining a Camera's Location and Field of View.

OPTIMAL CAMERA LOCATION AND FIELD OF VIEW

Camera Location

An optimal camera location is one that maximizes detection accuracy. As such, an optimal location is one that provides a stable, unobstructed view of each traffic lane on the intersection approach. The view must include the stop line and extend back along the approach for a distance equal to that needed for the desired detection layout. An example of an optimal camera location is identified by the letter "A" in Figure 2a. Its associated field of view is shown in Figure 2b.



a. **Illustrative Optimal Camera Location.** b. **Illustrative Optimal Field of View.**

Figure 2. Illustrative Optimal Camera Location and Field of View.

Field-of-View Calibration

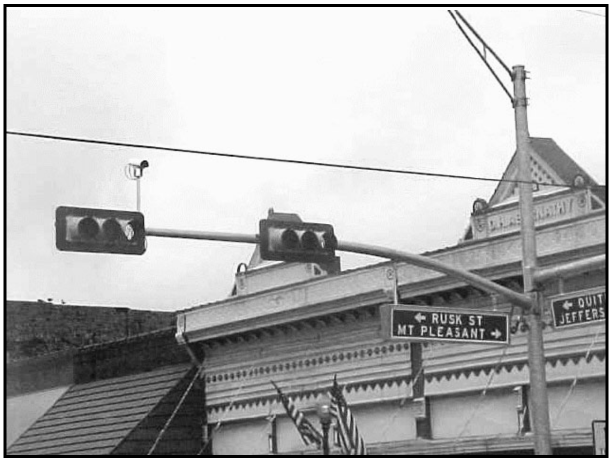
Calibration of the camera field of view is based on a one-time adjustment to the camera pitch angle and the lens focal length. An optimal field of view is one that has the stop line parallel to the bottom edge of the view and in the bottom one-half of this view. The optimal view includes all approach traffic lanes. The focal length would be adjusted such that the approach width, as measured at the stop line, equates to 90 to 100 percent of the horizontal width of the view. Finally, the view must exclude the horizon. An optimal field of view is shown in Figure 2b.

GUIDELINES

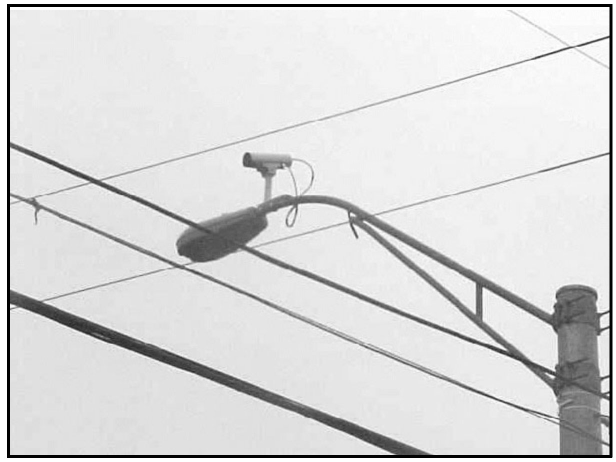
This section describes VIVDS design guidelines. These guidelines can be used to define a camera location and field of view that maximize detection accuracy. The following topics are addressed in this section: camera location and field-of-view calibration.

Camera Location

Desirable camera heights and offsets are often limited by the availability of structures that can provide a stable camera mount. Considerations of height, offset, and stability often require a compromise location that is subjectively determined to provide the best performance. Camera mounting locations vary widely with each intersection. Typical locations include luminaire arms, signal head mast arms, and signal poles. Figure 3 shows two commonly used camera mounts. Figure 3a shows a camera mounted on a mast arm. Figure 3b shows a camera mounted on a luminaire arm on a mast arm pole.



a. Mast Arm Camera Mount.



b. Luminaire Arm Camera Mount.

Figure 3. Common Camera Mounts.

