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Summary Report on Improving Diamond Interchange Operations Using Advanced Controller Features

Due to financial, environmental, and spatial constraints, it is becoming increasingly difficult to improve diamond interchange operations through geometric improvements alone. An alternative to geometric improvements is to maximize the use of technology, for example, by better using the capabilities of currently deployed traffic signal controllers. Modern traffic signal controllers include some advanced features that are not often used but have the potential to improve traffic operations at signalized diamond interchanges under certain conditions if applied correctly.

What We Did...

This research project explored traffic signal control at diamond interchanges and in particular how the features of existing traffic signal controllers can be used to improve traffic

operations at diamond interchanges. We developed guidelines to help Texas Department of Transportation personnel identify and apply the advanced features available in existing traffic signal controllers and improve the state of the practice in diamond interchange control.

We focused on the two traffic signal controllers that meet the current TxDOT traffic signal controller specification:

- Eagle Traffic Control Systems' EPAC300 controller (Figure 1), and
- Naztec Incorporated's Model 980 controller with Version 50 software (Figure 2).

We investigated the feature sets of these two controllers and identified features that could be useful for diamond interchange control. We then tested those features to verify that they were compatible with the diamond control mode that is normally

used for diamond interchange control. Some features were not investigated further because they were incompatible with the diamond control mode.

The remaining features were then evaluated using a technique called hardware-in-the-loop traffic simulation, which uses real traffic control hardware (the actual Eagle and Naztec controllers) to control traffic in a computerized traffic simulation running in real time. We used the CORSIM simulation model and connected it to a traffic signal controller through a TS2 controller interface device, as shown in Figure 3. Hardware-in-the-loop traffic simulation allowed us to effectively and accurately compare controller features for the following reasons:

- the same traffic conditions could be reproduced and evaluated under different control strategies



Figure 1. Eagle EPAC300 Controller



Figure 2. Naztec 980 Controller



- extensive measures of effectiveness could be used to compare the performance of the control strategies, and
- the real control hardware added a high level of realism.

Hardware-in-the-loop simulation was also used to evaluate the guidelines developed in this project using the geometry and demand from a number of real interchanges throughout Texas.

What We Found... Eight Useful Controller Features

The study identified eight controller features that can improve diamond interchange operations under certain conditions:

- separate intersection mode,
- diamond phasing sequence change by time of day,
- conditional service,
- dynamic maximum green times,
- dynamic split,
- volume-density control,
- alternate maximum green and passage times, and
- adaptive protected-permissive left turns.

The guidelines developed as part of this project describe the concept of operation of each of these features. They provide detailed application guidelines, including applicability under different geometric and demand conditions and compatibility with various detection technologies. The guidelines also provide detailed programming instructions to guide engineers and technicians in implementing these features on the Eagle and Naztec controllers.

A Useful Separate Intersection Mode

One of the main findings of this research was a realization of the potential usefulness of the separate intersection diamond control mode. The separate intersection diamond control mode is not commonly used,

