Linking Atlanta’s Regional Transportation Planning Model with Microscopic Traffic Simulation

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Abstract

The Atlanta Regional Commission (ARC) maintains a macroscopic planning model. This model covers the entire Region of Atlanta and has been used for several decades to evaluate travel demand and estimate impacts of transportation policies and infrastructure improvements of the highway and transit system.

Over the past two decades the Atlanta region has been challenged with increasing highway congestion. At the same time the possibilities to respond with infrastructure extensions have become more and more limited and consequently new policies that involve system operations became more prominent. As a result ARC’s staff had to acquire new methods that help to evaluate such policies. Microscopic traffic simulation is a modeling approach that is now increasingly used in the region including some of ARC’s projects. It provides a better representation of time dynamics and congestion build-up as well as the interrelation between operations and impacts.

This paper summarizes ARC’s experience with initial micro-simulation projects for the Downtown Atlanta area. The focus of this paper is a general methodology for integration of macroscopic planning models with micro-simulation models. It is a major challenge for a regional agency like ARC to keep the micro models consistent with the regional macro model and to define standards for the exchange of data and assumptions between the models. After a discussion of the differences between macro and micro models, our methodology of linking the two will be presented. Then, conclusions will be drawn from ARC’s experience in the Downtown simulation projects.

Introduction and Background

The Atlanta Regional Commission (ARC) is the federally-designated Metropolitan Planning Organization (MPO) for a 20-County area, which has a resident population of almost 5-million people. ARC develops regional transportation plans and policies to enhance mobility, reduce congestion and meet air quality standards. ARC policies also provide a range of approaches that give commuters transportation options instead of relying solely on the single-occupant vehicle.

Over several decades ARC has maintained a regional travel demand model, which is based on a Cube Voyager platform, computing environment. The plan year 2030 network contains over 57,000 links each with approximately 35 link attributes. There also exist nearly 27,000 nodes also storing an additional 17 fields. The area of model coverage is 6,402 sq mi. The model features 2024 traffic analysis zones (TAZ) and 91 external stations, for a grand total of 2115 TAZ.

The ARC regional travel demand model cannot reasonably deliver results at all levels of detail needed for a corridor analysis, due to its aggregate form. Given the macro, meso, micro recommended approach to corridor analysis, ARC has started to use a two-tier analysis in corridor or subarea studies: start with the macroscopic regional model, then focus on micro-analysis tool. The ARC now realizes the need to expand its traffic analysis toolbox by adding a microsimulation tool for in-house use. Other motivations to use traffic microsimulation include the ability to model congestion and queuing, traffic management technologies, the efficiency of transit preferential treatment in traffic environment and last but not least its visualization capabilities.

This paper will first compare macroscopic and microscopic models and contrast the differences that need to be bridged. Then the reasons why it makes sense to integrate the two approaches will be discussed. In the following, a general methodology for integrated subarea analysis will be presented, which is based on the authors' experience with several studies. The real-world example of ARC's integrated Downtown Model, which has been put in place by a group of consultants recently, will be used to illustrate this methodology. Finally conclusions and future directions will be sketched.

Comparing Macroscopic Planning Models and Microscopic Simulation Models

Macroscopic planning models and microscopic simulation models are very different analysis tools typically developed, maintained and used by transportation planners and traffic engineers, respectively. They are different with respect to model inputs, outputs, applications, assumptions, methodologies, and model characteristics in general. It is important to understand their difference and relative strengths and limitations of each model before we discuss the needs for integration. A comparison of these two types of models is made in Table 1.

From the comparison, we can see that planners basically take a systematic process to translate the land use, household and employment characteristics, and transportation supply into predictions of current and future travel patterns and demand, through mathematical formulation and simplification. The planning models thus developed provide a static view of the transportation system and aggregate traffic stream characteristics for long term planning in which microscopic details are not important. However, they cannot explain congestion and have limited capabilities to evaluate traffic management that involve dynamics changes in the system such as with the intelligent transportation system (ITS). The level of details that the macroscopic planning models can provide is also inevitably low for the purposes of operational analysis and improvement.

At the other side, microscopic simulation models consider the characteristics of individual vehicles and simulate vehicle interactions in the traffic stream based on car following and lane changing theories. Given travel demand, they can provide a dynamic view of the transportation system and performance changes including queue building and spillback. They are most effective in evaluating the dynamic evolution of traffic congestion and the effectiveness of myriad traffic management strategies (and system designs) in response to congestion. However, they are typically not used for demand forecasting but rather for short term and congestion related issues. In practice, the network size and modeling period of the microscopic simulations also have to be kept at a certain level, compared with the macroscopic planning models, due to more demanding data inputs, calibration efforts, and computational requirements for a higher level of details in modeling and analysis.

Depending on the purposes of analysis and the complexity that it involves, the macroscopic planning models and microscopic simulation models may be preferred one over the other. For a major transportation project, the macroscopic planning models are typically needed at the beginning for travel demand modeling, conceptual network planning and design, and interface with other analyses at regional or state level. The microscopic simulation models may be used late when it comes to preliminary engineering and alternative designs at local or corridor level. The simulation models, however, can also be a complementary tool when it comes to detailed plans and operational assessment. For example, the existing regional transportation planning model in Atlanta can answer questions related to trip generation, trip destination choice, mode choice, time-of-day travel choice and route choice in the region, but it would be insufficient when coming to questions of bus circulation and interaction with other modes from the perspective of traffic operations. That is why the Atlanta Regional Commission seeks to develop the simulation models in addition to the planning models.