Camera Offset

As shown in Figure 2, the optimal camera offset is approximately in the center of the approach being monitored. However, this location can vary slightly, depending on whether the approach being monitored has a left-turn bay. If it has a left-turn bay, the preferred camera location is over the lane line separating the left-turn bay and the adjacent (oncoming) through lane. This location is shown as point “A” in Figure 4, as applied to the eastbound approach. If the approach does not have a left-turn bay, the preferred location is centered on the approach lanes, as shown by location “B” for the westbound approach. Other camera locations, denoted by locations “C” and “D,” can be used when locations “A” or “B” are not available or when they do not provide the desired camera height.

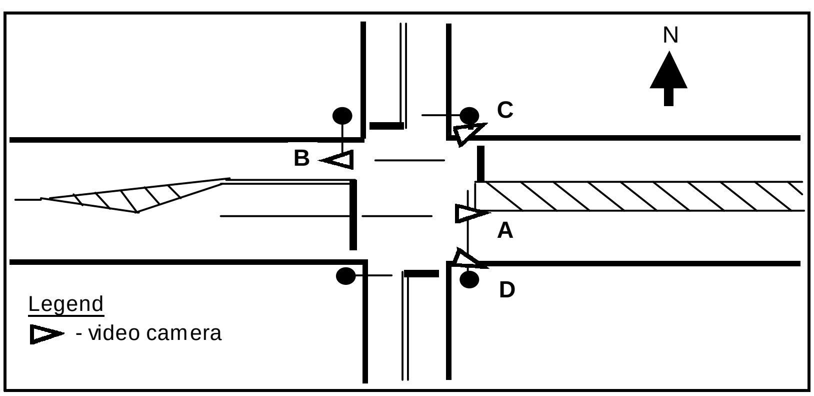


Figure 4. Alternative Camera Locations.

Camera Height

This section describes guidelines for determining the minimum camera height for a specified camera offset and distance to the stop line. Two minimum height controls are defined. The first minimum height control is intended to minimize the effect of adjacent-lane occlusion. The second control is intended to provide acceptable detection accuracy. The first control applies to all VIVDS installations. Both controls are applicable to high-speed approaches where advance detection is needed. In this situation, the larger of the two minimum values would define the applicable minimum height criterion.

Minimum Height to Reduce Occlusion. The minimum height needed to reduce adjacent-lane occlusion is obtained from Table 1. Interpolation between cell values is appropriate for offsets intermediate to the values listed. A minimum height of 20 ft is recommended in recognition of the dirt, spray, and mist that can collect on the camera lens at lower heights. Camera locations that require a camera height in excess of 42 ft should be avoided.

The trends in Table 1 indicate that a camera mounted in the center of the approach is associated with the lowest minimum height. This minimum increases with offset and is particularly large for cameras located on the left side of the approach.

The underlined values in Table 1 correspond to typical lateral offsets for the associated number of lanes *when* the camera is mounted within 10 ft of the edge of traveled way. For example, a camera mounted on the right side of a single-lane approach (with one left-turn bay) is likely to have an offset of about 15 ft, which corresponds to a minimum camera height of 20 ft. A camera mounted on the left side of this same approach is likely to have an offset of about 25 ft and require a minimum height of 21 ft.

Minimum Height for Advance Detection. The minimum heights needed for advance detection are listed in Table 2. Interpolation between cell values is appropriate for distances intermediate to the values listed. The distances shown in this table indicate that minimum camera heights range from 24 to 36 ft, depending on the distance between the camera and stop line and on the approach speed limit. The heights shown will always provide a view of the approach between the stop line and the upstream detection zone (provided that a lens focal length of 6.0 mm or larger is used).

Tables 1 and 2 should be used together to determine the minimum camera height for approaches with advance detection. The higher value obtained from either table would represent the required minimum height.

Table 1. Minimum Camera Height to Reduce Adjacent-Lane Occlusion.

