Project Bulletin 4160-10B
Project 0-4160: Operating Freeways with Managed Lanes

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Managed Lane Ramp and Roadway Design Issues

Managed lanes are being considered in congested urban corridors where expansion possibilities are limited and forecasted conditions point to continuing congestion. Because the existing experience in both design and operations of managed lanes is limited, researchers turned to work on high-occupancy vehicle lanes (HOVs) as a source of potential information. Criteria for HOVs have been examined in previous studies and the findings from those studies can be applied to managed lane facilities. A recent report, *Guidance for Planning, Operating, and Designing Managed Lane Facilities in Texas*, provides guidance for the geometric design of managed lane facilities and was used to generate draft chapters for the upcoming Managed Lane Manual.

A Managed Lane Symposium was held during the initial year of TxDOT project 4160 that set the primary direction for Task 10 toward ramp design issues.

What We Did...

Review of Current Literature and State-of-the-Practice for Ramp Design

A literature review and a review of state manuals were conducted to determine current practices. Most of the recent literature regarding ramp design has focused on ramp design speed and truck performance. An Internet search of each state's design manual found that 23 states had all or part of their design manuals online, 12 of which had some material available concerning the design of ramps.

Case Study

The potential Texas Managed Lane system could contain elements of systems that are currently in use in other communities. Information on how those elements are operating can help in the selection of components best suited for Texas. Examples include how special-use lanes are signed or marked, their typical dimensions for lane and shoulder widths, and how the special-use lanes are accessed. As part of this research project, members of the research team visited the New Jersey Turnpike (NJT) facility.

Computer Simulation

Simulation was used to obtain an appreciation of the effects of ramp spacing on freeway operations. A previous effort (Task 5) within TxDOT project 4160 focused on the impact of managed lane access and egress weaving behavior for a single pair of ramps. Simulation of several ramp pairs is needed to identify the impact on the corridor of vehicles from different entrance ramps consistently weaving across free lanes to access a managed lane facility. The simulation performed as part of Task 10 planned to quantify the effects of ramp spacing on freeway operations and continue the investigation of when to consider a direct ramp between the managed lanes and a generator or surface street system.

Speed was the primary measure of effectiveness used to evaluate the effects of the different ramp spacing, volume levels, and weaving percentages. Ramp spacing of 1000, 2500, 4000, and 5500 ft was used. Freeway initial volumes of 1250, 1500, 1750, and 2000 vehicles per hour per lane (veh/hr/ln) were also used. Finally, the percentage of freeway entrance ramp traffic that desired to maneuver to the next managed lanes access point was varied between 0, 10, 20, and 30 percent of the traffic on the (source) freeway entrance ramp. The 0 percent weaving scenario provided a baseline condition of how the freeway would operate without the managed lane facility.

What We Found . . .
Key Findings from the Reviews

A review of state design manuals demonstrated that the Texas manual includes more discussion and examples on ramp design than most other state manuals. An issue not well discussed in any document is where to place the ramp with respect to other entrance and exit ramps. General guidelines are provided (900 to 1000 ft or 300 m); however, these guidelines are not sensitive to the expected ramp volume, the anticipated destination of the ramp vehicles (e.g., the next exit ramp or a downstream entrance to a managed lane facility), or the number of lanes on the freeway.

Key Observations from the NJT Case Study

- A 32-mi (52 km) segment of the Turnpike was expanded to two separate roadways in each direction of travel (see Figure 1) with each same direction roadway called a barrel.
- The objective of the "dual-dual" roadway was to improve operations and safety by separating heavy vehicles from light vehicles and to increase capacity (heavy vehicles are restricted to the outer lanes). It was also intended to provide greater flexibility for using the roadway during periods of heavy congestion such as a major incident, since changeable message signs technology could be applied to warn approaching drivers and divert them to the less-congested barrel (see photo in Figure 2).
- Each barrel has its own exit and entrance ramps (see Figure 3). The inner roadway traffic does not weave across the outer roadway traffic to reach an exit. The traffic from barrels in the same direction merges prior to the toll plaza. The ramp designs used at the interchanges result in having all traffic moving through one toll plaza for each interchange (see Figure 4). This allows for consolidation of personnel and equipment (and resulting in cost savings) in the collection of tolls. Both trumpet and slip ramp designs are employed.
- Crash information available in the 2001 draft Handbook for Planning Truck Facilities on Urban Highways supports the theory that the dual-dual roadway system enhances safety. During the five years before completion of the dual-dual roadway (1965-1969), the average annual