Table 1: A Comparison of the Macroscopic and Microscopic Models

Macroscopic Travel Demand Models	Microscopic Traffic Simulation Models
Inputs:	
- Land use	- Highway network (geometry)
- Socioeconomic demographical data	- Traffic control
- Travel behaviors	- Vehicle characteristics
- Highway and transit network (travel cost, geometry and capacity)	- Driver behaviors
	- Traffic demand
Outputs:	
- Expected travel pattern and demand (time of day, current and future)	- Individual vehicle trajectory and states (can be aggregated for any time interval)
- Aggregate traffic characteristics (e.g. VMT and hourly link volume)	- Volume, speed, travel time, delay and queue length etc.
Applications:	
- Transportation planning	- Engineering study focus on intersections
- Long-term forecasting	- Short-term forecasting
- Impact study at regional or corridor level (e.g. new development)	- Operational analysis (including ITS)
	- Visualization tool
Modeling Approach:	
- Aggregation of vehicles (trips)	- Individual vehicles (trips)
- 4-step modeling process	- Monte Carlo methods (stochastic)
- Deterministic traffic flow models	- Car following and lane changing logic
- Static equilibrium assumption	- Signal control logic
Network Representation:	
- Node and link topology	- Links (curvature, gradient and lane use)
- Simplification of intersections	- Intersection geometry (multiple objects)
- Low level of details	- High level of details
Traffic Representation:	
- All trips are loaded simultaneously on a link (no queuing)	- Individual vehicle loading and moving (queue building and spill back)
- All trips share the same speed on a particular link and time period	- Vehicle speed varies in reaction to other vehicles and traffic control
- Capacity is a model input and can be exceeded by the flow volume	- Capacity is an implicit result of geometry constraints and vehicle behaviors

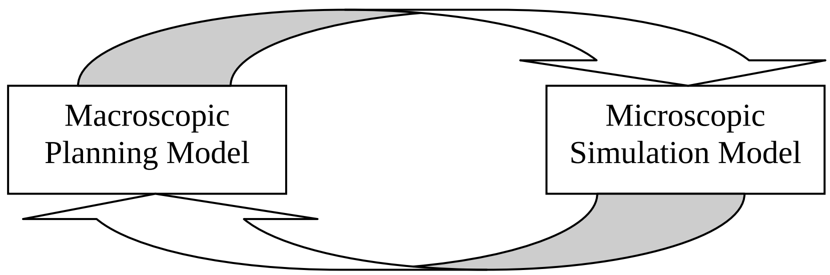
The Need for Integration

The microscopic traffic simulation models can be developed complementary to the macroscopic planning models for each transportation project if they are affordable and fast to develop. However, it is more desirable to have integrated models serving both planning and engineering needs in the long run and an efficient method for data exchange or model transformation from the macroscopic level to the microscopic level and vice versa. Both planners and engineers can benefit from model integration and data exchange at certain levels. For a successful project development, it is very important to maintain consistency between planning and operational analysis in terms of data inputs, key assumptions, measurements of efficiency, and results. Such consistency can easily be ensured through the model integration.

It is obvious that the macroscopic planning models can be an important data source for developing the microscopic simulation models. The microscopic simulation models require a plethora of input data in order to produce a high level of details for analysis. Among all required inputs, the travel demand is usually most difficult and costly to obtain, but the simulation models are highly sensitive to the errors and variation in the demand input. For a simple simulation network, including a few intersections, existing travel demand may be synthesized based on traffic counts on intersections. However, this method is unreliable and often infeasible as the network size increases to a certain level, for example, a corridor or sub-area of the metropolitan area, which attracts more and more interests to apply microscopic simulations. The macroscopic planning models can always provide demand inputs to the microscopic simulation models in a prompt and economic way with a good level of accuracy. Moreover, when it comes to future scenario analyses, the macroscopic planning models are the most viable sources with direct link to the urban development and growth.

On the other side, the macroscopic planning models can also benefit by linking to the microscopic simulation models. The results and decisions taken at the macroscopic level can be verified through the microscopic simulations which include a higher level of details in analysis. For example, planners design preferred bus routes and schedules based on travel time estimates from the macroscopic models which employ simple flow diagrams to relate link capacity, volume and speed to travel time. It will be more accurate to use the travel time measurements from the microscopic simulations to evaluate the bus circulation plan made at the planning level. Moreover, key assumptions and inputs in the macroscopic planning model can also be validated against the microscopic simulation results. For example, capacity is a model input in the macroscopic planning models, typically assumed based on the road functional classification of each link. The expected link flow is the result of the traffic assignment taken into consideration of link/turn capacity. In the microscopic simulation models, capacity is however a model measurement that depends on roadway geometry, traffic composition, vehicle behaviors and traffic control. Therefore, the capacity assumption at the macroscopic level can be evaluated against the capacity measure at the microscopic level. Through a feedback loop, the macroscopic model can be refined and improved based on the results and observations in the microscopic model. Figure 1 summarizes the possible data exchange and associated benefits between the macroscopic models and microscopic models

