Project Bulletin 4160-4B
Project 0-4160: Operating Freeways with Managed Lanes

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Managed Lanes – Traffic Modeling

The purpose of this project was to demonstrate the impacts of alternative operating strategies on design and traffic operations considerations. Using planning level vehicle demands and trip characteristics available to TTI staff, the corridor study team developed a simulation model to evaluate factors such as access design, access spacing, and geometric design to provide insight into signing, delineation, and traveler information needs. The results will be used to provide both corridor-specific and general managed lane implementation guidelines.

What We Did . . .

From among several traffic models capable of performing detailed modeling of managed lanes within freeway corridors, the VISSIM model was selected. A VISSIM model of the Katy Freeway corridor in Houston, Texas, was then created as a platform for an analysis of the frequency and location of at-grade (i.e., from within the freeway) access points for managed lanes. Researchers identified several key issues (not fully documented in current analytical practices and guidelines) that have a bearing on managed lanes operation. These issues, as illustrated in Figure 1, are:

- freeway weaving from a freeway entrance to a managed lane entrance,
- freeway weaving from a managed lane exit to a freeway exit, and
- intra-freeway vehicle stream separation of vehicles destined for managed lane access.

For each of these key issues, VISSIM models were constructed to examine different combinations of freeway volume level, percentage of weaving vehicles, weaving distance, and weaving complexity. In total, over 650 combinations of weaving distance, weaving complexity, and traffic volume conditions were designed into modeling experiments, and over 2000 simulations were performed.

What We Found . . .

For freeway weaving across five lanes between a standard, right-side freeway entrance ramp and a left-side managed lane entrance ramp, modeling indicates that the impacts of heavy vehicles in the vehicle stream are more pronounced at shorter weaving distances. Freeway operation tended to stabilize at weaving distances greater than 3000 feet for medium volume levels and 3500 to 4000 feet for high freeway volume levels. When an intermediate ramp was located between the freeway and managed lane entrances, operation stabilized at weaving distances greater than 3500 feet for moderate volumes and 4000 feet for high volumes.

For freeway weaving across three lanes between a left-side managed-lane exit and a right-side freeway exit ramp, modeling indicates that

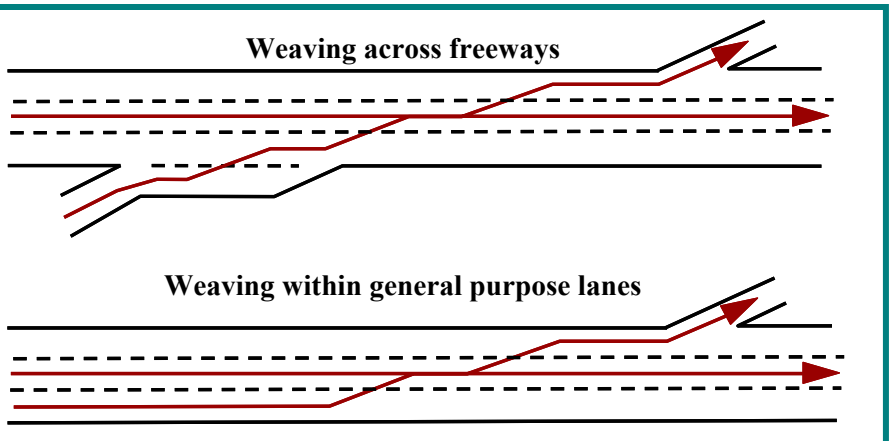

Figure 1. Complex Managed Lane Weaving

weaving and non-weaving freeway operations tend to stabilize at weaving distances greater than 3000 for medium volumes and 3500 for high volumes. In more complex exit ramp simulations, where an intermediate entrance ramp was located between the managed lane exit and the freeway exit ramp, weaving and non-weaving flow stabilized for a four-lane weaving section at distances greater than 3000 feet.

Intra-freeway weaving for accessing managed lanes is the "sorting" of vehicles destined for the managed lanes into the leftmost freeway lane. This maneuver can be viewed as the weaving distance required for a driver who has decided he/she is a candidate for using the managed lanes to reach the correct lane for a transition into the managed portion of the freeway facility. Consistent with expectations, greater selective separation weaving distance exhibits improved performance. Also as expected, non-weaving speeds are consistently higher than weaving speeds, as the non-weaving – or through – vehicle population was not required to discover and maneuver into gaps in adjacent lanes in order to reach the leftmost, managed facility access lane. For medium volume levels, selective separation results stabilize at distances greater than and equal to 1 mile. For high volume levels, selective separation results stabilize at distances between 1.5 and 2 miles and greater. Impacts of truck percentage on performance were determined to be more substantial than the impact of bus percentage. Again, such results were expected, as the truck vehicle class is both larger and slower to accelerate/decelerate than buses.

