Memorandum

SRF No. 11430

To: Brian Gibson, Executive Director
St. Cloud Area Planning Organization

From: Steve Wilson, Principal
Krista Anderson, Engineer

Date: January 3, 2019

Subject: Travel Demand Model Update

Introduction

This memorandum describes the process used to recalibrate and validate the St. Cloud Area Planning Organization's travel demand model to year 2015.

The St. Cloud Area Planning Organization (APO) maintains a travel demand model to support its long range regional planning efforts and to provide guidance to planning and design of major roadway projects in the region. The APO is developing its year 2045 transportation plan, which necessitates updating the model to existing (year 2015) conditions within acceptable industry standards.

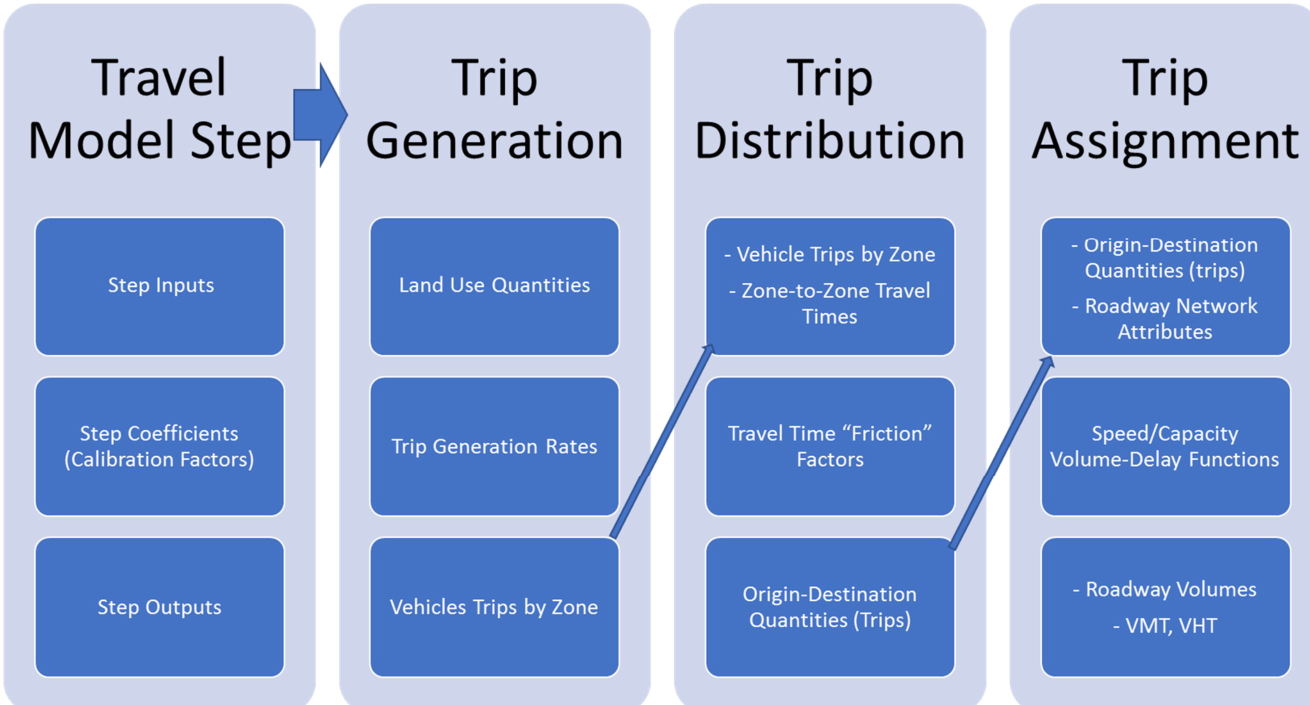
The recalibration of the current APO travel demand model (TDM) focused on cost-effective modifications to the trip generation and trip distribution components of the existing model structure using existing datasets in addition to professional judgement. These modifications were carried through the trip assignment step of the TDM and a set of validation measures were prepared to demonstrate the reasonableness of the model output is within acceptable margin-of-error guidelines recommended under the Federal Highway Administration's *Travel Model Validation and Reasonability Checking Manual.*

Model Structure

The flow of the APO's TDM is depicted in Figure 1 below. The current APO model is a simplified "four-step" model. The non-included model step, mode choice, is combined with the trip generation step to produce vehicle trips rather than separate estimates of person tips and transit market shares. This is a common simplification in small-to-midsize urban area models, where the transit market share is small and the resources available to develop transit models are limited.

Primary inputs to the model include a land use file with land uses and quantities for the trip generation program, and a network file of significant roadways and roadway characteristics.

Figure 1: St. Cloud APO "Simplified" Travel Demand Model Flow



Transportation Analysis Zones and Land Uses

The current land use-based trip generation program includes 13 land use categories plus an estimator for trips oriented to and from the APO region. The land use categories included in the TDM are shown in Table 1.

Land uses are grouped and summed within model Transportation Analysis Zones (TAZ) provided by the APO. Within the St. Cloud TDM extent, there are 261 TAZs, with an additional 30 TAZs representing "external stations" at the edge of the region. The TAZ structure is depicted in Figure 2. For analysis purposes, the TAZs were assigned to 13 districts, which are also depicted in Figure 3. Zone and district boundaries, and base year inputs have been compiled in a unified GIS file provided as part of the model.

