TEXAS TRANSPORTATION INSTITUTE
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PROJECT SUMMARY REPORT

Project Summary Report 0-4022-S

Project Number 0-4022: Detection-Control System for Rural Signalized Intersections

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New Detection System for Rural Signalized Intersections

Traffic engineers are often faced with operational and safety challenges at rural, high-speed signalized intersections. Vehicle-actuated control, combined with multiple advance detectors, is often used to improve operations and safety. However, this type of detection and control has not always eliminated rear-end or right-angle crashes. Crashes sometimes continue to occur at high-speed intersections, and delays to traffic movements can be unnecessarily long.

The existing multiple advance detector system holds the traffic signal in green until a suitably large gap occurs in the traffic stream. Through this action, the system ends the phase safely because the approach is empty. However, this gap occurs infrequently on high-volume approaches and often causes the corresponding signal phase to extend to its maximum limit (i.e., max-out). When the phase reaches this limit, it ends without regard to the number of vehicles on the approach and increases the potential for a rear-end crash. If the maximum green setting is large, then the resulting delays may also be large. The high-speed nature of most rural intersections heightens concerns about phase termination by max-out because crash severity increases significantly with speed.

Other problems exist with the multiple advance detector system. They include:

- Its operation is not sensitive to the type of vehicle on the approach (i.e., car or truck).
- Its operation is not sensitive to the delay experienced by motorists on the minor road.
- Its installation is often costly in terms of the number of advance detectors needed along the major-road approaches.

The objective of this research project was to develop and evaluate an intelligent detection-control system that is capable of overcoming the limitations of the multiple advance detector system.

What We Did...

First, the research team reviewed the capabilities of vehicle detection systems currently in use at high-speed intersections. Then, using information obtained from this review, they developed a new system that both detects vehicles and intelligently controls the major-road traffic movements.

The new detection-control system is based on the use of a computer, housed in the signal controller cabinet. This computer uses a detector speed trap, located 700 to 1000 ft upstream of the intersection, to monitor approaching traffic and predict the time *each* driver is within a "critical" section of the intersection approach. This critical section is sometimes referred to as the "dilemma zone" or the "indecision zone" because it represents that portion of the intersection approach within which drivers exhibit distinct differences in their desire (or ability) to stop when presented the yellow indication. On a typical approach, the indecision zone starts at about 5.5 seconds travel time from the intersection.

At the same time that the new system is monitoring approaching vehicles, it is also searching for a time in the near future when the total number of drivers in their respective indecision zones is at a minimum. This future time is defined as the "best time to end the phase." Other factors that are also considered when deciding the best time to end the phase include: (1) whether the vehicle is a large truck and (2) the delay to drivers waiting on the minor road.

At the start of each signal phase, the new system begins searching for the best time to end the phase. However, if it is unsuccessful after 30 to 40 seconds and *if* there are several drivers waiting on the minor road, the system relaxes the search criterion and ends the phase when there is a maximum of one car (no trucks) in its indecision zone.

In short, the most unique feature of the new system is its ability to "dynamically" identify the indecision zone for *each* vehicle, in *real time*, and *prior* to when the information is needed by the controller. This feature yields safe and efficient signal operation for the full range of intersection traffic volumes.

The researchers installed the new system at two intersections in Texas and studied its operation extensively. The studies included field measurements of the system's speed measurement capability and its ability to consistently find the best time to end the phase. The researchers also used hardware-in-the-loop simulation to fine-tune the system logic.

What We Found...

System Description

The detection-control system's detector layout and control strategy are illustrated in Figure 1 for one approach traffic lane. Unlike the multiple advance detector system, the new system does not monitor, and attempt to clear, a physical zone in the approach lane. Instead, it uses the speed and length information measured for each vehicle to dynamically define that vehicle's indecision zone prior to its arrival to the zone.

Figure 1 illustrates the indecision zone location for vehicles traveling at the 5th, 15th, 50th, 85th, and 95th percentile speeds. Limited space within the figure precludes showing additional zones but a unique zone exists for each possible speed with the new system. Through this process, the new system: (1) ends the phase sooner, (2) operates with less delay, and (3) catches fewer vehicles in the indecision zone than the multiple advance detector system.

Figure 2 is a flowchart showing the new system and its relationship to two other systems: the detection system and the traffic control system. The new system consists of a vehicle classifier, a computer to process the detection-control (D-C) algorithm, and an input/output (I/O) device to provide a two-way communications interface between the computer and the signal controller. This version of the system has been tested and is ready for immediate implementation at intersections in Texas. It is anticipated that the new system's logic will be consolidated into a signal controller (by a controller manufacturer) as its becomes more widely used.

The new system continuously communicates with both the vehicle detection system and the traffic control system. It uses the information provided by both systems to make decisions about holding the current phase in green or terminating it. The vehicle detection system provides information about vehicle length, speed, and lane location from the upstream major-road detectors. The traffic control system provides information about the presence of vehicles waiting at the stop line of each of the conflicting movements. It also responds to requests from the detection-control system to end the signal phase.

