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Practical guidance for using mesoscopic simulation tools

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Abstract

Mesoscopic simulation has many advantages such as requiring less effort for network building and calibration than microscopic simulation and generating more detailed simulation results in terms of traffic conditions than macroscopic simulation. As more and more transportation practitioners become interested in it, this paper aims at providing practical guidance by demonstrating the capabilities of mesoscopic simulation tools. In order to provide practical guidance, two commercially available mesoscopic simulation software, AIMSUN and VISSIM were chosen and a testbed network consisting of a system of freeways in Richmond, Virginia was prepared. The testbed was calibrated and used to evaluate the potential impacts of various levels of High Occupancy Vehicle (HOV) lane usage on system operations. The goal of the HOV lane implementation was to demonstrate practical guidance of utilizing mesoscopic simulation package as a tool for evaluating traffic management strategies. Results of the demonstration study, using both AIMSUN and VISSIM, were deemed to be reasonable. Some lessons learned during the study as well as through communications with the software vendors are also shared in the paper. This paper should provide transportation practitioners with practical guidance when selecting and/or conducting mesoscopic simulation.

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Keywords: Mesoscopic Simulation; AIMSUN; VISSIM; High Occupancy Vehicles

1. Introduction

Mesoscopic modeling is at an intermediate level of detail between macroscopic and microscopic simulation models. Compared with macroscopic models, mesoscopic models can simulate more details of individual vehicles' movements and produce more accurate simulation results. Compared with microscopic models, mesoscopic models can provide significant savings in modeling time and efforts, especially when analyzing large area networks, without unduly compromising the accuracy of results (Burghout 2005).

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Because of these advantages of mesoscopic simulation, many transportation agencies and researchers have used it to conduct evaluations. Toledo et al. used Mezzo, which is a mesoscopic simulation tool, to evaluate transit operations for a 14-km busy transit line in the Tel-Aviv metropolitan area in Israel (Toledo et al. 2010). Hou et al. (2013) used mesoscopic simulation to incorporate the impacts of adverse weather on traffic conditions estimation and prediction. Mesoscopic simulation models were established in Irvine, California, Chicago, Illinois, Salt Lake City, Utah and Baltimore, Maryland. Chiu et al. (2008) used mesoscopic simulation to evaluate contra-flow and phased evacuation strategies in a large area over a long time period and applied the proposed mesoscopic simulation model in the Houston-Galveston hurricane evacuation scenario. Palma and Marchal (2002) demonstrated the capabilities of mesoscopic simulation in modeling both within-a-day and day-to-day dynamics of large-scale transportation systems. Kristoffersson (2013) also used mesoscopic simulation to evaluate the impacts of cordon pricing on travelers' departure time, mode choice and route choice behaviors in Stockholm. Florian et al. used a mesoscopic simulation model to evaluate the impacts of ITS systems. The proposed model was applied in a relatively large network which consisted of 220 zones, 2080 links and 5000 turns in Stockholm (Florian, Mahut, and Tremblay 2001).

As shown in the literature, mesoscopic simulation is mostly used for large road networks which typically would require significant network building and calibration efforts if it were to be modeled in microscopic simulation and may ignore important details by using aggregate traffic flow behavior if done with macroscopic simulation. Thus, mesoscopic simulation provides transportation practitioners with another effective traffic simulation approach.

There are many commercial and research based mesoscopic simulation tools available. Examples of commercially available mesoscopic simulation models include AIMSUN, DynusT, VISSIM Meso-simulation, Dynameq, Cube Avenue, and TransModeler. An example of a research based mesoscopic simulation tool is DTAlite. Considering the goal of this research is to provide some references for transportation practitioners, commercially available mesoscopic simulation models are much easier to access. Thus, this paper picked two commonly used simulation software which offers mesoscopic simulation packages, VISSIM Meso and AIMSUN Meso.

2. Objectives and scope

The goal of this paper is to provide transportation practitioners with a practical guidance of using mesoscopic simulation tools by demonstrating the capabilities and required efforts with a testbed in Richmond, Virginia. A traffic control and management strategy, High Occupancy Vehicle (HOV) lane was chosen to evaluate the capabilities of mesoscopic simulation. The paper focuses on the procedure of applying mesoscopic simulation on a testbed and also sharing the lessons and experiences learned in this process. Two commercially available mesoscopic simulation packages, VISSIM Meso and AIMSUN Meso were selected for the study.

The rest of this paper provided a brief overview of the two selected mesoscopic simulation packages, described the road network that was used as a test bed, discussed the modeling effort including required data input, simulation network settings, calibration process, and demonstrated application through HOV implementation. Finally, lessons learned were summarized and conclusions were made.

3. Overview of selected mesoscopic simulation software

3.1. VISSIM

VISSIM is a traffic simulator developed by PTV in Karlsruhe, Germany. It has been widely used for microscopic traffic simulation. It focuses on the microscopic simulation but has started to incorporate a mesoscopic simulation module since VISSIM 8. The mesoscopic simulation is available for purchase as an add-on module. Since VISSIM Meso is relatively new there was not much literature on practical applications of the tool.

3.2. AIMSUN

AIMSUN is a software package that is developed by TSS-Transportation Simulation Systems. It is a traffic simulator that integrates the macroscopic, mesoscopic and microscopic simulations, as well as hybrid simulation which combines the mesoscopic and microscopic simulations. After the network is coded in AIMSUN, it can be used to conduct simulation at any level including macroscopic, mesoscopic, and microscopic simulations (TSS 2014). AIMSUN mesoscopic simulation has been used in many applications (Chen 2014; Liu, Danczyk, and He 2011; Casas, Perarnau, and Torday 2011; "Strategic and Mesoscopic Transport Modelling").