Table 1: Travel Demand Model Land Use Categories

Land Use	Units	Abbreviation
Single Family Residential	Dwelling Units	SFR
Medium/High Density Residential	Dwelling Units	MHR
Office	1,000 Square Feet	OFFICE
Industry	1,000 Square Feet	IND
Low Industry	1,000 Square Feet	LIND
Low Retail	1,000 Square Feet	LRET
Medium Retail	1,000 Square Feet	MedRET
High Retail	1,000 Square Feet	HighRET
Hotel/Motel	Rooms	HOT
School	Enrollment	SCH
Parks	Acres	PARK
Hospital	Beds	HOSP
College	Students	COLL
Existing Traffic Count	Vehicles per Day	ADT

Figure 2: St. Cloud APO Travel Demand Model Transportation Analysis Zones (TAZ)

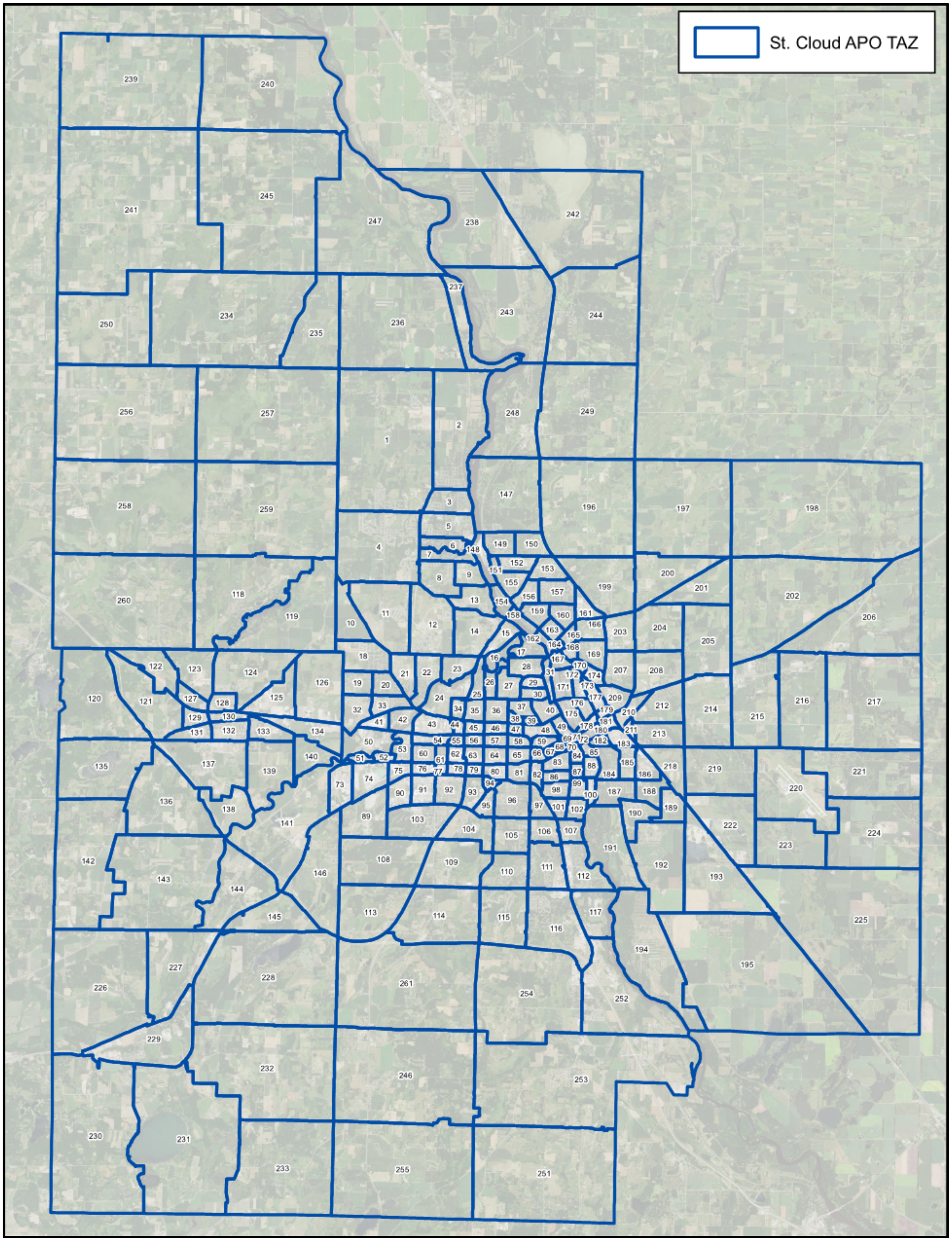
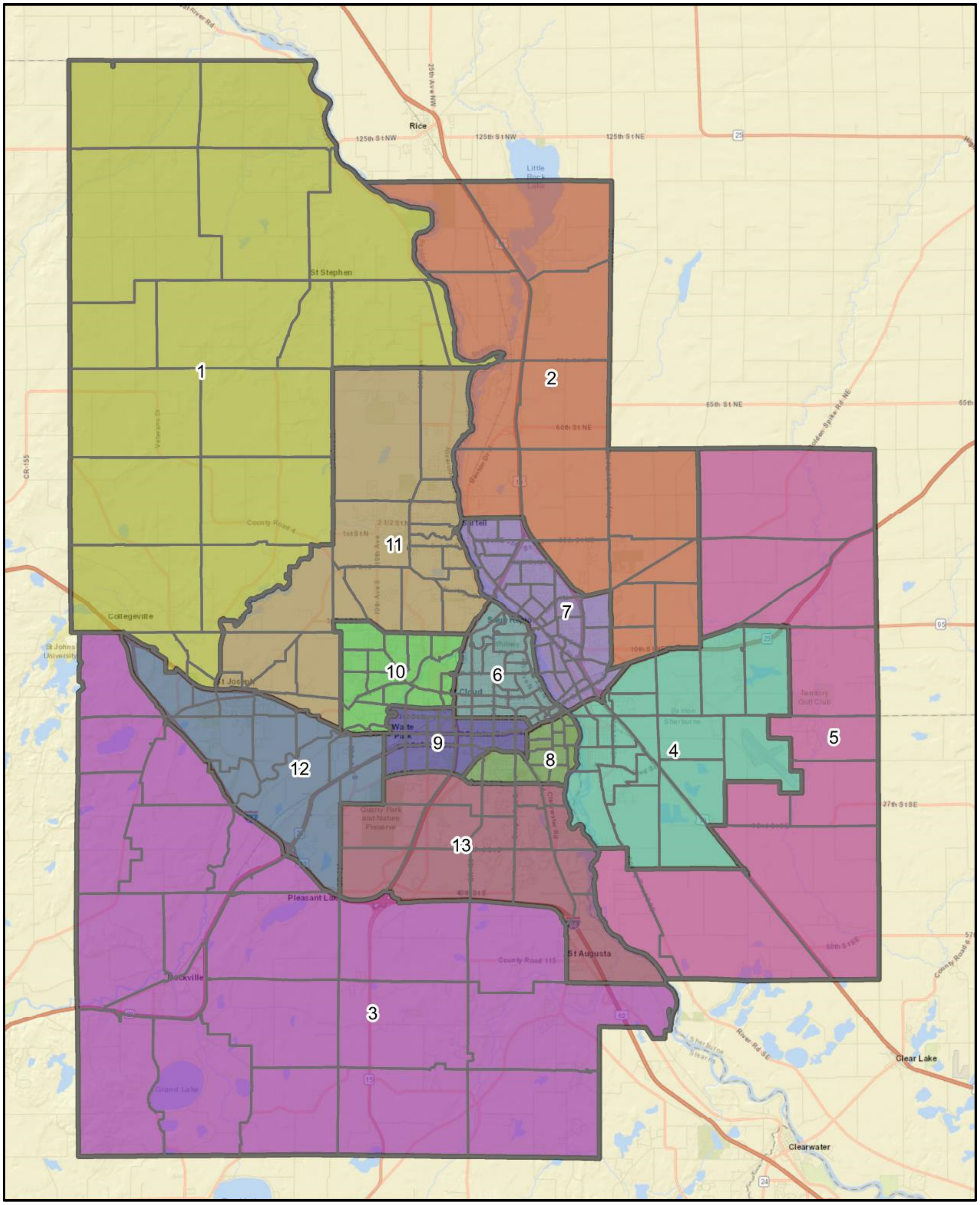


