REGIONAL MICROSIMULATION AS A TOOL FOR IMPROVING PROJECT EVALUATION AND CUTTING THE COSTS OF MICROSIMULATION STUDIES

Lan Jiang, Corresponding Author
Maricopa Association of Governments
302 North 1st Ave, Suite 300, Phoenix, AZ 85003
Tel: 602-254-6300; Email: ljiang@azmag.gov

Daniel Morgan
Caliper Corporation
1172 Beacon Street, Suite 300, Newton, MA 02461
Tel: 617-527-4700 Email: daniel@caliper.com

Vladimir Livshits
Maricopa Association of Governments
302 North 1st Ave, Suite 300, Phoenix, AZ 85003
Tel: 602-254-6300; Email: vlivshits@azmag.gov

Janet Choi
Caliper Corporation
1172 Beacon Street, Suite 300, Newton, MA 02461
Tel: 617-527-4700 Email: janet@caliper.com

Arup Dutta
Maricopa Association of Governments
302 N 1st Ave, Ste 300
Phoenix, AZ 85003
Tel: 602-254-6300; Email: adutta@azmag.gov

Wang Zhang
Maricopa Association of Governments
302 N 1st Ave, Ste 300
Phoenix, AZ 85003
Tel: 602-254-6300; Email: wzhang@azmag.gov

Bob Hazlett
Maricopa Association of Governments
302 N 1st Ave, Ste 300
Phoenix, AZ 85003
Tel: 602-254-6300; Email: bhazlett@azmag.gov

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ABSTRACT

Though often criticized for their high costs and highly variable quality, traffic microsimulation studies remain the best option for analyzing traffic operations, especially where operations are vulnerable to the rising influence of ever more complex factors and sources of uncertainty. Despite those criticisms, microsimulation, when applied with the appropriate discipline, judgement, and experience, is the only tool that can offer needed insights into how surface transportation systems may operate in the presence of dynamically priced lanes, connected and automated vehicles, and other established or emerging technologies.

High microsimulation study costs and a lack of standardization in calibration and validation are hurdles that can be ameliorated. We propose a novel approach to lessening the cost of microsimulation studies and to increasing quality and consistency in their application and, hence, faith in their outcomes. First, an initial investment is made in the development of a regional microsimulation model as a warehouse of microsimulation inputs including geometry, signage, signal timings, traffic counts, traffic demand, and more. From then on, the model can serve as a standard, consistent resource that can be drawn upon to more quickly initiate routine traffic simulation tasks, including, but not limited to:

1. Subarea and local traffic studies
2. Multimodal regional planning
3. Public presentations
4. Data sharing

Additionally, a regional microsimulation model need not be perfect, fully formed, nor fully calibrated to begin to be a useful resource for microsimulation studies. Such models can be maintained and improved with time as lessons are learned through regular usage.

INTRODUCTION

Surface transportation systems are becoming more complex with the increasing prevalence of new Intelligent Transportation Systems (ITS) technologies and with the emergence of new technologies, such as connected and automated vehicles. With added complexity comes increased uncertainty surrounding how the system will perform in the field and hence increased dependence on microsimulation because of its ability to, when properly validated, reliably capture individual drivers' behaviors, decisions, and interactions. Modeling individual drivers with behavioral fidelity and realism enables the analyst to model the system's response to a range of strategies and technologies more accurately than any other tool. The value of microsimulation, however, is not limited to the analysis of advanced strategies or new technologies. Microsimulation has long been a valuable tool for analyzing operations on congested facilities, where the dynamics and network effects of queuing and spillback are difficult to predict any other way.

While the value of microsimulation analysis and the importance of its responsible use is generally widely accepted, microsimulation is also widely viewed as expensive and time-consuming, an idea echoed by the Institution of Highways and Transportation in their Network Management Note (*1*). For example, a 2012 California PATH research report calculated that the coding, calibration, and use of simulation models ranged in cost from $503,800 to $1.29 million with an average cost of $871,900. On a per mile basis, the costs ranged from $12,600 to $67,200 with an average of $32,700. The project timelines ranged from 12 to 55 months with an average of just over 34 months (*2*). WisDOT similarly found that project timelines, costs, and general analysis were inconsistent from project to project. As an example, the number of hours to complete a traffic simulation study varied from 200 to 8,200 hours per project (*3*).

In addition to the costs associated with microsimulation studies, there is a lack of standardization in how they are applied, which contributes to the perception that the quality of microsimulation studies is also highly variable and ultimately to weakening support and trust in traffic microsimulation as a practice. In response to the lack of standardization, the MULTITUDE (Methods and tools for supporting the Use caLibration and validaTIon of Traffic simUlation moDEls) Project was created, supported by the European Union's Cooperation in Science and Technology (COST) office. This project's focus is on uncertainty in traffic simulation and how to use calibration and validation to manage that uncertainty. They found there was a clear need for standardization and definitions in basic methodology, such as which measures of effectiveness were essential and how parameters can be adjusted. They identified an important step to be the development of methods to help analysts apply simulation models correctly, effectively, and reproducibly. A survey conducted in 2011 as part of this project revealed the glaring lack of standardization that exists in the field today as of those polled, 19% conducted no model calibration, and of those that did, only 55% used guidelines during the calibration process (*4, 5*).

In addition to the MULTITUDE Project, there have been several other efforts to standardize the simulation practice, most likely in response to the variability in simulation work products that exist today. For example, one of the objectives of FHWA's Next Generation Simulation (NGSIM) is to improve the trustworthiness of existing models by developing new open behavioral algorithms and improve existing algorithms (*6*). Volume III of the FHWA's Traffic Analysis Toolbox established some guidelines for microsimulation projects (*7*). The development of the Transportation System Simulation Manual is another effort by FHWA as a follow up to Volume III to provide guidance on a national level to simulation projects with the hope that its content will become as familiar to users as the Highway Capacity Manual or Highway Safety Manual (*8*).

Waning confidence in microsimulation at a time when complex systems are increasingly deployed and congested facilities are commonplace is detrimental to the state of the practice as well as to the safe and successful implementation of projects that are not first appropriately analyzed. FHWA acknowledges that "as the transportation system environment grows in complexity, increasing pressure is placed on agencies to identify more innovative and efficient solutions to a wide range of issues. Simulation analysis has become increasingly vital for evaluating these solutions prior to implementation" (*8*).

While efforts to create simulation standards continue, we propose a new parallel approach to both increase consistency and fidelity and to reduce costs in microsimulation. This approach begins with investment in a regional microsimulation network and inventory for signage and signal timing data, traffic counts, measured speeds, and other traffic data. The regional network serves as a resource on which future studies can draw, which dramatically reduces the costs of conducting microsimulation studies and provides a consistent base from which to launch future studies.

Prior experiences with large-scale traffic microsimulation can be found in the literature, but their purposes have been quite different from that described in this paper. In Virginia Beach, a city-wide, sub-regional microsimulation model was developed and calibrated and used as a testbed for exploring the convergence properties of large-scale microsimulation-based dynamic traffic assignment (DTA) (9). In Jacksonville, FL, a regional microsimulation-based DTA was integrated with an activity-based model (ABM) to explore the impacts of connected and autonomous/automated vehicles (CAV) (10). A different kind of traffic microsimulation model – one based on cellular automata (CA) rather than the car following/lane changing paradigm that is most commonly associated with traffic microsimulation – has been proclaimed to be "technically feasible" (11). However, despite being a topic of academic interest, CA has not, to the authors' knowledge, found traction in practice, and, despite its computational advantages, has serious disadvantages in its treatment of microscopic vehicle dynamics (12). While these precedents are interesting and speak favorably to the prospect of regional microsimulation, they do not suggest regional microsimulation as a viable, credible decision-support tool for public agencies.

This paper will describe the first known application of this approach in the Phoenix, Arizona area, where a regional microsimulation model was developed and calibrated for the Maricopa Association of Governments (MAG) and was subsequently used as a resource for four purposes:

1. Subarea and local traffic studies
2. Regional, multimodal planning
3. Public presentations
4. Data sharing

MAG REGIONAL MICROSIMULATION MODEL DEVELOPMENT

The first step in this approach is the development of a regional microsimulation network. While there is a widely held perception that microsimulation models are too cumbersome to create for large geographic areas, several wide-area, and even regional, models have been developed and are in use today. A marriage of geographic information systems (GIS) and traffic microsimulation software has enabled the cost-effective preparation of models covering metropolitan areas without sacrificing geometric detail. The MAG regional microsimulation model was built using TransModeler. It spans two counties covering about 14,600 square miles and encompasses more than 3,600 signalized intersections and more than 200 metered ramps. During the AM and PM peak periods, there are 2.5 million and 4 million trips simulated, respectively.

The major regional model development steps included preparing the street network with accurate roadway and intersection geometry, the addition of centroid connectors between traffic analysis zone (TAZ) centroids and streets, the input of signal timing data for all signalized intersections in the region, the inclusion of the transit system representing bus and rail, and the attachment of relevant count and speed data to road segments in the model to be used for calibration and validation.

Model Development

Network Topology

To develop the street network, referred to as a simulation database in the microsimulation software, parts of the region were drawn by hand over high-resolution aerial imagery using editing tools in the software and parts were imported from centerline geography from MAG's regional travel demand model. The latter parts were subsequently modified using the editing tools to match aerial imagery, which is automatically streamed to the map window in the software from one of several free web map services each time the map center or scale is changed. The network covers the entire MAG service area, consisting of 25,713 nodes and 34,291 links. The entire network is mapped into 3,601 transportation analysis zones (TAZ).

Signal Data

Signal timing data were obtained by individually contacting the relevant officials from the cities, towns, jurisdictions, and transportation agencies within the modeling area. The signal data were received in different file formats from different agencies, but the vast majority of the signal plans were translated into formats readable by the microsimulation software through customized scripts. A relatively small number of signal plans, which were unavailable in electronic format, were manually inputted. Signal timings for a total of 3,607 signalized intersections were input to the model, complete with coordinated timing plans by time of day.