Conclusions Reached

The objective of the new detection-control system is to effectively and efficiently detect and control the major-road approaches to a rural signalized intersection. This objective is achieved by the new system's ability to determine when each driver is in his or her indecision zone and minimize the number of drivers that are caught in this zone at the onset of the yellow signal indication.

Improve Safety at High-Speed Intersections

The new system offers two safety benefits. First, it provides indecision-zone protection to *all* drivers. The existing system does not guarantee that the fastest or slowest 15 percent of vehicles are clear of their respective indecision zones at the onset of yellow. Second, the new system can relax its "gap-out" selection criteria after trying unsuccessfully to find an empty zone during the first 30 to 40 seconds of green. In its relaxed state, the new system allows up to one car per lane (but no truck) to be caught in its indecision zone at the onset of yellow. This feature is especially useful during higher flow rates when a search for a clear approach would frequently lead to max-out. Ending the phase with one car in the indecision zone is reasonably safe (from a rear-end crash) and preferable to ending with no protection (via max-out).

Reduce Design, Maintenance, and Installation Costs

Cost reductions are realized in two ways. First, the new system has a one-size-fits-all design such that its layout and operation are the same for all approach speeds. In

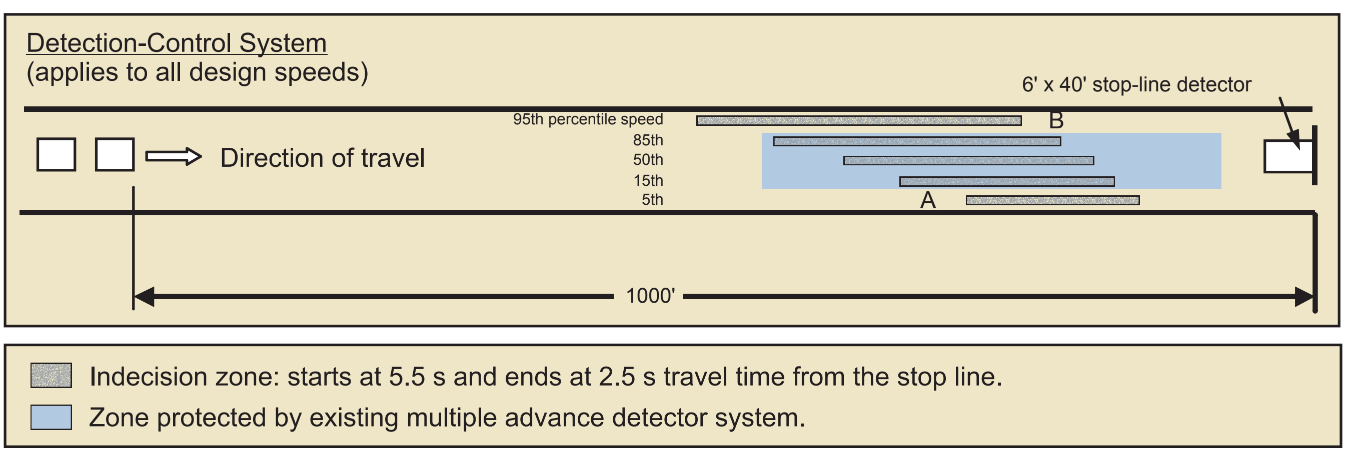

Figure 1. Detector Layout for the New Detection-Control System.