Figure 3: St. Cloud APO Travel Demand Model Transportation Analysis Zones (TAZ)



Network

The APO travel model highway network is depicted in Table 4. The existing roadway network was reviewed for accuracy. The APO model network includes several link attributes, which were reviewed and updated as necessary.

Table 2: Roadway Network Model Attributes

Link Attribute	Description
Distance	Roadway Assignment group classification of links (see Table 3) distance, used in estimating travel distance and travel time
Asgngrp	Placeholder descriptor in network (not used)
Linkgrp1	Placeholder descriptor in network (not used)
Linkgrp2	Placeholder descriptor in network (not used)
Linkgrp3	Placeholder descriptor in network (not used)
User	Placeholder descriptor in network (not used)
Ff_Speed	Free-flow speed (mph)
Capacity	Daily one-way capacity
Currvol	Current Volume (APO or MnDOT sources)

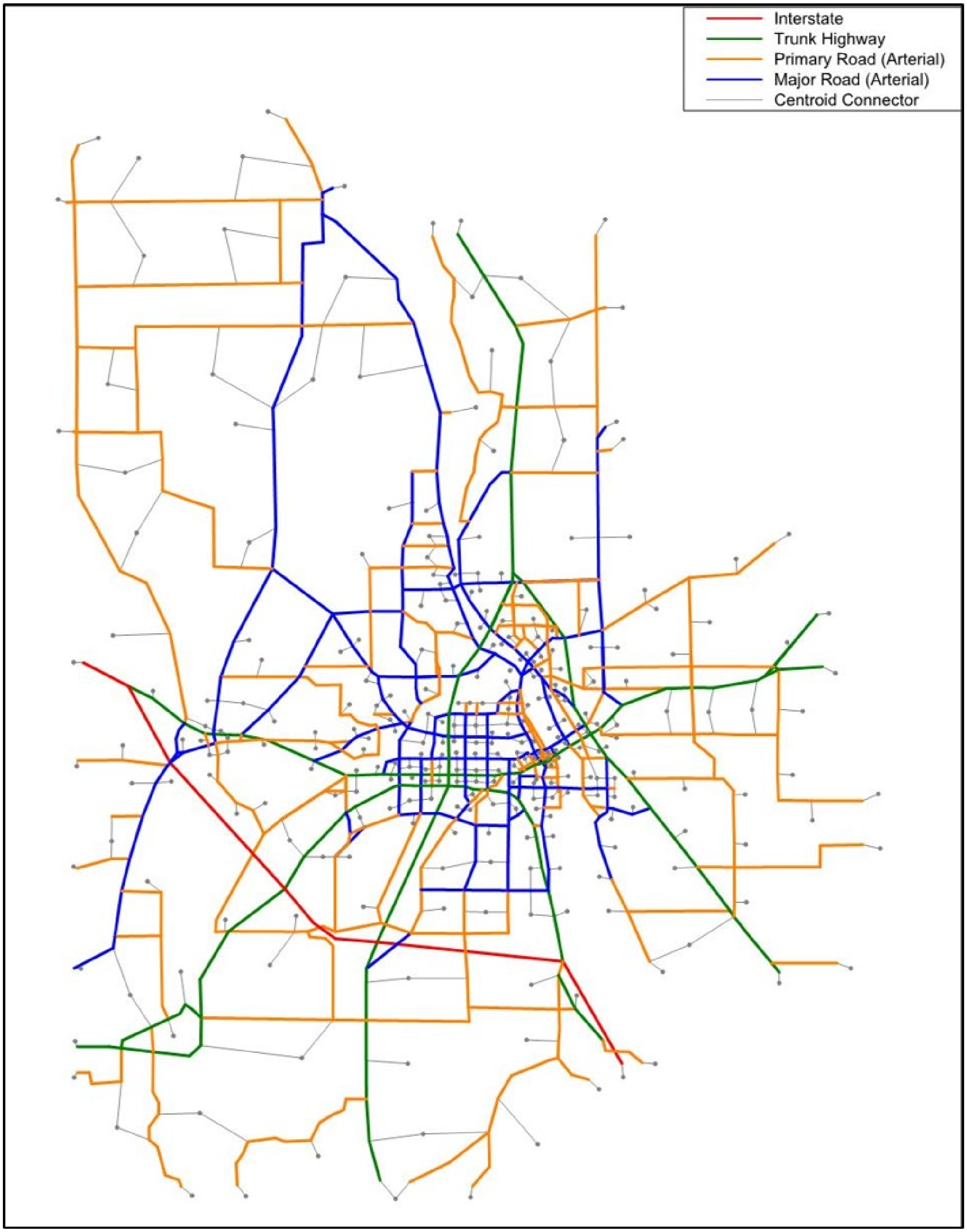
One attribute was added depicting eight screenlines used for model validation and reporting.

Four of the attributes included in the current model network are unused variables carried over from the previous TRANPLAN model network: Linkgrp1, Linkgrp2, Linkgrp3 and User. Future use of these variables and other network attributes is discussed in a subsequent section. Table 3 shows the current key attribute ranges for the demand model.

Table 3: Roadway Link Classifications

Assignment Group	Description	Free Flow Speed			Daily Capacity		
		Average	Low	High	Average	Low	High
1	Interstate	66.4	65	75	24,000	24,000	24,000
2	Trunk Highway	45.7	12	70	10,720	5,000	18,000
3	Primary Road (Arterial)	36	23	60	7,546	4,000	11,500
4	Major Road (Arterial)	37.1	6	63	5,329	3,750	11,500
6	Centroid Connector	15	6	15	-	-	-
7	External Station Centroid Connector	15	6	15	-	-	-

Figure 4: St. Cloud APO Travel Demand Model Roadway Network



Trip Generation

The current land use-based trip generation program includes 13 land use categories plus an estimator for trips oriented to and from the APO region. Standard travel demand modeling nomenclature considers trips to be "produced" at the household end (or trip origin if neither end is at the home) and attracted to the non-household end of the trip.