Like many mesoscopic simulation models, AIMSUN Meso and VISSIM Meso are both based on dynamic traffic assignment (DTA). The latest version of each software has both stochastic route choice based assignment and equilibrium based assignment, but the rules of path set generation and route selection are slightly different (TSS 2014; PTV 2016). Both of them adopted the same simplified car following model developed by M. Mahut (TSS 2014) to simulate vehicles' movements.

4. Case study

In order to assess the capabilities of the two mesoscopic simulation packages, the VDOT I-95/64 Overlap Study network was used as a test bed to conduct a case study (Kimley-Horn and Associates, Inc 2013).

4.1. Basic information

The Virginia Department of Transportation conducted a planning study in 2012-2013 of the I-95/64 overlap area in the City of Richmond and Henrico County. It is an approximately 7-mile long freeway corridor, as shown in Fig. 1. For more detailed information about the area, please refer to the study report (Kimley-Horn and Associates, Inc 2013). Based on the data availability, the study time period is set from 6:30 am to 9:30 am on August 10, 2011.

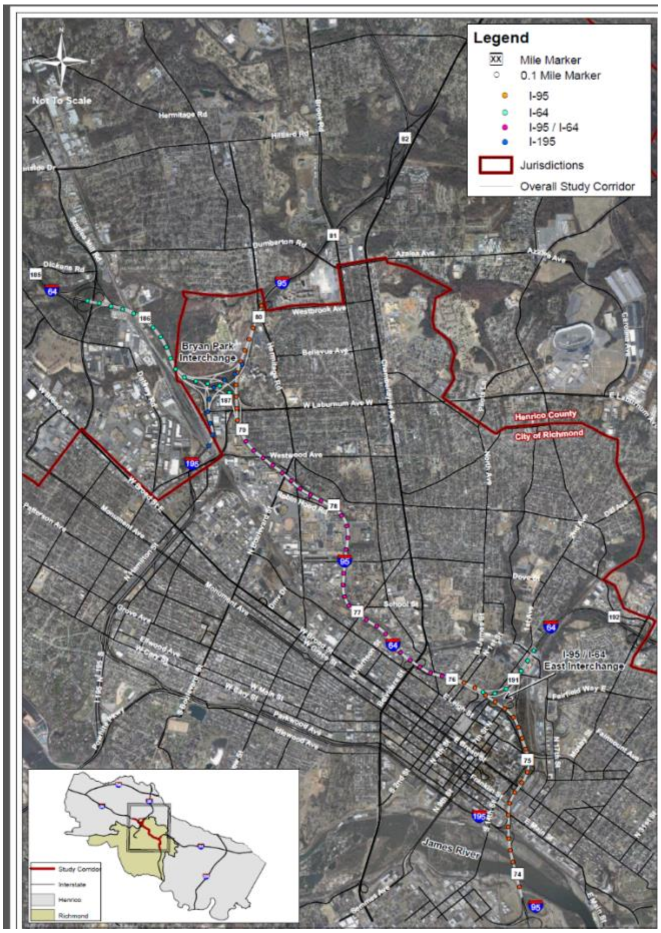

Fig. 1. Study area.

The I-95/64 Overlap Study project built the network of the study area with VISSIM 4.3 and the VISSIM network was available to the authors. The VISSIM network included information such as the network geometry, vehicle inputs, signal control settings, desired speeds, and static routing for predetermined paths for vehicles. The demand OD file was also available.

4.2. Network building

To build up a network for mesoscopic simulation, there are typically two approaches. The first one is to build the network from scratch, namely adding and editing link by link. The second approach is to import the network in other formats. Both of AIMSUN and VISSIM offer different levels of compatibility with other software.

Since the road network in the case study was available in VISSIM 4.3, the second approach was used. The existing network in VISSIM 4.3 was imported into AIMSUN and VISSIM Meso and checked for accuracy.

4.3. Data preparation

As mesoscopic simulation requires an origin-destination (OD) matrix as input demand data, the following three steps were conducted to get the input demand data ready.

Defining the traffic analysis zones (TAZ)

TAZ is a concept commonly used in transportation planning. TAZs divide the planning region into relatively similar areas of land use and activity and represent the origins and destinations of travel activity within the region. TAZs were defined by their geographic locations as they were done in transportation planning. The traffic coming from the same direction is defined as coming from one zone. For example, traffic entering toward I-64 eastbound is defined as one zone. The whole network was divided into 38 TAZs based on the physical layout of the network.

Obtaining the OD matrix

Given the TAZs locations, the OD matrices were obtained from the OD data of the I-95/64 Overlap Study project. The demand originating from one zone to the other was gathered and organized into OD matrix for every 15 minutes from 6:30 to 9:30 am. In total, there were 13 OD matrices.

Determining the locations of zone entrances and exits

Based on the OD data file from the I-95/64 Overlap Study project report, as well as the VISSIM microscopic simulation network, the zone entrances and exits were identified by considering the location description in the OD data file, the locations of vehicle inputs, and the destination of the static routing.

Most TAZs in this case study had only one entrance or exit. For zones that had multiple zone connectors, the OD demand was distributed among the origin or destination locations; that is, traffic could depart from one of the multiple locations of the origin zone and arrive at one of the multiple locations in the destination zone. AIMSUN Meso and VISSIM Meso follow different rules for distributing traffic. These are discussed below under the “network preparation”.