- Basic Roadway Geometry
- Existing & Future Demands
- Initial Plan & Alternative Designs



- Simulation Results
- Visualization
- Validated Assumptions
- Refined Network

Figure 1: Data Exchange between the Macroscopic and Microscopic Models

The integration of the microscopic and macroscopic models is not only a favorable discussion on paper but also works out in practice. Various agencies in the Atlanta region have started initiatives and projects to develop microsimulation models that integrate data from ARC's regional travel demand model. ARC's objectives are to keep all microsimulation projects consistent with the assumptions and forecasts of the regional planning model. For that purpose, ARC has recently been involved as advisor or leader in the following projects:

- **Downtown traffic management:** per requests of local business communities and planning agencies, a microscopic simulation model was developed and used to analyze traffic management plans in the Atlanta downtown area. The regional planning model took urban development assumptions as inputs and outputted estimated regional traffic flows going into and out of the Atlanta downtown area to the simulations.
- **Downtown bus circulation study**: Under ARC's leadership, the same integrated Downtown Model was also used to analyze bus circulation plans, following a major re-organization of transit lines with the planned implementation of a transit belt line.
- **Detour analysis**: small road closure projects which create traffic diversions have been modeled with the macroscopic assignment model. The microscopic model can then be used to estimate delays and queuing and to visualize the impacts to decision makers and the public.
- **Freeway analysis (I-285)**: The Georgia Department of Transportation is undertaking a major microscopic simulation study on the I-285 freeway ring around Atlanta to evaluate the impact of ITS investments such as variable message signs. The impact on flows needs a model for a time-dynamic and highly detailed analysis (e.g. using microscopic simulations), but the scale of the

project needs regional levels and regional impact analysis which can only be done with an assignment model at the regional level.

A General Methodology for Integrated Subarea Analysis

In this section of the paper we describe our experience from several integrated subarea studies we have conducted in previous years (for example Scherr et al., 2003). We will illustrate the different steps and topics with ARC's recent experience with the Atlanta Downtown Model and its application in a bus circulation study. The Atlanta Downtown modeling projects had three model tiers, which is very typical for integrated subarea studies:

- Regional macroscopic model (platform: CUBE)
- Downtown area macroscopic model with high network detail and traffic control data (platform: PTV Vision/VISUM)
- Microscopic model for the downtown core area. (platform: PTV Vision/VISSIM)

An integrated subarea study of this kind will typically process in several stages, which we believe being relatively independent from the software platform being used, and which have been observed in the practice of several projects in different urban areas (see Scherr et al., 2003; Siegel et al., 2005; Montero et al., 1998) and reflect ARC's practice in the Atlanta region as well:

- Identify subarea boundaries
- Cut traversal matrix and subarea network
- Macro network refinement
- Add intersection data (geometry and control)
- Flow calibration (assignment and OD matrix, based on turns)
- Export to microsimulation
- Calibrate existing microsimulation network
- Feedback micro to macro
- Transfer flows for future forecast scenario to microsimulation

In the following we will share some important aspects for each of the nine steps:

<u>Step 1: Identify subarea boundaries</u>
Data and computational complexity are the main reasons to keep microscopic models small enough to be able to finish a project within time and cost budgets. The actual size of the area will depend on the experience of the simulation modelers, the congestion levels and the degree of sophistication of traffic control in the area. The following table and figure show the size of the three model tiers in the Atlanta downtown model case:

Table 2: A Comparison of Model Size at Different Levels

	Regional Model (CUBE)	Downtown macro model (VISUM)	Downtown micro model (VISSIM)
Model area (sq. miles)	6402	4	1
Number of links	57726	3332	1658
Number of zones (internal/total)	2024 / 2115	45 / 95	30 / 76
Number of intersections modeled with control (total / signal)	None	392 / 121	392 / 121