Camera Location	Lateral Offset [1], ft	No Left-Turn Lanes			One Left-Turn Lane			Two Left-Turn Lanes		
		Through+Right Lanes [2]			Through+Right Lanes [2]			Through+Right Lanes [2]		
		1	2	3	1	2	3	1	2	3
		Minimum Camera Height and Typical Camera Mount [3, 4], ft								
Left Side of Approach	-65			P,R 38			P,R,L42			
	-55		P,R 35	P 30		P,R 39				
	-45		P 27		P,R 36	P 32		P,R,L41		
	-35	P 24	P 20		P 29			P 33		
	-25	P 20			P 21					
	-15	P 20						M 20	M 20	M 20
	-5				M 20	M 20	M 20	M 20	M 20	M 20
Center	0	M 20	M 20	M 20	M 20	M 20	M 20	M 20	M 20	M 20
Right Side of Approach	5	P 20	M 20	M 20	M 20	M 20	M 20	M 20	M 20	M 20
	15	P 20	P 20	P 20	P 20	P 20	M 23	P 20	M 20	M 20
	25	P 20	P 20	P 20	P 21	P 26	P 30	P 20	P 21	P 26
	35		P 20	P 20	P 29	P 33	P,R 38	P 24	P 29	P 33
	45								P,R 36	P,R,L41

Notes:
1 - Lateral offset of camera measured from the center of the approach traffic lanes (including turn lanes).
2 - Total number of through and right-turn lanes on the approach.
3 - Underlined values in each column correspond to typical lateral offsets when the camera is mounted within 10 ft of the edge of traveled way.
4 - Camera mounting hardware and maximum camera mounting height supported by the hardware:
M - mast arm (24 ft maximum).
P - strain pole (34 ft maximum).
P,R - camera on 5-ft riser on top of strain pole (39 ft maximum).
P,R,L - camera on 5-ft riser on luminare arm attached to the top of strain pole (41 ft maximum).

Table 2. Minimum Camera Height for Advance Detection.

Distance Between Camera and Stop Line [1], ft	Approach Speed Limit, mph			
	45	50	55	60
	Minimum Camera Height, ft			
50	24	26		
80	25	28	30	32
100	27	29	31	34
150	30	32	34	36

Note:
1 - Distance between the camera and the stop line, as measured parallel to the direction of travel.

To illustrate the use of Tables 1 and 2, consider a four-lane highway with intersection approaches that include two through lanes and one left-turn bay. The distance between the mast-arm pole and the stop line is 100 ft, as measured in the direction of travel. The approach speed limit is 55 mph. Table 2 indicates that the minimum height needed for advance detection is 31 ft. This height exceeds that available from a mast-arm mount (i.e., 24 ft), so a right-side pole mount is considered for the camera. Table 1 indicates that a camera mounted just outside the edge of traveled way (i.e., offset 18 ft from the center of the three-lane approach) will require a minimum height of about 22 ft (by interpolation). Of the two minimum heights specified (i.e., 31 and 22 ft), the larger value of 31 ft represents the minimum for this approach. Thus, the camera should be mounted at a height of 31 ft or more on the right-side mast-arm pole.

Height and Stability. Research indicates that increasing camera height tends to improve accuracy, provided that there is no camera motion. However, there is a "point of diminishing returns" with respect to camera height when the camera support structure is susceptible to instability. Specifically, data indicate that camera heights of 34 ft or more may be associated with above-average errors *unless* the camera is mounted on a stable pole.

Combined Offset and Height Considerations

The preferred camera offset and height are often achieved for low-speed approaches by locating the camera on a 5-ft riser attached to the signal head mast arm. This type of mounting is shown in Figure 3a. Unfortunately, the minimum camera height for high-speed approaches typically requires a right-side or left-side mount (as denoted by the letters "C" and "D" in Figure 4). Both locations have the camera mounted on the signal pole at the necessary height or on a luminaire arm extending from the pole. This type of mounting is shown in Figure 3b.

The choice between a right-side or a left-side mount is dependent on the phase sequence used to control the subject approach. For approaches without a left-turn phase, the camera is mounted on the right-side, far corner of the intersection (i.e., "D" in Figure 4).

