INTEGRATED MULTIMODAL CORRIDOR ANALYSIS USING A MICROSIMULATION MODELING FRAMEWORK: AN APPLICATION OF TRANSIMS

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ABSTRACT

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

Keywords: Microsimulation Model, Multi-modal Corridor, Subarea Analysis

INTRODUCTION

The era of microsimulation modeling has arrived. In the travel demand modeling arena, emerging activity- and tour-based models are being developed and applied at the level of the individual traveler. On a similar note, on the supply side, traffic networks are being modeled at increasingly disaggregate levels of detail with fine resolution representation of networks in time and space. The modeling of the impacts of operational improvements on roadways, such as ramp metering, signal coordination, managed lane policies, and lane restrictions, call for the deployment of microsimulation models of traffic that are capable of simulating movements of vehicles at a fine level of detail. Although there has been considerable progress in microsimulation modeling of corridors with respect to highway auto modes, little work has been done in the microsimulation of transit corridors or mixed highway-transit corridors. However, with many urban areas experiencing congestion, and increasing interest in implementing transit strategies to enhance mobility along these congested corridors while promoting sustainability goals, the need to model integrated multimodal corridors has never been greater. In many instances, urban jurisdictions are considering the implementation of Bus Rapid Transit or Light Rail modes in the medians of limited access highways or along urban arterials. When there is an integrated multimodal corridor of this nature, simulation models can be employed to analyze the performance of the corridor and assess the impacts of alternative operational strategies such as the implementation of ramp metering, signal prioritization for transit, signal preemption, and alternative transit headways. While existing travel demand models are capable of representing mode shifts and route choices that might result from the implementation of such a multimodal corridor, demand models are not able to provide an assessment of traffic performance from an operational perspective. A traffic operations microsimulation model that is capable of simulating auto and transit modes in an integrated framework is needed to identify bottlenecks, determine queue lengths, estimate vehicle delays, and quantify air quality benefits along a multimodal corridor.

The Phoenix Metropolitan Area in Arizona, U.S.A. has a population of 4.36 million people, making it the twelfth largest metropolitan area in the country. (U.S. Census Bureau, 2009). As such, the area’s highway network experiences periodic heavy congestion, causing a steady decrease in air quality and increase in peak hour travel times. In an attempt to alleviate highway congestion, Valley Metro, the metropolitan area’s transit authority, began service on a 20-mile light rail corridor in December 2008. The light rail line travels through the downtown areas of three area cities: Mesa, Tempe, and Phoenix. The transit line serves the main campus of Arizona State University, the Downtown Tempe shopping district, Phoenix professional sports arenas, Phoenix Sky Harbour International Airport, and the Phoenix central business district. In this research, a disaggregate modeling framework will be applied to the entire Phoenix Metropolitan Region while microsimulation will be specifically applied to a subarea encompassing the light rail corridor. By creating such a model, the researchers hope to create a calibrated disaggregate traffic demand model that can be applied to examine transit alternatives, providing information critical for the decision-making process.

METHODOLOGY

The microsimulation framework being applied in this work is the Transportation Analysis and Simulation System (TRANSIMS). This software, originally developed in the United States as part of the Travel Model Improvement Program (TMIP), has a wide array of capabilities and has been shown to be successful in developing disaggregate level travel demand estimates when applied to highway networks in many case studies of both small (Alexandria, Virginia) and medium sized (El Paso, Texas) metropolitan areas (Rilett et al, 2003). TRANSIMS consists of a series of executable programs that perform tasks ranging from reading highway network data files to microsimulating traffic on the network. Once the user has uploaded all network data files and the highway and transit networks have been read, he or she must then provide the system with demand files. The TRANSIMS program has the capability to simulate traffic patterns using travel demand data entered by the user, or to develop demand separately using a population generator, activity simulator, and mode choice model. The current research effort encompasses an application of both capabilities of TRANSIMS, with the former called a Phase I implementation and the latter a Phase II implementation. The research presented in this paper is the phase I implementation, although future work on the project involves migrating to a phase II framework (AECOM, 2009). Once demand has been simulated, TRANSIMS processes can be designed using combinations of the Router, an executable that creates a pre-planned route for every traveller over the course of the simulation, and the Microsimulator, an executable that closely follows each and every travelling vehicle in order to account for excess travel times caused by congestion. (Smith et al, 1995). Although TRANSIMS was used for this particular case study, the methods and lessons learned can generally be applied to any microsimulation framework.