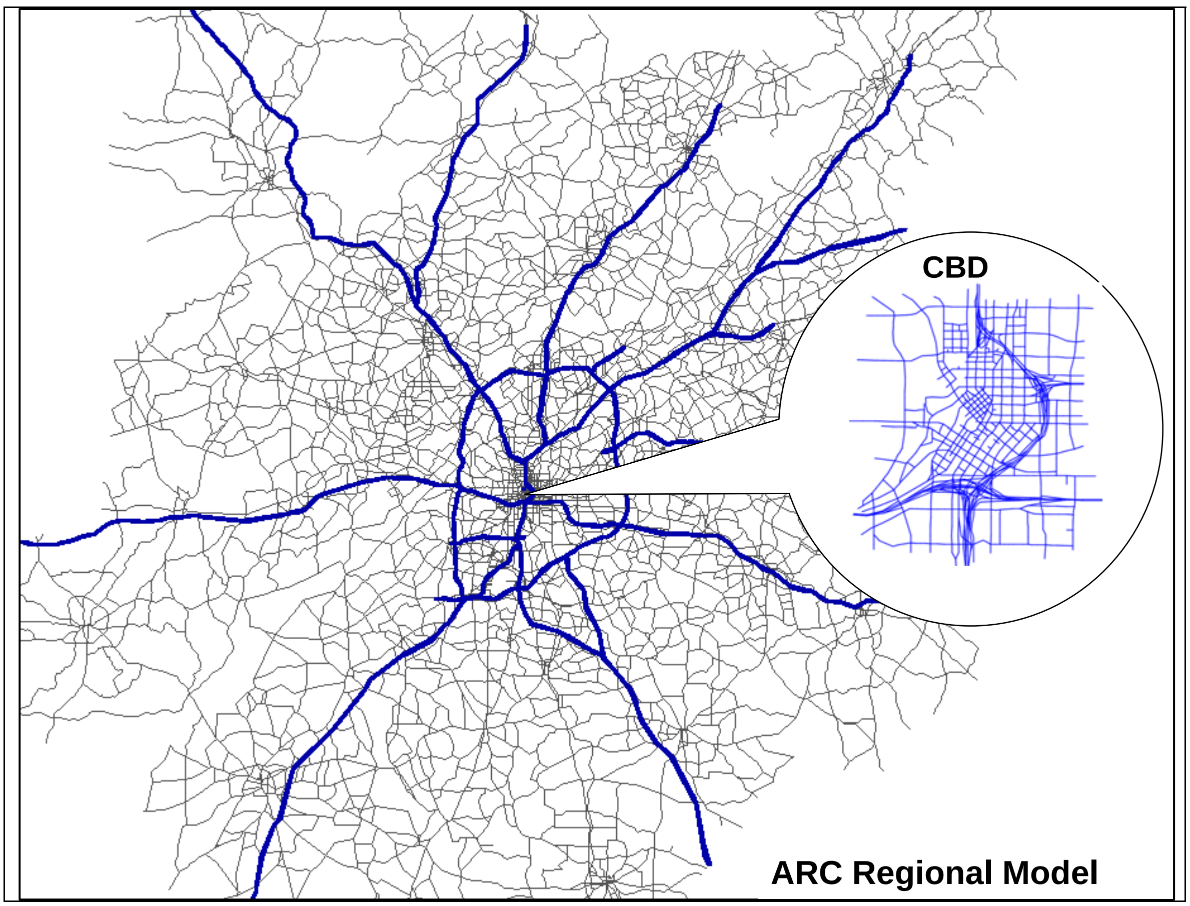


Figure 2: Atlanta Regional Model vs. Downtown Model Area

<u>Step 2: Cut traversal matrix and subarea network</u>
Depending on the software platform this step can be more or less time-consuming. In this process, external stations are defined at each point where the network is cut along the subarea boundary; then all traffic routes traversing the subarea boundary have to be cut and translated into a number of trips. With modern modeling software the subarea cut is highly automated, so the modeler only needed to repeat this step a few times until the boundaries were defined in all detail and the number of external stations was minimized.. For subarea studies with the ARC's regional model the subarea matrices have to be cut for the existing case and for each future scenario; in each scenario there will be separate subarea matrices for each of the highway modes in the ARC's model: SOV, HOV2, HOV3+, light trucks, medium trucks, heavy trucks. After the subcut, traffic assignment can be replicated in the subarea, as shown in Figure 3.