For approaches with a left-turn phase and bay, location "D" is problematic because the projected outline of a tall through vehicle can extend into the left-turn bay and unnecessarily call the left-turn phase. To avoid this problem, the camera is mounted on the left-side, far corner of the intersection (i.e., "C" in Figure 4). This location minimizes false calls for service to the left-turn phase; any false calls for the through phase by a tall left-turn vehicle would have limited impact because through vehicles are present during most cycles. A 10-s delay setting should be used for the left-turn detectors to prevent unnecessary calls by departing vehicles.

Field-of-View Calibration

Calibration of the camera field of view is based on a one-time adjustment to the camera pitch angle and the lens focal length. An optimal field of view is one that has the stop line parallel to the bottom edge of the view and in the bottom one-half of this view. The optimal view also includes all approach traffic lanes. The focal length would be adjusted such that the approach width, as measured at the stop line, equates to 90 to 100 percent of the horizontal width of the view. Finally, the view must exclude the horizon. An example of an optimal field of view is shown in Figure 2b.

The optimal field of view is not achievable for some right-side and most left-side camera offsets. In these situations, the approach width may not be parallel to the bottom of the view and it may not equate to 90 percent of the horizontal width of the view. A 90-percent width for the approach may be particularly difficult to achieve when advance detection is used. Nevertheless, the field of view should always be adjusted to maximize the approach width (as a percent of the view) at the stop line. Practical minimum widths are 40 and 60 percent for left-side and right-side camera offsets, respectively.

Two camera adjustments are available to minimize the deleterious effects of sun glare (or reflection) on detection accuracy. In some instances, glare can be blocked by adjusting the visor on the camera housing. If this adjustment does not eliminate the problem, then the camera pitch angle can be increased such that the horizon is excluded from the field of view. A minimum pitch angle of about 3.0 degrees (from horizontal) should be provided in all cases. Finally, VIVDS processors have the ability to minimize the effect of occasional glare by automatically invoking a maximum recall on the troubled approach whenever glare is detected.

The camera field of view should be established to avoid inclusion of objects that are brightly lit in the evening hours, especially those that flash or vary in intensity. These sources can include luminaires, signal heads, billboard lights, and commercial signs. The light from these sources can cause the camera to reduce its sensitivity (by closing its iris), which results in reduced detection accuracy. If these sources are located near a detection zone, they can trigger unnecessary calls.

If the pitch angle or focal length cannot be adjusted to avoid glare and brightly lit objects, then alternative camera locations should be considered. If such locations cannot be found, then careful detection zone layout can minimize the effect of light sources or power lines on detection accuracy.

Intersection Lighting

Intersections that have a minimal level of area lighting may experience a higher level of unneeded calls. These calls are triggered by the light from vehicle headlights in departing lanes and crossing lanes. Unneeded calls are likely to increase intersection delay. This problem can be avoided by increasing the number of luminaires at the intersection. The benefit to having several luminaires at the intersection is that they collectively minimize the problems associated with vehicle shadows and the degree of shadow contrast.

Communications

Significant signal degradation can occur when coaxial cable lengths of 1000 ft or more are used. When a length of 1000 ft or more is anticipated, the splices in the cable should be avoided, and separate conduits should be considered for the coaxial cable and the power cable.

Wireless communication between the VIVDS cameras and processor is an alternative to the use of coaxial cable. At least one VIVDS manufacturer offers a wireless camera. In this instance, the video information is transmitted to a receiver in the controller cabinet. Power for the camera is provided by a cable or solar panel.

CHAPTER 3. OPERATIONS GUIDELINES

OVERVIEW

This chapter describes guidelines for VIVDS operation and maintenance. VIVDS operation is defined by its detection zone layout, which includes consideration of zone location, detection mode, detector settings, and controller settings. VIVDS maintenance is defined by the on-site performance checks conducted after the initial installation and the routine maintenance activities that follow installation.

