TRANSIMS Implementation for a Small Network and Comparison with Enhanced Four-Step Model

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Travel demand forecasting is a major tool to assist decision makers in transportation planning. While the conventional four-step trip-based approach is the dominant method to perform travel demand analysis, behavioral advances have been made in the past decade. This paper proposes and applies an enhancemnt to the four-step travel demand analysis model called Sub-TAZ. Furthermore, as an initial step toward activity-based models, a TRANSIMS Track-1 approach is implemented utilizing a detailed network developed in Sub-TAZ approach. The conventional four-step, Sub-TAZ, and TRANSIMS models were estimated in a small case study for Fort Meade, Maryland, with zonal trip tables. The models were calibrated and validated for the base year (2005), and the forecasted results for the year (2010) were compared to actual ground counts of traffic volume and speed. The study evaluated the forecasting ability of TRANSIMS versus the conventional and enhanced four-step models and provided critical observations concerning strategies for the further implementation of TRANSIMS.

BACKGROUND

Traffic pattern prediction is necessary for infrastructure improvement, and travel demand modeling provides tools to forecast travel patterns under various conditions. This modeling involves a series of mathematical equations that represent how people make travel choices. Traditional travel demand models use the four-step method, which was introduced in the 1950s and has been used widely in transportation planning. Although the four-step method has been practical in producing aggregate forecasts, it has some shortcomings. For example, in short-range planning networks, existing and newly constructed roads become congested much faster than forecasted (TRB 2007) and the performance of current four-step models is not always satisfactory. Additionally, these models are not behavioral in nature and as a result they are unable to represent the time chosen for travel, travelers' responses to demand policies (e.g., toll roads, road pricing, and transit vouchers), non-motorized travel, time-specific traffic volumes and speeds, and freight and commercial vehicle movement (TRB 2007). Some researchers have modified the four-step model to improve its efficiency while others have proposed new alternatives such as activity-based models.

One modification designed to yield more realistic traffic volumes on roadways adjacent to zone-centroid connectors was developed and used by the Virginia Department of Transportation for its regional, county, corridor, subarea, and intersection studies (Mann 2002). This modified four-step model, designated b-node, used zone-level network trip tables and performed a subzone capacity-restrained traffic assignment. The model allocated the zone trip table into subzones by land activity (when there is information on land use in the subzone) or by equal weights. It was reported that despite lumpiness where the centroid connectors tied into the network, the model produced smoother traffic volumes (Mann 2004).

The fixed-order sequential approach of the traditional four-step models suffers from inconsistency among the flow values in each step. Recent research has made some improvements to the traditional sequential approach. Zhou et al. (2009) developed a combined travel demand model using random utility theory. This model brought consistency to travel choice and incorporated behavioral aspects in the traditional four-step models. In another study, a model was developed to assess changes in system performance measures due to slight changes in the network (Yang and Chen 2009). Festa et al. (2006) improved travel demand forecasting by employing experimental sequential models that simulate trip chains. They calibrated and validated behavioral random utility models to simulate the traveler's decision process.

Four-step models employ static traffic assignment (STA), which assumes that traffic is steady-state, link volumes are time-invariant, the time to traverse a link depends only on the number of vehicles on that link, and that vehicle queues are stacked vertically and do not traverse to upstream links in the network. STA has very restrictive assumptions, which limit its applicability. To enhance STA, Jeihani et al. (2006a) calculated link delay as a function of link flow and flow on adjacent links using intersection delay calculations. In their proposed method, a combination of the Frank-Wolf[1] algorithm and the method of successive averages was used to model multi-path vehicle assignment within reasonable computational time for small- and medium-sized transportation networks (Jeihani et al. 2006a).

Dynamic traffic assignment (DTA) models were introduced as an extension of STA. In DTA models, demand is allowed to be time-varying so that the number of vehicles passing through a link and the corresponding link travel times become time-dependent. These complexities are implemented in some traffic simulation software using microscopic models (Cheng and Wang 2013). Demand estimation, supply presentation, methods for computing dynamic traffic assignment, and convergence among several well-known computer packages were compared by Jeihani (2007).