4.4. VISSIM network preparation

The mesoscopic module in VISSIM 9 is used in this paper. To import the existing VISSIM 4.3 network into VISSIM 9, VISSIM 5.4 was used to open and save the network in a higher version. Then, VISSIM 9 was used to open the network because VISSIM 9 cannot open the file made in the version that is earlier than VISSIM 5.4.

Setting zones, zone entrances and exits

VISSIM uses parking lots to represent TAZs and zone entrances/exits. After putting a parking lot on a link section, a few characteristics of the parking lots need to be defined: parking lot type, capacity, desired speed, and the relative flow ratio. Based on the locations of zone entrances and exits, users can put parking lots on the links accordingly and define which TAZ this parking lot serves.

Demand input

OD matrices were created for every 15 minutes, which contained the number of vehicles traveling from origin zones to destination zones. The percentages among several origin parking lots within a zone can be defined by users. At destination zones, based on parking cost, parking lot attraction, and distance to parking lot parameters, the utility of going to each parking lot is calculated and VISSIM uses a logit model to select the destination parking lot in the destination zone.

Defining mesoscopic nodes

In VISSIM mesoscopic simulation, the network is recognized by VISSIM Meso as a graph made of meso edges and meso nodes. Meso edges are connected by meso nodes. After defining the nodes, the sections between meso nodes were automatically recognized as meso edges. However, VISSIM can only create some of the meso nodes automatically and most of the nodes need to be created manually. Thus, meso nodes were created at various locations in order to make VISSIM recognize the network structure; for example, before origin parking lots, after destination parking lots, at intersections, and at link merging areas and link split areas, etc. The specific rules of defining the meso nodes can be found in VISSIM manual. In the example network of this paper, there are 278 meso nodes and 240 of them were created manually while preparing the network for dynamic traffic assignment. VISSIM Meso requires a DTA-ready microsimulation network as a starting point for mesoscopic simulation, which may be a disincentive for practitioners especially in situations where simulation time is not an issue.

DTA settings

Travel time from same time interval in previous simulation run was used for path search in DTA process. The cost used for path selection model is calculated as the sum of edge travel time. The assignment model used in this project was an equilibrium traffic assignment method. The convergence criterion was set to be the volume on edge does not change by more than 50 vehicles in two consecutive iterations (PTV 2016).

4.5. AIMSUN network preparation

The latest version of AIMSUN (version 8.14 as of October 2016) was used in this paper. The VISSIM file from the I-95/64 Overlap Study project study was imported to AIMSUN directly. The network geometry that could be imported into AIMSUN included information like the number of lanes, lane width, and lane length; but the road type could not be imported. The OD matrix and some of the vehicle attributes could also be imported into AIMSUN. After importing the network into AIMSUN, the network configuration was checked to make sure the imported network was equivalent to the original network configuration; for example, if the links were properly connected, characteristics of road types, desired speed, etc. Given the test bed of this paper, required efforts to adjust the imported network in AIMSUN was not much.

Setting zones, zone entrances and exits

In AIMSUN, zones are represented by centroids. Based on zone divisions, 38 centroids were defined in the AIMSUN network to represent 38 TAZs. For each TAZ, zone connectors were defined which allow generated traffic to enter into and exit from the network. AIMSUN automatically distinguishes the inbound and outbound link and set connectors as “generate to” and “attract from.” (TSS 2014)

AIMSUN offers several different options to determine the demand distribution among entrances and exits. In this example, centroids used the “defined percentages” for origin connectors and used the “best choice” for destination connectors. For origin connectors, the percentages of demand shared by different origin links were available from the data preparation step. For destination connectors, when “best choice” is selected, AIMSUN uses the shortest path or the route choice model to select the destination connector.

Demand Input

For AIMSUN mesoscopic simulation, the demand is required in the format of OD matrix. Besides importing the OD matrix files, AIMSUN also offers the option to copy and paste the OD matrix from an Excel file or other resources. The study period is from 6:30 to 9:30 am. The OD matrices were inputted for every 15-minute interval.

DTA setting

User equilibrium traffic assignment was selected for AIMSUN. The evaluation time interval was set to be 15 minutes which is consistent with the demand interval. Method of Successive Average (Sheffi 1985) was selected for the assignment model. The stopping criteria set in this case study was either a maximum of 50 iterations or a relative gap 0.5% was reached.

4.6. Calibration

Calibration data

The observed data used for the calibration for this case study was mainly from two resources.

Speed Data from the I-95/64 Overlap Study project From the I-95/64 Overlap Study project, the hourly speed data at various locations was available for the periods from 7:15 to 8:15 am and from 8:15 to 9:15 am. The locations (link IDs) where speed data was available were identified in the network. During the calibration process, the simulated speeds on these links were compared with the observed data.

Traffic counts data from VDOT permanent count station The study area covers one permanent count station maintained by VDOT. The sections include the northbound and southbound of I-95 and I-64 overlap section. The traffic counts data for every 15-minutes interval was available. The observed traffic counts data for every 15-minute interval from 6:30 to 9:30 am on August 10th, 2011 was retrieved from VDOT's databases.

VISSIM calibration

With all required inputs prepared, VISSIM mesoscopic simulation was conducted. Several critical parameters need to be determined in VISSIM Meso. Table 1 summarizes the parameters and their values used in the simulation. The parameters are discussed.

Table 1. Calibration parameters in VISSIM.