SUBAREA ANALYSIS

The Phoenix Metropolitan Area covers approximately 1,800 square miles and includes a total of 13,210 roadway links. As with any large metropolitan area, it was found that performing a microsimulation analysis over the entire region was extremely time intensive. Because the focus of this research project is microsimulation over a multi-modal corridor, it was decided that a subarea analysis should be performed with the subarea constructed around the light rail alignment. The following subsections describe the process of designing a subarea microsimulation analysis.

Subarea Construction

The multi-modal transportation corridor that surrounds the Phoenix Light Rail line contains roadways of every level – from collectors to major interstate freeways – as well as local bus, rapid bus, and rail transit. This corridor is also host to multiple bicycle routes and pedestrian-oriented neighbourhoods. It was decided that the subarea of microsimulation should be focused around this existing light rail line and that the area of influence around the rail was approximately five (5) miles (APTA, 2009). Because the ultimate goal of the project involves analysing transit alternatives, the research team worked with Valley Metro to obtain details regarding two proposed future light rail line extensions. In order to obtain a true comparison between the traffic patterns with and without these proposed extension lines, the subarea was created by first constructing a five-mile buffer around the entire light rail line, including future extensions. These proposed lines will be examined in more detail as the project continues. At the current time, this project is using a TRANIMS phase I implementation, meaning that travel demand is entered into the system in the form of zone-to-zone origin-destination tables. There are a total of 1,995 internal and 11 external traffic analysis zones in the metropolitan region. In order to avoid any problems that may arise by microsimulating only a portion of any zone, the five-mile buffer was modified by extending its boundary to meet the boundaries of any traffic analysis zone that may have been only partially included in the original buffer. The result is an irregularly shaped subarea including the entirety of the existing light rail line and its two proposed extensions as well as the entirety of any traffic analysis zone deemed to be part of the rail's area of influence. Figure 1 displays the Phoenix Metropolitan Region highway network, the existing light rail line, the proposed extension lines, and the subarea.

