Modeling Violations in High-Occupancy Toll Lane Studies

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To mitigate congestion along freeways, managed lanes, e.g. high occupancy vehicle (HOV) or high occupancy toll (HOT) lanes, operating concurrently with general purpose (GP) lanes have gained popularity across the nation. Among the construction options to separate managed and GP lanes, non-barrier separation techniques, which use only solid pavement markings, are increasingly employed. These techniques inform drivers that crossing between GP and managed lanes is prohibited; however, they permit nearly unlimited improper ingress/egress to/from the managed lanes. Even with significant enforcement, violation rates related to non-barrier separated managed lanes in the U.S. are considerable. In fact, the national average annual managed lane violation rate, which includes both occupancy- and access-type violations, was estimated in 2005 to involve between 10 and 15 percent of all vehicles using managed lanes. These violations negatively impact mobility, safety and revenue. Despite this, no prior model developed for the purpose of predicting improvements in traffic performance metrics and the potential revenue that can be raised through the introduction of a new HOT lane facility within an existing roadway or to assess potential practicable operational strategies and facility designs has incorporated this violation behavior. Nor has any prior study systematically considered the impact of violation on the performance of these facilities or quantified the impact of violations on safety. This study sought to assess the importance of these omissions.

In this study, the potential impact of violations related to HOT lane access and vehicle occupancy on traffic performance in managed and GP lanes was quantified for an existing roadway segment with single HOV lane and proposed HOT lane facility conversion. Techniques were developed for modeling violation behavior in concurrent flow lane operations within a widely used microscopic traffic simulation tool. The significance of the violation impact on traffic performance for future managed flow lane facility performance and benefit analyses was assessed in extensive and systematically designed experiments.

Results of this study indicate that vehicles choosing to violate restrictions placed on the studied non-barrier separated, limited access HOT lane facility significantly impact roadway facility performance estimates. Moreover, this impact grows nonlinearly with increasing rate of violation. The impact of occupancy violations on the performance of a continuous access HOV lane was shown to be similarly significant. The effects of violation behavior were noteworthy at the 10% violation rate. The performance of the GP lane is similarly impacted; however, the direction of impact differed for the two managed lane types studied. The average travel time on the GP lanes increased substantially with increasing occupancy violation rate under a continuous access HOV lane design, while a decrease in average travel time (i.e. performance improvement) was noted for similar occupancy violations under the limited access HOT lane facility design. Where violations involving toll avoidance arose, no such improvement occurred.

These observations imply that it is critical to model violation behavior in simulation-based performance analysis of proposed HOT lane facilities. Given experienced violation rates for non-barrier separated HOV and HOT lane facilities around the U.S. and the potential contribution to system performance that these violations play as noted in the simulation study conducted herein, simply ignoring the potential impact of violators may result in a misrepresentation of the benefits of a proposed managed lane facility, particularly at violation rates of 10% and higher.

In the same context, this study investigated and quantified the safety impact of access-type violations. Specifically, it was hypothesized that violations, particularly those pertaining to managed lane egress and ingress, lead to sudden changes in speed of approaching vehicles. These sudden changes in speed can propagate upstream, further resulting in congestion and increased speed variance (or traffic instability) over the affected portion of the roadway.

A three-step simulation-based methodology was developed to quantify the impact on safety as a consequence of increased speed variation and changes in congestion. In the methodology, safety is measured by the length of discontinuities in traffic speed resulting directly from violation incidents as determined through inspection of traffic speed contour maps. The larger the total length of discontinuities in the traffic speed contour map, the greater the speed variability and the less safe the situation is presumed to be. In addition to safety implications of increased speed variability, increased congestion may result as a consequence of a sudden decrease in vehicular speeds. Under certain levels of traffic flow, as congestion increases, interactions among vehicles increase, and there may be secondary safety effects.

Results of simulation experiments corroborate the hypothesis that illegal traffic maneuvers between managed and general purpose lanes operating concurrently can greatly affect safety.

This study has additional implications for enforcement planning for such managed lane facilities. Results of this study indicate that an enforcement plan must be put in place to reduce violation rates to levels at which any degradation in safety and performance of the managed lane due to violations does not outweigh the benefits of construction of such a facility. Additionally, one can replicate conditions under an overall reduction in violation rate or changes due to selective enforcement plans using the modeling techniques described herein. In addition to modeling enforcement plans that target specific violation types, location-based reductions consistent with fixed enforcement locations as might arise when technology-based enforcement is employed can be replicated.

This study resulted in two journal articles (Chou et al., 2010; Chou and Miller-Hooks, 2010) and was presented in two sessions of the 2010 annual meeting of the Transportation Research Board (Chou et al., 2010; Miller-Hooks, 2010).

References

1. Chou, C.-S., E. Miller-Hooks and X. Chen (2010). "Modeling Violations in Studies of Concurrent Flow Lanes," in press in *Transportation Research Record*.
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