TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM

Project Summary Report 4913-S
Project 7-4913: Operational Strategies for Arterial Congestion at Interchanges

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PROJECT SUMMARY REPORT

Timing Diamond Interchanges and Closely Spaced Signals

Diamond interchanges serve as critical links between roadway facilities of two different classifications: freeways and surface street systems. Thus, the operation of a diamond interchange can affect or be affected by the location, design, and operation of adjacent traffic signals and ramps. Especially during peak traffic conditions, inefficient operation of a diamond interchange and adjacent traffic signals may cause either system to become a bottleneck, downgrading not just the capacity of the interchange, but also that of the arterial and in some cases even the capacity of the freeway ramps. In many cases, the already complex nature of traffic flow through a diamond-interchange and adjacent traffic-signal system is further complicated by weaving and queuing caused by traffic movements to and from offices, shopping malls, and gas stations located in the vicinity of the interchange.

Many Texas Department of Transportation (TxDOT) districts and Texas cities face similar operational problems within diamond interchange environments on a daily basis. However, no guidelines or optimization/analysis tools are currently available to TxDOT and local agencies for solving these problems. TxDOT initiated this two-year project to fill existing gaps in technologies for analyzing and optimizing the flow of traffic in congested diamond interchange environments and for developing guidelines for coordinating diamond interchanges with adjacent traffic signals on the arterial.

What We Did . . .

In this project, the researchers performed the following work:

- evaluated existing technology;
- evaluated current practice in Texas by surveying all TxDOT districts and seven cities;
- performed simulation and theoretical analysis of three commonly used diamond interchange control strategies for a range of traffic conditions and interchange geometry;
- developed a procedure for determining the ideal capacities of diamond interchange control strategies for any traffic pattern;
- developed an iterative procedure for simultaneously calculating phase times for a system including a diamond

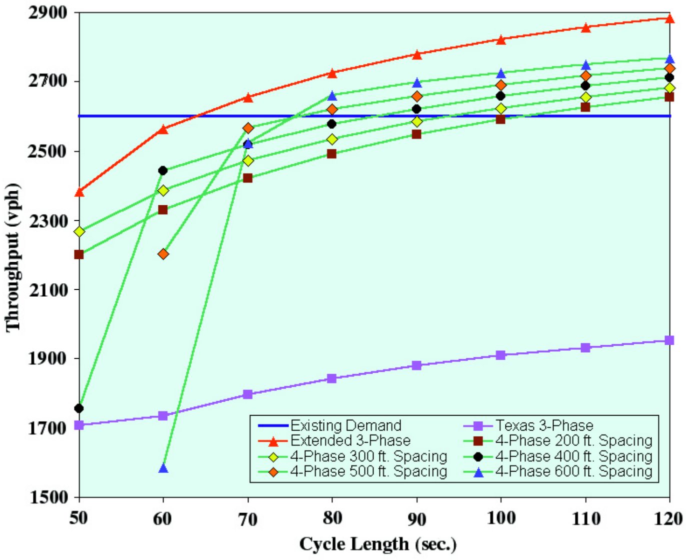

Figure 1. Heavy demand at one signal and light demand at the other signal

interchange and adjacent signals on the arterial; and

- developed improved timing plans for one site in Corpus Christi and one site in Weslaco.

What We Found . . .

Status of Technology

From the review of existing technology, we found that the current technology, including procedures and software tools, is inadequate for timing a near-congested or congested arterial system consisting of a diamond interchange and closely spaced adjacent signals. Also, there exist no guidelines for developing timings based on the analysis of the complete system.

State of Practice

From the survey, we found the following:

- TxDOT and city engineers agree that minimizing queues at the frontage-roads/ramp-terminals should be the primary objective in selecting a control strategy for the interchange. There are differences in opinion about the importance of minimizing internal queues, balancing delay on external approaches and maximizing arterial progression. Finally, providing access to adjacent properties was rated as the lowest objective.
- Engineers often use the tools and methods that are easy to use and whose use requires the least amount of time and data.
- Engineers use the distance criteria (conventional, tight, or compressed diamond) and demand levels to select the control strategy (Texas 3-Phase, Texas Transportation Institute (TTI) 4-Phase, or separate intersection control). Furthermore, for safety reasons, engineers prefer to use only one control strategy for an interchange at all times.
- TTI 4-Phase is the most commonly used strategy.
- In order to correct operational problems, the engineers first try signal retiming, followed by other approaches (changing lane assignments, adding lanes, and relocating ramps).
- During peak periods, engineers use cycle lengths as high as 280 seconds.