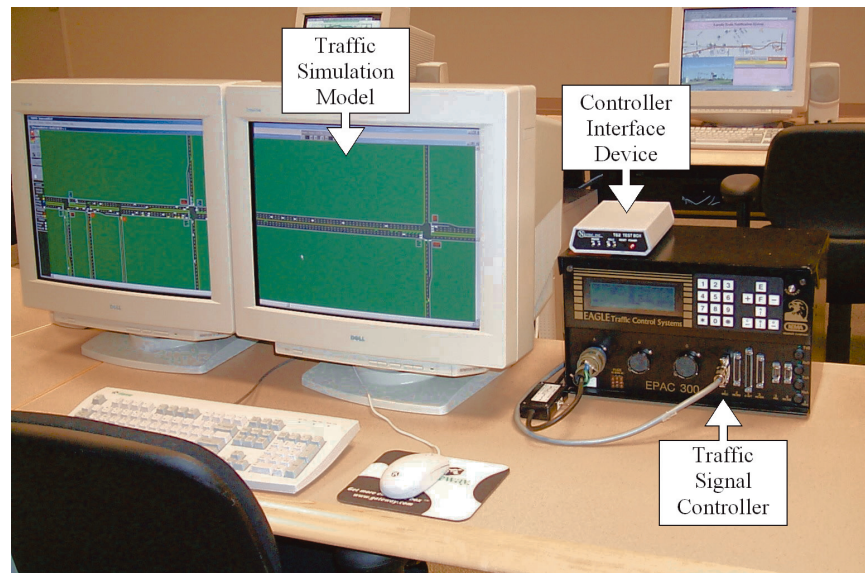


Figure 3. Hardware-in-the-Loop Simulation Setup

but if applied judiciously it has the potential to provide more efficient control than the three-phase or four-phase sequences. The separate intersection mode can be used in both free and coordinated mode.

The free separate intersection mode can significantly reduce stops at interchanges under low-volume conditions, especially if the interior left turns can operate as permissive left turns and steps are taken to reduce the activation of the interior left-turn phases.

Figure 4 shows the results of a hardware-in-the-loop simulation performance evaluation of the Bagby/Texas 6 interchange in Waco, Texas. The leftmost bar indicates the percentage of stops when using the three-phase sequence, which is currently used during low-volume conditions. The other bars show reduced stops using the free separate intersection mode with different left-turn phasing treatments. The rightmost bar represents the free separate intersection mode with the interior left turns omitted, which results in a 34 percent reduction in stops compared to the three-phase sequence.

The coordinated separate intersection mode has the potential to provide more efficient operation than the three-phase or four-phase sequence under certain conditions

that can be determined with signal optimization software such as PASSER III and Synchro. The “ring lag” feature provided by the Eagle controller can be used to specify the offset between the coordinated phases, allowing the separate intersection mode to provide progression through the interchange under a wide range of geometric and demand conditions.

A hardware-in-the-loop traffic simulation of the Briarcrest/Texas 6 interchange in Bryan, Texas, indicated that at that interchange the coordinated separate intersection mode is more efficient in handling the afternoon peak-hour traffic than the three-phase mode. Specifically, the analysis indicated that on average the separate intersection mode results in an overall delay reduction of 2 to 9 percent over the three-phase mode.

Video Detection May Be Restrictive

Another important finding of this research is that not all of the controller features listed above are compatible with video detection. Video detection is very suitable for zone detection, but may not be sufficiently accurate to serve as input to controller features that rely on the accurate point detection of vehicles, such as volume-density control and adaptive protected-permissive left



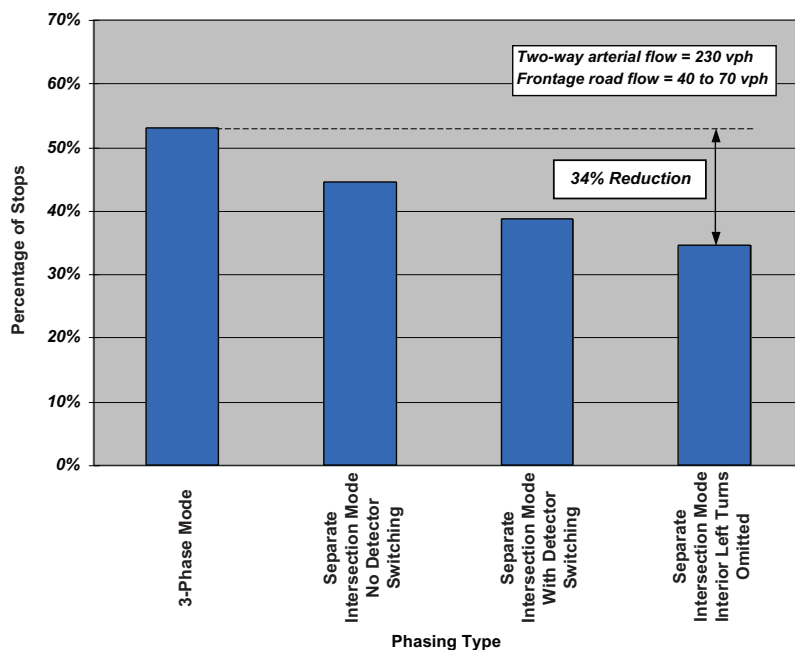


Figure 4. Example of Percentage of Stops Under Low-Volume Conditions Based on Bagby/Texas 6 Simulation

turns. Problems include the irregular gap measurement and occlusion of vehicles by other, larger vehicles.