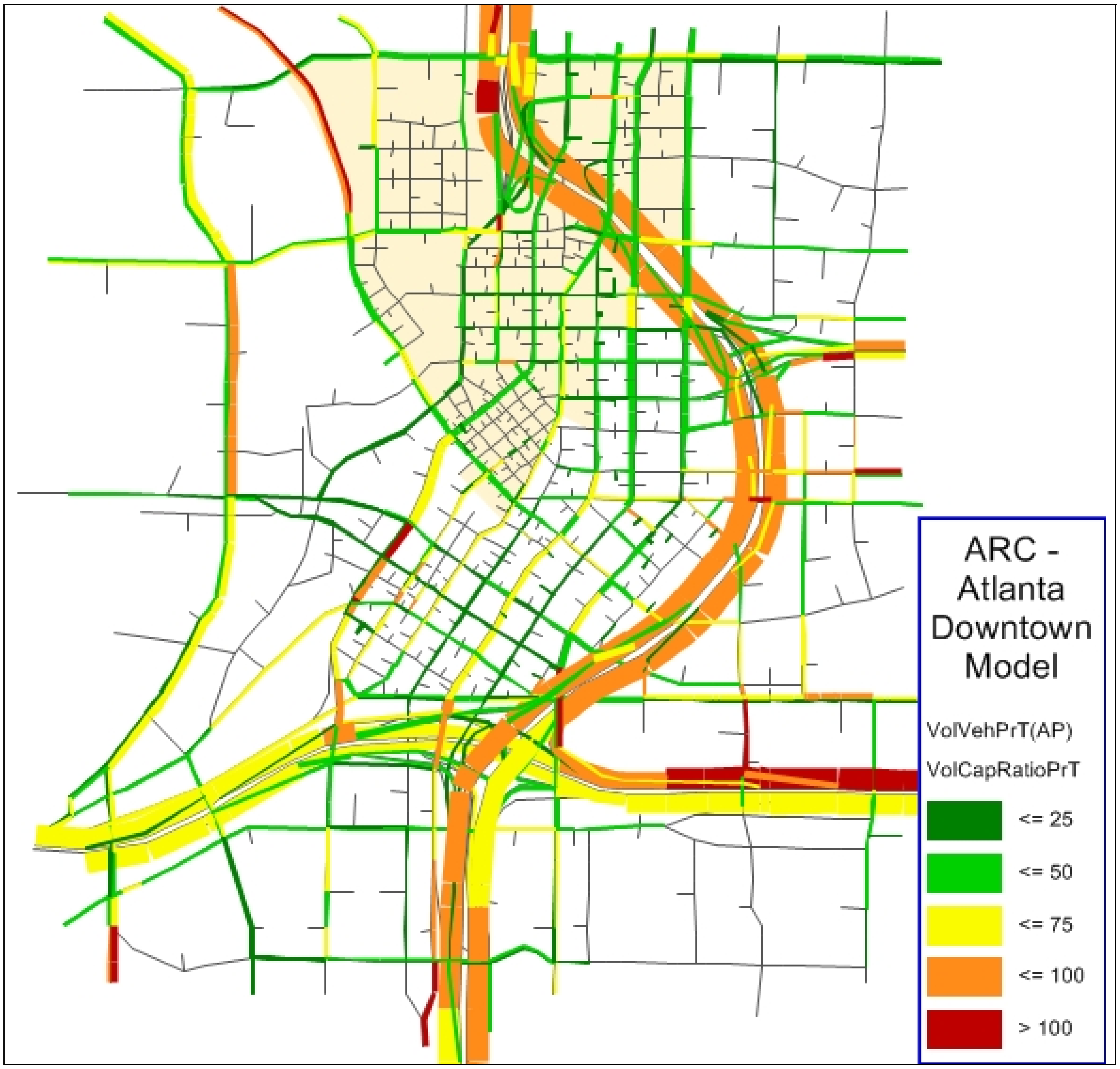


Figure 3: Refined Macroscopic Model for the Atlanta Downtown Area

Step3: Macro network refinement

To be able to integrate macro and micro models, the macro model needs to be refined at the subarea level in two dimensions: node/link network and zone/connector system. In the Downtown Model case, the software platform VISUM is used for the refinement step, mainly to take advantage of the increased data integration with the microscopic model VISSIM. In the node/link refinement, the Downtown Model derived the entire network graph from NAVTEQ data set which is a high resolution street network used for navigation purposes. The model includes all relevant side-streets plus all important driveways, for example to major parking facilities. For TAZ/connector refinement, the model uses the ability in the VISUM software to add multiple connectors to each zone with an automated internal splitting of the trip ends. That can avoid splitting of zones and ensure that zone numbers in the downtown model are identical with the ARC's regional model. In general, it is necessary for microsimulation to create a system of numerous sources and sinks for the traffic flows to make sure that each major parking facility has some trips assigned and also to avoid artificial spill-back during the microscopic simulation, which can result from unrealistic flow build-up on side streets. Figure 4 shows an example of multiple connectors in the refined macro model (left) and corresponding driveways in the microscopic network view (right). It might be noted here that in a corridor study with mainly freeway or access-controlled highway analysis, the zone/connector refinement will not be as important as in a model of a dense urban environment, like a downtown business district.

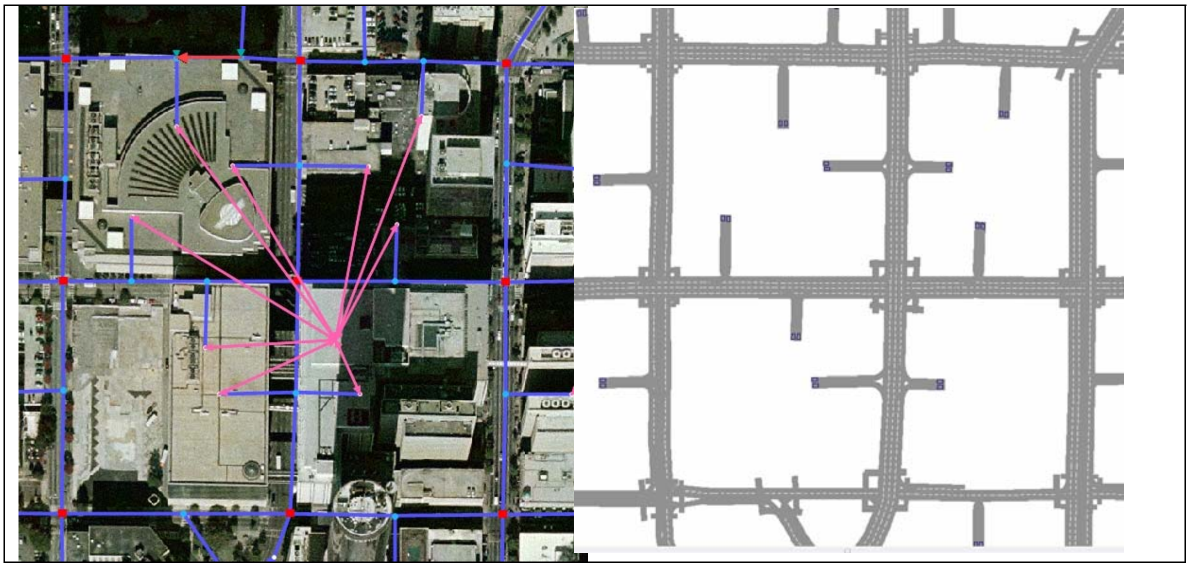


Figure 4: Connectors in the Macroscopic Model vs. Driveways in the Microscopic Model

