CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

PROJECT SUMMARY REPORT

Project Summary Report 1844-S
Project 0-1844: Operational Flexibility for Controlled Access Facilities

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FREEWAY OPERATIONAL FLEXIBILITY CONCEPTS

Today and for the coming decades, freeway operators must diagnose design-related operational problems and devise "temporary" solutions that will last until the facility can be significantly renovated. As funding becomes available, freeway designers may have opportunities to incorporate new design concepts into freeway renovation or re-build projects.

As these new designs are devised, many lessons learned over 50 years of urban freeway use should certainly be incorporated. One of those conceptual lessons is that over many decades of use urban freeways will serve traffic demands that will change both spatially and through time. Land use adjacent to freeway corridors will change in intensity, sometimes increasing travel demands and sometimes decreasing them, with such changes occurring across a time dimension that encompasses decades.

These land-use-induced travel demand changes will create freeway traffic problem areas (sometimes called bottlenecks). Freeway operators will seek solutions to these problems and will desirably find quick, inexpensive, effective solutions. Freeways of the future should, therefore, be designed to provide operational flexibility. Based on experiences with freeway bottleneck problems, design concepts that enable implementation of solutions should be devised. These design concepts, called operational flexibility design concepts, are a primary subject of this research.

In addition to treating bottleneck problems, operational flexibility design concepts can play a significant role in ameliorating the debilitating effects of freeway incidents. Once considered rare events, incidents, including crashes, disabled vehicles, lost cargo, and other obstructions, are routine events on most urban freeways.

Recognizing these needs, the researchers have examined a wide range of urban freeway congestion mitigation concepts that are being implemented on today's freeways in an effort to increase people movement potential. These concepts range from high-occupancy vehicle lanes to ramp metering to basic bottleneck treatments.

What We Did ...

Incident Management

The term "incident" is commonly used to describe many kinds of traffic stream interruptions. Incidents include accidents involving collisions between vehicles or vehicles and roadside objects, disabled vehicles, objects such as vehicle parts or lost cargo, or literally any unplanned traffic flow disruption. Particularly on controlled access facilities, incidents may cause secondary accidents, and, during peak hours, may cost travelers significant time delays that may equal large economic costs.

Operational flexibility can contribute to incident management by reducing the likelihood of incidents and, maybe more significantly, by reducing the incident duration, thereby reducing traveler delay and associated costs. In order to define potential roles for operational flexibility in incident management, the researchers studied more than 100 incidents using Houston and San Antonio traffic control center capabilities.

Detailed characterizations of the incidents, emergency responses, and effects upon freeway traffic were prepared. From this analysis, a clear need for a pathway for emergency vehicles to reach incident sites was identified. Additionally, a clear need for a haven for disabled or damaged vehicles was identified.

Such a haven would permit faster incident clearing and re-opening of main lanes. An obvious solution to both the access path and haven problems is a paved shoulder. This conclusion led to a recommendation to maintain a minimum 8-foot-wide shoulder on at least the freeway right side for freeways having three or fewer lanes and maintenance of minimum 8-foot-wide paved shoulders on both the left and right freeway sides on freeways having more than three lanes per direction.

Operational Flexibility for Freeway Bottleneck Resolution

The operational flexibility concepts are described through application to a case study of the Loop 1 freeway in Austin, Texas. Loop 1 bottleneck sites, suggested solutions, and design concepts that could enable easier solution implementation are described.

Four characteristics were used to locate potential freeway bottleneck sites: lane drops following exit ramps, demand exceeding capacity following entrance ramps, weaving sections, and acceleration lane lengths. Using the four identifiers, the researchers identified potential and observed bottlenecks on Loop 1 for southbound and northbound directions.

What We Found ...

Lane Drops Following Exit Ramps

Bottlenecks often develop where a lane is dropped after an exit. Under heavy flow conditions, bottlenecks form at lane drops because the exiting demand is too small to reduce the main lane demand to the capacity of the reduced freeway section immediately downstream. There are eight lane drop locations on the southbound Loop 1 study section and seven northbound. Each of these has either already become a bottleneck or is likely to become one as demand grows and changes. The only practical solution to a lane drop bottleneck is extension of the dropped lane beyond the exit. The number of lanes decreases eight times but it also increases eight times along the 11-mile section. Provision of a minimum 12-foot-wide, full-depth paved right-side shoulder from each lane drop location to the next location where the number of lanes increases would provide the operational flexibility needed to treat lane-drop-induced bottlenecks. This leads to **operational flexibility concept number 1: Provide minimum 12-foot-wide, full-depth paved right-side shoulder from each lane drop location to the next lane number transition or for at least 2,500 feet.**

Demand Exceeding Capacity Downstream of an Entrance Ramp

In addition to lane drop locations, bottlenecks occur where traffic demand on a freeway section exceeds capacity. This situation can occur immediately following any entrance ramp where the acceleration lane associated with the ramp does not become a basic freeway lane. This situation is currently problematic on nine northbound Loop 1 locations and on five southbound locations, all within the 11-mile case study section. At these locations, the main lane traffic demand is near capacity; an entrance ramp permits enough additional traffic to force the section demand above the capacity, resulting in a bottleneck.