Public Transportation Data

The representation of the public transportation system in the model was prepared almost exclusively from Valley Metro General Transit Feed Specification (GTFS) data and included routes, stops, and schedules. Weekday service patterns were used because models were calibrated and validated for weekday peak periods.

Count Data

Weekday traffic counts are routinely collected and maintained by MAG in geographic files in ESRI Shapefile format. The GIS on which the microsimulation software is built reads the Shapefile format natively, allowing for additional customized scripts to be written to efficiently and cost-effectively transfer directional counts from the source geography to the simulation database. The counts that were used were collected during the peak travel seasons in Fall 2014 and Spring 2015. In total, traffic volumes in 15-minute intervals spanning three-hour AM and four-hour PM peak periods were imported for over 2,000 directional segments on freeways and arterial streets throughout the region.

Speed Data

MAG, as a metropolitan planning organization (MPO), had access to a database of average travel time and speed, also in Shapefile format, throughout the region from the National Performance Monitoring Research Data Set (NPMRDS) for 2015. The raw 5-min interval NPMRDS data were aggregated up to average speeds in 15-minute interval by day of week and by month and were subsequently used for validation purposes to ensure the regional model matched key bottlenecks in the region. The microsimulation software's GIS architecture was leveraged again to transfer the speed data to the simulation database using a process called conflation. Conflation seeks to match roadway centerlines in the source geography to road segments in the simulation database by location and direction so that the speed data can be copied to the microsimulation model.

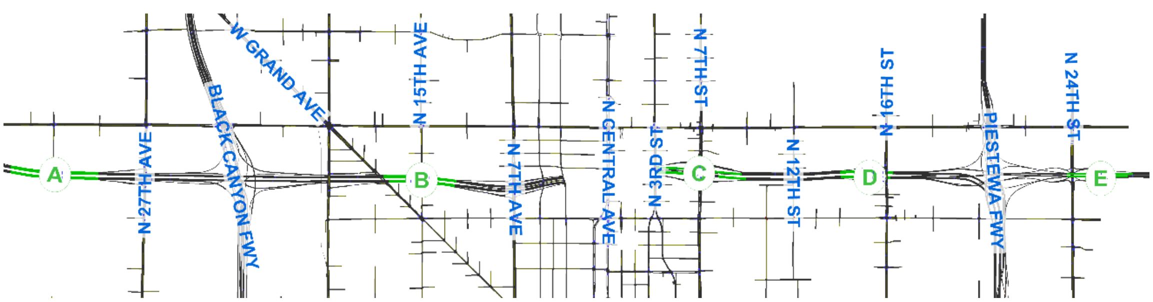
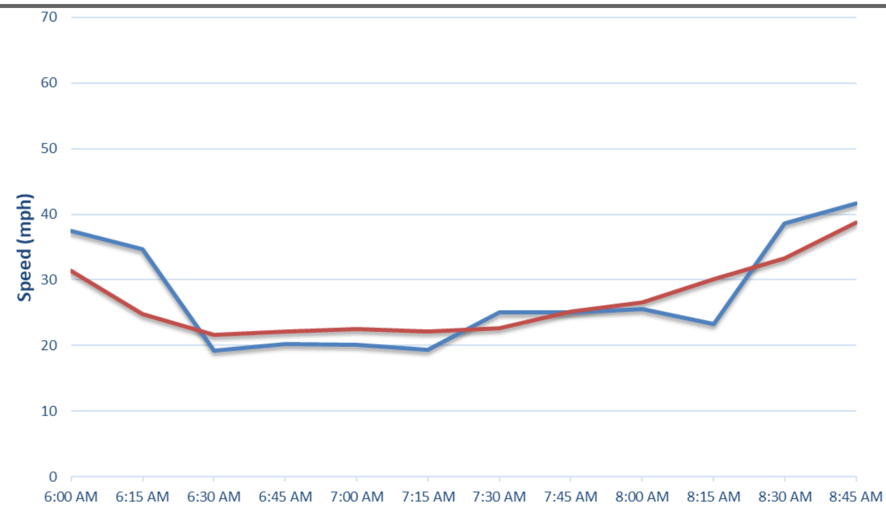
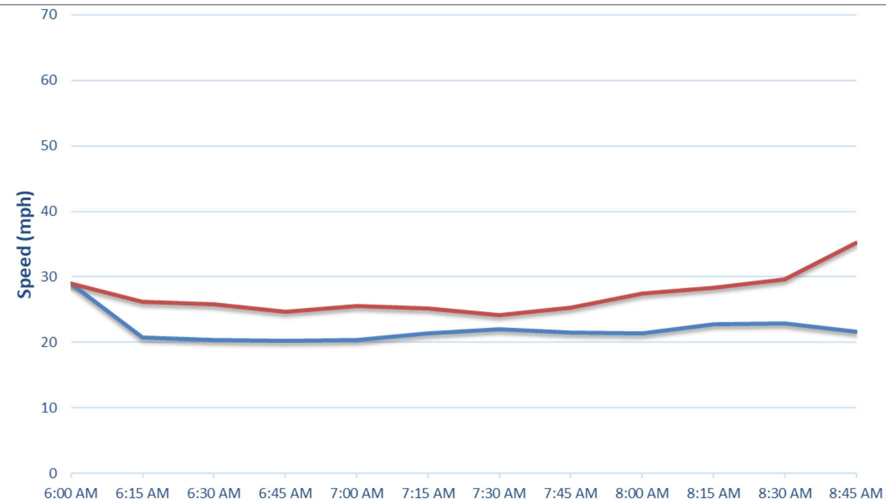
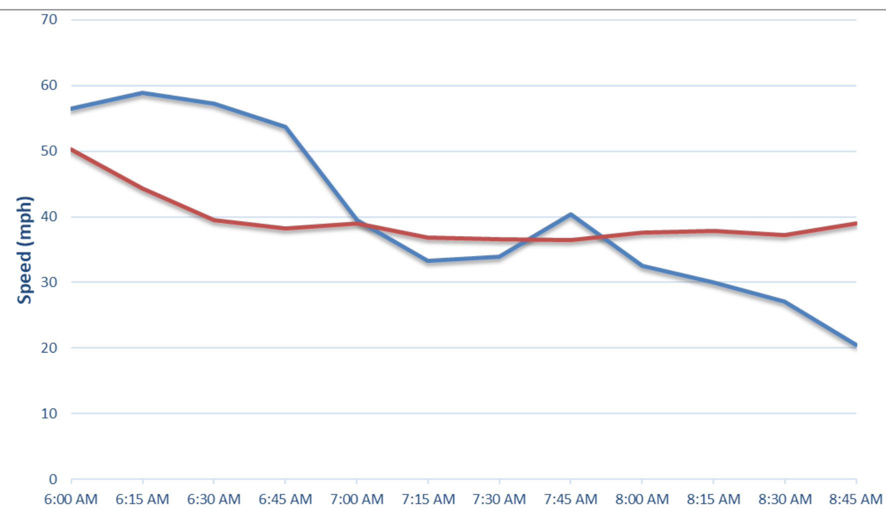


FIGURE 1 Locations of segments where speed profiles were analyzed

The plots that follow summarize the model and NPMRDS speeds during the AM peak period in the eastbound direction at the locations on I-10 shown in FIGURE 1.

Location	Average AM Model and NPMRDS/HERE Speeds Eastbound Model speed NPMRDS Speed
A	
B	
C	