Many of the trip generation rates were originally developed using Institute of Transportation Engineers (ITE) estimates that have since been updated by ITE. The model's trip generation rates were reviewed, and it was determined that most of the rates fall within the typical ITE range. Three land uses (office, medium-density retail, and high-density retail) use trip generation rates consistent with ITEs. The trip generation rates for office and medium-density retail are logarithmic with an effective trip generation rate of 13.18 and 63.32 per 1,000 square feet, respectively. High-density trip generation is specific to the Crossroads shopping center, and has an effective rate of 33.95 trips per 1,000 square feet. Trip generation rates by land use category are depicted in Table 4.

Table 4: Trip Generation Rates by Land Use/Trip Purpose

	Production			Attractions		
	Home-based Work	**Home-based Other**	**Non-home Based**	**Home-based Work**	**Home-based Other**	**Non-home Based**
SFR	2.42	5.25	0.71	0.00	1.01	0.71
MHR	1.45	3.17	0.43	0.00	0.61	0.43
OFFICE	-	-	-	-	-	-
IND	0.00	0.00	1.68	2.80	0.84	1.68
LIND	0.00	0.00	0.96	1.60	0.48	0.96
LRET	0.00	0.00	14.25	3.33	15.68	14.25
MedRET	-	-	-	-	-	-
HighRET	-	-	-	-	-	-
HOT	0.00	0.00	2.61	0.61	2.87	2.61
SCH	0.00	0.00	3.10	0.07	0.34	0.31
PARK	0.00	0.00	3.00	0.70	3.30	3.00
HOSP	0.00	0.00	2.35	1.77	5.30	2.35
COLL	0.00	0.00	0.47	0.24	1.19	0.47
ADT	0.30	0.40	0.10	0.06	0.07	0.06

Previously, the trip generation step of the TDM was done outside of the model catalog. SRF updated the TDM to include the trip generation program within the CUBE model catalog.

Trip Distribution

To begin the trip distribution review, existing year (2015) zonal estimates were compared to the observed trip length frequency distribution (TLFD) curves. Data from the 2006-2010 U.S. Census Transportation Planning Package (CTPP) was used to develop home-based work (HBW) trip distribution patterns and TLFD curves. The CTPP 5-year data was used to calculate the average trip times between St. Cloud zones and the TLFD was compared to the trip length frequency from the current model. The frequency distribution was then used as a friction factor input to the TDM to develop the origin-destination tables (calibrated using CTPP frequency distribution). The 2015 trip distribution for all trip purposes is shown in Figure 5, and average trip length by purpose is shown in Table 5. Trip lengths apply only to the portion of trips within the APO model area.