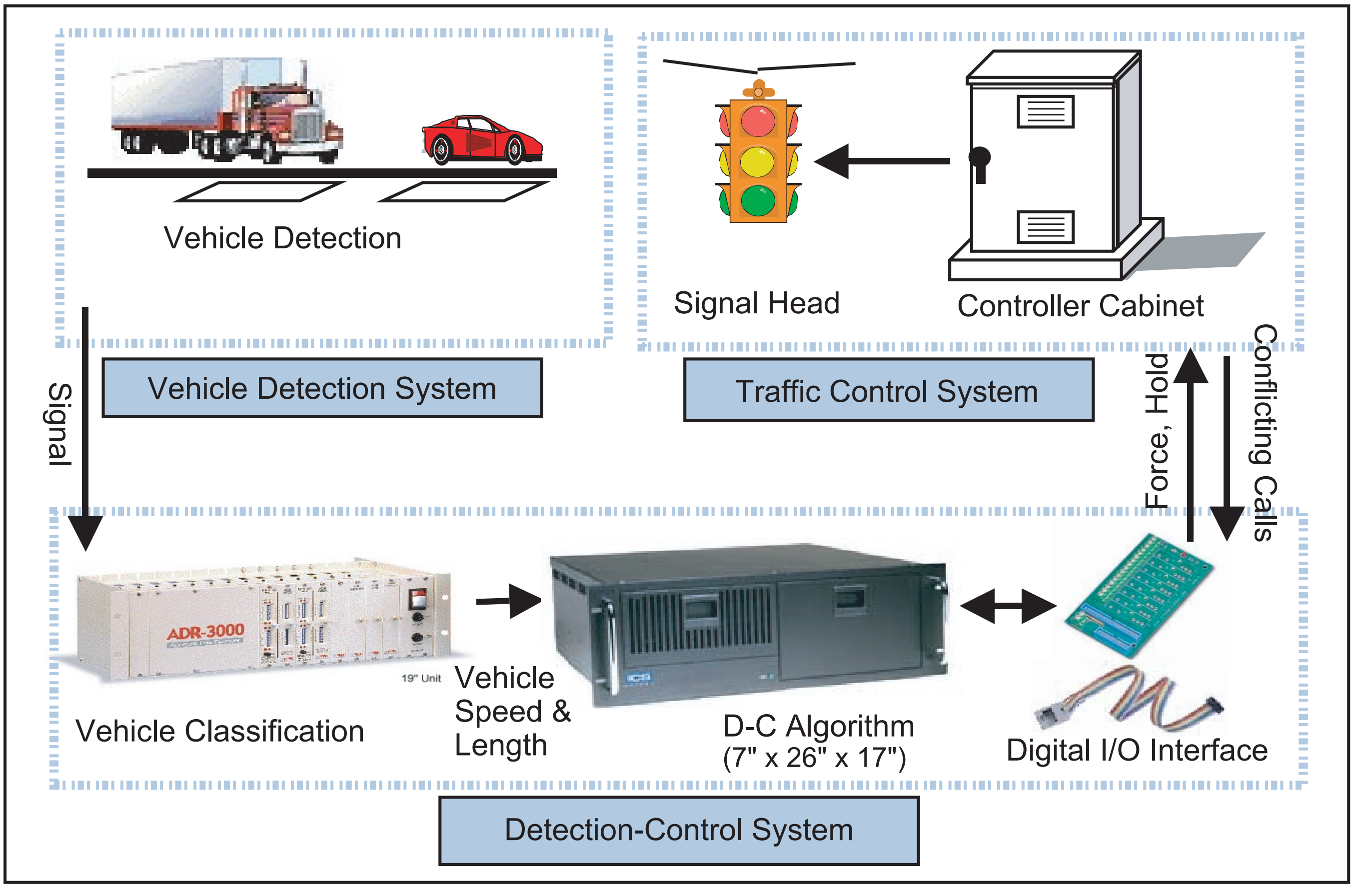

Figure 2. Concept System Components.

contrast, the existing system requires engineering oversight during its design and installation as several key design elements and controller settings are dependent on the one approach speed used for design. Second, the new system is robust in terms of its ability to adapt (without manual intervention) to changes in speed over its design life (e.g., due to a change in the posted speed limit) and, thereby, maintain a high level of safety and efficiency over time. In contrast, the detectors for the existing system would have to be reinstalled if the approach speed limit is permanently changed.

Provide Sensitivity to Trucks in the Indecision Zone

Truck sensitivity is realized by measuring the length of the approaching vehicles and using this information to postpone phase termination whenever trucks (i.e., vehicles more than 25 ft in length) are in the indecision zone. The existing system does not provide this sensitivity.

Maintain or Reduce Overall Delay

Motorist delay is maintained or reduced in two ways. First, the new system's dynamic indecision-zone monitoring process is often able to find the "best time to end the phase" sooner than the existing system. This process can translate into shorter phases and lower overall delay. Second, the new system does not allow the stop-line detector to extend the phase once the queue has been served. This feature reduces wasted green time at the end of the phase and minimizes delay to waiting vehicles. These benefits are most evident at higher flow rates.

The Researchers Recommend...

The new detection-control system is recommended for use at all high-speed, full-actuated intersections. It can be used at intersections characterized as having low, moderate, or even high traffic volume. The intersection should have a major road and a minor road where the major-road approach has an 85th percentile speed (or posted speed limit) of 45 mph or more. A speed trap detector must be installed in each lane of both major-road approaches. The intersection must operate in isolation of other, adjacent signalized intersections. A left-turn bay is required for each major-road approach and a right-turn bay (or full-width shoulder) is desirable.

The new system should be considered at all new intersections whenever multiple advance detection is being contemplated. At existing intersections with multiple advance detectors, the new system should be considered as a replacement system when the design life of the existing detection system has been reached.

For More Details . . .

The research is documented in Report 4022-2, *Intelligent Detection-Control System for Rural Intersections*.

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TxDOT Implementation Status
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This research project involved the development and testing of a detection-control system that is capable of minimizing both delay and crash frequency at rural intersections. Three products were required for this project:

1) design guidelines to describe procedures for implementing a recommended detection-control system,
2) a specification document to provide details of parameters, functions and performance of a recommended detection-control system, and
3) detection-control hardware and related equipment for installation at two sites.

The design guidelines and specifications are currently being implemented to develop an advanced detection-control system as part of an ongoing implementation project. If the advanced detection-control system operates favorably throughout implementation, it is recommended that this system be used on a statewide basis at rural intersections where conditions are warranted.

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