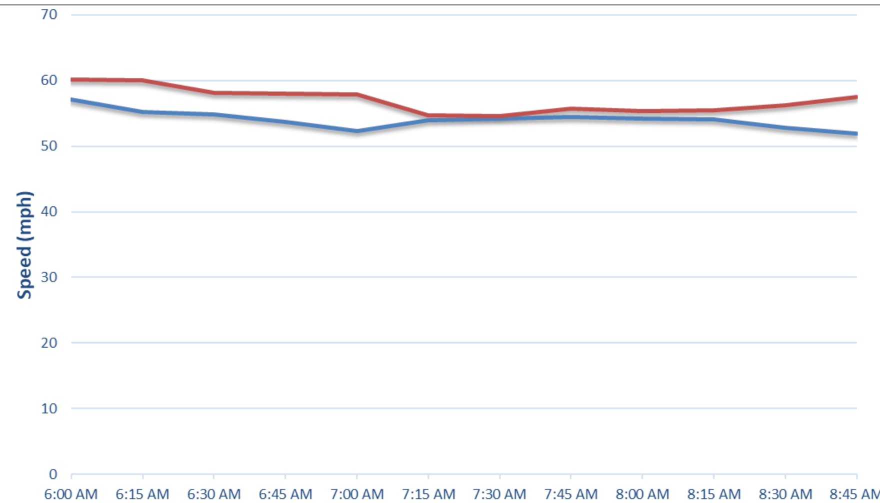
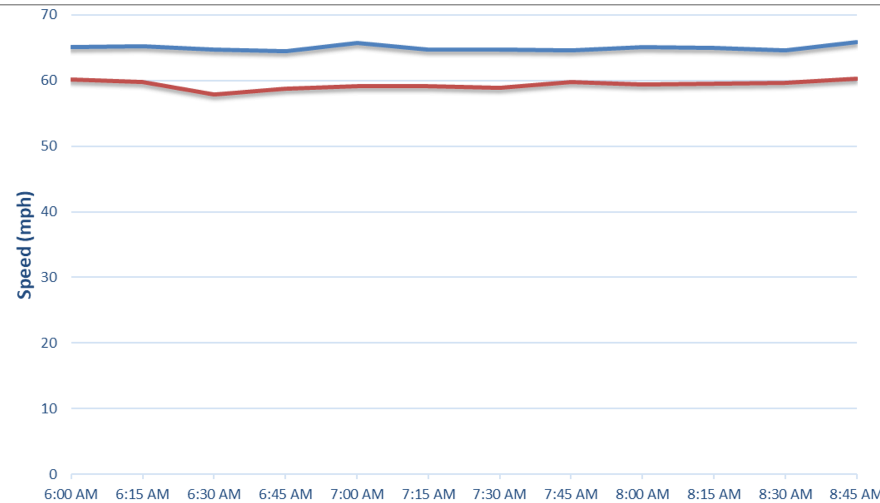
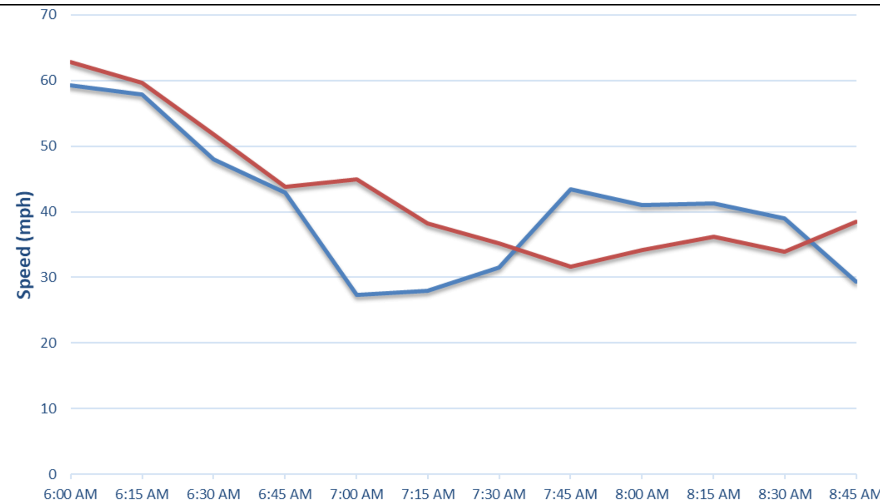
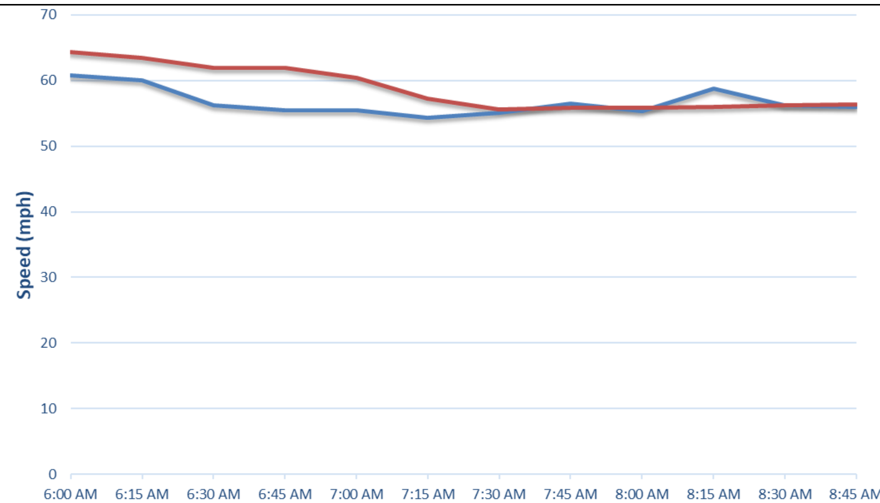
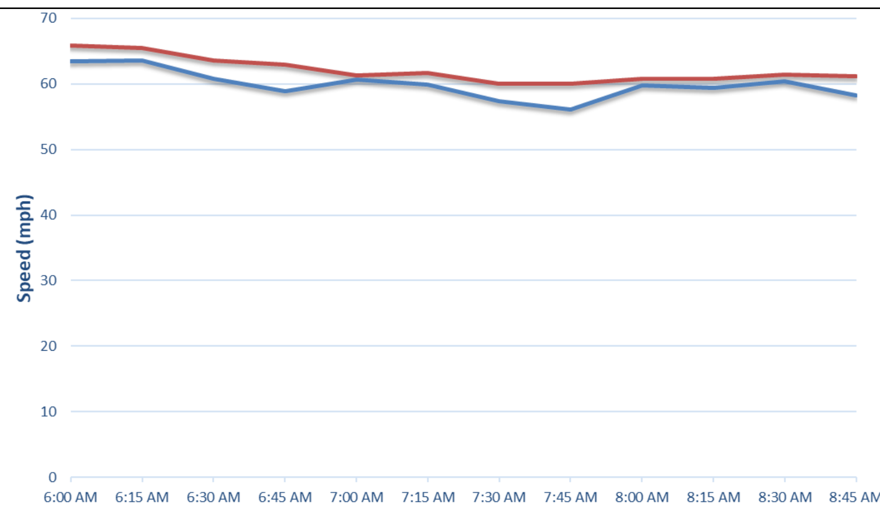
Location	Average AM Model and NPMRDS/HERE Speeds Eastbound Model speed NPMRDS Speed
D	
E	

FIGURE 2: Speed profiles along EB segments during the AM peak

The plots that follow summarize the model and NPMRDS speeds during the AM peak period in the westbound direction at the locations on I-10 shown in the map above.

Location	Average AM Model and NPMRDS/HERE Speeds Westbound Model speed NPMRDS Speed
E	
D	
C	

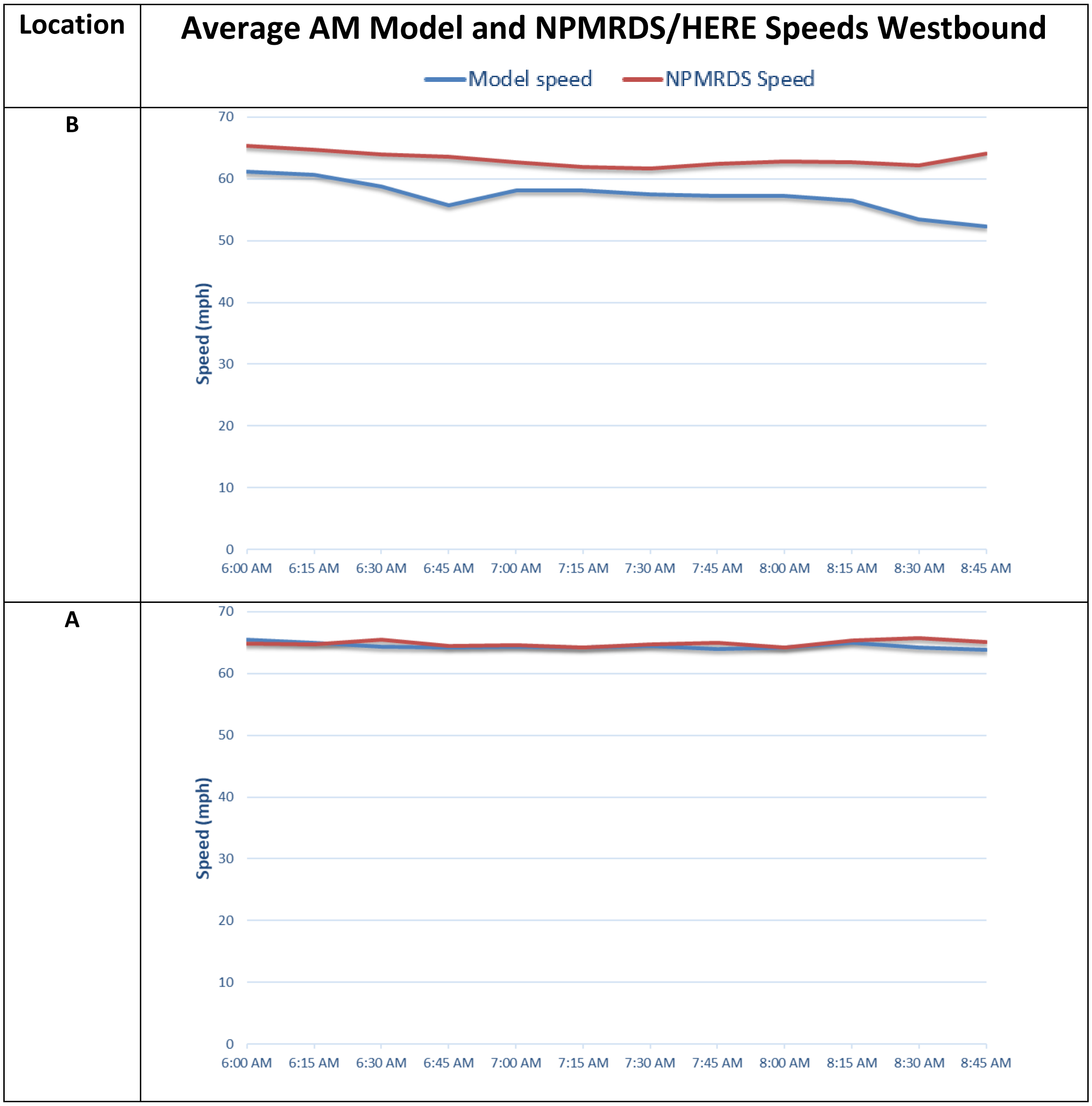


FIGURE 3: Speed profiles along WB segments during the AM peak

Model Calibration

Advanced modeling techniques, such as microsimulation-based dynamic traffic assignment (DTA) and simulation-based dynamic origin-destination matrix estimation (ODME) were used to calibrate the model.

DTA is a technique for estimating the routes that drivers are likely to take at different times of the day depending on expected congestion patterns in a way that, unlike traditional static traffic assignment, captures the "interaction between travel choices, traffic flows, and time and cost measures," which are subject to time-varying network performance and travel demand (*12*). A microsimulation-based DTA captures those interactions with all the driver behavioral and temporal fidelity a microsimulation model affords.

ODME is a technique for improving upon an estimation of the numbers of trips traveling between all origins and destinations in an area under study in a way that improves the goodness of fit between model volumes and traffic counts (*13*). ODME methods generally rely on traffic assignments to determine those model volumes. In the MAG microsimulation model, a microsimulation of the region is used to determine the model volumes.