Figure 5: 2015 Trip Distribution Average Trip Lengths

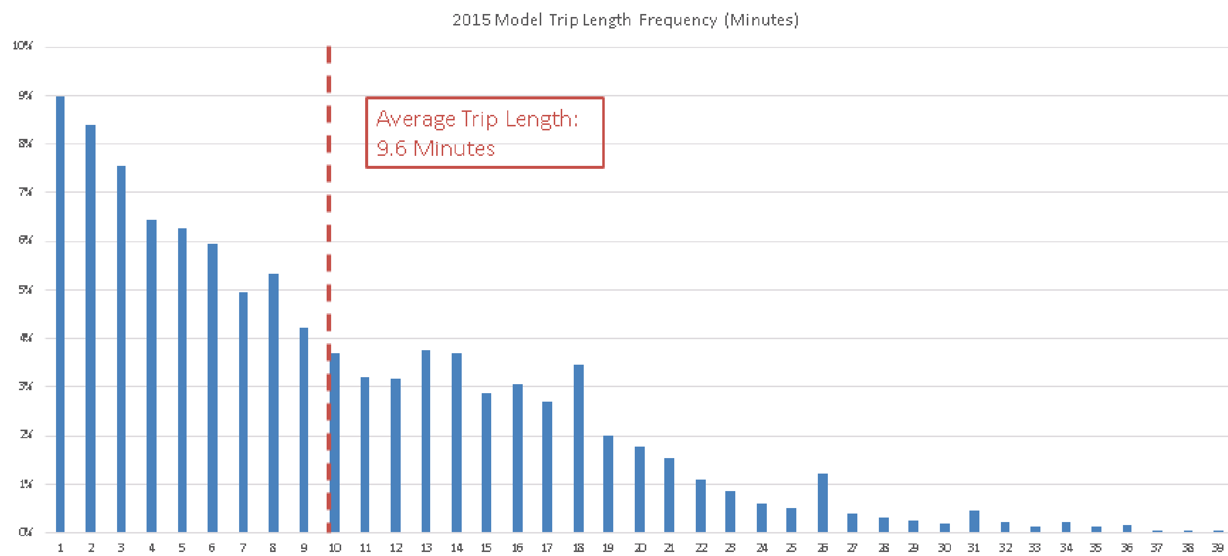


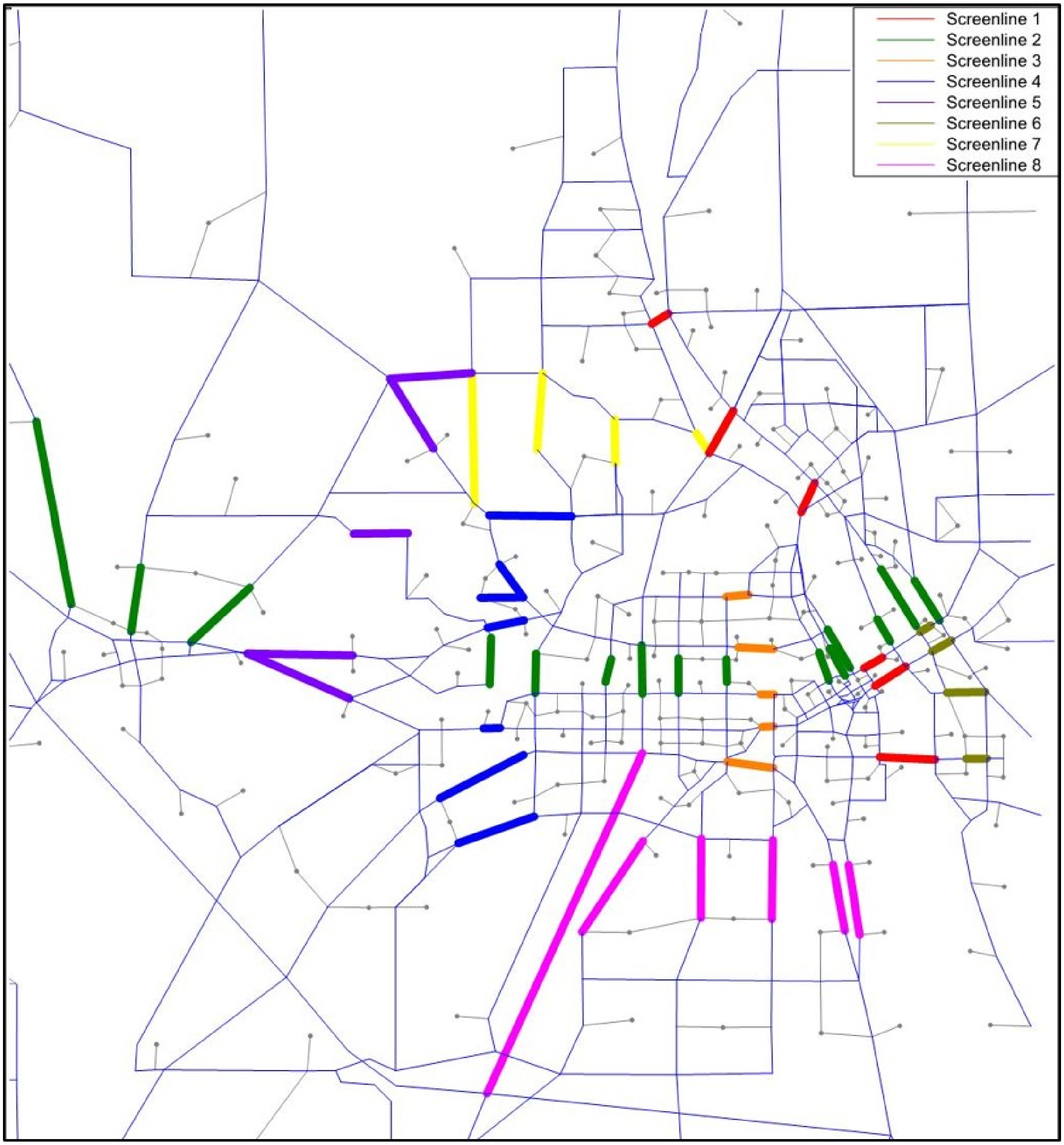
Table 5: Average Trip Length by Trip Purpose

