Integrated Multimodal Corridor Analysis Using a Microsimulation Modeling Framework: An Application of TRANSIMS

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Abstract

This paper presents a detailed description of a recent study to microsimulate travel along a mixed highway – light rail corridor in the Greater Phoenix region of Arizona in the United States. The multimodal corridor is 20-miles long and includes a light rail line running in mixed highway traffic along major arterials with numerous intersections. The research effort involves an initial step of modeling demand for the entire region as a whole, followed by a detailed subarea analysis for the mixed light rail – highway corridor area. The TRANSIMS microsimulation model is used in this study, although the lessons learned from this experience may be applicable to any other microsimulation modeling exercise. The paper describes how the subarea analysis is conducted, how the subarea network is enhanced with greater detail to be consistent with a microsimulation approach, and how the model was implemented in an iterative fashion to achieve stability in the outputs. The calibration procedures adopted in the study, and the data used for model calibration, are described in detail. Finally, the calibrated model is applied to test the impacts of alternative operational strategies along the corridor to demonstrate how the model can be used in a practical multimodal operational planning context.

Introduction

In the travel demand modeling arena, emerging activity- and tour-based models are being developed and applied at the level of the individual traveler. On a similar note, on the supply side, traffic networks are being modeled at increasingly disaggregate levels of detail with fine resolution representation of networks in time and space. The modeling of the impacts of operational improvements on roadways, such as ramp metering, signal coordination, managed lane policies, and lane restrictions call for the deployment of microsimulation models of traffic that are capable of simulating movements of vehicles at a fine level of detail. Although there has been considerable progress in microsimulation modeling of corridors with respect to highway auto modes, little work has been done in the microsimulation of transit corridors or mixed highway-transit corridors. However, with many urban areas experiencing congestion, and increasing interest in implementing transit strategies to enhance mobility along these congested corridors while promoting sustainability goals, the need to model integrated multimodal corridors has never been greater.

In many instances, urban jurisdictions are considering the implementation of Bus Rapid Transit or Light Rail modes in the medians of limited access highways or along urban arterials. When there is an integrated multimodal corridor of this nature, simulation models can be employed to analyze the performance of the corridor and assess the impacts of alternative operational strategies, such as the implementation of ramp metering, signal prioritization for transit, signal preemption, and alternative transit headways. While existing travel demand models are capable of representing mode shifts and route choices that might result from the implementation of such a multimodal corridor, demand models are not able to provide an assessment of traffic performance from an operational perspective. A traffic microsimulation model that is capable of simulating auto and transit modes in an integrated framework is needed to identify bottlenecks, determine queue lengths, estimate vehicle delays, and quantify air quality benefits along a multimodal corridor.

The above discussion presents the backdrop for the problem that this study is aimed at addressing. On the one hand, the profession has seen remarkable developments in the implementation of microsimulation models of activity-travel demand. These models are capable of replicating human behavior under a wide variety of conditions and simulate human activity-travel choices in the time-space domain. Activity-travel microsimulation models are able to capture changes in activity engagement patterns, mode and destination choices, and spatial and temporal patterns of travel in response to changes in modal network conditions. When a light rail corridor is introduced, changes in all of these aspects of travel demand may result, particularly for those who fall within the buffer area of the light rail corridor. Thus, there are activity-travel demand models that purport to simulate the demand patterns that emerge from changes in system conditions.

From a more operational perspective, the profession has seen remarkable developments in the implementation of microsimulation models of traffic flow that simulate the movements of individual vehicles in networks. These models are able to mimic vehicle trajectories and use a fine-grained representation of links and intersections (including intersection control information, turning bay data, and so on) to determine queue lengths, delays, turning movements, and other traffic flow information literally on a second-by-second basis. These models are great for analyzing small sub-networks in the context of deploying operational strategies that improve traffic flow (ramp metering, coordinated signal timing, changes in lane geometry or turn bay lengths, and so on).