Activity-based modeling is a relatively new method that replicates the activities of individuals in a network for a 24-hour period. The four-step model aggregates the trip generation process and finds the total number of trips produced by each development type (e.g., residential and commercial) in traffic analysis zones. Conversely, the activity-based model is disaggregated and finds trips for each traveler. Four themes characterize the activity-based framework: travel derives from the demand to participate in an activity, and sequences or patterns of behavior are the basic unit of analysis; household and activities influence travel behavior; spatial, temporal, transportation, and interpersonal interdependencies constrain activity or travel behavior; and activity-based approaches reflect the scheduling of activities in time and space (McNally 2000). The Virginia Department of Transportation (VDOT 2009) reports that activity-based models are currently used by the New Hampshire Department of Transportation (since 1998), San Francisco County Transportation Authority (since 2001), Mid-Ohio Regional Planning Commission (since 2005), New York Metro Transportation Commission (since 2005), Tahoe Regional Planning Agency (since 2007), and since 2007 by the Sacramento Area Council of Governments. The Atlanta Regional Commission, Denver Regional Council of Governments, Portland Metro, Ohio Department of Transportation, Metropolitan Transportation Commission, and the Puget Sound Regional Council all have activity-based models in development (VDOT 2009).

Transportation Analysis and Simulation System (TRANSIMS) is an integrated travel demand activity-based modeling system developed by the Los Alamos National Laboratory to eventually replace the four-step travel demand model. It is a microsimulation model that addresses current legislative policy issues facing transportation planners, including sustainability, environmental impact, and the emerging intelligent transportation systems. It consists of a series of modules that produce synthetic households. The modules are the Population Synthesizer, the Activity Generator, the Route Planner, the Microsimulator, the Emission Estimator, and the Feedback.

While TRANSIMS has been available for about two decades, it has not been widely employed because it is data intensive, complex, and difficult to implement. Several researchers and practitioners have attempted to operate it on different networks. A component of TRANSIMS (referred to as Track-1 by practitioners) was implemented and calibrated in Chittenden County, Vermont (Lawe et al. 2009). It was reported that TRANSIMS and the four-step model for three screen lines (imaginary lines to select traffic count locations in an organized manner so that the major travel movements are measured) produced similar results. TRANSIMS nearly replicated the daily trip distributions; however, there were shifts in both the exact time and value of the morning and afternoon peak periods possibly caused by inaccuracies in the trip table (Lawe et al. 2009). TRANSIMS Track-1 was also employed by Rilett et al. (2003) in a case study of El Paso, TX, by importing the origin-destination (OD) matrix and network from the four-step models. It was found that TRANSIMS needed more input data and more sophisticated troubleshooting than the four-step model (Rilett et al. 2003). Dixon et al. (2007) compared TRANSIMS estimates of intersection delay to field data and concluded that TRANSIMS' delay estimates for signalized intersections were very close to the real-world observations, but overestimated unsignalized intersection delays. Track-1 TRANSIMS was also applied to a small sized MPO in Illinois. In comparison with the four-step model, the TRANSIMS results were better for links, which were collector roads, than those obtained following FHWA guidelines (Ullah et al. 2011).

Jeihani et al. (2006b) developed a new heuristic algorithm to determine dynamic user equilibria (DUE) and incorporated it into TRANSIMS. The developed DUE model was applied to networks in Blacksburg, Virginia, and Portland, Oregon. An improved distribution of travelers was obtained while consuming less than 17%–33% of the computing time required by the original assignment model in TRANSIMS. Zhang and Mohammadian (2008) developed a new methodology to facilitate household travel data transferability for local areas. With their proposed data simulation tool, metropolitan planning organizations (MPOs) can avoid the high costs associated with data collection for micro-simulation models such as TRANSIMS.