The relative Root Mean Square Error (%RMSE) on hourly volumes ranged from 14.9 to 24.3 on freeway segments during both peak hours. Figure 4 provides an example of the goodness-of-fit with freeway counts during the PM peak hours.

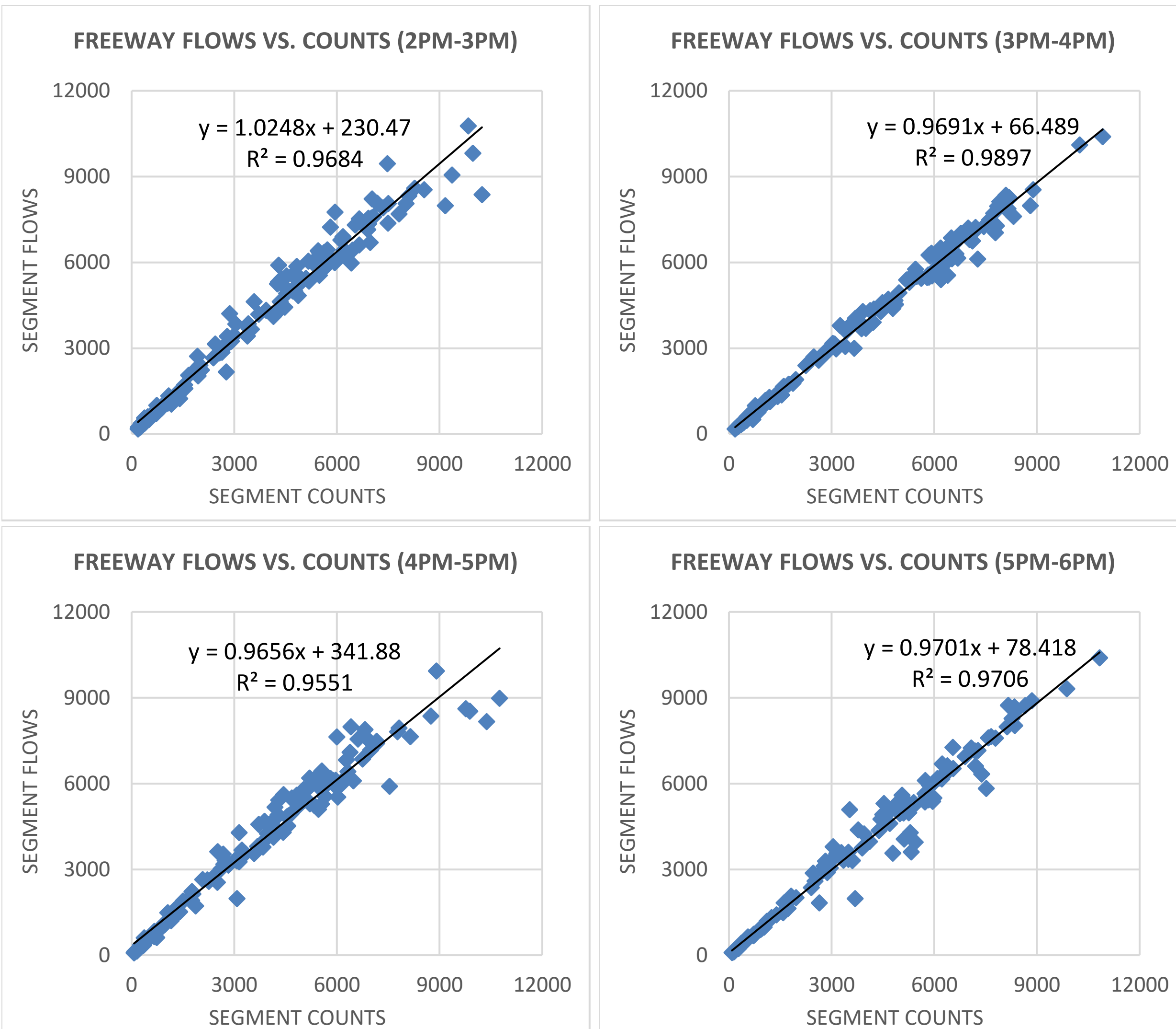


FIGURE 2 Scatterplots of PM freeway flows in the regional microsimulation model

Model Validation

Once calibrated to counts, the model was validated using the NPMRDS speeds and vehicle trajectory data. The 15-minute average NPMRDS speeds were compared visually to simulated 15-minute average speeds at multiple critical bottlenecks around the region and were determined to reflect congestion in time, duration, and severity.

The model was also validated using vehicle trajectories derived from time-lapse aerial photography of a five-mile stretch of I-10 just north of downtown Phoenix. As part of an earlier study, second-by-second trajectories were derived from images taken over a span of two days in October 2014 during the morning and evening peak periods (*14*). Origin-destination (OD) patterns between major entrances and exits along the interstate, shown in Figure 5, were subsequently derived from the vehicle trajectories for 1.5 hours during each peak period.

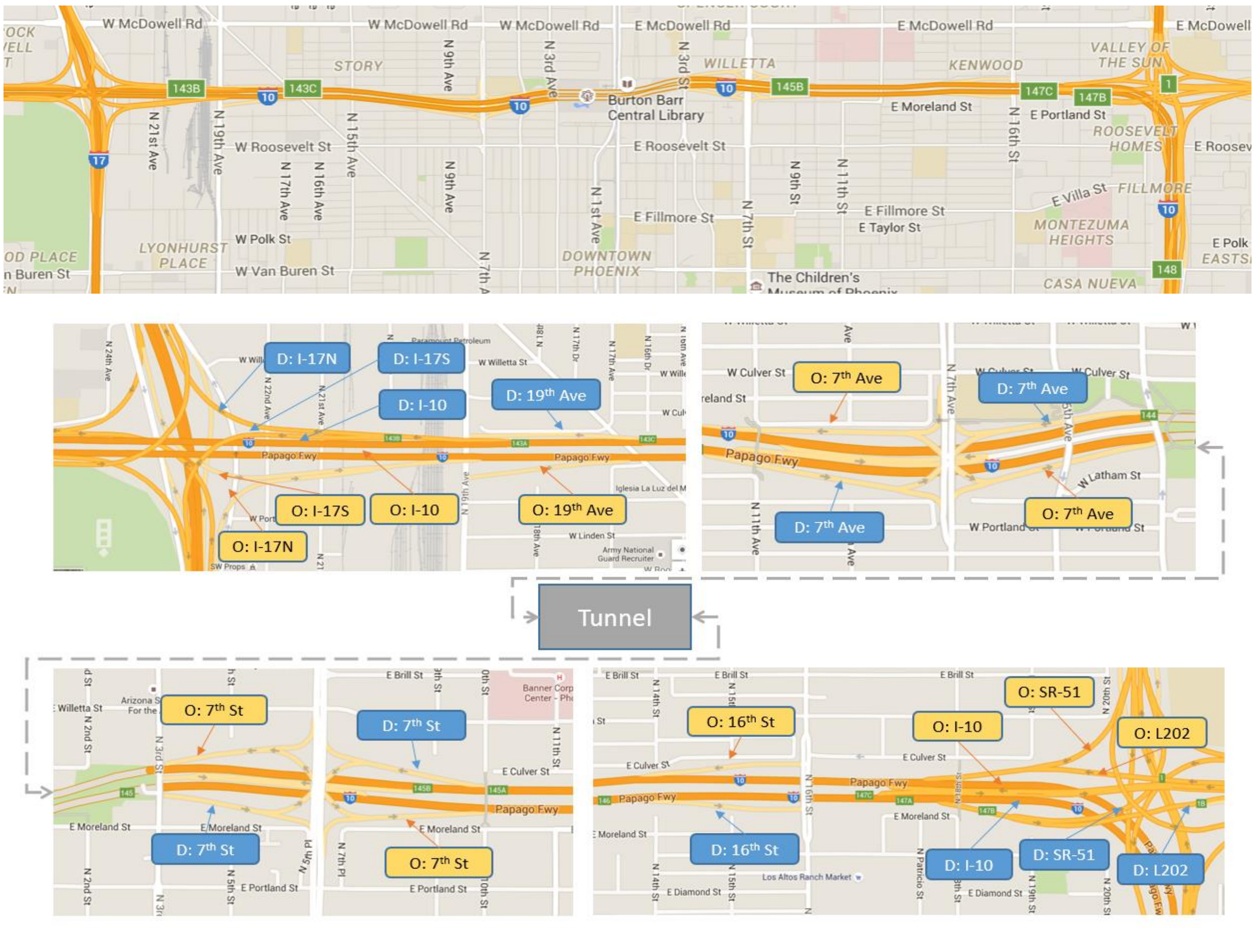


FIGURE 3 I-10 Corridor and OD locations

OD volumes between the same ramp origins and destinations and during the same 1.5 hours were output from the microsimulation model and averaged from 10 simulation runs. A comparison of how the patterns from the observed and simulated OD matrices is presented in the scatter plots shown in Figure 6. The scatter plots are grouped by time period and travel direction. As shown in the plots, in general, the simulated volumes for this five-mile corridor are similar in pattern to the volumes estimated from the vehicle trajectory data, and the estimates are better for westbound trips and AM trips. The outliers in the four scatter plots are mostly from a common set of OD pairs and are likely the consequence of higher rates of driver diversion to adjacent arterials during the most severely congested periods in the model.