OPTIMAL DETECTION ZONE LAYOUT

Detection zone layout is an important factor influencing the performance of the intersection. There are several factors to consider when laying out each zone. These factors include: zone location relative to the stop line, the number of VIVDS detectors used to constitute the zone, whether the detectors are linked using Boolean logic functions, whether the zone monitors travel in a specified direction, and whether the zone's call is delayed or extended. An example of an optimal detection zone layout is illustrated in Figure 5.

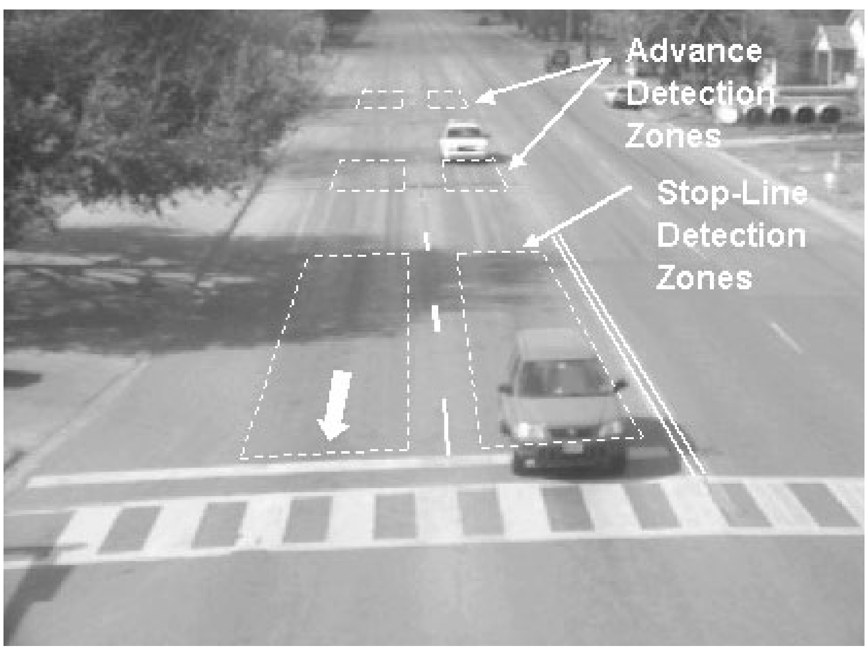


Figure 5. Illustrative Optimal Detection Zone Layout.

GUIDELINES

This section describes guidelines for detection zone layout and operation. Detection zone layout guidelines include zone location, detection mode, detector settings, and controller settings. VIVDS operation guidelines describe activities needed to verify the adequacy of the initial installation and the checks needed during a routine maintenance visit.

Detection Zone Layout

Detection Zone Location

Like inductive loops, VIVDS detectors can be placed within a lane or across several lanes. They can be placed at the stop line or several hundred feet in advance of it. The VIVDS product manuals offer some guidance for locating a VIVDS detection zone and the detectors that comprise it. These guidelines are summarized and described in Table 3.

Table 3. Guidance for Locating Detection Zones and Individual Detectors.

Application	Guideline	Rationale
Stop-Line Detection	Stop-line detection zone typically consists of several detectors extending back from the stop line.	For reliable queue service, stop-line detection typically requires monitoring a length of pavement 80 ft or more in advance of the stop line.
	Put one detection zone downstream of the stop line if drivers tend to stop beyond the stop line.	Avoid having one long detector straddle a pavement marking.
	Use specific techniques to heighten detector sensitivity (e.g., overlap individual detectors slightly).	Vehicle coloration and reflected light may combine to make some vehicles hard to detect.
Advance Detection	Advance detection typically consists of two detectors strategically located on the approach.	Advance detection uses passage time to extend the green for vehicles in the dilemma zone.
	Advance detectors can reliably monitor vehicles at a distance (from the camera) of up to 500 ft, provided the field of view is optimal.	Detection accuracy degrades as the location being monitored by the VIVDS becomes more distant from the camera.
Individual Detector	Avoid having pavement markings cross or straddle the boundaries of the detection zone.	Camera movement combined with high-contrast images may confuse the processor and trigger an unneeded call.
	The individual detector length should approximately equal that of the average passenger car.	Maximize sensitivity by correlating the number of image pixels monitored with the size of the typical vehicle being detected.