Trip Purpose	Average Trip Length (minutes)
Home-Based Work	24.6
Home-Based Other	17.3
Non Home-Based	10.9

Trip Assignment

Trip assignment was calibrated and validated based on link specific comparisons to traffic counts. Screenlines and cutlines (not crossing entire urban area) were used to tabulate the magnitude of traffic flow in general corridors. This analysis was used to assist in the validation of the trip distribution and assignment steps of the TDM. The screenlines are shown in Figure 6.

Figure 6: APO Model Screenlines/Cutlines



Validation of Existing Model

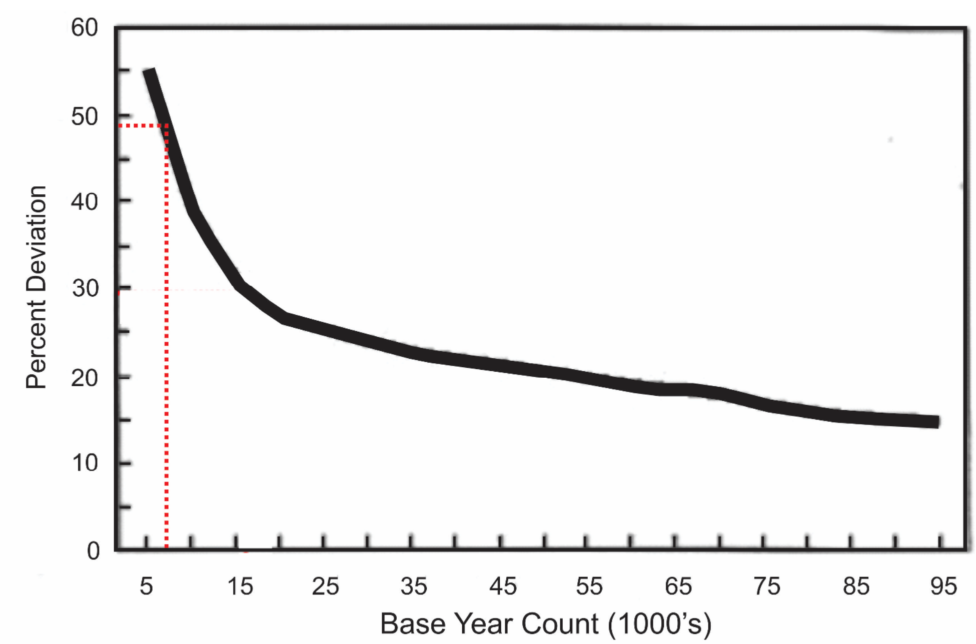
For this study, model validation is defined as the degree to which the travel demand model replicates known ground counts. Based on Federal Highway Administration guidance, link Root Mean Square Error (RMSE) gauges this degree of validation. Existing MnDOT traffic counts were provided by the APO. In addition, district level trip and vehicle miles travelled (VMT) analyses were performed to better understand model validation.

Validation Results

Link Root Mean Squared Error (RMSE): Analysts frequently use a restrictive error measure called Root Mean Squared Error (RMSE), which compares the average modeled volume to the average count volumes and does not allow an exceedingly high volume to be averaged and offset against an exceedingly low volume. Furthermore, error on higher volume facilities is weighted more heavily compared to lower volume facilities.

For the St. Cloud TDM, a RMSE of 37 percent was achieved with an average count volume of 8,100 vehicles per day. As shown in Figure 7, this RMSE value is reasonable given the standard tolerates higher percentage errors with low numeric differences (a result of typical count deviations on low-volume roads and the low impact of those deviations on forecast lane requirements). Model performance for low volume roads is affected by the resources available to refine the geographic size of model zones, the roadway geometrics and traffic control parameters in the model.

Figure 7: Maximum Desirable Error for Link Volumes



Source: Model Validation and Reasonability Checking Manual Second Edition (FHWA, 2010)