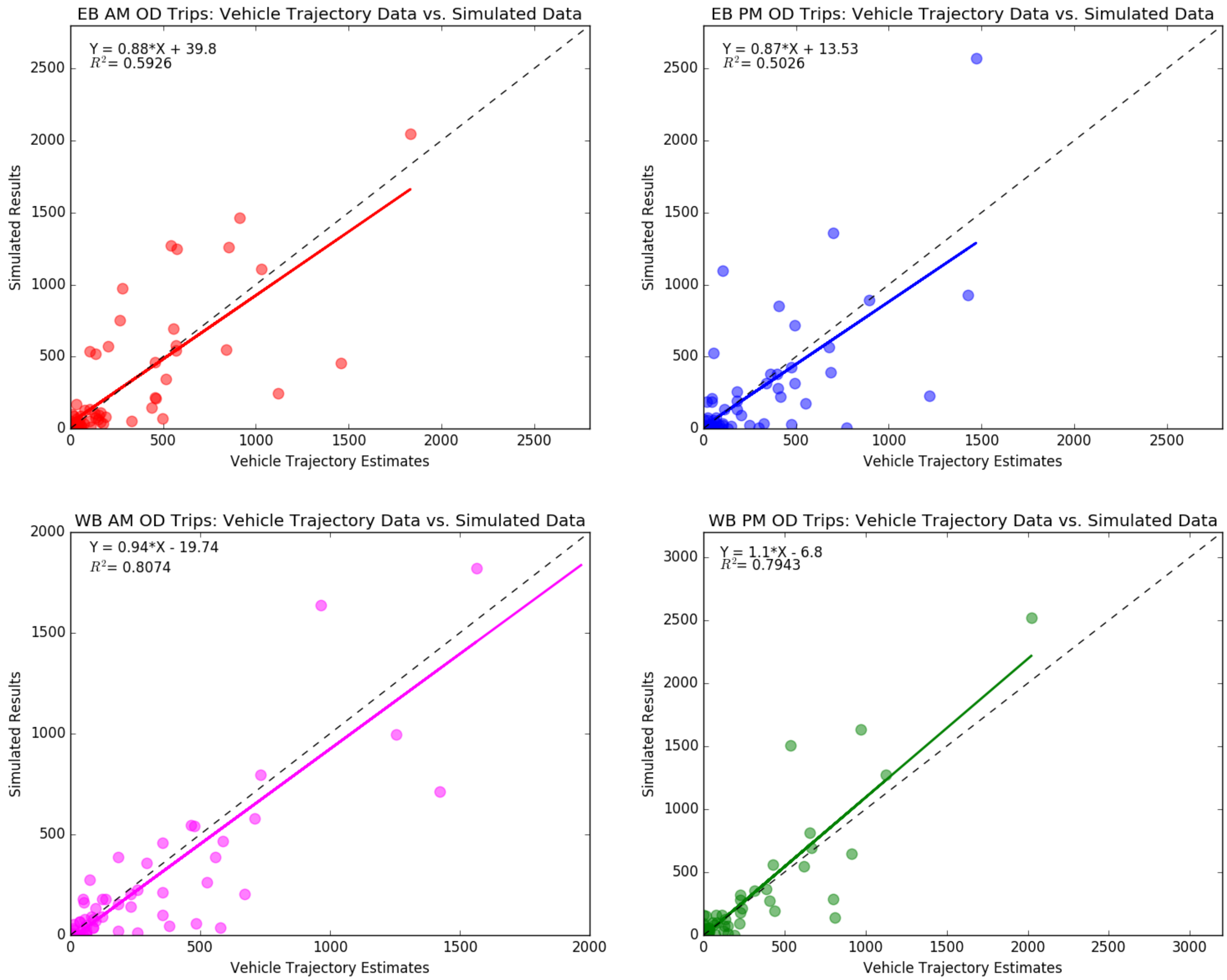


FIGURE 6 Scatter plot – simulated OD trips vs. estimated OD trips from vehicle trajectory data

MODEL APPLICATIONS

After investing in the development, calibration, and validation of the regional model, the model is well-suited to serve as a resource for a variety of applications. Four of these applications are highlighted in this paper:

1. Subarea and local traffic studies: The I-10/I-17 Corridor Master Plan Study
2. Multimodal regional planning: Assessment of bus-only ramps on the freeway system
3. Public presentations: A 3D simulation in Tempe, 2D simulation on Indian School Road, A 2D simulation of a single interchange
4. Data sharing: Interactive maps of link volumes, speeds, and trip tables to be shared via the web or other means

The Regional Model as a Resource for Other Traffic Studies

The first application for which the regional model is a valuable resource is as a source of input data for subsequent simulation studies. A typical microsimulation study will cover an area much smaller than a region – a corridor, a few city blocks around a proposed development, or even just a single intersection or interchange – and will likely require additional local calibration and validation. However, in borrowing most input data from the regional model, such studies can be accelerated to the calibration and validation phases, saving significantly on time and cost. All simulation studies derived in such a way from the regional model would be inherently consistent in terms of their representation of demand and of boundary conditions with the surrounding regional model.

In one such example, the model was used to evaluate long-term solutions to improve traffic flow along the I-10 and I-17 corridors through downtown Phoenix by 2040. The project, known as the I-10/I-17 Corridor Master Plan, was developed by MAG and its planning partners, the Arizona Department of Transportation and the Federal Highway Administration-Arizona Division. More information about this project and its accompanying Planning and Environmental Linkages (PEL) Statement may be found at *spine.azmag.gov*. The I-10/I-17 corridor is referred to as the "Spine" because it serves as the backbone of the surface transportation system in the metropolitan Phoenix area.

To conduct the Spine Corridor Master Plan Study, a microsimulation model was developed from a subarea of MAG's regional microsimulation model. The resulting Spine microsimulation network covers the Phoenix downtown area and is bound on the east by 24th Street and on the west by 51st Street. Happy Valley Road and I-17 bound the network from north to south, respectively. The Spine study area covers about a 25-mile stretch of I-17 and I-10 and is shown in Figure 7 relative to the regional network.

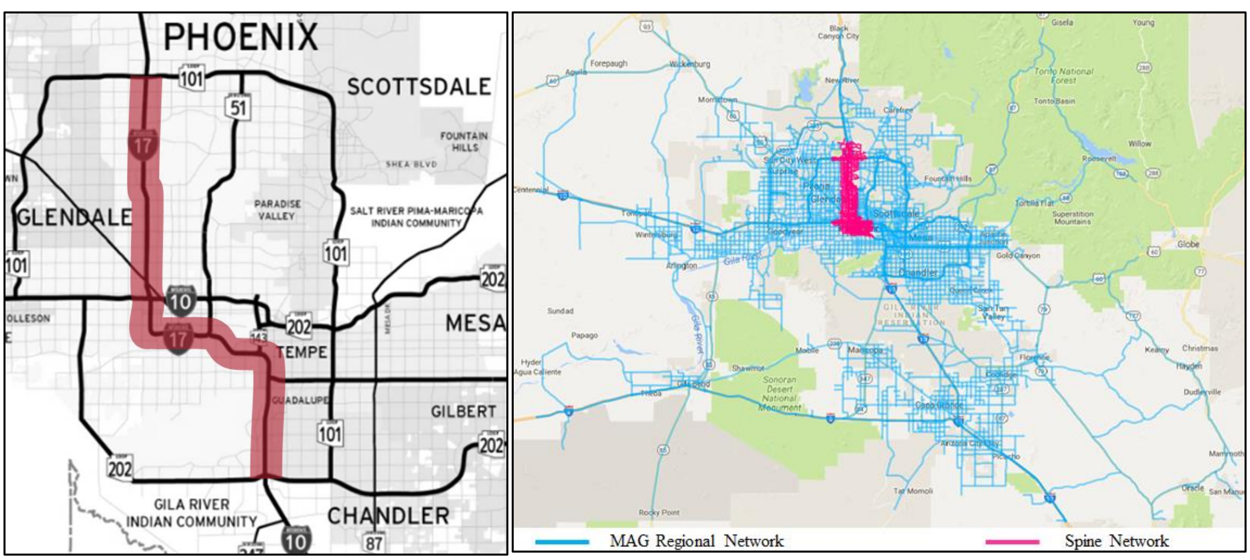


FIGURE 4 Spine corridor and subarea

In the 2015 base year model, a total of about 624,000 vehicle trips were simulated during the 4-hour AM period (5:00 – 9:00) and 866,000 trips during the 5-hour PM period (13:00 –

18:00). These trips represent five vehicle classes (heavy trucks, medium trucks, light trucks, low occupancy vehicles, and high occupancy vehicles), the shares of which are largely derived from MAG's regional travel demand model (TDM) and were estimated using dynamic ODME in 15-minute trip tables.

The calibrated Spine model fits well with the 2015 traffic count data in the subarea. Table 1 summarizes the %RMSE measures computed for hourly volumes across both peak periods for 32 freeway and 216 arterial count locations.

TABLE 1 Simulated Volumes vs. Count Data

Period	Facility	Hour Starting	%RMSE	sumOfCount	sumOfFlows	%Diff
AM	Freeway	6:00 AM	8.78%	169,627	174,771	3.03%
		7:00 AM	7.46%	180,981	182,714	0.96%
		8:00 AM	10.34%	178,011	179,317	0.73%
	Arterial	6:00 AM	31.10%	146,897	161,605	10.01%
		7:00 AM	23.74%	210,063	196,876	-6.28%
		8:00 AM	26.87%	189,865	179,110	-5.66%
PM	Freeway	2:00 PM	8.10%	193,365	191,336	-1.05%
		3:00 PM	9.20%	197,407	196,068	-0.68%
		4:00 PM	14.37%	188,692	191,556	1.52%
		5:00 PM	19.55%	182,387	171,550	-5.94%
	Arterial	2:00 PM	23.82%	187,634	171,544	-8.58%
		3:00 PM	24.55%	216,960	194,941	-10.15%
		4:00 PM	27.50%	238,350	205,700	-13.70%
		5:00 PM	30.26%	239,615	198,544	-17.14%

To estimate future year (2040) demand, growth factors by vehicle class were applied to the calibrated 2015 trip tables based on percent increases in volumes on I-17 between the 2015 and 2040 planning horizon forecasts generated by the TDM.