This study proposes a three-phase process to transition from the traditional four-step model to an activity-based model. The first step is an improvement to the four-step model, which will be referred to as the Sub-TAZ model. The Sub-TAZ model provides smoother traffic than the four-step model and requires a detailed network that includes minor roads and driveways. It also divides the traffic analysis zones (TAZs) into smaller segments called Sub-TAZ. The second step is TRANSIMS Track-1, which uses the detailed network and origin-destination matrices from the first step and performs a dynamic traffic assignment. The final step is TRANSIMS Track-2, which is an activity-based model. The study then applies the traditional four-step model, the proposed Sub-TAZ model, and TRANSIMS Track-1 on a small network and then validates and compares them for two horizons. The study also compares the ability of TRANSIMS to that of the prior four-step models regarding planning and future demand forecasting.

FOUR-STEP MODEL FOR A SMALL AREA NETWORK

The selected case study includes Maryland Route 175 (MD-175) and the surrounding roads, in a 100-square kilometers area in central Maryland. This area is growing and has many new developments constructed. A four-step model for this small area was developed based on the Baltimore Metropolitan Council's (BMC) regional model (i.e., a travel forecasting model for Baltimore metropolitan area). The developed model is calibrated and validated for the base year 2005 and it is called the base model. As presented in Figure 1, there are 28 traffic analysis zones (TAZs) and 327 links in the study area. Thirteen of the 28 TAZs are external (i.e., outside the study area) and all trips outside the study area are assumed to traverse one of these TAZs to enter the study area.

Ground counts of traffic were obtained for approximately 13% of the links in the study area. Individual link errors were calculated by subtracting the estimated model's volume from the link's ground count. The model was calibrated and validated according to the Federal Highway Administration's (FHWA) guidelines to reasonably represent reality (Ismart 1990). Equations (1) to (3) were used to measure how well the calibration performed:

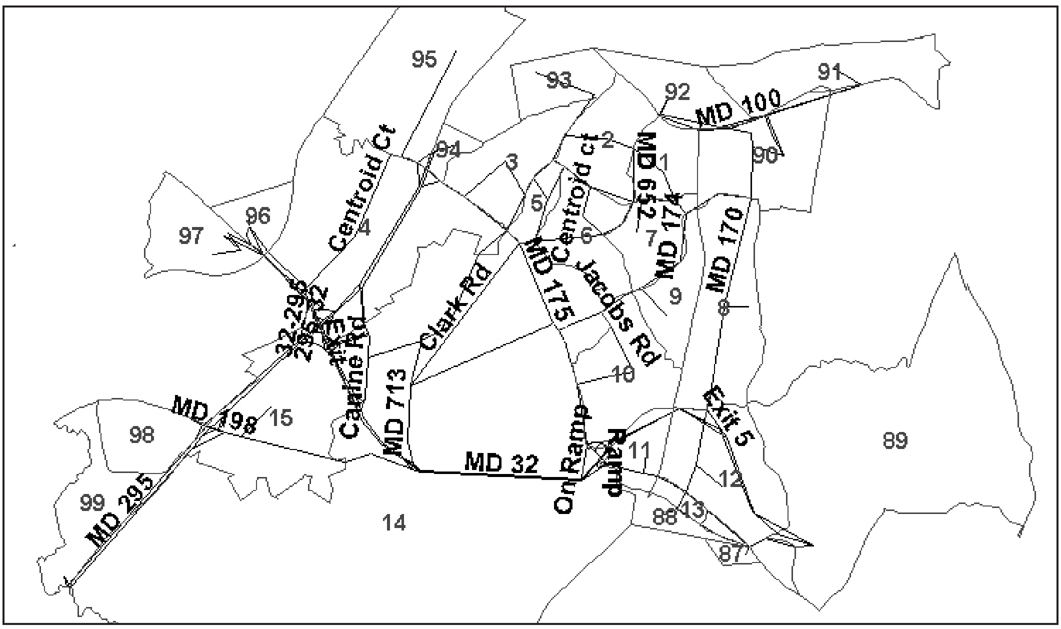
(1) $$r = \frac{\sum(x.y) - n\bar{x}\bar{y}}{\sqrt{(\sum(x^2) - n\bar{x}^2)(\sum(y^2) - n\bar{y}^2)}}$$

(2) $$RMSE = \frac{\sqrt{\frac{\sum[(x-y)^2]}{n}}}{\frac{\sum x}{n}} ee$$

(3) $$AE = \frac{\sum|y-x|}{\sum x} \times 100\%$$

where, r is the correlation coefficient; RMSE is the root mean square error; x is ground count of traffic; y is the calibrated traffic volume; n is the number of observations; and AE is the absolute error. The calibration and validation results for the base model are in Table 1.