Items	Settings
Meso reaction time	1.05 seconds
Meso maximum waiting time	120 seconds
Meso standstill distance	6.5616 feet
Meso speed model	Vehicle based
Meso critical gap	3.5 seconds
Meso follow up gap	0 seconds

- Meso reaction time is the parameter in the car following model that measures how fast the drivers respond to the traffic conditions. The smaller this parameter is, the faster the simulated speed. During the study, the authors also found that the value of reaction time also influences the number of vehicles that cannot enter the network. If the network cannot incorporate all the demand due to over congestion, then the rest of the vehicles cannot enter the network. Decreasing the reaction time reduced the number of vehicles that cannot enter the network. The default value of reaction time in VISSIM Meso module is 1.2 seconds. The calibration process explored several values of reaction time ranging from 0.9 seconds to 1.5 seconds. The value of 1.05 seconds generated results closer to the observed data in terms of the simulated speed and the traffic counts.

- Meso maximum waiting time is the longest time that a vehicle of subordinate flow can wait to enter a node. When the maximum waiting time is reached, the vehicle will enter the node even if the gap of the main flow is very small.
- Meso standstill distance is the parameter that corresponds to the jam density. The smaller this value is, the more vehicles that a link can hold at congested conditions.
- Meso speed model was chosen to be the vehicle based model. VISSIM also has the link based model with which the desired speed, priority rules and other settings that influence vehicles are no longer effective.
- Meso critical gap and the follow up gap are two parameters for conflict zones. Their specific definitions can be found in VISSIM manual. Basically, these two parameters can influence the maximum capacity of a subordinate flow within a node.

As suggested by VISSIM technical support team (PTV Support US 2017), when the observed speed data are available, users can set the desired speeds at those locations as observed speeds. Then, if the speed generated from simulation is lower than observed ones (desired ones), users can adjust the critical gap at downstream nodes to make it more realistic. On the other hand, if the simulated speed is higher than the observed, users can lower the desired speed at that location to make the simulated speed more consistent with the observed field data.

The calibration results were compared with the observed data. Speed in VISSIM simulation was on average 14% lower than the observed speed. The comparison made between traffic counts in simulation and observed counts data shows that the average relative difference was approximately 9%.

AIMSUN calibration

The impacts of four mesoscopic simulation parameters, shown in Table 2, are discussed.

Table 2. Calibration parameters in AIMSUN.

Parameters	Settings
Reaction time factor	0.9 seconds
Penalize slow lanes	Check/uncheck, vary by locations
Penalize shared lanes	Check/uncheck, vary by locations
Look ahead distance	Vary by locations.

- The reaction time factor in AIMSUN Meso has similar effects as the one in VISSIM Meso. The default value is also 1.2 seconds. Increasing the reaction time factor decreases the simulated speed and may result in an increase in the number of vehicles that cannot enter the network. There are two reaction time factors: one for reaction time on the road sections and the other one is for the signals. Since this case study does not include traffic signals, only the reaction time factor on roadways was adjusted. Values of reaction time factor ranging from 0.9 seconds to 1.5 seconds were explored. Considering calibration accuracy, the reaction time factor was set at 0.9 seconds in AIMSUN.
- The “penalize slow lanes/shared lanes” are check/uncheck options. After the simulation, the simulation results can be checked by lanes. If some lanes on certain road sections have unreasonably low speeds, then these options can be used to switch the demand from congested lane to other lanes.
- The look ahead distance can be determined for different road types or for specific road sections. After simulation, when the simulation results do not look reasonable within certain areas, especially the upstream of any possible turns, the look ahead distance can be adjusted to make the simulation results more close to the observed field data.
- In addition, the possible speeds allowed on road sections can be adjusted to achieve better simulation results. It serves a similar function as the desired speeds in VISSIM simulation. Vehicles traveling on a link cannot exceed the allowed maximum speed.
- In addition to these parameters, the length of road section could also affect the simulation results. Unlike VISSIM Meso, AIMSUN Meso considers lane selection behavior. When traffic is about to enter next link, the lane

selection model evaluates the traffic conditions of downstream lanes. Unnecessary short links may block the traffic because traffic has to make lane selection at the end of every short link and this causes unnecessary traffic weaving. Avoiding unnecessary short links can avoid unrealistic congestions.

The calibration process was conducted as discussed above to make sure the simulation model could properly represent the real world conditions. AIMSUN offers several built-in tools to help conduct the calibration process including static check, dynamic check, path statistic check and static comparison. These tools can help users check if the network is properly built, see if there are any abnormal situations happening in the simulation, check if the generated paths are reasonable and compare the observed traffic conditions with simulated ones with statistical indicators such as GEH index, etc.

4.7. Output Display

VISSIM

After running the simulation, the results were shown as Meso edge results and Meso lane results which could be checked in VISSIM. Performance measures such as the volume, speed, density, counts, and delay were displayed as lists in the table window of the VISSIM interface. This list was exported to Microsoft Excel for further analysis.

The results were also visualized in a more intuitive way by modifying the graphic parameters for links to display aggregated results. After defining the color and width variation, the network could be visually assessed for reasonableness as the link color and width varied across the network based on the level of the performance measure; for example speed, density or volume for certain time periods in certain evaluation intervals.