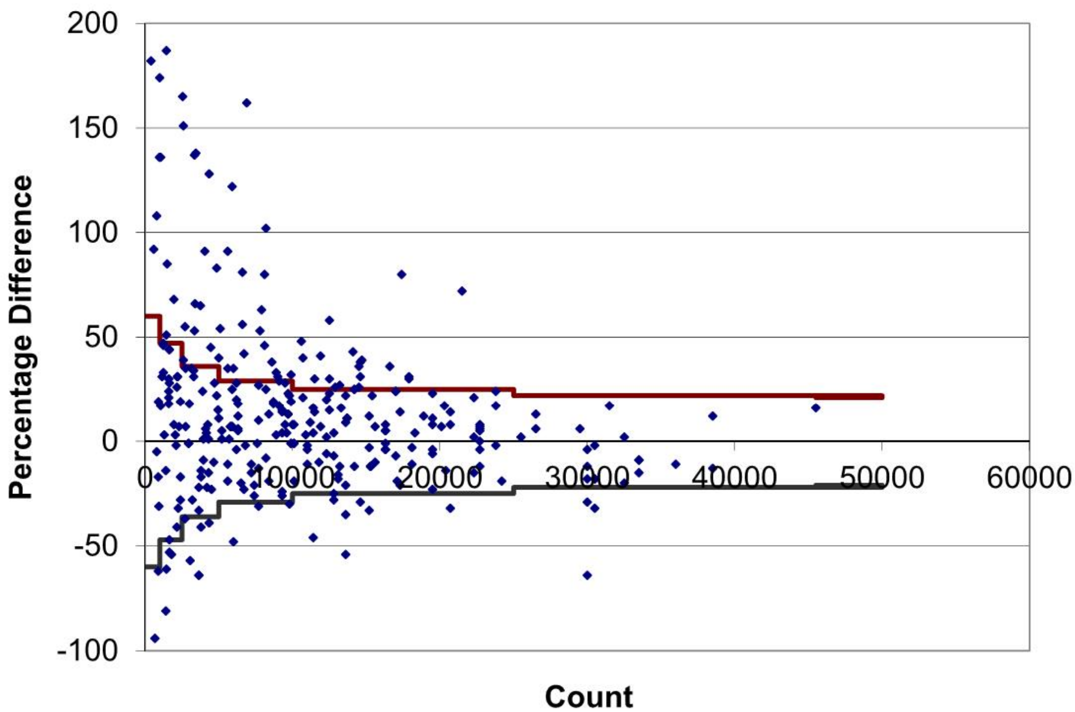
Link Deviation from Count: Differences between modeled volumes and ground counts are expected in a model. The significance of any difference depends on whether the difference affects roadway requirements (such as the number of lanes) and accounts for variance in traffic counts. For this analysis, the model attained a 37 percent RMSE, which will necessitate applying an industry-standard post-model adjustment process. As shown in Figure 8, high volume roadways had the best fit; some roadways, particularly low volume roadways, exceeded the desirable deviation. Link variation from ground counts by volume group is shown in Table 6. Note that low volume/high deviation links are most commonly areas where not all of the local roadways are represented in the roadway network, which concentrates traffic onto the roadways that are included in the roadway network.

Table 6: Link Deviation by Volume Group*

Volume Group	Links With Counts	Sum of Model Volume	Sum of Existing Volume	Total Deviation from Count	RMSE
0 - 2,499	244	415,344	304,105	40%	129.6%
2500 – 4,999	89	421,853	326,536	32%	77.7%
5,000– 9,999	125	1,090,001	924,100	18%	43.7%
10,000– 19,999	113	1,733,375	1,620,000	7%	25.4%
20,000– 29,999	54	1,293,862	1,257,200	3%	16.7%
30,000 – 40,000	24	707,368	786,000	-10%	19.2%
>40,000	1	52,620	45,500	16%	16.0%
Total	650	5,714,423	5,263,441	9%	37.0%

* Links with counts

Figure 8: Model Performance for Segments with Counts



Q:\Projects\11430\ModelRun\StCloud_TDM_SRF_Rev_112414\Base\Validation\Validation_20181107.xlsx 11/8/201810:24 AM

In addition to calculating the link deviation by volume group, screenlines were also used to evaluate model validation. Model performance across the screenlines is shown in Table 7. Three screenlines exceed desirable deviation as defined in Figure 7. Screenline 1 (measuring Mississippi River crossings) is slightly higher than the desired maximum (projected), but the nearby Screenline 6 paralleling TH 10 and Lincoln Avenue shows a high deviation of 39 percent and appears to be affected by zone sizes and centroid connections. A large portion of the deviation in Screenline 8 is the result of the existing model's treatment of the heavily access-controlled Highway 15 relative to its classification. Systematic remedies for these differences are addressed in the following section.

Table 7: Screenline Validation

Screenline	Sum of Model Volume	Sum of Existing Volume	Total Deviation from Count	RMSE
1	121,326	104,300	16%	25.5%
2	132,501	132,150	0.3%	29.1%
3	78,464	84,800	-7%	17.1%
4	46,394	49,350	-6%	43.9%
5	37,373	33,300	12%	39.9%
6	60,872	43,900	39%	51.5%
7	29,621	28,400	4%	36.2%
8	80,164	54,700	47%	69.5%

Potential Model Improvements

SRF previously reviewed the APO's TDM in 2014 and developed a memo documenting suggested model or modeling process improvements. These recommendations are repeated where appropriate. However, this section is more focused on structure changes, in the model, data inputs, and calibration.

Overall Model Structure

Continued use of Citilabs CUBE software for the APO model platform is recommended. The software is widely used by the other Metropolitan Planning Organizations in North Dakota, Minnesota and Wisconsin which increases the opportunities to efficiently collaborate and increases the availability of the APO model to non-national consulting firms. CUBE also provides the advantages of both user-friendly interfaces and option, as well as the ability to make incremental improvements to the model itself. For example, an option truck modeling process was recently added within the Duluth-Superior model.

Zone and District Structure

In the near-term, the APO should work with the State of Minnesota and others as part of the Census Participant Statistical Areas Program (PSAP). The 2020 Census is expected to discontinue a number of the small area geography estimates. The impact of this can be reduced by well-defined relationships between TAZs and other census geographies that are being continued. See https://ctpp.transportation.org/policy-change-on-small-geography/psap-update-on-small-geography-delineation-criteria-oct-24-2018/ and similar sources of information for additional detail.