There is increasing interest in the profession to bring these two bodies of work together. The “planning” models need to be integrated with “operations” models to better capture the changes in traffic patterns that result from changes in system conditions. The changes in travel demand characteristics and the changes in traffic flow characteristics should not be considered as two separate entities, but rather as two sides of the same coin. As long as travel demand models were aggregate macroscopic models, such an integration was difficult to achieve. While travel demand models operated at an aggregate macroscopic level, traffic flow models operated at a microscopic simulation level. Now that travel demand models are also becoming microsimulation-based, it is potentially feasible to bring the planning and operational models together and represent traveler behavior on multimodal networks in a robust framework.

TRANSIMS is a model system that attempts to microsimulate travel patterns – from activity-travel demand generation to vehicular flow and movement on multimodal networks. TRANSIMS is an open-source software enterprise capable of simulating activity-travel patterns and traveler movements along multimodal networks. The objective of this study is to apply TRANSIMS to microsimulate demand and corridor performance along a mixed highway – light rail corridor in the Greater Phoenix region of Arizona and demonstrate the feasibility of applying microsimulation models to the analysis of multimodal corridors. The lessons learned from this effort may be valuable to any multimodal corridor analysis and modeling effort. The paper provides a detailed description of the modeling effort, data preparation, network coding and preparation, and model execution. The paper also describes the model calibration and validation process. Finally, the paper presents results from application of the TRANSIMS model system to analyze the impacts of alternative highway – light rail corridor improvements in the region.

Methodology

The research effort is aimed at deploying a microsimulation model of individual traveler behavior to simulate traffic along a multimodal mixed highway-light rail corridor. The TRANSIMS software package is used in this study as part of a research effort funded by the Federal Highway Administration of the US Department of Transportation. This research effort serves as a case study application of the TRANSIMS software system with a view to demonstrate the ability of such microsimulation model systems to address a range of planning applications. In this particular study, TRANSIMS is being used to simulate travel along a multimodal corridor.

TRANSIMS includes a series of modules that are together able to simulate the activity-travel demand and patterns of individual travelers. The first module is a population synthesizer that generates a synthetic population for the entire region while controlling for known distributions of household characteristics available from census data. The second module is an activity-travel generator that generates activity schedules and agendas for individuals in the synthetic population. The third module is a router that routes trips from origins to destinations according to the schedule provided by the activity-travel generator. Trips are routed on the respective modal network in a time-dependent fashion so that the activity schedule can be fulfilled. Where network conditions prohibit a trip from being undertaken in a manner consistent with the activity schedule (say, because the arrival time is delayed due to congestion), trips are rerouted in this module until all (or nearly all) problems associated with trip execution are eliminated. Finally, the routed trips are actually simulated on the network with vehicular movements being tracked in continuous time. The final step is executed in the traffic microsimulator module of TRANSIMS and provides the basis for performing operational analysis of corridors.

In this study, there are two phases. In the first phase, the research team is using origin-destination matrices from a fully validated four-step travel demand model of the Maricopa region as the source of travel demand. Trip tables were obtained by time-of-day (peak versus off-peak), mode (SOV, HOV, Bus, Light Rail), and purpose (home-based work, home-based non-work, and non-home-based). In other words, in the first phase, activity-travel demand is directly generated from trip tables and only the router and microsimulator modules of TRANSIMS are being applied to simulate travel. The roadway network was obtained from the traditional four-step regional. Activity locations were inserted along links in the network to provide a disaggregate representation of space. All centroid connectors were eliminated from the network. Thus, the zonal representation of space is discarded in favor of a more disaggregate representation of activity locations along network links. The origin-destination trip tables are then used to load trips on the network at the activity locations by associating each origin-destination pair with a pair of links in the network. Trips are routed on the network in an iterative process until the number of "problem trips", i.e., those that cannot be routed in a time that is realistic or consistent with known origin-destination travel times, becomes very low. In the current stage of this particular research study, the Router was run through 10 iterations and the number of problem trips at the end of 10 iterations was found to be just about 50 trips among 13 million trips in the region. Future investigation may reveal that further runs of the router yield further reductions in the number of problem trips. It is yet uncertain as to whether zero problems can be achieved within a reasonable computational effort given the level of benefit of such an achievement.