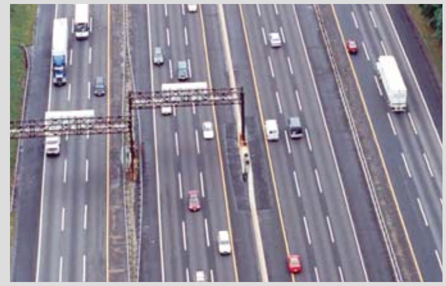

Figure 1. Dual-Dual Roadway of the New Jersey Turnpike

Figure 2. Entrance Ramp to the Dual-Dual Section of NJT

Figure 3. NJT Interchange

Figure 4. NJT Toll Plaza

accident rate was 94.1 accidents per million vehicles miles; in the succeeding five years the rate was 79.2 accidents per million vehicles miles, a reduction of over 18 percent. For the five-year period from 1994 to 1998, the crash rate on each of the dual-dual roadways (outer and inner) was 26 to 61 percent less than on the segments of the Turnpike without separate roadways. It is still unknown how much of the difference is due to the separation of vehicles and how much is due to other factors such as fewer lanes and higher levels of congestion on the non-separated portions. The data, however, clearly indicate that accident rates are lower in the areas with the dual-dual roadways.

Key Findings from the Simulation

- In the simulation, ramp spacing only affected average freeway speeds when the initial freeway volumes were very high (2000 veh/hr/ln) and ramp spacing was at the lowest value used in the simulation (1000 ft) (see the graph in Figure 5).
- In each weaving level comparison, the average freeway speed dropped faster for the shorter ramp spacing (see Figure 6). This shows that operations are more sensitive to small increases in traffic volumes when ramp spacing is shorter.
- The number of vehicles attempting to weave across the four freeway lanes to enter the managed lanes can have a pronounced impact on the operations of the freeway. With the exception of short spacing in combination with high initial freeway volumes, the average freeway speeds recorded from the simulation runs are generally above 45 mph until approximately 500 vehicles per hour are attempting to weave across the freeway and enter the manage lanes. When the plot of the lowest freeway speed recorded is reviewed, the point when less than desirable operations occur is at approximately 250 veh/hr (see Figure 7).

The Researchers Recommend . . .

The dual-dual portion of the New Jersey Turnpike clearly demonstrates the operational and safety benefits of separating vehicle modes. Having the entrance to a HOV or passenger-car exclusive facility located in the center of a freeway corridor without a dedicated ramp requires vehicles to weave across each of the general purpose lanes. The direct access to each barrel provided on the New Jersey Turnpike eliminates this weaving maneuver (which promotes a safer and more operationally efficient system). Maintaining similar geometric criteria for both barrels also provides greater flexibility in moving traffic between the barrels as needed for incidents and maintenance. In addition, the finding that the dual-dual portion has a lower crash rate supports separating trucks and passenger cars The High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual indicates that a direct connect ramp should be considered when ramp volume is 400 veh/hr. The findings from the simulation performed as a part of this TxDOT project support that number. When considering average speeds, the number is about 500 veh/hr for the freeway traffic and about 300 veh/hr for the entrance weaving traffic. Using this simulation, a value of 400 veh/hr could be a reflection of a rounded