AIMSUN

After the simulation, AIMSUN showed a summary of the simulation including basic information about the simulation, such as relative gap, simulation time, etc. The results could be generally categorized into three levels:

- Network level: AIMSUN generated network level results when the simulation was done, for example, the network delay, density, flow, input count, missed turns, travel time, total travelled distance, etc.
- Path level: AIMSUN also summarized the path level statistics, including the number of vehicles assigned to each path, the path travel time, path cost for each OD pair in different evaluation time intervals. These results can also be used to conduct calibration so that the paths can be checked if they are realistic or not.
- Link level/ Turn level: for each link section or turn movement, AIMSUN showed the performance results such as count, delay, density, speed and other statistics. In addition to that, when multiple scenarios are run and their results need to be compared, AIMSUN could display the results from the different simulations together for comparison, in the form of figures or tables.

AIMSUN also features a drawing mode for results display. Users can choose the criteria to draw the network. Then AIMSUN displays the links with different colors differentiated by levels of the criteria. It is intuitive to visualize the performance and investigate the network.

4.8. HOV lane implementation

An HOV strategy was selected to demonstrate the capabilities of mesoscopic software packages in implementing traffic management strategies that transportation practitioners might be interested in. Both VISSIM Meso and AIMSUN Meso models of the test bed were used for this demonstration after the network was carefully calibrated.

The implementation of HOV lanes can have different levels of impacts on traffic demand. It usually requires detailed survey and research to obtain the expected demand changes and travelers' reactions. Considering the goal of this paper was to demonstrate the capabilities of mesoscopic simulation software instead of actually designing HOVs, typical demand changes reported in the literature was used. According to a study by the Seattle Department of Transportation (Seattle Department of Transportation 2008), the implementation of HOV lanes can lead to 4% to 30% vehicle trips reduction. In this paper, different levels of vehicle trip reductions were assumed and corresponding impacts were tested, including 5%, 10%, and 15% vehicle trips reductions. The levels of demand reduction were assumed to be the same for all the OD pairs during the whole evaluation periods.

When and where to implement the HOV lanes can also have different impacts. In this paper, the overlap section of I-95 and I-64 was chosen to implement HOV lanes. The leftmost lanes on both the northbound and the southbound overlap section were set to be HOV lanes which could only be used by vehicles with at least two passengers. The relative location of the overlap section is shown in Fig. 2. The HOV lanes were set to be effective for the whole evaluation time period, from 6:30 to 9:30 am.

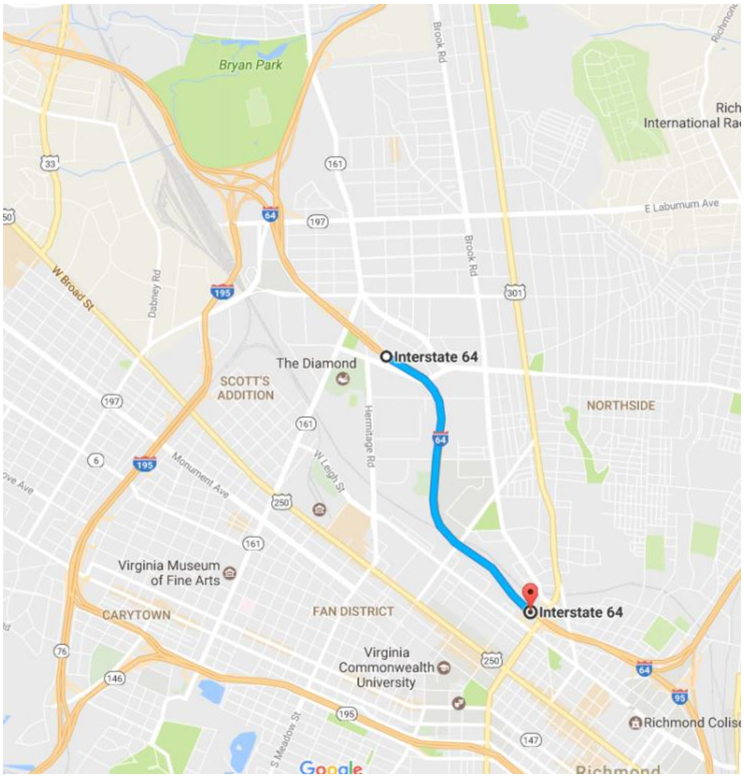

Fig. 2. HOV lanes settings.

In this case study, it was assumed that 90% of vehicles were Single Occupancy Vehicles (SOVs) and 10% of vehicles were HOVs before the implementation of HOV lanes. After the implementation, part of the SOV drivers switched to two-passenger carpool. As a consequence, the total vehicle trips were reduced by 5%, 10% and 15%. The new OD matrices containing updated HOV and SOV demands were prepared for simulation for every 15 minutes within the evaluation time period.

HOV Scenario in VISSIM

The OD matrices include the demands for all different vehicle types in VISSIM, rather than separating the OD matrices for different vehicle types. User-defined percentages were used to determine the demand for different vehicle types. This also means that the demand percentages for different vehicle types across OD pairs are the same. The updated OD matrices can be imported through *.fma file and also can be copied and pasted from Microsoft Excel.

To set up the HOV lanes in VISSIM, the "vehicle block" feature was used. That is the section that HOV lane was to be set was selected and "block vehicle type Car" checked on the leftmost lane. This means HOVs could use both the general purpose lanes and the HOV lane but SOVs could only use the general purpose lanes.