The study identified a set of corridor-wide alternatives for evaluation based on factors related to infrastructure, safety, public acceptance, and corridor operations, especially at traffic interchanges and weaving segments within the corridor (*15*). Two alternatives were selected and coded into the microsimulation model. For the sake of brevity, this paper discusses only one of the alternatives in detail, hereby referred to as Alternative 1, involving the following infrastructure changes:

1. The addition of an HOV lane on I-17 in both directions between the I-10 interchange (southeast of downtown) and the SR-101L interchange. Some sections of this corridor already had an existing HOV lane in the 2015 base scenario. For these sections, the number of HOV lanes per direction was increased to 2 in the build scenario.
2. Road configuration changes at the I-17 ramps to Bell Road, Thunderbird Road, Northern Avenue, Camelback Road, and Indian School Road. Study team members noted the need

for higher capacity for the arterials than along the freeway mainline at those interchanges The existing diamond interchanges are converted to three-level platforms to allow high east-west arterial through volumes to flow at the third level uninterrupted by ramp movements served at the second level (Figure 8).

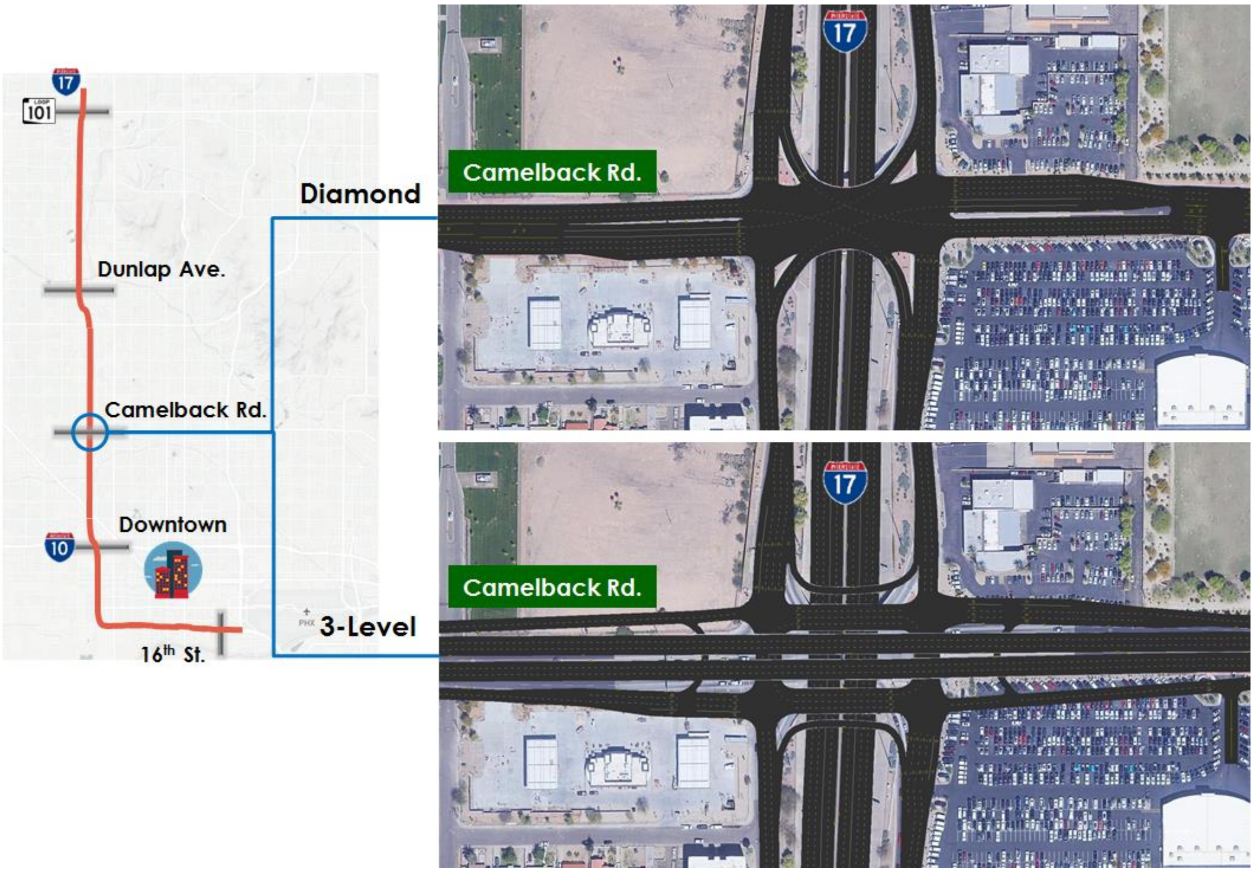


FIGURE 5 Infrastructure changes under Alternative 1

Speed contour plots produced by the Spine microsimulation model give us a time-space map of the congestion along the I-17 corridor. Figures 6-7 illustrate the travel patterns along 20 miles of I-17 from three scenarios: 2015 Base Year, 2040 No-Build, and 2040 Alternative 1. The horizontal axis represents time stamps for the 4-hour PM peak (14:00–18:00), and the vertical axis represents distance along the corridor. The color of each cell ranges from red, indicating lower speeds, to green, indicating higher speeds. The speed contour plots demonstrate that Alternative 1 partially mitigates the 2040 congestion and helps keep traffic moving at a reasonable speed in both the northbound (Figure 9) and southbound (Figure 10) directions.

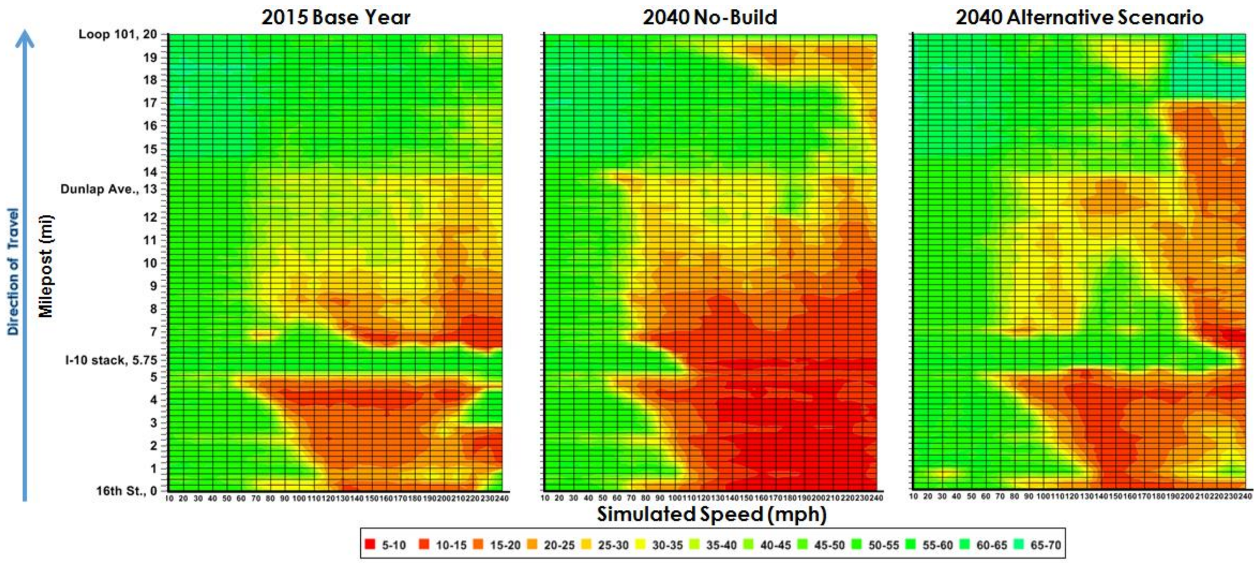


FIGURE 6 Simulated speed contours along I-17 northbound (14:00-18:00)

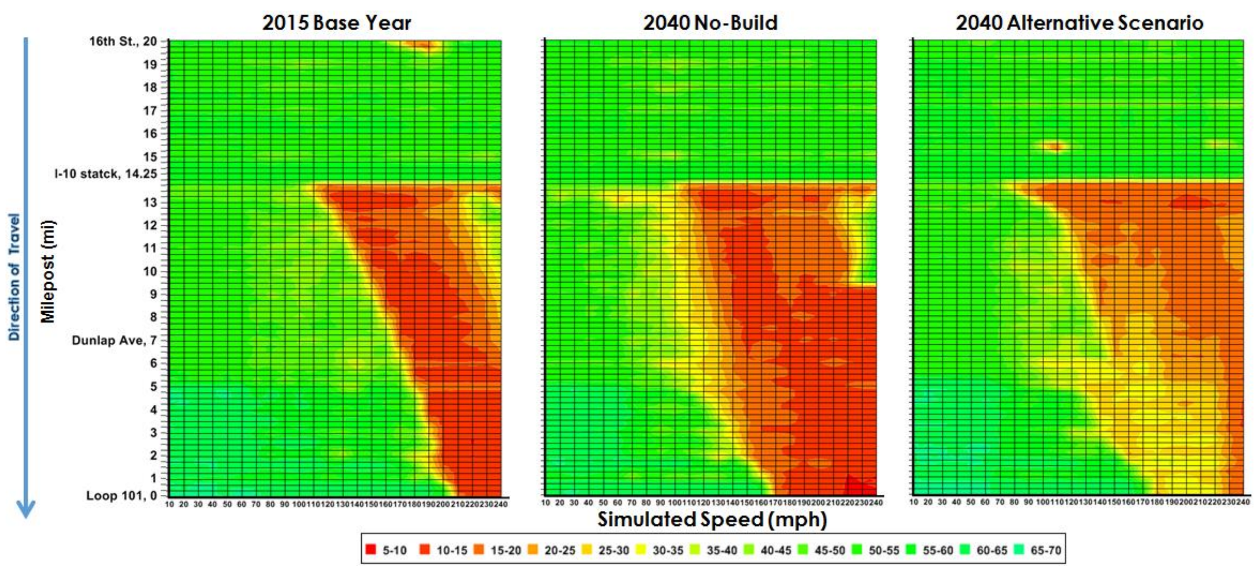


FIGURE 7 Simulated speed contours along I-17 southbound (14:00-18:00)

As a starting point for the Spine study, the regional model supplied all the street network data that was needed for the existing conditions model. Any time spent coding the network, intersection geometry, and signal timings was obviated because of the initial investment in the regional model. Thus, any other similar project in the greater Phoenix area can also save valuable model development time and costs by starting with a subarea of the regional model.

