TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM

Project Summary Report 4285-S
Project 0-4285: Video Detection for Intersections and Interchanges

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PROJECT SUMMARY REPORT

Guidelines for Using Video Detection at Intersections and Interchanges

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.

It is estimated that about 10 percent of the intersections in Texas currently use VIVDSs. The collective experience with the operation of these intersections has generally been positive; however, this experience is limited to a short amount of time (relative to the life of such systems). Moreover, experience with the design and installation of a VIVDS for intersection control has been limited. This limitation is due to the fact that most intersection control applications have been "turnkey" arrangements with the product vendors. Further increases in VIVDS application will require greater participation by TxDOT engineers in the planning, design, operation, and installation stages.

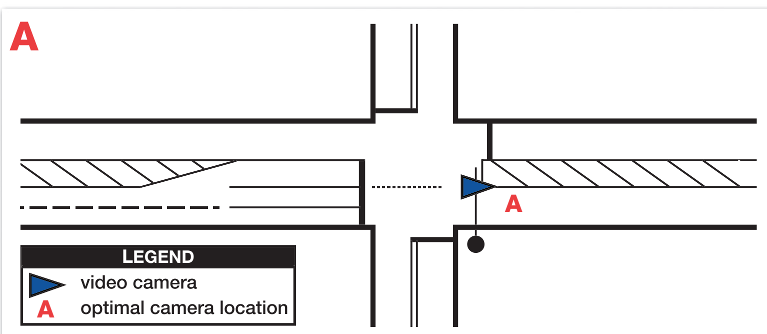

Figure 1. A) Illustrative optimal camera location; B) Illustrative optimal field of view.

What We Did . . .

The objective of this project was to develop guidelines for planning, designing, installing, and maintaining a VIVDS at a new or existing intersection or interchange. This objective was achieved by conducting the following activities:

- evaluating several VIVDS products with a focus on detection accuracy, system performance, and ease of set-up;
- developing guidelines describing when and how to use a VIVDS; and
- developing guidelines for detection design and detection layout.

The guidelines developed for this project address the use of VIVDSs to detect vehicle presence at a signalized intersection or interchange in Texas. 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.

A series of work tasks were conducted for this project. The activities associated with these tasks include:

- gathering experiences with the installation and maintenance of VIVDSs from TxDOT engineers,
- developing guidelines for VIVDS design and operation,
- conducting field studies at eight intersections and two interchanges in Texas,
- evaluating data from the field studies and refining the guidelines, and
- documenting guidelines in an intersection video detection manual and a field handbook.

The manual (Report 4285-2) was developed to help engineers determine when a VIVDS is appropriate, what functionality is needed, and how the detection components should be designed and operated. Information useful to signal technicians regarding VIVDS operations is presented in the handbook (Report 4285-3).

What We Found . . .

Application Considerations

For signalized intersection applications, a VIVDS is most often used to provide vehicle presence detection in the vicinity of the stop line. The VIVDS cameras are mounted on the mast arm or on the mast-arm pole. A VIVDS is found to provide reliable presence detection when the detection zone is relatively long (approximately 40 ft or more).

A VIVDS is sometimes used to provide advance detection on high-speed intersection approaches. However, some agencies are cautious about this use because of difficulties associated with the accurate detection of vehicles that are distant from the camera. Among those agencies that use a VIVDS for advance detection, the most conservative position is that it should not be used to monitor vehicle presence at distances more than 300 ft from the stop line. Experience with VIVDSs in Texas indicates that acceptable presence-mode operation is achieved at distances up to 500 ft.