Figure 1: TAZs and Links in the Base Model



ENHANCEMENTS TO THE FOUR-STEP MODEL

Sub-TAZ and TRANSIMS Track-1 models were developed as modifications to the four-step model and calibrated and validated for the small study area for the base year 2005.

Sub-TAZ Model

One of the reported problems associated with the current four-step models is the lumpiness of loadings around centroid connectors. This is because all trips are generated from a centroid in one zone and destined to other zones via a few imaginary centroid connectors. As a result, the connection between the imaginary centroid connectors and the major roads becomes very congested with traffic while other segments of the major road are less utilized. The proposed new approach, the Sub-TAZ model, addressed this problem by including minor roads and driveways in the network and allowing each zone to be divided into up to 12 subzones depending on local road and driveway locations. Also, each zone can be divided based on land use instead of roads if it has land available for development.

If land use and socio-economic data for all subzones are available, the input data to the four-step model can be expanded to reflect subzone information and the regular four-step model applied at the subzone level. However, since all the required data are usually unavailable at the subzone level, the proposed method applies the trip generation step in the zonal level. The productions and attractions of each zone—the trip generation output—are then divided between the subzones. This division is performed equally among the zones if there is not much information about sub-zonal land use. For example, if a zone is divided into four subzones, each subzone is allocated one-fourth of the total trip productions and attractions of the original zone if information is unavailable about sub-zonal land uses such as trip generators. If this information is available, then total trip productions and attractions are distributed proportionally and not equally. Due to the absence of data on sub-zonal land uses, the distributions are based on equal weights.

In comparison with the b-node model (Mann 2004), which divides the origin to destination trips and zones into subzones in the last step (traffic assignment) of the four-step model, the Sub-TAZ divides the zones into subzones in the second step (trip distribution). Therefore, the output of the trip generation procedure is divided into the number of subzones in each zone, and the rest of the steps of the four-step model use the extended matrices. The result is a detailed network that includes all local streets and developments' driveways and represent a more realistic road network than the base model.

In Figure 2, the Sub-TAZ model includes 55 zones whose detailed network consists of 1,782 links and 1,461 nodes. As in the four-step model, the Sub-TAZ model assumes that all vehicles originate from and travel to zone centroids and uses imaginary links (centroid connectors) to connect to the highway network. The Sub-TAZ model was developed, calibrated, and validated for the study area. The results are presented in Table 1.

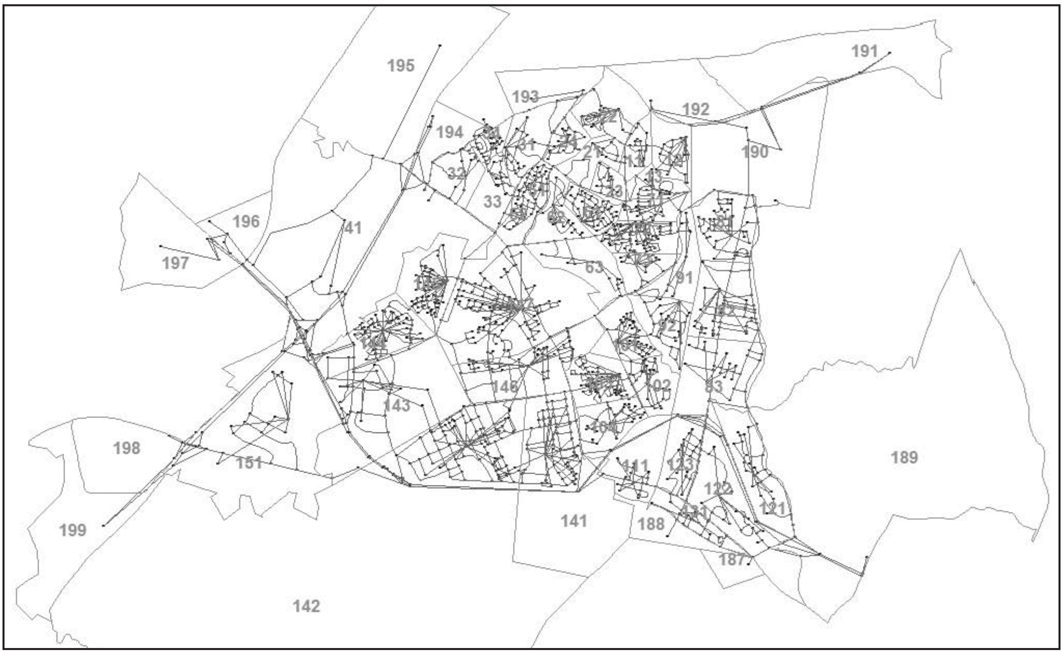
Table 1: Calibration/Validation Results of the Base, Sub-TAZ, and TRANSIMS Models