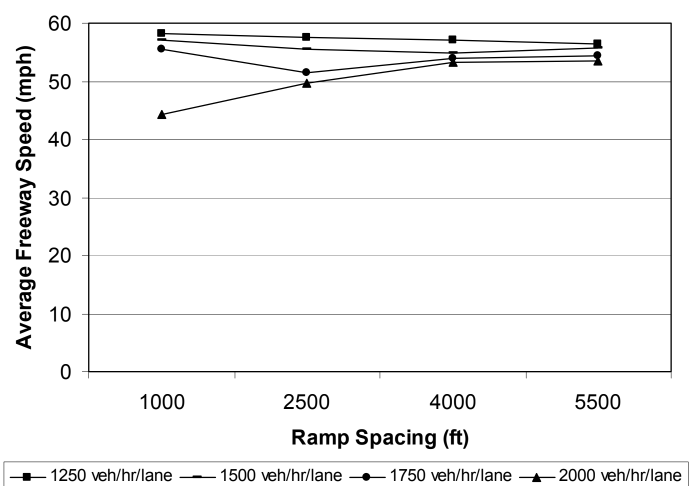

Figure 5. Average Freeway Speed vs. Ramp Spacing

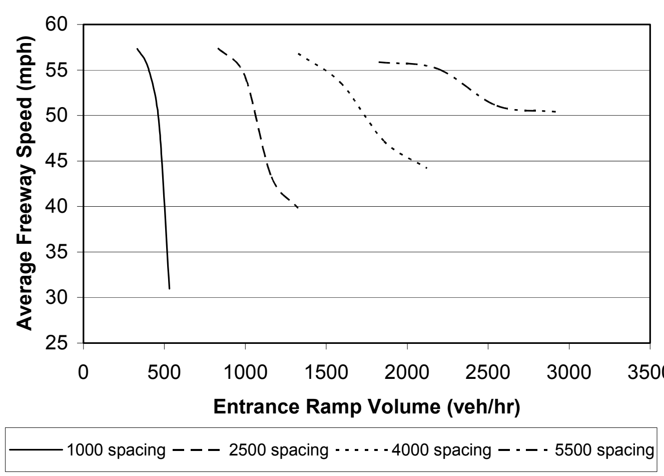

Figure 6. Average Freeway Speeds for 20 Percent Weaving

value that gives consideration for both average freeway speeds and average entrance vehicle speeds. If the preference is to consider lowest speeds observed (a more conservative situation), then a direct connect ramp should be considered at 275 veh/hr.

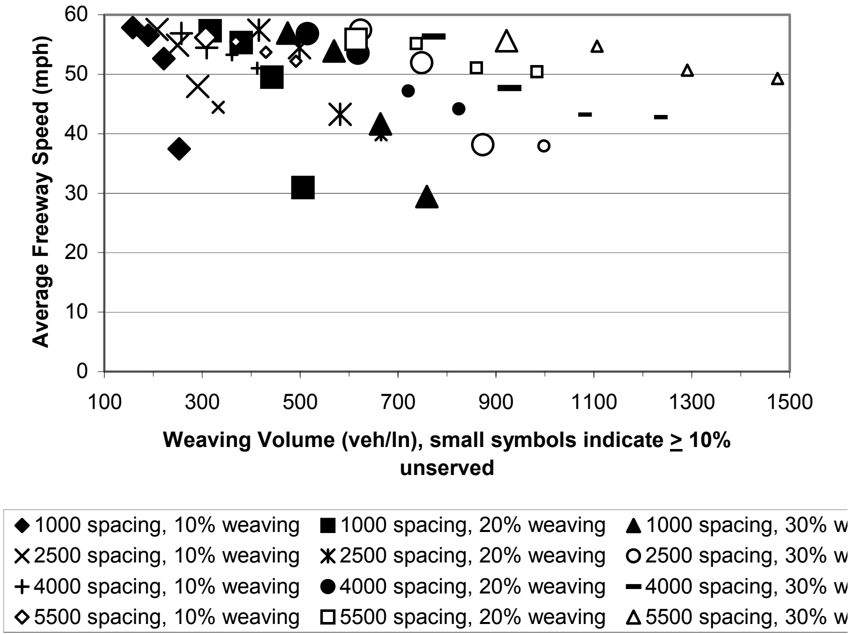

Figure 7. Freeway Speed vs Weaving Volume

For More Details . . .

Related Report:
Report 4160-2, *Year 1 Annual Report of Progress: Operating Freeways with Managed Lanes*
Report 4160-4, *Managed Lanes – Traffic Modeling*
Report 4160-10, *Managed Lane Ramp and Roadway Design Issues*

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