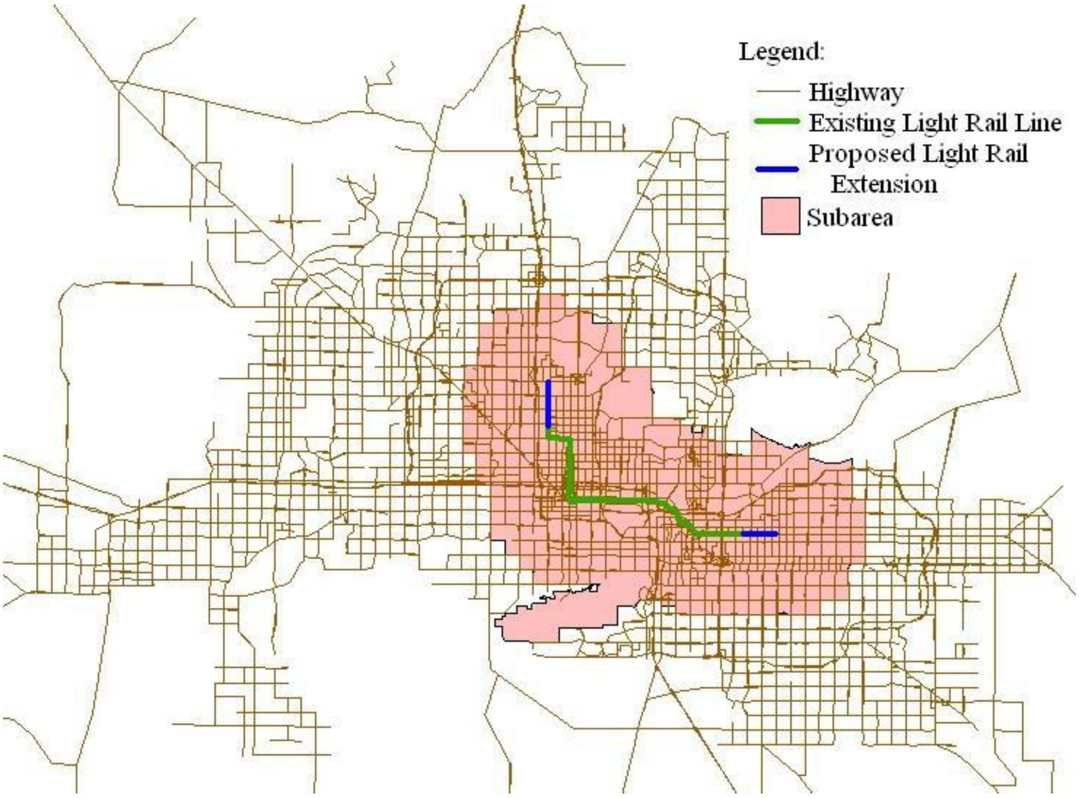

Figure 1: Phoenix Area Highway Network with Subarea and Light Rail Alignments

Enhancing the Subarea Network

Initially, the highway and transit networks were constructed by simply converting link, node, and zone data files from a standard travel model provided to the researchers by Maricopa Association of Governments (MAG), the area's metropolitan planning organization, for the highway network and transit stop and transit route data files for the transit network. These files, though useful for constructing a base network and applying the designed process, proved insufficient in detail for a microsimulation study. Thus, the entire network was enhanced to reflect greater detail in link, node, transit route, and transit stop information.

In the initial network specification, trips travelling to or from certain traffic analysis zones were lost due to the absence of activity locations in that particular zone. In a microsimulation model, trips are assigned to and from activity locations along the roadways rather than to and from zone centroids. Therefore, the modeler must be certain that there exist at least two activity locations assigned to each and every zone that hosts a trip-end. Another important network enhancement was the close examination of the input link data file. In particular, the team examined capacities and free flow speeds of the various links, making certain that these characteristics for each roadway classification were reasonable. Those links found that did not show a reasonable measure of either capacity or free flow speed were enhanced by recalculating the erroneous characteristic. These enhancements in activity location / zone correlation and link details were vital to obtaining satisfactory validation results. At this very preliminary juncture, roadway volumes are being estimated within a 17% margin of error.

Designing the Iterative Simulation Process

During the simulation of a disaggregate-level traffic model, travellers are first assigned a route by which each trip is made. This is followed by a microsimulation of each traveller carrying out his or her route plan. The result is a travel time performance measure or congestion level of each roadway. In a day-to-day real world setting, if a roadway is overly congested or has an otherwise poor performance rating, a traveller will generally choose to take another route. In order to reflect this in a microsimulation model, the modeler must employ an iterative process: routes are planned, congestion and travel times are determined, routes are re-planned for those travelling on congested routes, congestion and travel times are re-calculated, etc. The majority of TRANSIMS case studies deploy three processes that result in an area-wide simulation of roadway and transit line performance. These three processes are the router stabilizer, microsimulator stabilizer, and user equilibrium (AECOM, 2009; VNTSC, 2009; Rilett et al, 2003).

Router Stabilizer

Because microsimulation can be time consuming and computationally intensive, the majority of TRANSIMS case studies have chosen to perform many iterations of the router in order to reach a state of relative stability before entering travel plans into the microsimulator (Nagel and Rickert, 2001). This process is called the router stabilization. The first step in the process being employed in this case study is to route all trips in the regional trip files. This step is generally the most time consuming and results in very large plan files which list the route planned for each trip made during the simulation period. The next step is to evaluate these plans based on a simple volume to capacity ratio calculated for each roadway. The result of this analysis is the delay experienced on each roadway due to the current route plans. Next, the modelers select those households for which travel time could be improved. These are households that have at least one trip that travels along a congested roadway. Those selected households are then re-routed, producing a smaller plan file of only the selected households. Finally, the small plan file is merged with the large regional plan file by choosing the plan resulting in the shortest travel time for each household. This overall plan file is then used to re-calculate delay on the roadways and the process begins again. In TRANSIMS, each of these steps has a designated executable, enabling simple execution of the process.

