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Summary Report

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Summary Report 1237-S
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DESIGNING URBAN ARTERIAL INTERCHANGES

PROBLEM STATEMENT

With growing urban congestion on freeways, existing and future street systems surrounding them must provide mobility to diverting traffic. Arterial mobility can be difficult in highly developed areas that have streets with many intersections. In these areas, simply widening a street is often not possible because of limited right of way, so traffic engineers and highway planners must look to other solutions. In recent years, grade separation—creating an overpass or underpass at an arterial intersection—has become a feasible alternative for reducing congestion along streets. Decision-makers need accurate information concerning the variety of these arterial interchange designs, each with its own set of benefits and costs, as well as geometric and operational issues.

OBJECTIVES

The Texas Transportation Institute (TTI) conducted study 1237, *Application and Design of Urban Arterial Interchanges*, in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA) to develop geometric guidelines and criteria for replacing congested urban arterial at-grade intersections with interchanges. The final report (1237-2F) addresses the geometric issues, operational issues, benefits, and costs of three interchange configurations—the Tight Urban Diamond Interchange (TUDI), the Single Point Urban Interchange (SPUI), and the Left-Hand Exit Single Signal (LHESS).

The researchers reviewed literature on the costs, benefits, impacts on access, and types of arterial interchanges. They then addressed design elements for a typical high-volume grade-separated arterial interchange keeping in mind that some intersections may have unique characteristics and site constraints which must be taken into consideration. Operational characteristics such as geometrics, volumes, mixture of vehicle types, presence of pedestrians, and signal phasing, were analyzed for the three configurations. This phase of the research utilized TRANSYT 7F, a macroscopic, deterministic traffic model that can be run on most microcomputers and assists traffic engineers in evaluating both individual signalized intersections and arterial networks. Finally, the study investigated the benefits and costs associated with grade separation based on data gathered from six congested intersections in the state of Texas (see TTI Research Report 1237-1). Two case studies, based on data from two of the sites and the issues addressed in the study, serve to illustrate the suggested approach for deciding whether or not to use a certain type of arterial interchange.

FINDINGS

Design Elements

In making the decision of what kind of grade-separated interchange is right for a certain intersection, or whether or not an interchange is the best option, numerous design controls and criteria must be considered. Engineers must examine the following:

- what type and size of vehicle will frequent the intersection (design vehicle),
- how the vertical and horizontal curves will affect the drivers' ability to see the intersection and respond appropriately (sight distance),
- whether an overpass or underpass will offer more advantage (vertical alignment),
- the distance required and the distance available to adequately design an arterial grade separation (length of grade separation),
- which design elements common to all urban grade separations (taper, median, or island) would best serve the environment,
- safety and political issues involved in removing the unlimited access to surrounding businesses, and
- how much right-of-way is required to build the grade-separated interchange.

This research found that in terms of right-of-way, the SPUI has no evident advantage over the TUDI. Anywhere a SPUI can be constructed, a TUDI can be constructed less expensively. In contrast the LHESS can be constructed with minimal right-of-way. The TUDI also has an advantage over the SPUI when an accident occurs between the ramp gores; traffic can be diverted through the at-grade intersection using the off- and on-ramps.

In the area of vertical alignment, which can increase distance of left turn restrictions and add to cost if vertical curves are long, analysis revealed that overpass SPUIs require a 10 to 15 percent *longer* vertical curve than comparable overpass TUDIs. No differences were observed between the underpass TUDI and SPUI. With LHESS, researchers found that if median bents are used, the LHESS requires the same length as the TUDI, otherwise, the lengths are similar to those found in the SPUI design.

In deciding whether to use the overpass or underpass design, it is important to first consider utility relocation, drainage issues, aesthetics, sight distance, and traffic handling. This research points out, however, that underpass design does offer savings in the required vertical curve length because of the longer sight distance a driver

CHARACTERISTIC	TUDI	SPUI	LHESS
ROW Requirement	Moderate	Moderate	Low
Costs	Moderate	High	Moderate
Sight Distance Requirements	Low	Moderate	High
Length of Vertical Curves	Low	Moderate	Low
Driver Expectancy	Meets	Violates Slightly	Violates
Accommodation of Pedestrians	Good	Poor	Good
Accommodation of Heavy Vehicles	Poor	Good	Poor
Operation Under Varying High Volume Scenarios	Good	Fair	Poor

Table 12. Comparison of the Analysis Results for TUDI, SPUI, and LHESS

naturally has when passing through the lowest part of the underpass.

Operational Characteristic of Arterial Interchanges

The TRANSYT 7F simulations performed on all three configurations (TUDI, SPUI, and LHESS) indicated that the SPUI operated with the least delay for each approach/turning volume scenario (four were conducted for each). The TUDI operated within 14 percent of the SPUI on all four scenarios, and the LHESS gave poor results compared to the TUDI and the SPUI, except under the low approach volume and low turning movement scenario.

Although it appears at face value that the SPUI performs best under all scenarios, research shows that this assumption may be incorrect in an urban setting. Here, many other variables, such as the complex off-ramp right turn movement and pedestrian volumes, have the potential to rapidly reduce the SPUI's performance. In fact, unlike the simulations presented in this study's final report, simultaneous left turn traffic is usually not perfectly balanced since travel patterns in the urban area can change significantly over time. Earlier data collected for Research Report 1237-1 indicates that the larger the disparity between simultaneous left turning movements, the poorer the performance of the SPUI. Since in most cases, the TUDI is capable of accommodating a greater range of traffic demand more efficiently, it is the optimal urban design configuration from the operations standpoint.

Analysis indicates that the TUDI is a better design in densely developed urban areas because of its familiar geometrics, efficient operation, and relatively lower cost.

Benefits and Costs

The benefits of grade separation are time savings, fuel savings, and emission reduction. The costs associated with arterial interchanges involve the cost of the structure itself, at-grade roadway improvement costs, traffic control devices, utility relocation, and traffic handling. Benefit/cost analysis performed on six Texas sites and case studies of two sites concluded that grade separation becomes cost-effective (the delay savings are enough to justify the high cost of grade separation) only for sites with approach volumes greater than 5000 vehicles per hour (vph).

CONCLUSIONS

The results of this research will aid engineers in addressing relevant design issues *prior to* designing an interchange in a densely developed area. This should then lead to improved operations and safety for motorists navigating urban streets. The TUDI clearly came out ahead of the other configurations (SPUI and LHESS) in all areas—with analyses indicating that, in general, the TUDI is the most appropriate design in densely developed urban areas because of its familiar geometrics, efficient operation, and relatively lower cost. Designers should carefully analyze individual circumstances of intersections before applying general numbers used in this study's simulations.

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The information described in this summary is reported in detail in TTI Research Report 1237-2F, "Guidelines for the Design of Urban Arterial Interchanges in Densely Developed Areas," by Johnnie R. Pate, Jr. and Virgil G. Stover, February 1992; Revised December 1992. TTI Research Report 1237-1, "An Analysis of Expected Delay Reduction by Replacing a Congested At-Grade Intersection with an Interchange," by Syed Shariq Raza and Virgil G. Stover, July 1991; Revised November 1992. The contents of the summary do not necessarily reflect the official views or policies of TxDOT or the FHWA.

FURTHER READING

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