Formal adoption and use of district-level aggregations of model TAZs can provide useful summary of model inputs and outputs, Districts identified in this analysis have been included as part of the GIS information provided in this update.

Zonal geodatabases make processing of input information such as land use data, census or other demographic information more efficient.

Roadway/Transit Networks

Perhaps the most significant improvement that could be made in the APO model would be an update of the travel model roadway network. The current model uses a "link-and-node" vestige of the old travel model that dates to the TRANPLAN software over 20 years old. With advances in both the CUBE software and geographic information systems (GIS) a more efficient and integrated roadway network is achieved:

- Within CUBE, the network can be built directly from a GIS geodatabase. Any available (or model-developed) roadway or other attribute can be directly incorporated to the network

- The model can/should be based on MnDOT's updated linear referencing system, which provides access to much of the potential data
- The GIS-based network enhances quality control, review and display of both input and output networks
- GIS-based maps are more efficiently processed for reporting purpose
- Version control of roadway network alternatives is better maintained

In addition to the roadway system, if the APO is considering adding transit modeling, the agency in conjunction with the transit agency should consider adding GTFS (General Transit Feed Specification, https://developers.google.com/transit/gtfs/) to its transit GIS. This would not only provide enhanced online transit information but could be directly imported to the travel demand model GIS.

Regardless of the use of GIS, the APO's network updates should include more systematic and rule-based criteria for estimating speeds and capacities, to reflect general speeds, access spacing, intersection geometrics, etc. The current model relies significantly on manual adjustments to speeds to achieve reasonable volumes.

Trip Generation

Trip generation rates used in the model fall within generally accepted practice for small-medium MPO models as noted previously. However, there are areas where the MPO model would benefit from improvements or updates.

If the APO is considering implementing a mode choice model, the APO should convert the trip generation to a person-trip based model. This can be done applying a variety of conversation factors to the current vehicle trip-based trip generation.

One area where significant improvement could be made would be the use of a special generator treatment of the St. Cloud State University area. The university, with 15,000 students, is a large traffic generator with unique travel characteristics.

A second area where the APO model exhibits atypical behavior is external trips model. The last comprehensive internal/external travel survey in the St. Cloud was in 1997 and trip patterns are likely to have changed significantly.

For example, based on analysis of U.S. Census data, the APO study area contains 76,000 jobs, with 45 percent of the workers commuting in from outside of the model area. Conversely, 30 percent of the 60,000 employed labor force in the region commutes to jobs outside the region. These strong extra-regional flows would alter the typical work trip production and attraction rates in the travel demand model.

New methods in travel behavior data collection have improved the ease (though not always cost) of collecting travel behavior data. The current household travel survey in the Twin Cities area is using nearly exclusively cellphone-based data collection, with additional online options available. Such a survey would be used for area-specific trip generation (frequency, purpose and demographic), trip distribution, mode and roadway assignment information.

Similarly, new methods of "big data" analytics, such as INRIX, Airsage and Streetlight Analytics provide opportunities to estimate overall trip generation from an area, which can be used to approximate trip rates.

Trip Distribution

The above-mentioned "big data" travel flow data sources can also provide a good source of calibration data for trip distribution, although trip purposes can generally only be estimated without a true household survey with trip purpose-specific trips.

The APO should consider the viability of an agency user seat under MnDOT's recent purchase of Streetlight Analytics data. This data can be used for origin-destination information, although the trip production/attraction capabilities are limited to estimations of the direction of the trip movements.

Finally, the current APO model does not use K-factors. While it is generally best not to use them there are situations, including major river crossings, where K-factors are valid.

Mode Choice

APO staff has expressed interest in incorporating mode choice into the APO's TDM. The mode choice step in the TDM determines the mode which is used for each trip prior to trip assignment. This can include walk, SOV, HOV, local bus, express bus, LRT, CRT, and CRT.

Properly calibrated mode choice models require a comprehensive transit on-board survey, those general approximations can be made using borrowed sources of data, and a more simplified zone-based transit mode share approximation can be used.

Time-of-Day Assignment

The TDM assigns trips at the daily level. Assigning trips based on larger time periods (i.e. daily) assumes that there is no variation in travel times and paths within that time period, for example losing the impact of peak hour congestion within a broader peak period.

The APO should consider converting the TDM to peak hour (or peak period) assignment to better replicate actual travel conditions.

Advanced Traffic Assignment Practice

Currently, the APO's TDM uses a static, daily, capacity constrained assignment. This assignment type is the most commonly used method in local TDMs, However, it limits the ability to use the model for many potential transportation system performance measures such as speed. In particular, peak intersection delay is difficult to model in traditional link-based daily assignment. Modeled volume-capacity ratio may exceed realistic levels and underestimate delay.

One option would be to better reflect the link or node capacities using appropriate capacity modifications, which may include capacity and volume-delay adjustments for roadway function, access spacing and type.

CUBE software program also supports junction-based assignment, which incorporates it does require the additional coding of intersection movements and controls within the model.

Dynamic Traffic Assignment (DTA) models address period aggregation assignment problems by simulating individual vehicles over time. There are several advantages of the DTA methodology, including:

- Peak-impacted travel routing
- Intersection control modeling
- Individual vehicle simulation
- Better realism in modeled speeds, flows, and paths
- Better visualization capabilities for analysis and presentation

A drawback for DTA is integration with a travel demand model greatly complicates the modeling process and would require greater training and expertise for the APO staff. Additionally, a variety of competing DTA products exist, resulting in a shortage of experience with any given product.