Step 4: Add intersection data (geometry and control)

The regional transportation planning model does not contain information on signal control and intersection geometry, which includes the number and length of turn bays on intersections and their assignment to turn movements. At one point of the project, this information needs to be added, as it is needed for traffic microsimulation. In the case of ARC's Downtown Model, this information is included in the refined macroscopic subarea model, from where it can be exported automatically to the VISSIM software. Figure 5 shows the extent of intersection control data included in the model.

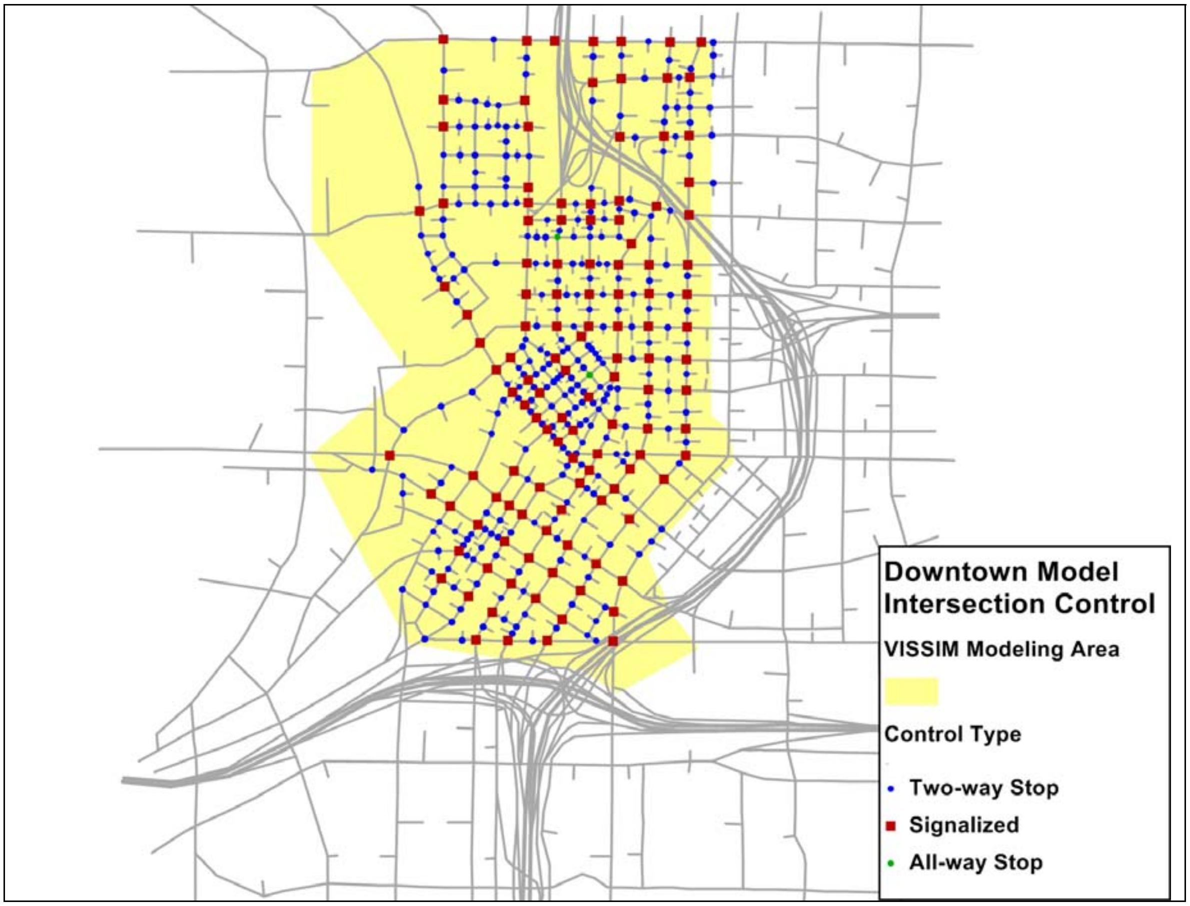


Figure 4: Intersection Control Designation in the Atlanta Downtown Model

Step 5: Flow calibration

The traffic assignment in regional models is typically calibrated for screen line volumes and on link volumes on the principal highways. This level of flow calibration is appropriate for regional planning but insufficient for microsimulation as it often implies overestimation of flows especially on smaller roads which will lead to artificial spill back and artificial congestion in the micro model. Network and matrix need to be calibrated to more rigorous standards for an integrated study. In practice this will include calibration based on turn volume counts and involve automated trip table calibration methods. Automated trip table calibration has the advantage that it eliminated artificial spill back; however it has two draw-backs that needed to be addressed by the modeling team:

- The OD flows in the trip table can not be replicated by the forecasting model. In step 9 we will describe how this issue has been addressed in ARC's Downtown Model.
- Counts do not always reflect the real travel demand as those cars that want to traverse a certain street; they only reflect those travelers who were able to travel given the current capacity constraints. To overcome this, the traffic count methodology has to include the queue volumes to the total flow.