Because of the camera angle and resulting parallax error, vehicle lengths observed by the video detection system are longer than actual vehicle lengths by a factor that varies with the height of the rear of the vehicle traversing the detection zone. Therefore, the measured gap between vehicles is always less than the actual gap, and the difference depends on the height of the rear of the leading vehicle. Since vehicle heights in the traffic stream vary randomly, measured gaps will vary randomly, and functions that rely on accurate vehicle gap measurement—such as the adaptive protected-permissive left-turn feature that uses measured gap sizes to determine left-turn capacity—may not operate correctly.

Figure 5 shows the related problem of vehicle occlusion. As shown, it is possible that a larger vehicle may obscure a smaller vehicle following behind it, resulting in the smaller vehicle not actuating the video detector. This may lead to problems in controller features that depend on accurate vehicle counting, such as the added initial feature of volume-

density control and the adaptive protected-permissive left-turn feature that uses left-turn vehicle counts to determine left-turn demand.

Increasing distance between the camera and the detection zone exacerbates the irregular gap measurement and vehicle occlusion problems if the camera height does not increase in the same ratio. Since there is typically a maximum height at which a camera can be mounted, setback detectors often used for diamond interchange control will be more susceptible to these types of errors. One potential solution would be to relocate the camera to a location closer to the setback detector.

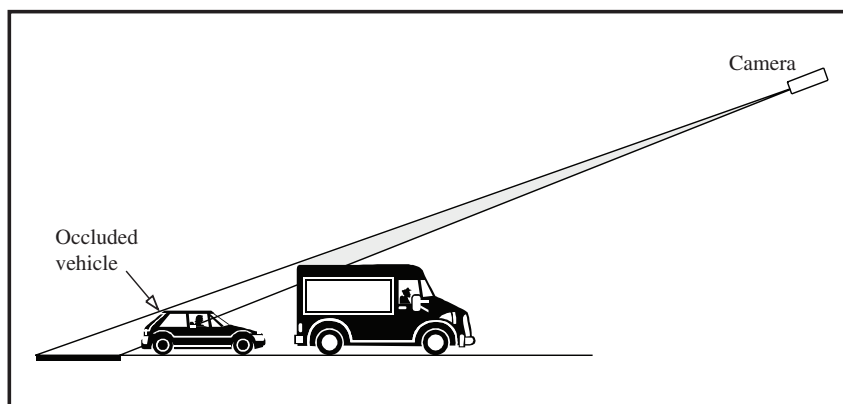


Figure 5. Vehicle Occlusion with Video Detection

The Researchers Recommend...

Since the coordinated separate intersections mode with “ring lag” proved very useful, we recommend that the TxDOT specification be extended to include the “ring lag” or “individual ring offset” feature that is required to implement the coordinated separate intersections mode in the most flexible manner. The Eagle controller already implements the ring lag feature, but the Naztec controller does not.

We recommend that the potential drawbacks of video detection, as discussed above, be taken into account when deciding on the vehicle detection technology to use at new signalized diamond interchanges, or when a change in existing detection technology is considered.

We recommend that the guidelines developed in this research be used when reevaluating existing diamond interchange operation or when developing timing for new interchanges. The controller features identified in this project should be implemented, as appropriate according to the guidelines, but in all cases, driver expectation and other safety issues should be taken into account.



For More Details . . .

This research is documented in

Related Reports: [Report 4158-1, *Research Report on Improving Diamond Interchange Operations Using Advanced Controller Features*](#)

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The product resulting from this research was a guideline for use of advanced traffic control features, including matching of features with conditions, programming changes, and hardware needs. Advanced features of Eagle EPAC300 and Naztec 980 controllers were evaluated using CORSIM simulation and field testing. The guidelines were published with report 4158-1. The guidelines have been incorporated into the “Diamond Interchange Signal Timing Workshop” that was developed as part of Project 5-1439-01: Transportation Research Implementation Consortium for Operations and Management. The workshop will be presented at a number of locations in Texas over the next 3 years.

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