Calibration/Validation	FHWA Guideline	Base	Sub-TAZ	TRANSIMS
Correlation coefficient	0.88	0.94	0.92	0.93
Percent error regional-wide	5%	-5.7%	5.8%	10.9%
Sum of differences by functional class				
Freeway	7%	-5.6%	-1.7%	11.5%
Principal Arterial	10%	-11.5%	0.2%	14.9%
Minor Arterial	15%	1.0%	44.4%	4.7%
Collector	25%	-41.2%	-5.4%	-1.4%

TRANSIMS Model

TRANSIMS is based on individual behavior and interactions. It traces and simulates the movements of each individual traveler in a fully described network as that traveler accomplishes travel activities in a 24-hour period. TRANSIMS also collects statistics on traffic, congestion, and pollution. The major goal of applying TRANSIMS for such a small study area is to compare its forecasting capability to that of the four-step models.

Figure 2: The Sub-TAZ Network for MD-175



TRANSIMS as a travel model improvement program aims to precisely model the interaction between demand and supply. Micro-simulation is typically the supply side of TRANSIMS, while Track-1 and Track-2 are the two approaches to enhance the demand side. In most studies, researchers utilize the standard trip origin-destination matrix for the demand side, which can be simply extracted from the existing four-step models of the desired study area. The Track-1 approach is mainly a trip-based approach to the TRANSIMS model that only employs Route Planner and Microsimulator modules. Track-1's advantage over the four-step models is its dynamic traffic assignment capability.

The Track-2 approach, which is activity-based, utilizes the whole TRANSIMS model package (including the Population Synthesizer, Activity Generator and Router modules) to forecast travel demand. This approach is more complicated and more data intensive, but is microscopic and addresses many of the existing problems in the four-step models. Track-2 was also developed in this study. However, the results were not plausible due to the small size of the network. The Track-2 model underestimated traffic volumes because of trip-to-activity conversion problems for external zones. That is, the current Track-2 model does not convert external trips to activities and, therefore, does not include external trips. This issue does not affect models for large areas since external trips are negligible compared with the areas' trips.

Two major inputs from the four-step model are required to create Track-1 of the TRANSIMS model. The first is network data, which must be converted into TRANSIMS format. TRANSIMS requires considerably more detailed network data than the traditional four-step models. Since this research created a detailed network for the Sub-TAZ model down to the local level of roadway classification, the detailed network is completely compatible with the TRANSIMS' model requirement. Therefore, TRANSIMS network was completed by removing the virtual centroid connectors from the Sub-TAZ model. The second input to Track-1 is demand files, which are represented by the four-step OD trip matrices. The demand files matrices were converted into TRANSIMS format (see the Convert Trip Section).