Simulation Analysis

Our initial investigation revealed that optimum operation of a diamond interchange is key to providing optimum traffic control for systems in which adjacent signals on the arterial are located in close vicinity. We used PASSER III and CORSIM to analyze 612 different scenarios resulting from various combinations of the following factors:

- two control strategies (Texas 3-Phase and TTI 4-Phase);
- three interior distances (200, 400, and 600 feet);
- four volume conditions; and
- two volume distributions.

From these studies, we found that TTI 4-Phase results in less vehicular delay than Texas 3-Phase for distances of 400 feet or less. For a distance of 600 feet, the two strategies produce similar delays. Also, the delay for TTI 4-Phase increases, and the delay for Texas 3-Phase decreases, with an increase in interior distance. For all interior distance and optimum cycle lengths, TTI 4-Phase consistently resulted in lower internal delays and higher external delays than Texas 3-Phase. In addition, we observed that Texas 3-Phase performance is poor for unbalanced heavy demand conditions. The results of this analysis confirmed that the distance between the two intersections of an interchange, along with knowledge of traffic patterns at a facility, can be reliably used to select the most appropriate diamond control strategy.

Capacity Analysis of Control Strategies

One question that remains unanswered deals with the selection of optimum cycle length for a diamond interchange. In order to answer this question, we developed an easy-to-use mathematical procedure for predicting the throughput capacity of an interchange for a given timing plan and a given traffic pattern. This procedure is generic and can be applied to a system with any number of signals.

Figure 1 illustrates the graph for a condition in which there is heavy exterior demand at one signal and light exterior demand at the other intersection. The horizontal line on this graph depicts an instance in which the total traffic demand for an interchange is 2600 vehicles per hour (VPH). As can be seen from the graph, Texas 3-Phase does not provide sufficient capacity to handle this demand, but TTI 4-Phase does with the appropriate cycle length. Finally, if the interchange were more than 3000 VPH, none of these control strategies would provide sufficient capacity.

Coordination with Adjacent Signals

In this task, we developed conditions for coordinating a diamond interchange with an adjacent signal and described how to apply these conditions. In addition, we developed an iterative procedure for simultaneously calculating green splits for the entire system of signals. It detects undersaturated or saturated conditions and produces better results than the customary approach of independently calculating green splits for an interchange and each signal in a system.

Application of Procedures

We used a computer spreadsheet to apply the procedures developed in this project to two interchange-plus-one-signal systems in Texas. One of these systems is located in Corpus Christi, and the other is located in Weslaco. Simulation showed that the timing plans proposed by researchers for these systems perform better than the existing plans. Figures 2 and 3 provide a comparison of existing and proposed timing plans for the Corpus Christi system. As can be seen from these figures, the proposed timing plan developed using new procedures eliminated the westbound queue. Furthermore, the Pharr District has already implemented the noon- and evening-Peak timing plans developed by the researchers for the Weslaco system. The district staff reports that there has been a significant improvement in traffic operations after implementing these plans.

The Researchers Recommend . . .

We recommend that TxDOT adopt the procedures and guidelines developed in this project for timing isolated diamond interchanges as well as those that have adjacent traffic signals in close vicinity. We also recommend that the proposed procedures be incorporated into a computer program.