The Researchers Recommend . . .

The recommendations of the managed lanes modeling effort are summarized in list format:

1. Standard analysis techniques, especially the Highway Capacity Manual (HCM) and Highway Capacity Software (HCS), are appropriate for isolated entrance, exit ramp, and one-sided weaving section analysis where these features must be studied within corridors with managed lanes applications. More complex issues, such as cross-freeway weaving and intra-freeway weaving, are most appropriately and practically studied using simulation.

2. The simulation tools CORSIM and Integration offer sufficient data input flexibility to accommodate a variety of managed lane simulation modeling issues, including complex geometrics, signalization/control, and some routing capabilities. However, where multiple vehicles classes and selective real-time control and routing must be modeled, the simulation tools Paramics and VISSIM are most applicable.

3. Typical managed lane design guidelines specify either minimum (500 feet) and desirable (1000 feet) weaving distances per lane, or a preferred minimum distance (2500 feet) between a freeway entrance or exit and a managed lanes facility entrance or exit. The current research updates and places conditionality on these generic guidelines. A recommended weaving distance application table has been developed for anticipated conditions in the design year (see Table 1). The managed facility designer has the option of:

   (1) specifying medium or high volume in the design year (based on HCM level of service – LOS),
   (2) allowing for or not allowing for up to a 10 mph reduction in operating speed due to managed lane related weaving, and
   (3) having or not having intermediate ramp/ramps between the freeway

Table 1. Weaving Distances for Managed Lane Cross-Freeway Maneuvers

Design Year Volume Level	Allow up to 10 mph Mainlane Speed Reduction for Managed Lane Weaving ?	Intermediate Ramp (between freeway entrance/exit and managed lanes entrance/exit) ?	Recommended Minimum Weaving Distance Per Lane (feet)
Medium (LOS C or D)	Yes	No	500
		Yes	600
	No	No	700
		Yes	750
High (LOS E or F)	Yes	No	600
		Yes	650
	No	No	900
		Yes	950
Note: The provided weaving distances are appropriate for freeway vehicle mixes with up to 10% heavy vehicles; higher percentages of heavy vehicles will require increasing the per lane weaving distance. The value used should be based on engineering judgment, though a maximum of an additional 250 feet per lane is suggested.			

entrance/exit and the managed lanes entrance/exit.

4. For general managed lane planning purposes, the recommended minimum and desirable distances between a freeway entrance/exit ramp and a managed lanes entrance/exit are 2500 feet and 4000 feet, respectively. The minimum distance applies in cases where a speed reduction of up to 10 mph is acceptable and freeway volumes are moderate. For high freeway volumes, especially in cases where an intermediate ramp is present between the freeway entrance/exit and the managed lanes entrance/exit, 4000 feet of cross-freeway weaving distance is appropriate.

5. Under moderate volume freeway conditions (i.e., LOS C or D), a maximum weaving volume of 450 vehicles per hour is recommended between any given freeway entrance and the next downstream managed lanes entrance (and conversely, for any given managed lanes exit and the next, downstream freeway exit). Under high volume freeway conditions, a maximum weaving volume of 350 vehicles per hour is recommended for the same conditions. In corridors where freeway ramp location, spacing and origin-destination patterns cause managed lane-related weaving volumes that exceed these values, it is recommended that direct access from park and ride/transit facilities to the managed lanes be provided.

6. To preserve freeway quality of service in the vicinity of managed lanes entrance and exit ramps, it is recommended that for moderate freeway volumes in the design year, a transition distance of 1 mile be allowed for vehicles to selectively maneuver from their initial position in any freeway lane to the leftmost (or rightmost) freeway lane so that they can access a managed lane facility. Under high volume freeway conditions in the design year, a transition distance of 1.5 to 2 miles is appropriate. For both moderate and high volume freeway conditions, the presence of ramps within the transition distance requires that the given value be increased. Note that these distances are the required transition distances once drivers have already determined whether or not they are candidates for the managed facility. Sign locations should be designed based on driver perception and decision distances that are added onto the values given here. Also note that the transition distance values given here provide sufficient upstream warning so that mainlane speeds are not

significantly impacted by the selective separation weaving vehicles; if lesser transition distances are used, mainlane and weaving vehicle speed will be reduced.

For More Details . . .

Related Report:
Report 4160-4, *Managed Lanes – Traffic Modeling*

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