Microsimulator Stabilizer

In a similar fashion to the router stabilizer, it is also important when using TRANSIMS to run several iterations of the microsimulator in order to reach a stable solution to the congestion levels on subarea roadways. Microsimulation is a computationally intensive effort, which is why this case study chose to microsimulate over a subarea network only (Nagel and Rickert, 2001). In order to perform microsimulation stabilization over a subarea, one must first use the final route plans file created at the end of router stabilization to create a file of subarea plans. These should be the routes taken by travellers that at some point pass through the subarea. These subarea plans can then be entered into the microsimulator to create a file listing delay on each roadway based on the specific path of each traveller at their specific times of travel. This link delay file can then be used to identify those households whose travel times can be shortened by choosing an alternate route. These chosen households are then re-routed and the new plan file is merged with the previous plan file (which included plans over the entire network) by choosing the plan from each file which experiences the shortest travel time. Finally, this merged file of travel plans is re-evaluated to create a new file of subarea plans and the process begins again on a new iteration.

User Equilibrium

In order to best simulate a real network situation, TRANSIMS case studies have often deployed a process known as user equilibrium. The purpose of this simulation process is to converge on a state in which no person can reduce his or her travel time by changing routes. In order to achieve user equilibrium while using a subarea for microsimulation, the modeler will first use the route plans file resultant from the microsimulation stabilization to create a file with delay on all roadways over the region using only volume to capacity ratios, as in the router stabilization process. The same file of travel plans will be used to create a file of subarea plans and these will be input for the microsimulator, which creates a file of link delays by following each individual traveller. The modeler will then possess a file of roadway delays for the entire region and a more detailed file of link delays for only the subarea. These two files can be merged by calculating the average delay for both roadways. This average delay can be used by the router to create a route plan for every household on the network. Finally, the new plans created for each traveller are compared with that traveller's previous plan and the route with less travel time is accepted. This user equilibrium process is repeated until less than 2% of all travellers are changing their paths in one iteration (AECOM, 2009). The final result of these three simulation processes is the best possible path of travel for each trip being made during the simulation time and the resulting performance on each roadway in the network.

RESULTS

At the current time, the three microsimulation processes for a subarea analysis have been completed in the Phoenix Metropolitan Area using a starting-point network as well as starting-point routing and microsimulation parameters. As research continues, the network and simulation parameters will continually improve, eventually reaching a point where the simulated network may be considered as adequately replicating conditions on the observed network. Preliminary results are described here.

The purpose of the router stabilizer and microsimulation stabilizer processes is to reach a point of convergence. This convergence can be described by the number of travellers who can change their route paths in order to reduce travel time. When this number of travellers ceases to decrease from one iteration to the next, convergence has been achieved. In the user equilibrium process, convergence can be achieved by reaching a point where no more than 2% of travellers could reduce their travel time by changing routes. These numbers of travellers for each of the three simulation processes are shown in Table I.

Table I: Convergence Analysis for Each Simulation Process

Router Stabilization			Microsimulator Stabilization			User Equilibrium		
Iteration	Households Re-Routed	% of Total Households	Iteration	Households Re-Routed	% of Total Households	Iteration	Households Selected	% of Total Households
2	91537	0.62	1	219862	2.78	1	164128	1.11
3	24150	0.16	2	203937	2.58	2	52450	0.35
4	16688	0.11	3	193008	2.44	3	34885	0.24
5	14081	0.09	4	186917	2.37	4	27779	0.19
6	12879	0.09	5	181467	2.30	5	18802	0.13
7	12303	0.08	6	179732	2.27	6	19410	0.13
8	12052	0.08	7	180988	2.29	7	14641	0.10
9	11902	0.08	8	179745	2.27	8	13556	0.09
10	11826	0.08	9	180526	2.28	9	12032	0.08
11	11795	0.08	10	181007	2.29	10	9368	0.06
12	11780	0.08						
13	11775	0.08						
14	11772	0.08						
15	11772	0.08						