Stop-Line Detection. This section describes guidelines for determining an efficient detection zone layout for stop-line detection. Stop-line detection is typically used on low-speed intersection approaches and in left-turn bays. Guidelines for determining the layout for advance detection zones are provided in the next section.

The recommended stop-line detection zone lengths are listed in Table 4. Interpolation between cell values is appropriate for distances or heights intermediate to the values listed. The recommended lengths require a 0.0-s controller passage time. These recommended values should result in lower delay than that realized by longer passage times or shorter detection zone lengths.

Table 4. Stop-Line Detection Zone Length for VIVDS Applications.

Distance Between Camera and Stop Line [1], ft	Camera Height, ft				
	24	28	32	36	40
	Stop-Line Detection Zone Length [2], ft				
50	100	100	100	100	100
100	90	90	95	95	95
150	80	85	85	90	90

Notes:
1 - Distance between the camera and the stop line, as measured parallel to the direction of travel.
2 - Lengths shown are based on a 0.0-s passage time setting.

During the initial VIVDS setup, the detection zone length should be measured along the roadway with a distance wheel. The most distant upstream edge should be marked with a traffic cone placed on the outside edge of the traveled way. One or more VIVDS detectors should then be drawn on the VIVDS monitor such that the entire length of the resulting detection zone is monitored by the VIVDS processor. The traffic cone can then be removed.

Stop-Line Plus Advance Detection. This section describes guidelines for determining an efficient detection zone layout when advance detection is needed. This type of detection is typically used to provide a safe phase termination for the high-speed through movements on an intersection approach. Stop-line detection is also included with the advance detection to provide efficient service to the queue during the initial portion of the phase.

The recommended advance detection zone locations and extension settings for VIVDS applications are listed in Table 5. Interpolation between cell values is appropriate for distances or heights intermediate to the values listed. The recommended advance detection design requires a passage time of 1.0 s. These recommended values should provide lower delay than that incurred with other locations or passage times.

When used with advance detection, the stop-line detection zone layout should follow the guidelines described in the previous section, "Stop-Line Detection." Specifically, the length of this zone should be obtained from Table 4.

Table 5. Advance Detection Zone Layout for VIVDS Applications.

Approach Speed Limit, mph	Distance to 1st Det. Zone [1], ft	Distance Between Camera and Stop Line [2], ft	Camera Height, ft									
			24	**28**	**32**	**36**	**40**	**24**	**28**	**32**	**36**	**40**
			Distance to 2nd Det. Zone [1], ft					Extension on 2nd Det. Zone, s				
60	470	80	280	295	305	310	315	0.0	0.0	0.0	**0.5**	**0.5**
		150	270	285	295	300	310	0.0	0.0	0.0	0.0	**0.5**
55	430	80	255	265	275	280	285	0.0	0.0	0.0	**0.5**	**0.5**
		150	245	255	265	275	280	0.0	0.0	0.0	0.0	**0.5**
50	390	50	235	245	250	255	260	0.0	0.0	**0.5**	**0.5**	**0.5**
		150	220	230	240	245	250	0.0	0.0	0.0	0.0	**0.5**
45	350	50	210	215	220	225	230	0.0	0.0	**0.5**	**0.5**	**0.5**
		150	190	200	210	215	220	0.0	0.0	0.0	0.0	**0.5**

Notes:
1 - Distances shown are based on a 20-ft detection zone length and a 1.0-s passage time setting.
2 - Distance between the camera and the stop line, as measured parallel to the direction of travel.