In addition to providing the infrastructure for the study, the regional model also provided the calibrated 2015 base demand, which gave the process of calibrating the subarea a substantial head start. The calibration and validation of the Spine study area was thus far less onerous and time-consuming than is typical of a microsimulation study of similar size.

The Regional Model as a Resource for Multimodal Regional Planning

The regional microsimulation model offers more operational fidelity than the regional TDM and thus can serve as a useful extension of the TDM for multimodal planning purposes. As public transportation services often serve disperse parts of a region, accurately assessing their impacts requires a regional model. The microsimulation model allows the analyst to capitalize on accurate treatment of operations where a proposed project may be sensitive to factors such as merging and weaving or queuing and spillback. The regional microsimulation model was used to evaluate the potential benefits of bus-only ramps on certain sections of the freeway system. Several bus routes were diverted to the bus-only ramps to estimate the travel time savings such a project might yield relative to existing conditions. The travel time differences provided useful quantifiable performance metrics that were used by planners to inform their decision-making.

The Regional Model as a Resource for Public Presentations

Microsimulation models are valuable not only for their detailed treatment of operations but also for their capacity to engage the public with compelling 2D and 3D animation. While the public may focus on less critical aspects of a 2D and 3D animation than the transportation operations it is meant to illustrate, it is common practice to use microsimulation-based animation to supplement tables and charts of measures of effectiveness to convey a study’s findings to the public, whose buy-in and support are often critical for project approval. Using the regional microsimulation model as a starting point, MAG has developed various 2D and 3D movies quickly and cost-effectively to support a number of traffic studies and impact assessments for MAG’s own projects and those of its member agencies.

For example, a subarea of approximately three square miles in downtown Tempe, AZ was extracted from the regional microsimulation model for the evaluation of access junctions, capacity, routing and diversion, and overall network performance in the vicinity of a number of proposed new commercial and business district site locations. 3D simulations were used to illustrate traffic operations with the proposed developments, as shown in Figure 11.

FIGURE 118 3D simulation of AM peak traffic along Mill Avenue, Tempe, AZ

In another study, a corridor-level microsimulation model was developed along two miles of Indian School Rd, a major arterial in Central Phoenix, to analyze current traffic conditions and to evaluate recommended infrastructure changes. Figure 12 is a screenshot of a video created with the microsimulation model to illustrate conditions before and after the project at a key intersection.

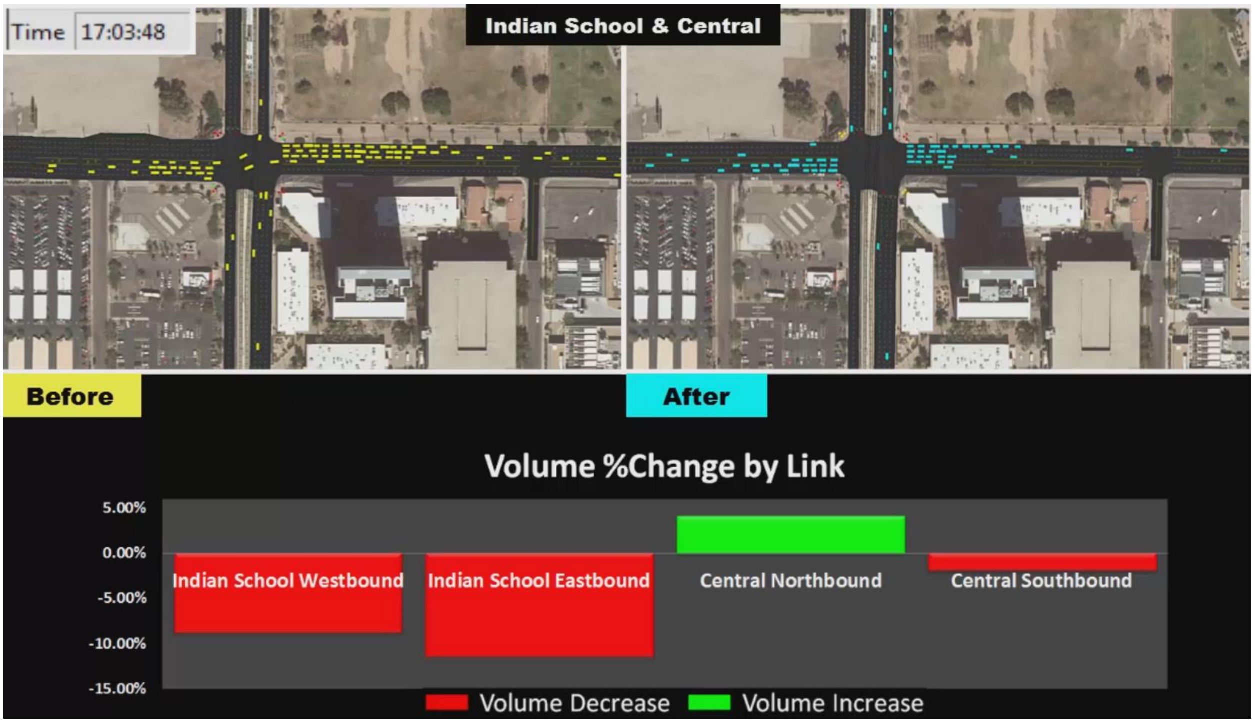


FIGURE 9 2D simulations of before and after traffic flow along Indian School Road

The regional model was also used to develop a model of the Camelback Road interchange on I-17 to evaluate a proposed 3-level interchange. Figure 13 illustrates a snapshot of the 2D animation of the future traffic flows at the interchange. The animation proved valuable at a public meeting in communicating the potential changes associated with the proposed alternative.

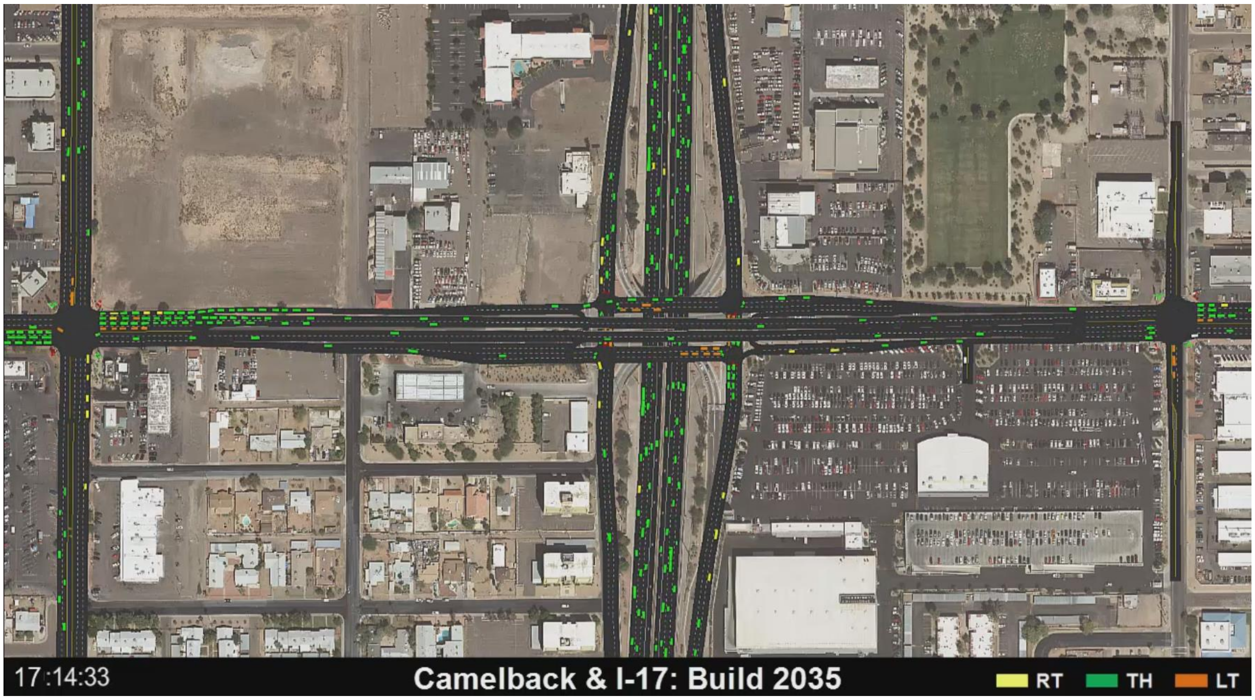


FIGURE 10 An aerial view of the 2D animations of the 3-level platform at Camelback Road and I-17

The Regional Model as a Resource for Data Sharing

Traffic microsimulation models produce rich and detailed data sets that are potentially of great benefit to many users. As a public agency, MAG seeks open and powerful tools to share and visualize data that are not confined to any specific commercial software. To that end, MAG produced user-friendly interactive maps on the web using data from the regional model. The interactive maps achieve the goal of providing dynamic data to many users, who are able to customize the maps for their own purposes.

Figure 14 provides an example of an interactive map of the time-dependent simulated roadway volumes and speeds from the regional microsimulation model. The map was developed in JavaScript using Mapbox libraries. At the top left corner, there is a display control panel that allows users to select what will be displayed on the map (e.g., simulated speed or volume, time of day, centerlines). After choosing the display settings, the user can then view the simulated data dynamically and navigate to any location in the region. Figure 14 displays the simulated volumes and speeds at 4:45 PM near downtown Phoenix. The roadway colors indicate simulated speeds, with colors ranging from red to green as speed increases. The widths of the roads represent the simulated volumes. A time slider bar allows users to change the visualization to different times of the day. Users can also point the mouse to a specific link, and an Info Box will display the street name, speed, and volume.