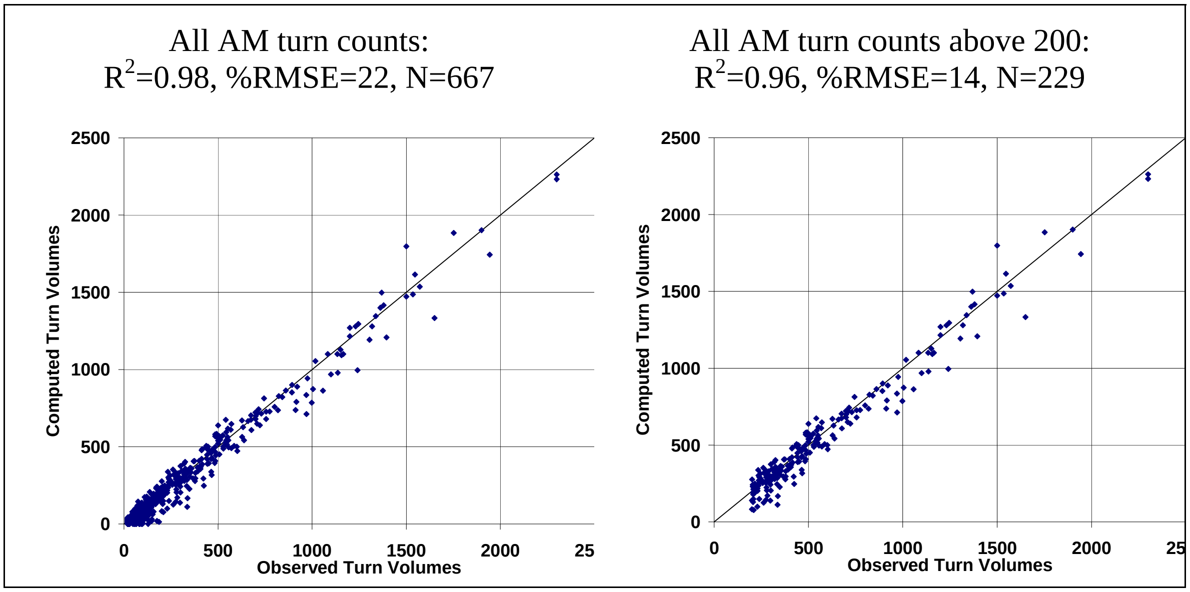


Figure5: AM Model Assignment Calibration based on Turn counts

<u>Step 6: Macro-micro export</u>

From the refined macroscopic models, two components can be exported into the micro model: first the network and second the traffic flows, which can be exported as OD flows, path flows and/or turn flows. Flow export is a must-do for integrated studies. Network export is optional as there are other methods to create the microsimulation model and not all software packages support automated network generation as macro-micro export. When the Downtown Model was built, the refined network was converted into a microsimulation network only for the existing case. Then by keeping the node-link-graph consistent between macro and micro models, path flows can be exported for any given model scenario and microsimulation will replicate the traffic flows from the refined macroscopic model.

The Atlanta downtown model is also set up so that in future applications, flows can be exported as OD flows (trip tables) and path flows will then be computed in the micro model with a dynamic-traffic assignment which is based on microscopic car flow.

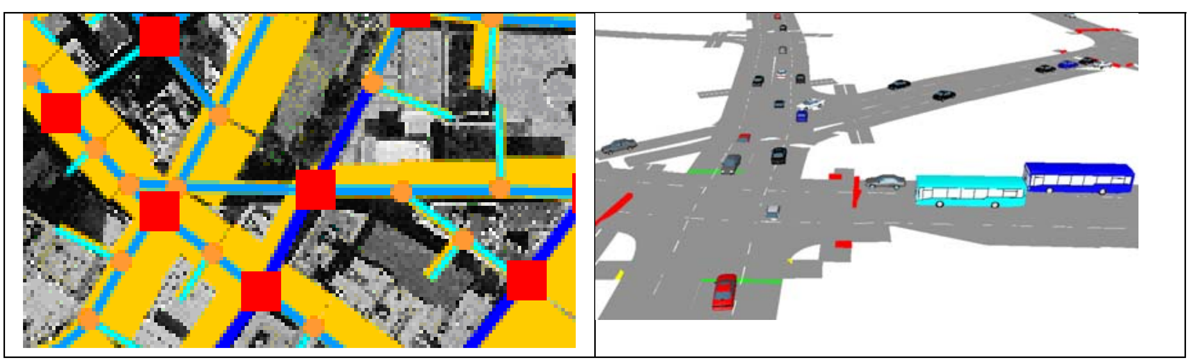


Figure: Graphical Representation of Network and Flows in the Macro and Micro Models

Step 7: Calibrate existing microsimulation network

The flow model in the microscopic model has different assumptions than the macro flow model, including car following models, lane change models and gap acceptance models. All these models need to be calibrated to obtain realistic simulation. For a large microsimulation model, this calibration entailed several man-weeks of work in addition to the network and data refinements that were already performed in steps 1 through 5. In general, the staff for step 7 has an educational background in civil or traffic engineering, where steps 1 through 6 involve typically transportation planners or demand modelers. We do not explain step 7 in too much detail, as there are many publications available on the subject.