One difference exists between the layout of the stop-line detection zone *with* advanced detection and the layout of the stop-line zone *without* advance detection. When used with advance detection, the controller has a 1.0-s passage time that is required by the advance detection zones. When used without advance detection, a 0.0-s passage time is required. Because the 1.0-s passage time is required when the stop-line detection zone is used with advance detection, it is necessary to make a slight modification to the stop-line detection zone's operation. Specifically, the detector channel serving the stop-line detection zone should have the "inhibit" feature (e.g., Special Detector Mode 4 in Eagle controllers) invoked. The stop-line detector channel in the controller should also have 0.0 s set on its delay and extend timers. The inhibit feature disables the stop-line detection zone after the queue, waiting at the start of the phase, has been served. It should be noted that the advance detection zones should be served by a detector channel that is separate from that of the stop-line detection zone.

During the initial VIVDS setup, the beginning and end of each advance detection zone should be measured along the roadway with a distance wheel. The location of the beginning of the zone is listed in Table 5. The end of the zone is 20 ft closer to the stop line. Each edge should be marked with a traffic cone placed on the outside edge of the traveled way. One or more VIVDS detectors should then be drawn on the VIVDS monitor such that the entire length of the resulting detection zone is monitored by the VIVDS processor. The traffic cones can then be removed.

As a last step in the setup, the extension setting on the second advance detection zone should be set at the value listed in Table 5. This setting should be set in the VIVDS. It should be applied to all detectors that comprise the second detection zone. The delay and extend timers provided in the controller for each detector channel should be set at 0.0 s.

Detection Mode

One benefit of a VIVDS is the large number of detection zones that can be used and the limitless ways in which they can be combined and configured to control the intersection. Both pulse-mode and presence-mode detectors can be used, where the latter can have any desired length. In addition, VIVDS detectors can be set to detect only those vehicles traveling in one direction (i.e., directional detectors). They can also be linked to each other using Boolean functions (i.e., AND, OR). The use of these features is shown in Figure 6. The detector labeled "delay" in this figure is described in the next section.

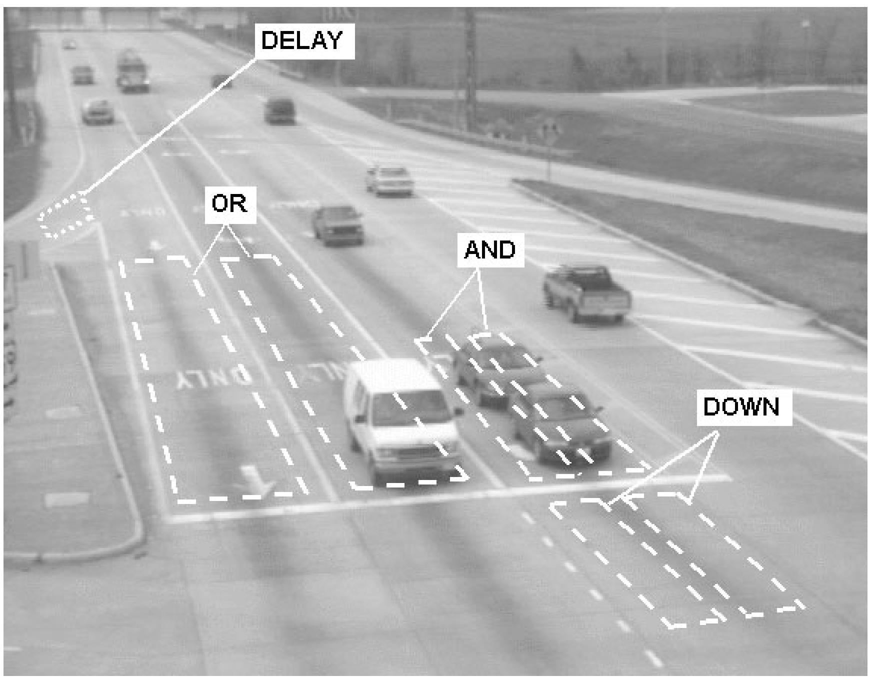


Figure 6. Alternative Detection Modes.