Following the routing of trips, the research team carved out a subarea that pertains to the 20-mile light rail corridor. This subarea includes a 5-mile buffer around the 20-mile light rail corridor. The research team enhanced the subarea network by adding network details. Additional roadway links were coded into the subarea network to help enhance the fidelity of the traffic microsimulation. Intersection controls were coded to represent traffic control devices at key nodes on the network. The bus and rail links were checked for accuracy and enhanced where appropriate to ensure completeness of stop and schedule information. The trips routed in this subarea were extracted to undertake the microsimulation effort. The research team is currently in the process of testing and calibrating the microsimulator against known ground conditions to ensure that the microsimulator is accurately replicating conditions along the existing 20-mile light rail corridor in the region.

In the second phase, the research team will use all modules of TRANSIMS to model travel demand at the level of the individual traveler. The population synthesizer and activity-travel demand generator will be run for the region to simulate activity-travel patterns of individual travelers. This phase of the research study is just about to get underway and will be completed in the Spring of 2010 well in time for presentation at the conference. Thus, as opposed to using aggregate origin-destination trip tables as the source of the demand for the microsimulation, actual individual traveler activities and trips will be simulated through time and space for the entire region. Then, those trips that are within the subarea will be microsimulated using the traffic microsimulator to analyze demand along the multimodal corridor and simulate corridor performance in terms of queue lengths, delays, turning movements, and vehicular travel times.

In the presentation, the authors will present a detailed description of the two phased approach to the research effort. Detailed results will be presented for each module of TRANSIMS (for both phases) and comparisons will be presented to show how the disaggregate generation of activity schedules is better able to capture the dynamics of travel demand over the course of a day. In particular, this presentation is going to focus on the incorporation of transit into the microsimulation modeling environment. Whereas past efforts have extensively examined microsimulating highway auto modes, this effort has an explicit focus on modeling premium transit and auto modes in mixed corridors. The presentation will describe how planning-level demand analysis can be combined with corridor-level operational analysis to simulate traveler behavior, corridor performance, and compare alternative design configurations and modal scenarios. The authors will present detailed results from runs performed on several alternative light rail scenarios to show how the model responds in the event of system changes. Finally, the authors will detail the calibration and validation procedures that go into the development and implementation of an integrated microsimulation model system. In particular, the authors will focus on calibration and validation procedures for the transit side of the analysis, in terms of representing boardings and alightings, tracking individuals in addition to vehicles, replicating observed ridership patterns by time of day, representing traveler adherence to transit schedules, and modeling access and egress legs of the trip.

Summary

The research team is currently in the final stages of completing the Phase 1 work and has initiated tasks for Phase 2 of the project. More than 13 million trips have been loaded onto the network and routed through the entire region. A subarea multimodal network that allows for travel in personal auto, carpool, bus, light rail, walk, and bike modes, and encompasses a 5-mile buffer of the light rail corridor, has been created. This subarea is currently being refined with additional detail on links and intersections to provide for a high-fidelity microsimulation of traffic along the corridor. At the conference, the project team will present results of the entire model development and implementation process including validation and calibration techniques, as well as results of the scenario analysis. Results will be presented from both phases of the research effort and comparisons will be presented to show how results differ based on the source of demand estimates – aggregate origin-destination trip tables versus disaggregate activity-based travel schedule generation models.

The study aims to add to the body of literature on implementation of microsimulation-based travel models to planning applications. The project team will present results and lessons learned from this project to further aid in advancing microsimulation model development and implementation in transportation planning and operations analysis.