One can see that after 15 iterations of the router, the number of households that are chosen for re-routing no longer decreases. After 10 iterations of the microsimulator, the number of households chosen for re-routing no longer decreases steadily. In fact, after the fifth iteration, the number chosen households tends to jump up and down, converging near 2.3% of all households in the subarea. In this particular implementation, the user equilibrium process reveals that after only one iteration, less than 2% of the households in the region could improve travel time by changing their route. This process was repeated for 10 iterations in order to investigate the extent to which the number of households being selected could decrease. It was found that the number of households being selected does decrease to less than 0.1% and could possibly continue to decrease by adding more iterations.

The results of the TRANSIMS microsimulation have been compared to the results of a model that uses the traditional 4-step framework. The results of this comparison by roadway volume for the entire network are shown in Table II while the results for only those links in the subarea are shown in Table III.

Table II: Model Comparison Results for the Entire Region

Volume Level	Observations	TRANSIMS Estimate	4-Step Model Estimate	Abs. Difference	% Difference
0 to 1000	2030	7009682	897998	6111684	680.6
1000 to 2500	1752	7415205	3058048	4357157	142.5
2500 to 5000	3458	19933834	13017464	6916370	53.1
5000 to 7500	2724	18147238	16629178	1518060	9.1
7500 to 10000	1974	15671384	17302724	-1631340	-9.4
10000 to 25000	6831	81987575	105312849	-23325274	-22.1
25000 to 50000	715	14259105	24064717	-9805612	-40.7
50000 to 75000	422	13317499	26768982	-13451483	-50.3
75000 to 100000	345	15917439	29019936	-13102497	-45.1
100000 to 500000	205	12977930	24212879	-11234949	-46.4
Total	20456	206636891	260284775	-53647884	-20.6

Table III: Model Comparison Results for the Subarea

Volume Level	Observations	TRANSIMS Estimate	4-Step Model Estimate	Abs. Difference	% Difference
0 to 1000	366	3243074	158841	3084233	1941.7
1000 to 2500	267	1403584	455726	947858	208.0
2500 to 5000	1079	10056333	4136711	5919622	143.1
5000 to 7500	856	8059623	5201294	2858329	55.0
7500 to 10000	728	6666665	6404742	261923	4.1
10000 to 25000	3940	50337289	63186198	-12848909	-20.3
25000 to 50000	342	7291810	10597521	-3305711	-31.2
50000 to 75000	126	4595209	8336051	-3740842	-44.9
75000 to 100000	241	12279093	20295981	-8016888	-39.5
100000 to 500000	178	11577186	21354116	-9776930	-45.8
Total	8123	115509866	140127181	-24617315	-17.6

One can see that the total number of trips resulting from the microsimulation is approximately 21% lower than the number of trips resulting from the 4-step model. However, this same comparison over the subarea roadways only reveals a difference of 18%. It is unclear whether this difference indicates that the subarea network is indeed more accurate than the general roadway, but results are encouraging. One will notice that the microsimulation model estimates very heavy volumes on the low-level roadways. This is a phenomenon indicative of microsimulation models and results from the absence of centroid connectors in the microsimulated network. Because centroid connectors are not used, trips must originate from activity locations dispersed over the low-level roadways, resulting in much higher volumes on this links.

DISCUSSION AND FUTURE WORK

As large metropolitan areas move toward disaggregate models as decision-making tools, it will be important to have a body of research revolving around such models and case studies detailing methods and lessons learned during their implementation. The research presented here is an example of the preliminary results of just such a case study. Work is currently underway to improve results by continuing to enhance the regional network, performing sensitivity analyses on the simulation parameters in order to match observed traffic volumes, and including elements of the area's transit network in the validation results. Researchers expect a much more accurate model of both highway and transit trips within the month. On a larger scale, this research can be extended to a "phase II" analysis, in which demand is created through a synthetic population generator and activity-based model. The promising future of microsimulation models allows an array of possibilities for improvement in multimodal transportation decision making processes.

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