Step 8: Feedback micro to macro

As described in step 6, macro-micro data flow is typically highly automated – at least in integrated software packages - and will be performed all over the subarea. The opposite direction however is less systematic in common practice. Possibilities for micro-macro-feedback include reporting capacity information (links with excessive v/c ratios) or feeding back travel time information (as average speed along network segments for various v/c situations). Practitioners often skip the micro-macro feedback to avoid an additional calibration cycle in an already complex methodology. Another more theoretical reason is that model convergence with travel times based on microscopic car flow can not be mathematically guaranteed.

Step 9: Transfer flows for future forecast scenario to microsimulation

As mentioned above, there are various ways to export flows from macro to micro. However, a major issue is how to combine the macroscopic forecasting capability with the calibrated OD tables used in microsimulation that are no longer linked to the forecast. The Atlanta Downtwon Model bridges between the calibrated matrices for the simulation model and the forecasted matrices from the regional model by computing delta matrices for each forecasting case and adding them to the calibrated existing matrix:

$$Trips_{OD}^{2015} = CalibratedTrips_{OD}^{Exist} + DeltaTrips_{OD}^{2015-Exist}$$

With:

$$DeltaTrips_{OD}^{2015-Exist} = ForecastTrips_{OD}^{2015} - ForecastTrips_{OD}^{Exist}$$

Challenges of Macro-Micro Integration

Integrated analysis with macroscopic and microscopic models is challenging in several ways. The key challenges observed during the Atlanta applications are typical for integrated studies and have been experienced in previous modeling projects by the authors. In similar fashion other transportation professionals report similar aspects sometimes with different software packages (Siegel et al. 2005).

Filling the data gap

In a microscopic model every intersection and piece of infrastructure is described in detail. As a result it is a lot more demanding in terms of input data than macroscopic modeling. Typically there are no centralized data systems for traffic control information, where all the information that describes an intersection could be obtained from. So the data collection itself is more labor intense than for macroscopic analysis, involving typically extensive field surveys on traffic volumes and infrastructure geometry. During the definition of the subarea for microscopic analysis, the cost of data collection typically determines the size of the subarea.

<u>Preserving graph consistency and correspondence</u>:
To enable data exchange and integrated analysis, the network graphs need to maintain identical node IDs for the micro and for the macro models. If the micro and macro tools are from different software providers, as it was the case in several Atlanta projects, the modelers are challenged to maintain consistent network graphs during the study. But even with tools from only one software platform or family of tools, modelers are challenged to keep corresponding graphs through all calibration stages and project scenarios. In the Atlanta Downtown Model this challenge is addressed by using the PTV Vision software's functionality that facilitates the macro-micro data exchange and automates it.

<u>Different goodness of fit requirements in macro and micro</u>:
Regional models will have lower requirements in goodness of fit than microscopic models. In the Atlanta case, the regional macroscopic model has 30% RMSE for link flows. The microscopic downtown model achieves less than 10% RMSE for link volumes and less than 20% RMSE for turn volumes. Both kinds of models have reasons for their specific requirements: a regional planning model would loose forecasting capability if it was calibrated too close to the counts. The microscopic model however would not be functional with unrealistically high turn volumes as they will lead to artificial grid-lock and model malfunctioning.
We solved this conflict by introducing a middle-stage : a macroscopic subarea model that was calibrated to the goodness of fit requirements of the operational micro model.

<u>Combining the right skill set in the modeling team</u>:
Rarely one can find transportation professionals who are fit in microscopic as well as in macroscopic modeling and analysis. In North-America macroscopic modeling skills are typically found in the community of transportation planners with significant background in mathematics and urban economics. Microscopic modeling skills are found with traffic engineers, who are typically not educated in macroscopic network and assignment modeling. As a result, the modeling team for an integrated study will be interdisciplinary and expose the participants to intercultural conflicts; they will be forced to learn new things and to rethink their paradigms of work. In short, not only technical skills but communication and other social skills will be important assets in such a study.

Perspectives and Areas for Further Research

A general methodology for integrated subarea analysis has emerged over the last 10 years and has been applied in many urban areas. In recent years ARC has been increasingly involved with microscopic traffic simulation projects. ARC's major challenge is to make sure that the data and assumptions used in such studies are consistent with the regional model. ARC has found that the integrated approach of linking its macroscopic model with microscopic ones has helped to address that challenge. In cooperation with the City of Atlanta and the Atlanta Airport, ARC will make an effort to maintain integrated models like the Atlanta Downtown Model, and keep them updated to contribute to integrated and consistent micro analysis in the region.

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