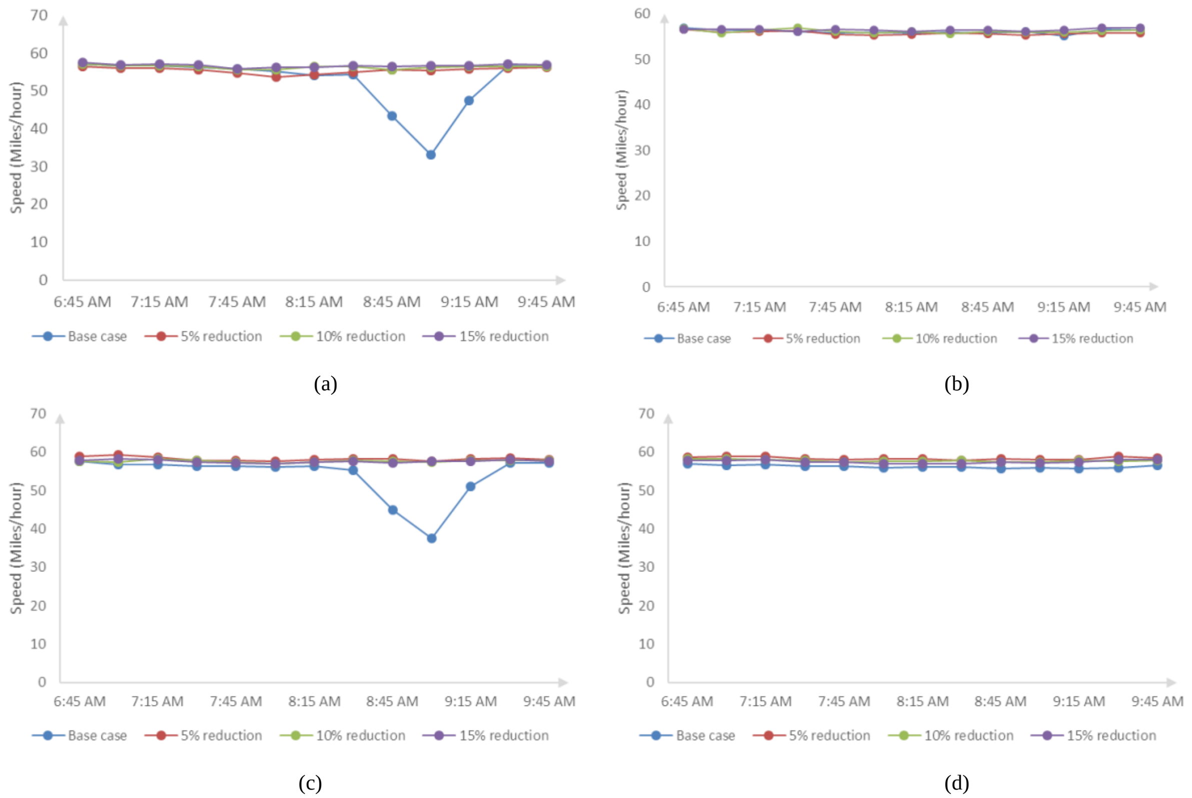

Fig. 3. VISSIM- speeds on different lanes of the section having HOV lanes: (a) Speed on general purpose lane (North); (b) Speed on general purpose lane (South); (c) Speed on HOV lane (North); (d) Speed on HOV lane (South).

With different levels of traffic demand, the mesoscopic simulation runs were made in VISSIM. The performances of the road sections that HOV lanes were implemented on are shown in Fig. 3. For both the northbound and the southbound directions, the speeds on both general purpose lanes and HOV lanes did not change much at the different levels of demand. A notable exception is the northbound direction where, for the 30-minute period from 8:45 to 9:15, speeds increased from a low of 35 mph in the HOV lanes (and 33 mph in the general purpose lanes) before HOV was implemented (i.e., base case) to approximately 55-60 mph when the HOV lane was in operation. A plausible reason for this observation is weaving (in the section immediately downstream of the HOV lane) as vehicles exit the HOV lane and attempt to change lanes onto the rightmost lane of the segment immediately after the HOV lane so as to use the adjoining exit ramp. However, it may be seen from the figures that speeds on the HOV lane were generally lower in the base case than in the other scenarios. Also, speeds on the general purpose lanes were lower in the "5% demand reduction" scenario than in the other cases.

HOV Scenario in AIMSUN

To set up the HOV lanes on the overlap section of I-95 and I-64, a new lane type named "HOV" was created. It was "optimal reserved" for HOVs, which means HOVs could use either general lanes or the HOV lane depending on which was the better. The leftmost lanes of overlap sections (for both northbound and southbound) in AIMSUN were set to be HOV lanes.

After having different levels of demand and the HOV lanes prepared, the simulation was conducted in AIMSUN. Other settings remained the same as in the base case (before HOV lanes were implemented). For all levels of demand, the simulation took less than 5 iterations to reach equilibrium and the simulation time was less than 3 minutes. Speeds along the section of the network that had the HOV lanes are shown in Fig. 3.