Network. TRANSIMS developers have developed some utility programs to create all required files using four major inputs: node, link, shape, and zone files converted from a four-step model. As a result, other inputs such as parking and activity locations are not required to be entered manually. The four aforementioned files are similar to those from four-step models but are more detailed. For example, turn pockets (pocket lanes to turn right or left) and merge lanes (high-occupancy-vehicle lanes) are determined. Three files of highways (links), endpoints (nodes), and TAZ were exported from TransCAD to shape files (geographical format) and then converted to TRANSIMS format using GISNet and TRANSIMSNet. Some manual adjustments were made to make the files acceptable by GISNet, which is a useful control key that exports shape files to text files. The TRANSIMSNet utility program was then utilized to synthesize the TRANSIMS network and generate other network inputs such as activity locations. The log file was checked for warning messages after TRANSIMSNet was run and corrections were made as required. The following files were generated as TRANSIMS network files: link, node, process link, signal, transit, activity location, parking, shape, and zone.

TRANSIMS conceptually views the network as a set of interconnected single-mode layers. Thus, a separate layer exists for each travel mode (walk, bike, car, bus, rail, and trolley). At designated locations in each layer (activity location, parking location and transit stops), a special link called a process link connects one single mode layer to another. These process links allow intermodal interactions to take place from one layer to another. For example, a person can switch from walk (W) mode to car (C) mode, then transit (T) mode, and then go back to walk mode to go from his home to his work place using process links, and this trip can be presented by WCTW. The parking file includes information about parking such as identity (ID), type, capacity, and location. TRANSIMS assumes vehicle start and end locations are in a parking lot. An activity location represents a place where a household member would travel to and from and includes such information as ID, node, link, and zone.

Activity locations in the external zone required specific attention. This is because external links in the study area were mostly freeways with separate origin and destination activity locations. Also, external trips may not be routed properly when an inbound link is the destination or an outbound link is the origin.

Convert Trip. To develop the Track-1 approach in TRANSIMS, the four-step model's zone-to-zone trip tables for different trip purposes and travel modes were converted to trips between activity locations for each second during the day. To do so, the Convert Trip utility program in TRANSIMS was utilized. Daily trip volumes from the TransCAD model were extracted to form a TRANSIMS trip table, and the TRANSIMS smoothing tool was employed to modify the daily distribution of trips from this table. Household and vehicle files were the other two major outputs of the Convert Trip program.

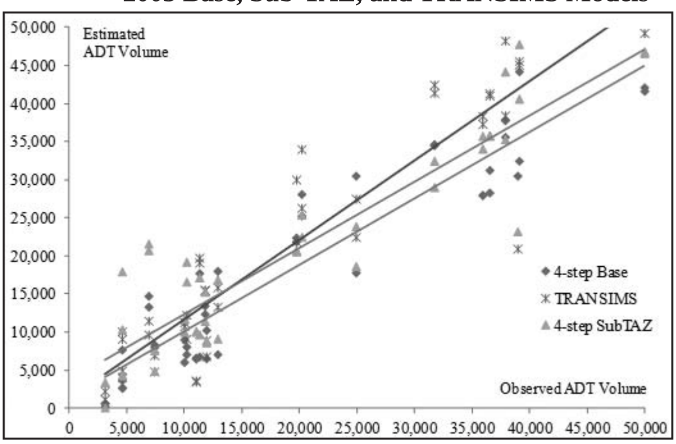
Feedback Module and Calibration. The feedback process is the calibration tool in TRANSIMS and can be run between two or more modules. It is used to calibrate the model, stabilize travel times in the network and yield the desired mode choice, and to correct the network, locations, modes and activity times. Connection problems between the links and process links were addressed manually. Because TransCAD is not sensitive to network geometry, some links in the imported network, especially ramps, did not follow the proper curvature. As a result, the Microsimulator could not load vehicles on the links that exceeded the restriction of maximum connection angle (the angle between two links). The authors modified the network by reducing connectivity angles. Several feedbacks were performed to improve the activity and plan files and address trips with problems. Two of the most common problems were path-building (due to network limitations) and zero-node path (due to the aforementioned activity locations for external trips or when the origin and destination are in the same link).