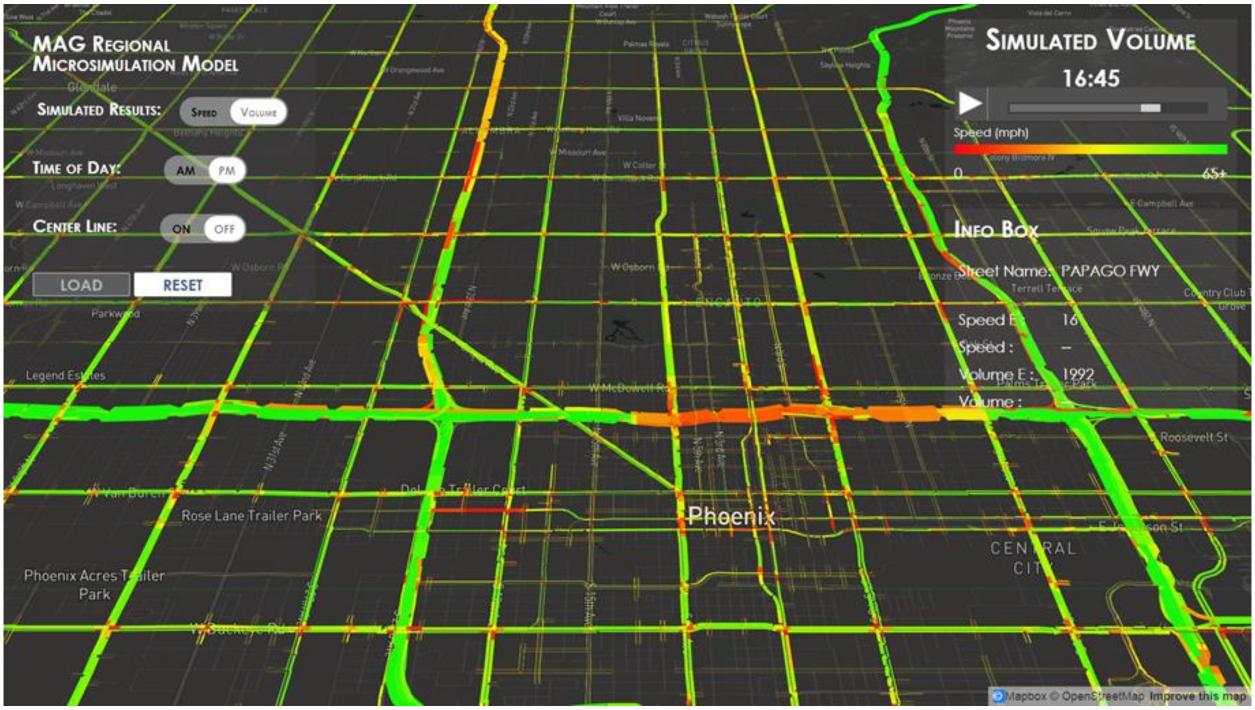


FIGURE 11 Interactive map of time-dependent simulated link volume and speed

In a similar fashion, an interactive map was developed to visualize the time-dependent trip tables from the regional model. The interactive map provides users an easy way to explore spatial data in a 2D or 3D view of the entire MAG region (Figure 15). The number of trips produced or attracted by each transportation analysis zone is indicated in 2D by different shades of blue (the lighter the color, the higher the value) and in 3D by the height of the extruded polygons.

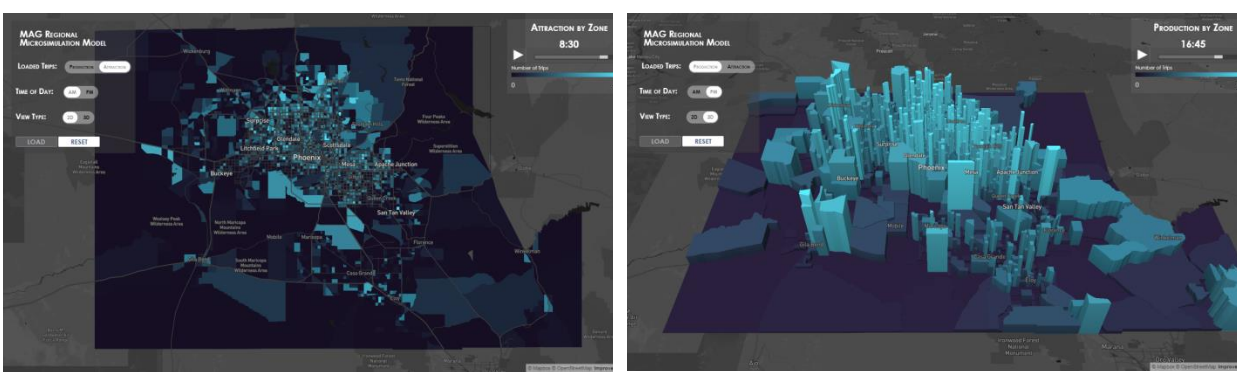


FIGURE 12 2D and 3D interactive map of time-dependent trip tables

Summary

The MAG regional microsimulation was evaluated on a 64-bit Windows 7 platform and a machine with an Intel® Xeon® 2.6 GHz dual-processor CPU and 128GB RAM. With basic outputs (trip statistics, flow and travel time statistics by road segment), the average simulation run time is about 1.85 hours for the AM period and 2.85 hours for the PM period. An initial subarea network trip tables for a subarea or local simulation study can be extracted from the MAG regional microsimulation model within a couple of hours for the peak periods. Although the regional model was coded and calibrated for the planning year 2015, updates to the network and signal timing inputs representing subsequent years can be readily incorporated into a subarea model extracted from the MAG regional model. The time-dependent trip tables may require some time to be re-calibrated for the subarea microsimulation model depending on the scale of the subarea network and the goodness of fit with observed data (e.g., measured counts and speeds).

The preparation of the time-dependent trip tables for future years remains a challenge because of the necessity of estimating future-year trip tables incorporating growth predicted by the MAG regional travel demand model. Also, microsimulation models are prone to gridlock if the future volumes exceed capacities in the network even partially or temporally. Erroneous trip tables or assumptions about the distribution of trip departures over time lead to system failure and unrealistic outputs. In addition to the time-dependent trip tables, microsimulation models in general are very sensitive to network topology, signal timing plan, driver behavioral parameters (global and/or local), parameters in routing decisions, and other inputs. Should one observe any unrealistic outputs during visual audit of the simulation, these inputs are the first inputs warranting further review.

While the microsimulation models provide an effective and practical approach for capturing the probabilistic nature of traffic patterns in the traffic network, there is no consensus on how many simulation runs are required to achieve the best estimators of the traffic measurements. The simulated statistics in general distribute in a reasonable range. However, depending on the simulation models, one may observe extreme values, especially at the most congested bottlenecks during the most congested time periods generated by certain simulation runs.

Overall, the MAG regional microsimulation model provides a convenient starting point for analyzing complex transportation systems and evaluating alternatives in a fast and inexpensive manner. The potential benefits of this model are:

- The MAG regional microsimulation model was developed that is independent of any specific projects. This study leverages the knowledge and data from various MAG member agencies. The model is configured and calibrated for 2015 base year.
- This regional microsimulation model could serve as generic databases of both supply data (e.g., link characteristics, traffic control devices, lane widths) and demand data (e.g., OD trip tables by vehicle class).

- With the calibrated regional microsimulation model, it will involve considerably less work and fewer resources when microsimulation models are needed for any specific projects in the MAG region compared to starting from scratch.
- The microsimulation models can be used to explain complex transportation projects to the general public. The graphics and animations generated by the model both in 2D and 3D are fairly sophisticated and can be used readily to illustrate complex topics during public meetings.
- The introduction of WebGL (Web Graphics Library) enables delivering advanced graphics content to the end user in a web browser. This adds a number of benefits such as easy exploration of the data set at user’s own control, less data transfer, and easy sharing.

CONCLUDING REMARKS

Microsimulation analysis is an indispensable tool for a range of routine activities including traffic analysis and public involvement and is increasingly critical to understanding and analyzing complex transportation systems. However, potentially high project costs and a lack of standardization in calibration and validation threaten the credibility and acceptance of microsimulation as a practice.

While efforts to create microsimulation standards are underway, we illustrate a complementary approach to address the dual problems of cost and consistency. In that approach, an upfront investment in the development of a regional microsimulation model, such as the one developed for MAG, can go a long way to address consistency and high project costs. The regional microsimulation model can then be used as a resource for various applications, including but not limited to:

1. **Subarea and local traffic studies:** The regional microsimulation network minimizes future project costs for model development and increases consistency as it serves as a database of both supply data (e.g., link characteristics, signal timings, lane widths, etc.), and demand data (OD matrices by vehicle class, etc.). Considerably less work is required to develop a new model for a smaller area in the region because the calibrated regional network can be leveraged as a starting point for all of the model’s most critical inputs.
2. **Multimodal regional planning**: A regional microsimulation model can be used to evaluate regional public transportation services with greater fidelity and accuracy than a traditional planning model.
3. **Public presentations**: The regional model is also a source of data immediately available to produce 2D and 3D animations of complex transportation projects for public presentation that are more easily understood and digested by non-technical audiences.
4. **Data sharing**: The regional network is a rich source of valuable data that can be shared with others by developing interactive maps published on the web. Users can create custom maps of dynamic model data anywhere in the region.

As illustrated by a real example of a regional microsimulation model developed for MAG, the initial investment in a regional microsimulation model enabled subsequent studies to be conducted more efficiently and provided added value by creating opportunities for a range of other applications.

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AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Vladimir Livshits, Bob Hazlett, Daniel Morgan; data collection: Arup Dutta, Wang Zhang; analysis and interpretation of results: Lan Jiang, Daniel Morgan; draft manuscript preparation: Vladimir Livshits, Lan Jiang, Daniel Morgan, Janet Choi. All authors reviewed the results and approved the final version of the manuscript.

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