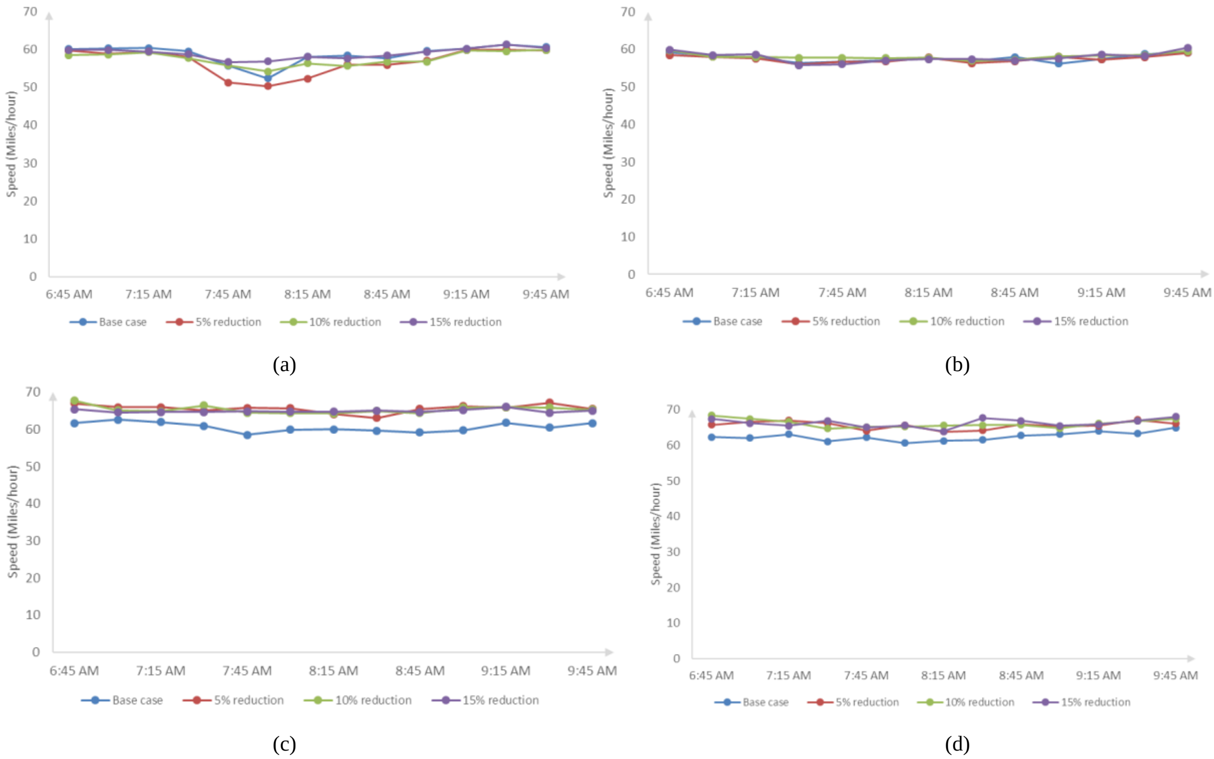

Fig. 4. Aimsun- speeds on different lanes of the section having HOV lanes: (a) Speed on general purpose lane (North); (b) Speed on general purpose lane (South); (c) Speed on HOV lane (North); (d) Speed on HOV lane (South).

Figures 4(a) and 4(b) show the average speeds (weighted by traffic counts) on the general purpose lanes at different levels of demand. Figures 4(c) and 4(d) show the speed on HOV lanes at different levels of demand.

For the northbound direction (Figures 4(a) and 4(c)), speeds ranged between 58-63 mph in the leftmost lane (HOV lane) and between 53-60 mph in the other two lanes (general purpose lanes) before HOV was implemented (i.e. base case). With the HOV in operation, speeds increased to between 64-68 mph in the HOV lane for all levels of HOV demand tested. However, speeds remained in the 53-60 mph range in the general purpose lane, except for the 5% reduction case where speeds dropped by up to 3 mph below the pre-HOV deployment levels during the time period from 7:45 to 8:15 am. This speed reduction may be explained by noting that reducing the total number of trips effectively increased traffic volumes (on a per lane basis) in the general purpose lanes; this effect decreases as the percentage reduction in the total number of trips is increased.

For the southbound (Figures 4(b) and 4(d)), speeds were between 60-65 mph in the leftmost lane (HOV lane) and between 56-60 mph in the other two lanes (general purpose lanes) before HOV was implemented (i.e. base case). With the HOV in operation, speeds increased to between 65-69 mph in the HOV lane for all levels of HOV demand tested while speeds remained in the 56-60 mph range in the general purpose lanes. The results indicate that the implementation of HOV increased speeds in the HOV lanes. These results seem reasonable and consistent with expectations.

In general, VISSIM mesoscopic simulation generated relatively lower speeds compared to AIMSUN. However, the differences were generally moderate, except for the time period from 8:45 to 9:15 in the northbound base case scenario where VISSIM generated speeds between 30 mph and 50 mph compared to a speed of approximately 60 mph generated by AIMSUN.

5. Lessons learned

This section summarized the lessons learned from the exploration of Meso simulation tools and the communication with software vendors. While this summary is solely based on authors' own judgement, we expect this provides some guidance to practitioners.

- For both software packages, the reaction time factor has really obvious effects on the simulation results, including the number of vehicles that network can incorporate and simulated speed. During calibration, this could be the first parameter to adjust within a reasonable range.
- Including unnecessary short road sections in AIMSUN network could cause unrealistic congestion. This is not always obvious as the congestion effects may not be observed in the immediate vicinity of the responsible short link. Sometimes, the short links causing congestion in the network could be located further upstream of the congested locationså.
- Although VISSIM Meso does not offer the ability to import files from many other software packages, VISUM could be used to import the network first and then export to VISSIM Meso.
- In both software, the paths in the assignment results should be checked to see if the simulation results are reasonable. For instance, long detours or routes containing loops means more calibration adjustment is needed.
- Modeling networks that contain actuated traffic signal controlled elements in VISSIM Meso could be problematic. VISSIM Meso can still run the simulation, but the results could be misleading.
- In VISSIM Meso, additional meso nodes could be placed on a long road section to allow lane change behaviors within a road section.
- The VISSIM support team suggested setting the desired speed to be same as the observed speed for calibration. Then based on the results, downstream intersection parameters such as meso critical gap and signal timing could be adjusted to match the observed data.