Also, a feedback was created between the Route Planner and the Microsimulator to stabilize travel times. The feedback loop randomly re-routed 10% of travelers until link travel times stabilized. The relative stabilization (when the difference between the travel time of the current iteration and the previous is negligible) happened after 10 iterations in this study. Despite following this approach, it is better always to ensure that user equilibrium occurs. At the first iteration, the Route Planner used free-flow travel times to find the shortest path. However, after all vehicles were loaded onto the network, the link travel times were higher than the free-flow travel time, especially in congested areas. As a result, some routes no longer provided the shortest time path. The random re-routing of travelers stabilized link travel times. The results of the calibrated Track-1 TRANSIMS model in Table 1 were validated with traffic counts in the same way as the base model and the Sub-TAZ model.

New Approaches Versus the Base Model

Table 1 compares the calibration/validation results of the three models developed for the base year 2005 along with the FHWA guideline. As the table shows, the base model offers a slightly better correlation coefficient but it poorly estimates collector roads. The Sub-TAZ model and TRANSIMS estimate traffic volumes on collector roads generally better. Except minor arterials, the Sub-TAZ estimation outperforms the base model for all classes of roads. TRANSIMS outperforms the other two models for collectors and overestimates traffic on arterials and freeways probably due to a large number of external traffic. The estimated traffic volumes versus actual ground traffic counts for all three models are in Figure 3.

Figure 3: Estimation-Observation Regression Lines for the 2005 Base, Sub-TAZ, and TRANSIMS Models



For validation, the three calibrated models were employed to forecast traffic in 2010 and then validated with traffic counts. As indicated in Table 2, the TRANSIMS and Sub-TAZ models had a higher correlation coefficient than the base model. The base model forecasted freeway traffic best with a 6.2% error compared with the Sub-TAZ model's 12.1% and TRANSIMS' 13.2%. However, the TRANSIMS model could be calibrated in just the same way as the four-step model. In Table 1, the freeways' error was 11.5%, which is more than the 7% error following the FHWA guidelines in the base model. If user equilibrium is applied to the TRANSIMS model and a lower error rate is obtained for freeways in 2005, then the 2010 prediction model will give a lower error rate and a better forecast of freeway traffic volumes. Traffic volumes on principal and minor arterials were forecasted better in TRANSIMS (5.3% and 6.9% error, respectively) than in the Sub-TAZ (8.6% and 39.9% error) and the base models (16.6% and 44.3% error). The forecasted volumes and 2010 traffic counts in Figure 4 verify that TRANSIMS and Sub-TAZ models produce less discrepancy in short-run forecasting of traffic volumes than the base model.

Table 2: 2010 Forecast Validation Results of the Base, Sub-TAZ, and TRANSIMS Models

Validation	Base	Sub-TAZ	TRANSIMS
Correlation coefficient	0.86	0.94	0.94
Percent error regional-wide	8.0%	16.4%	10.5%
Sum of differences by functional class			
Freeway	6.2%	12.1%	13.2%
Principal arterial	-16.6%	-8.6%	-5.3%
Minor arterial	44.3%	39.9%	6.9%

Although traffic counts have been widely used to calibrate and validate the traditional four-step models for facilities not affected by signals, speed checks may be a helpful measure to evaluate model performance. Consequently, the study used the observed 2010 speed data for the major roads in the study area obtained from the Regional Integrated Transportation Information System (RITIS) in the CATT Laboratory at the University of Maryland, College Park to evaluate performance. The average speed data for mid-weeks (Tuesday to Thursday) of spring and fall 2010 were calculated. These average speeds were then compared with the modeled speeds of the base, Sub-TAZ and TRANSIMS models. Figure 5 shows the percentage differences between the modeled speeds in each of the three models compared with observed speeds for congested periods (morning and afternoon peak hours separately) for three selected corridors in both directions. Percentage differences in traffic volume for Sub-TAZ and TRANSIMS are less than that for the four-step model; whereas, TRANSIMS is the best predictor for morning peak traffic volume and Sub-TAZ is the best for afternoon peak traffic volume.