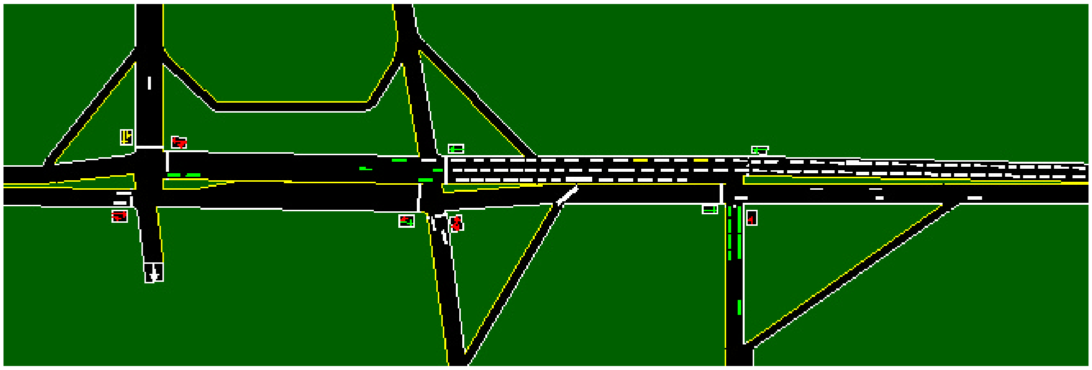

Figure 2. Simulation of existing timing plan for the Ayers interchange in Corpus Christi

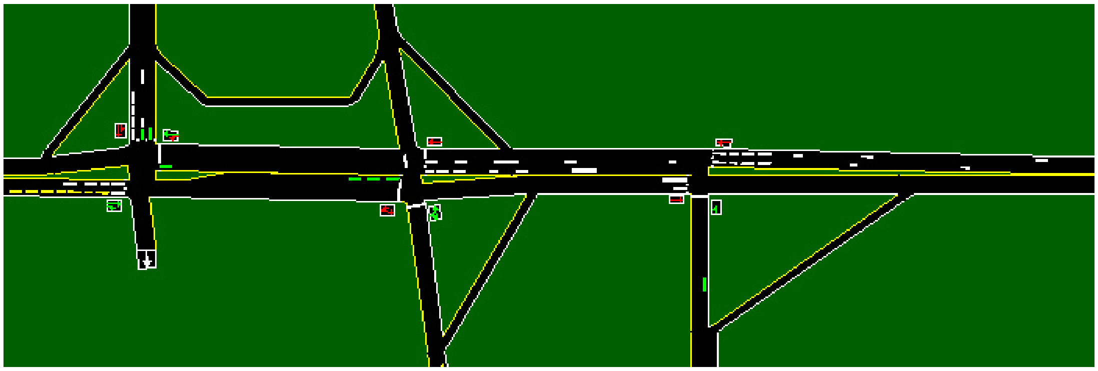

Figure 3. Simulation of proposed timing plan for the Ayers interchange in Corpus Christi

For More Details . . .

The research is documented in the following reports:

Report 4913-1, *Coordination of Diamond Interchanges with Adjacent Traffic Signals*
4913-2, *Guidelines for Timing and Coordinating Diamond Interchanges with Adjacent Traffic Signals*

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To obtain copies of the reports, contact Dolores Hott, Texas Transportation Institute, Information & Technology Exchange Center, (979) 845-4853, or e-mail d-hott@tamu.edu. See our on-line catalog at http://tti.tamu.edu.

TxDOT Implementation Status
December 2000

District staff has reported significant improvement in traffic operations after implementing the new timing plans at the Weslaco Site.

This research product should provide TxDOT and Texas cities with guidelines and procedures to use to improve the timing of isolated diamond interchanges and adjacent traffic signals, if applicable.

For more information, please contact: Dan Maupin, P.E., RTI Research Engineer, (512) 302-2363 or e-mail dmaupin@dot.state.tx.us.

YOUR INVOLVEMENT IS WELCOME!

Disclaimer

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are solely responsible for the facts and accuracy of the data, the opinions, and the conclusions presented herein. The contents do not necessarily reflect the official view or policies of TxDOT or FHWA. This report does not constitute a standard or regulation, and its contents are not intended for construction, bidding, or permit purposes. The use of names or specific products or manufacturers listed herein does not imply endorsement of those products or manufacturers. The engineer in charge of the project was Nadeem A. Chaudhary, P.E. (TX-66470).