Two possible solutions might be derived for such situations. One approach would reduce demand allowed to enter the freeway using the problematic ramp through ramp metering or provision of route guidance information to motorists. This approach can be effective under certain conditions in which alternative routes are av ailable and acceptable. The other approach would provide for future re-striping of the freeway section, adding a lane downstream of the entrance ramp through provision of a minimum 12-foot-wide, full-depth paved right-side shoulder from the entrance ramp acceleration lane end to the next entrance ramp. The leads to **operational flexibility concept number 2: Provide a minimum 12-foot-wide, full-depth paved right-side shoulder from each entrance ramp acceleration lane end to the next exit ramp.**

Weaving Sections

Weaving sections are freeway sections where an auxiliary lane begins at an entrance ramp and ends at an exit ramp. In these sections, drivers perform weaving maneuvers to enter or exit the freeway. In weaving sections of less than 2,500 feet, these maneuvers reduce the capacity of the section, and, under heavy main lane and ramp flow conditions, the weaving section will begin to break down and become a bottleneck.

One solution to weaving section congestion is the use of ramp metering to reduce the entrance ramp flow coming into the section. According to the 1997 Highway Capacity Manual, increasing the weaving section length to more than 2,500 feet would essentially remove any weaving effects. Therefore, an excellent design concept is to maximize the distance between entrance and exit ramps that signify the beginning and end of the section. However, owing to existing street geometry and to many other common constraints, and particularly for an existing freeway like the Loop 1 case study section, this concept may not be practical. A more practical solution to weaving area congestion is the addition of another freeway through lane within the weaving area. An additional through lane will supplement section capacity, providing more gaps for entering traffic and potentially easing the weaving process. Since an additional lane cannot be easily added to the freeway right side, the left side becomes the logical place for the supplementary lane. This leads to **operational flexibility concept number 3: At least 1,500 feet before and after weaving sections, provide a minimum 12-foot wide, full-depth paved left-side shoulder.**

Acceleration Lengths

Entrance ramp acceleration lane lengths are very important to uninterrupted flow on freeway sections. Inadequate or short acceleration lane lengths do not allow entrance ramp vehicles enough time or space to find suitable gaps to merge safely and smoothly into the main lanes. Furthermore, when short acceleration lane lengths are combined with main lane flow nearing capacity, gaps become more difficult to find and friction between main lane and ramp vehicles increase. As a result, freeway operations deteriorate and bottlenecks form at the entrance ramp.

To avoid this situation, AASHTO developed design guidelines for minimum acceleration lane lengths for one-lane entrance ramps, with such guidelines based on the average speed of vehicles using a ramp and on the freeway design speed. Clearly, if one were designing a new or remodeled freeway, she (he) would design adequate ramp facilities. However, over time, design specifications change in response to many external influences, not the least of which are vehicle characteristics. Therefore, a new or remodeled ramp may meet design standards when designed but may become inadequate during its working life. This is another reason for implementing **operational flexibility concept number 2: Provide a minimum 12-foot-wide, full-depth paved right-side shoulder from each entrance ramp acceleration lane end to the next exit ramp.**

This concept will provide a means for increasing the acceleration lane length through re-striping if or when it becomes necessary. Provision of the right-of-way and shoulder will also prove beneficial for incident management.

The Researcher Recommends ...

A detailed case study of bottleneck sites on the Austin, Texas, Loop 1 freeway was described. The examination of individual bottleneck sites and recommended solutions, some already implemented, led to development of a series of operational flexibility design concepts. These concepts were devised to provide implementation ease for the very typical types of bottleneck solutions proposed for the Loop 1 case study. These concepts are:

Concept number 1:

Provide minimum 12-foot-wide, full-depth paved right-side shoulder from each lane drop location to the next lane number transition or for at least 2,500 feet.

Concept number 2:

Provide a minimum 12-foot-wide, full-depth paved right-side shoulder from each entrance ramp acceleration lane end to the next exit ramp.

Concept number 3:

At least 1,500 feet before and after weaving sections, provide a minimum 12-foot-wide, full-depth paved left-side shoulder.

These concepts imply that while other congestion mitigation measures are considered and implemented, steps must always be taken to maintain the shoulder room noted. They also imply that, if available, these shoulder spaces will enable bottleneck treatment through lane re-striping, which is much faster and more practically implemented than adding pavement or acquiring right-of-way.

An obvious potential conflict exists between the need to maintain continuous shoulders for emergency vehicle paths to incidents and the shoulder reservations for re-stripping associated with the operational flexibility design concepts. The two concepts should not be considered as mutually exclusive but rather as complementary. If the two requirements are simply added together they would produce 20 feet of paved shoulder. However, the intent of the shoulder reservations for lane re-striping is to produce an additional lane through bottleneck sections. Although 12 feet is the normal lane width, significant experience has indicated little loss of operational effectiveness with 11-foot lane widths. The 1994 Highway Capacity Manual suggests a 5 percent reduction in flow potential for 11-foot as opposed to 12-foot lane widths. If all main lanes are re-stripped to 11-foot widths through bottleneck sections, then the additional shoulder space required to produce the required additional lane is substantially less than 12 feet.

For More Details ...

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The research is documented in the following report:
Report 1844-1, *Freeway Operational Flexibility Concepts, Draft — October 2001*

To obtain copies of the report, contact: CTR Library, Center for Transportation Research, phone: 512/232-3138, email: ctrlib@uts.cc.utexas.edu.

TXDOT IMPLEMENTATION STATUS AUGUST 2001

The research developed new freeway design measures to effect freeway congestion mitigation, including incident management, emergency egress, and the treatment of bottleneck locations. The research recommended enhancing shoulder design practices in order to provide improved freeway operational flexibility. TxDOT is using some of the operational flexibility design concepts developed by this research in the Austin District.

For more information please contact Bill Knowles, P.E., Research and Technology Implementation Office (512) 465-7648 or email wknowle@dot.state.tx.us.

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