Figure 4: Forecast-Observation Regression Lines for the 2010 Base, Sub-TAZ, and TRANSIMS Models

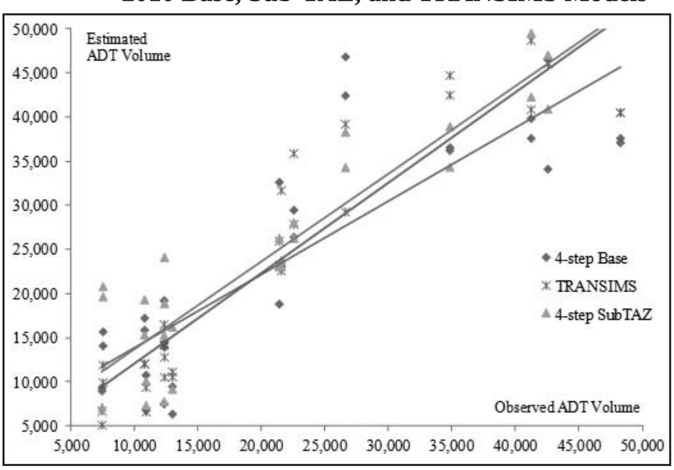
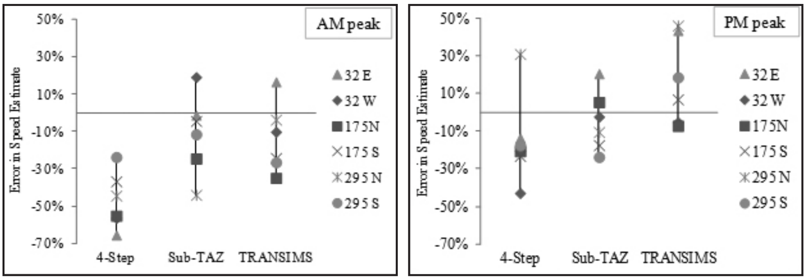


Figure 5: Observed Speeds Compared to 2010 Modeled Speeds of Base, Sub-TAZ, and TRANSIMS Models for Three Bi-Directional Corridors (32, 175, and 295)



SUMMARY AND CONCLUSION

This study applied the TRANSIMS model to a small area in Maryland. The objective was to provide critical guidance in transitioning from the traditional four-step modeling to activity-based modeling. Many transportation agencies are considering adopting dynamic traffic assignment and/or activity-based modeling. Since this adoption is a major change, it requires significant effort and human resources. This paper proposes a three-phase process to make the transition easier and less overwhelming. These phases are labeled Sub-TAZ, Track-1 TRANSIMS, and Track-2 TRANSIMS. In the first phase, Sub-TAZ, a transportation agency develops a more detailed transportation network and divides the zones into smaller subzones. The result of this phase is a smoother traffic volume than the traditional four-step model. The second phase, Track-1 TRANSIMS, converts the detailed network provided in the first phase and trip tables into TRANSIMS format and the model is implemented. In the third phase, Track-2 TRANSIMS, a complete activity-based model is achieved. The second and third phases can be achieved using packages other than TRANSIMS. However, small MPOs can reduce costs by using the FHWA-funded TRANSIMS package instead of expensive commercial software (Ullah et al. 2011).

The paper also examines the forecasting capabilities of the models by comparing the results to ground traffic counts. The results show that Sub-TAZ yields better forecasts than the conventional four-step model. The Track-1 TRANSIMS model showed promising results; it performed well in forecasting future travel demand even without full calibration. Applying user equilibrium in TRANSIMS is likely to result in more accurate output data. The TRANSIMS model estimated and forecasted traffic volumes on minor arterials and collectors better than the two four-step models. It also offered better model fit with less error in forecasted data for each facility type. TRANSIMS was not successful in replicating observed traffic volumes for freeways due in part to the selected study area, which is affected by interference from external traffic entering freeways that cannot be properly associated with activity locations. A future direction of this study is to modify Track-2 TRANSIMS to account for external trips and apply it to the study area.

Endnotes

1. The Frank-Wolf method was suggested by Frank and Wolf in 1956 (Sheffi 1985). It is widely used in determining equilibrium flows in static transportation network problems.

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