6. Summary and Conclusions

While mesoscopic simulation tools have become readily available, practitioners have not well adapted to these tools. In this paper, we presented practical guidance by conducting a case study of HOV lane using two commercially available mesoscopic simulation tools. The guidance includes how to build the network, input data and network preparation, and calibration. The HOV evaluation study based on AIMSUN and VISSIM would provide a practical guidance of efforts required to develop and implement mesoscopic modeling tools. Lessons learned while exploring these tools and communicating with software vendors were shared in the paper. We expect this paper provides transportation practitioners with useful guidance when they need to conduct mesoscopic simulation or select proper simulation tool.

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References

Burghout, Wilco. 2005. "Mesoscopic Simulation Models for Short-Term Prediction." *PREDIKT Project Report CTR2005* 3. https://www.researchgate.net/profile/Wilco_Burghout/publication/255654806_Mesoscopic_Simulation_Models_for_Short-Term_Prediction/links/54201da10cf2218008d440f8.pdf.

Casas, Jordi, Josep Perarnau, and Alex Torday. 2011. "The Need to Combine Different Traffic Modelling Levels for Effectively Tackling Large-Scale Projects Adding a Hybrid Meso/Micro Approach." *Procedia - Social and Behavioral Sciences*, The State of the Art in the European Quantitative Oriented Transportation and Logistics Research – 14th Euro Working Group on Transportation & 26th Mini Euro Conference & 1st European Scientific Conference on Air Transport, 20 (January): 251–62. https://doi.org/10.1016/j.sbspro.2011.08.031.

Chen, B. 2014. "Application of Transport Hybrid Modelling for New Town Planning." In . https://trid.trb.org/view.aspx?id=1326880.

Chiu, Yi-Chang, Hong Zheng, Jorge A Villalobos, Walter Peacock, and Russell Henk. 2008. "Evaluating Regional Contra-Flow and Phased Evacuation Strategies for Texas Using a Large-Scale Dynamic Traffic Simulation and Assignment Approach." *Journal of Homeland Security and Emergency Management* 5 (1). https://doi.org/10.2202/1547-7355.1409.

Florian, M., M. Mahut, and N. Tremblay. 2001. "A Hybrid Optimization-Mesoscopic Simulation Dynamic Traffic Assignment Model." In *ITSC 2001. 2001 IEEE Intelligent Transportation Systems. Proceedings (Cat. No.01TH8585)*, 118–21. https://doi.org/10.1109/ITSC.2001.948640.

Hou, Tian, Hani Mahmassani, Roemer Alfelor, Jiwon Kim, and Meead Saberi. 2013. "Calibration of Traffic Flow Models Under Adverse Weather and Application in Mesoscopic Network Simulation." *Transportation Research Record: Journal of the Transportation Research Board* 2391 (December): 92–104. https://doi.org/10.3141/2391-09.

Kimley-Horn and Associates, Inc. 2013. "I-95/64 Overlap Study." 117306011. Virginia Department of Transportation. http://www.virginiadot.org/projects/richmond/i-95-64_overlap_study.asp.

Kristoffersson, Ida. 2013. "Impacts of Time-Varying Cordon Pricing: Validation and Application of Mesoscopic Model for Stockholm." *Transport Policy*, Special Issue on Transportation Pricing PoliciesSpecial Issue on Transport Security - Policies and Empirical Perspectives, 28 (July): 51–60. https://doi.org/10.1016/j.tranpol.2011.06.006.

Liu, Henry X., Adam Danczyk, and Xiaozheng He. 2011. "Development of the Next Generation Metro-Wide Simulation Models for the Twin Cities' Metropolitan Area: Mesoscopic Modeling." Report. http://conservancy.umn.edu/handle/11299/101448.

Palma, André de, and Fabrice Marchal. 2002. "Real Cases Applications of the Fully Dynamic METROPOLIS Tool-Box: An Advocacy for Large-Scale Mesoscopic Transportation Systems." *Networks and Spatial Economics* 2 (4): 347–69. https://doi.org/10.1023/A:1020847511499.

PTV. 2016. "PTV Vissim 9 User Manual."

PTV Support US. 2017. "#PTV193887# Your Support Inquiry on Meso Lane Results," February 24, 2017.

Seattle Department of Transportation. 2008. "Best Practices in Transportation Demand Management."

Sheffi, Yosef. 1985. *Urban Transportation Networks: Equilibrium Analysis With Mathematical Programming Methods*. Englewood Cliffs, N.J: Prentice Hall.

"Strategic and Mesoscopic Transport Modelling." n.d. Bitzios Consulting - Traffic Engineering & Transport Planning. Accessed March 11, 2017. http://www.bitziosconsulting.com.au/strategic-and-mesoscopic-transport-modelling.html.

Toledo, Tomer, Oded Cats, Wilco Burghout, and Haris N. Koutsopoulos. 2010. "Mesoscopic Simulation for Transit Operations." *Transportation Research Part C: Emerging Technologies*, Special issue on Transportation SimulationAdvances in Air Transportation Research, 18 (6): 896–908. https://doi.org/10.1016/j.trc.2010.02.008.

TSS. 2014. "Aimsun 8.14 Users' Manual."