Figure 6 is an idealized illustration of alternative detection modes. The approach shown has presence-mode stop-line detection in each of the through and left-turn lanes. The zones in the two through lanes are linked using an OR logic function. Detection of a vehicle in either lane will trigger a call to the through phase. This operation is identical to that achieved when both detectors are assigned to the same channel. However, the linkage allows for the specification of a common delay or extension time for both detectors.

The left-turn bay in Figure 6 uses two parallel detection zones for improved selectivity and sensitivity. Specifically, the right-side camera offset raises the possibility of an unneeded call from a tall vehicle in the adjacent through lane. The AND linkage for the two left-turn detection zones minimizes this problem. Also, for some VIVDS products, the use of two detectors in the same lane improves detection sensitivity.

Lastly, the intersection approach shown in Figure 6 is skewed from 90 degrees, which results in a large distance between the stop line and the cross street. This setback distance is especially significant for the left-turn movements. In anticipation that left-turn drivers may creep past the stop line while waiting for a green indication, additional detectors are located beyond the stop line. However, they are directional detectors (as denoted by the word DOWN), such that they prevent crossing vehicles from triggering an unneeded call.

Detector Settings

Video detectors have delay and extend settings that can be used to screen calls or add time to their duration, as may be needed by the detection design. These settings are identical in performance and purpose to those available with inductive loop amplifiers. The use of the delay setting is shown in Figure 6. The detector in the right-turn lane is used as a queue detector to trigger a call to the through movement in the event that the right-turning drivers cannot find adequate gaps in traffic. The delay is set to about 2 s, such that a turning vehicle does not trigger a call unless it is stopped in queue.

The delay setting is also used to reduce the frequency of unneeded calls. Specifically, a few seconds of delay is often set on the detectors in the stop-line detection zone of each minor-road approach. This setting offers two benefits. First, it eliminates false calls to the minor-road phases by major-road vehicle headlights (such as when a major-road vehicle makes a right turn and its headlights sweep across the minor-road stop-line detection zone). Second, it eliminates false calls to the minor-road phases by tall major-road vehicles (i.e., when tall vehicles cross the view of the minor-road camera and momentarily project their image onto the minor-road stop-line detection zones).

The delay setting is also appropriate for the detectors in the left-turn bay when monitored by a left-side-mounted camera. This delay setting will screen unneeded calls for the left-turn phase that are placed by a tall through vehicle traveling away from the intersection. A 10-s delay setting should be sufficient to prevent unnecessary calls by departing vehicles.

On-Site Performance Checks

Return Visit to Verify Operation

In the days following the VIVDS installation, the engineer or technician should return to the intersection on one or more occasions and reevaluate the VIVDS performance. The purpose of each visit is to verify that the intersection is operating in an acceptable manner and that the VIVDS detectors are detecting vehicles with reasonable accuracy. In general, operation and accuracy should be checked at midday and during the late afternoon, nighttime, and early morning hours. In most cases, each time period is checked during a separate return visit. If sun glare or reflection is a problem during the late afternoon or early morning, it might be mitigated by adjusting the visor on the camera housing. If this adjustment does not eliminate the problem, then the camera pitch angle should be increased.

Maintenance

A periodic check (say, every six months) of the camera field-of-view and detection layout is encouraged. During this check, the engineer or technician should: (1) verify that the detection zones are still in the proper location relative to the traffic lanes, (2) assess the impact of seasonal changes in the sun's position on detection accuracy, (3) verify that the VIVDS is using the latest software version and upgrade it if needed, and (4) check the camera lens for moisture or dirt buildup and clean if needed. In areas with high humidity and extended concentrations of smoke, dust, or other airborne particles, the camera lens may need to be cleaned as frequently as every six weeks.

REFERENCES

1. Bonneson, J., and M. Abbas. *Video Detection for Intersection and Interchange Control.* FHWA/TX-03/4285-1. Texas Transportation Institute, Texas A&M University System, College Station, Texas, September 2002.