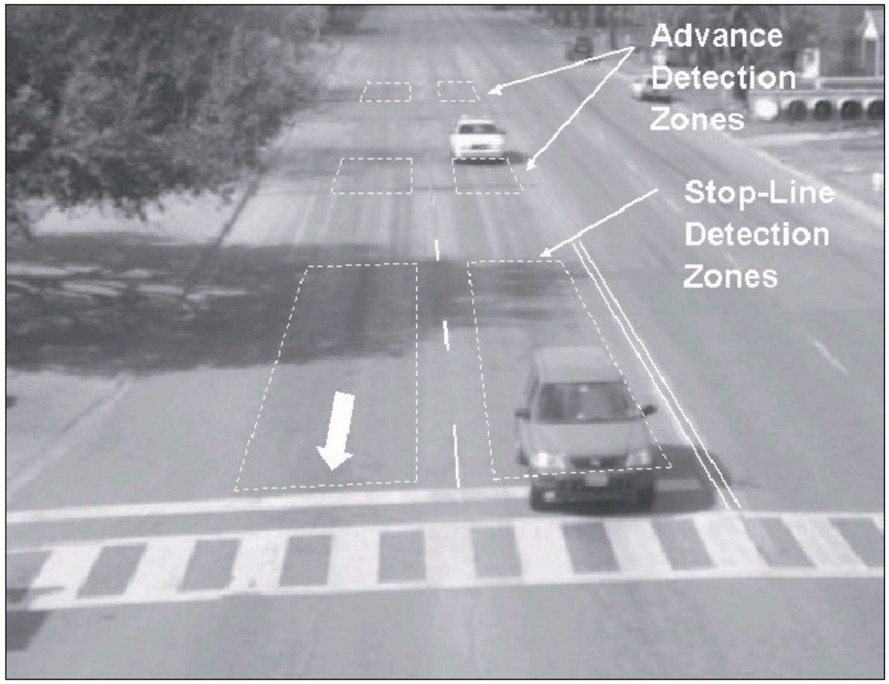

Figure 2. Illustrative optimal detection zone layout.

A VIVDS is primarily used in situations where its high initial cost is offset by that associated with installing and maintaining inductive loop detectors. VIVDSs have been generally recognized as cost-effective, relative to alternative detection systems, in the following situations:

- when more than 12 stop-line detectors are needed at the intersection or interchange,
- when inductive loop life is short due to poor pavement or poor soil conditions,
- when extensive intersection reconstruction will last for one or more years,
- when the loop installation is physically impractical due to the presence of a bridge deck, railroad tracks, or underground utilities, and
- when the pavement in which the loop is placed will be reconstructed in less than three years or during overlay projects at large intersections where the cost of replacing all loops exceeds the cost of installing the VIVDS.

Design Considerations

Camera location is an important factor influencing detection accuracy. According to several VIVDS product manuals, an optimal location is one that provides a stable, unobstructed view of each traffic lane on the intersection approach. Moreover, 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.

The VIVDS product manuals indicate that detection accuracy will improve as camera height increases within the range of 20 to 40 ft. This height improves the camera's view of each approach traffic lane by minimizing the adverse effects of occlusion.

Calibration of the camera field of view is based on a one-time adjustment to the camera pitch angle and the lens focal length. According to several VIVDS product manuals, 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 optimal camera location is indicated by the letter "A" in Figure 1-A. An optimal field of view is illustrated in Figure 1-B.

Operation Issues

Detection zone layout is an important factor influencing the performance of the intersection. Guidance provided by several VIVDS product manuals indicates that there are several factors to consider, including:

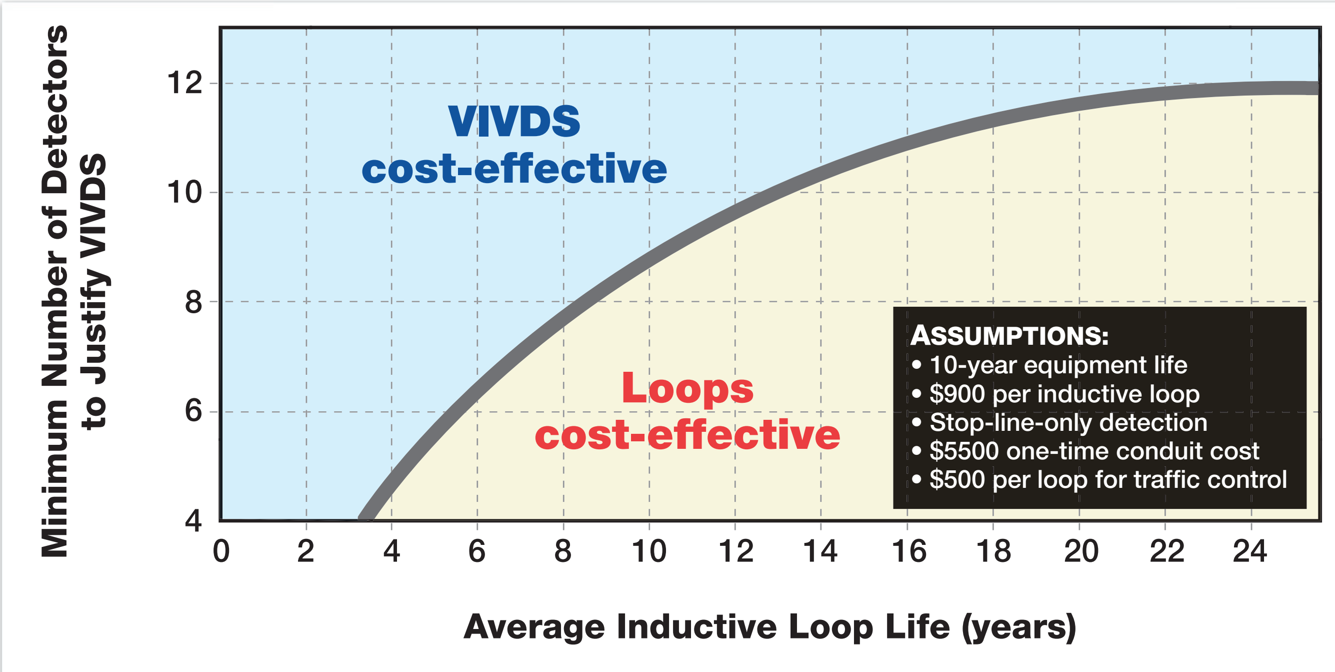

Figure 3. Minimum number of detectors to justify a VIVDS.

- zone location relative to the stop line,
- the number of VIVDS detectors used to constitute the detection zone,
- whether to link the detectors using Boolean logic functions,
- whether to have the detector monitor travel only in a specified direction, and
- whether the detector's call is delayed or extended.

A typical detection zone layout is shown in Figure 2. The actual detectors provided by the VIVDS product would be placed in the zones shown in the figure such that the area is fully monitored.

Unlike that of inductive loops, the performance of a VIVDS is adversely affected by camera motion, daily changes in light level, and seasonal changes in the sun's position. In recognition of these factors, at least one VIVDS manual encourages an initial check of the detector layout and operation during the morning, evening, and at night to verify the operation is as intended. Periodic checks at specified time intervals (e.g., every six months) are beneficial.

The Researchers Recommend . . .

A life-cycle cost analysis comparing a four-camera VIVDS and an inductive loop system indicated that a VIVDS is more cost-effective than a loop system under certain conditions. These conditions relate to the number of inductive loops needed at the intersection and the expected life of these loops. In general, a four-camera VIVDS is cost-effective at intersections requiring 12 or more stop-line loop detectors, regardless of loop life. However, in areas where the average loop life is only four years, a VIVDS is found to be cost-effective when only five loops are needed. The relationship between loop life and the minimum of detectors needed to justify the cost of a VIVDS is shown in Figure 3.

Researchers developed minimum camera height guidelines to reduce occlusion. The minimum heights vary from 20 to 50 ft, depending on the width of the approach and camera offset. The minimum height for a camera mounted in the center of the approach is 20 ft. Larger minimums are needed as the camera is moved left or right from this central position. Field measurements of detection accuracy indicate that intersection approaches served by cameras that exceed the minimum height have significantly fewer unneeded or missed calls.

Researchers also developed minimum camera height guidelines to maintain acceptable detection accuracy. This minimum height is required when the VIVDS is used to monitor sections of the approach that are well in advance of the stop line. The minimum height needed for advance detection ranges from 24 to 36 ft, depending on the distance between the camera and stop line and on the approach speed limit. The higher distances are needed for higher speeds or greater distances.

Field measurements indicate that increasing camera height tends to improve accuracy, provided that there is no camera motion. However, camera heights of 34 ft or more may be associated with an above-average detection error rate unless the camera is mounted on a stable pole.

Researchers developed guidelines for designing stop-line-only detection and stop-line plus advance detection using VIVDSs. These guidelines describe the recommended number of detection zones as well as their location and length. The guidelines for stop-line-only detection are based on the use of a long detection zone and a 0.0-s controller passage time. The guidelines for stop-line plus advance detection are based on a 1.0-s passage time and two advance detectors. Both simulation and field data indicate that the use of these guidelines can reduce delay and improve intersection operation.

For More Details . . .

The research is documented in Report 4285-1, *Video Detection for Intersection and Interchange Control*. Related reports include: Report 4285-2, *Intersection Video Detection Manual*, and Report 4285-3, *Intersection Video Detection Field Handbook*.

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This research examined the effectiveness of video imaging vehicle detection systems (VIVDSs) on Texas highways. Application and design issues are critical in determining the proper location to install a VIVDS at an intersection. Operational issues are important factors in influencing the performance of VIVDSs. This research is incorporated into the *Intersection Video Detection Manual* and the *Field Handbook*, which will aid traffic engineers and technicians in the effective use of VIVDS.

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